

Journal of Information and Organizational Sciences

UDC 004:005:3
ISSN 1846-3312
e-ISSN 1846-9418
DOI: <https://doi.org/10.31341/jios>

Publisher

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From the Editor

Dear readers,

As the new editor, in the beginning I would like to thank former editor dr. Dijana Oreški for her efforts to improve the Journal in the quality of the papers, visibility and recognition in the scientific society.

This Journal has been continuously published for 43 years, and yet, improvements are possible. Such a tradition demands severity in work and devotion in efforts. And I hope that I will be, as a new editor, on the level for these tasks.

The Journal could not exist without the thoughtful leading, for which I thank all previous editors, without hard work in selecting papers, for which I am thankful to all members, current and previous, of the editorial board, keeping the quality of the papers on the high level, which is the merit of our reviewers, the work on the design and layout of the Journal, which is in the continuous process of improvement, thanks to publishing board. The Journal could not exist without the content, the papers. Therefore, I want to thank all authors that, in 43 years, recognized our Journal as an adequate place to publish their scientific results.

All this work must go on. Therefore, I am proud to present the new issue of the Journal containing 10 high quality papers from the authors from Europe, Asia and Africa. Three continents authors come from justify the status of internationality of the Journal and assure us that we are still on the right track. Among the papers we have seven original scientific papers, two survey papers and one preliminary communication.

I hope that readers will enjoy reading this issue and that they will find papers presented in it inspiring for their future research.

Alen Lovrenčić

Editor



UDC 004:005:378

Survey paper

Relating Smart Governance as a University Feature to Students' University Perceptions

Mario Jadrić*mario.jadric@efst.hr**Faculty of Economics, Business and Tourism
University of Split, Croatia***Maja Ćukušić***maja.cukusic@efst.hr**Faculty of Economics, Business and Tourism
University of Split, Croatia***Tea Mijač***tea.mijac@efst.hr**Faculty of Economics, Business and Tourism
University of Split, Croatia*

Abstract

Following the results of recent studies on the creative use of smart technologies in urban and university settings, there is a growing number of promising research areas under smart university as an umbrella term. Starting from the differentiation between six standard “smart” dimensions in the university, the paper focuses on one smart university feature in particular – it explores the level and the relation of smart governance to the attitudes towards university management, fellow students, and Perceived External Prestige (PEP) as antecedents of university affective commitment. The paper presents multivariate analysis results based on the feedback from over 400 students. Participants were first-year students from the second biggest university in Croatia. While the effect of smart governance on the positive attitude towards university management is found to be positive and significant, the effect of the perception of university management on students' university commitment is low and not significant in the given context.

Keywords: Smart University, Smart Governance, University Commitment

1. Introduction

The level of technological provision in everyday activities continually evolves with the emergence of new concepts and tools that impact all aspects of our lives. In Higher Education (HE) settings, the change in the way the individuals interact in the university environment is well-acknowledged according to Smyrnova-Trybulska [1], understanding that to stay competitive on a global level, the changes must be reflected in the university organization [2]. In particular, the availability of certain technologies should reflect on how the relevant processes should be performed and what high-

quality services should be offered [3]. The imperative for change did not bypass the HE institutions in Croatia either. In particular, two goals from the currently valid national strategy for education and technology, which are aligned within these given settings, could be highlighted [4]: (1) Increasing the quality of student life and internationalization of HE and (2) Improving the information and communication infrastructure. Identified challenges have been addressed at the university level, prompting, for example, the University of Split to set its aim to become the leading regional university in this part of Europe while pointing out that the key tasks are to conduct teaching, scientific research, artistic creation and professional activity, based upon principles of quality control and assurance and the EU standards [5].

To help cope with related challenges, the area of research, design, and development of smart universities has become central to various pioneering (inter)national studies, events and projects, governmental and corporate initiatives, institutional agendas, and strategic plans [2]. Specifically, in November 2019, over 6.800 papers (excluding citations and patents) were available after performing a search via Google Scholar, a bibliographic search engine on topics “smart university” or “smart campus” [6], while in March 2021, the number of papers is almost 8.600. Even though smart universities' primary focus is in the area of education, other aspects, for instance, management, require radical change [7]. Education is just the upper layer, and other aspects must be considered, such as [2]: (1) communication; (2) social interaction; (3) transport; (4) management; (5) wellness (safety and health); (6) governance; (7) energy management; (8) data storage and delivery; (9) knowledge sharing; (10) IT infrastructure, and (11) environment.

The rationale behind universities' tendencies to become smart is convincing – the aspiration is not only to increase efficiency but also to improve the experience for students and staff [8]. Providing a better experience for students could become the main element that helps them distinguish their offerings from the competition to attract and retain the best students and staff internationally. It could become a challenge since the goal is to satisfy new generations of students who are very connected, informed and stay in touch with the outside world [7].

The study presented in the paper builds on the two presented aspects – increasing the number and organization of smart university features with the purpose to increase the quality and personal experiences on the one hand, and the students' opinions about the university resulting in varying levels of commitment and affection on the other hand. More specifically, the aim was to explore how smart governance, perception of fellow students, attitude towards university management and perceived external prestige affect students' university commitment. The study's theoretical background is presented in Section 2, followed by the methodological considerations that were taken into account for results analysis in Section 3. The results are presented in Section 4, and the discussion and conclusion in Sections 5 and 6, respectively.

2. Research Model and Hypotheses Development

The research model is based on the one introduced by Udir Mišič and Podnar [9]. Their model was tested with citizens from two cities when the results showed that

Perceived External Prestige (PEP) and the Perception of fellow residents of the city were significant drivers of City commitment. Also, Perception of city management has a significant impact both on Perceived External Prestige and on the Perception of fellow residents, without a significant direct effect on City commitment. The reasons for testing the variables of the model that was tailored to a city context in the HE context has been elaborated in another paper [6]) already. In general terms, the potential of campuses to serve as valuable (smart) city prototypes is widely recognized, mostly due to a growing need for conducting more focused research in the smart city domain as it grows more mature. Also, in the introductory part of this paper, the key reasons for assessing the technological advances in relation to improving student experiences and university commitment are given. That is why the original model of city commitment was contextualized and extended to include the technological aspect. Out of the six well-known smart city characteristics introduced by Giffinger *et al.*[10], presumably, smart governance could significantly impact the attitude towards university management, fellow students, and Perceived External Prestige – and therefore, an indirect impact on students' university commitment. The reasons for these assumptions and specific hypotheses are given in the following.

2.1. Students' University Commitment (Affective Commitment)

Students' commitment reflects their overall satisfaction, sense of belonging, perception of educational quality, and willingness to attend the university again [11]. It is defined as the firm belief in acceptance of the university and also presents a desire to maintain a long-term relationship with a specific university [12], [13]. A survey conducted at the University of Split, Faculty of Economics, Business and Tourism, showed that dropout rates are the highest among first-year students, which could point out that HEIs need to put more effort into improving the efficiency of educational processes [14]. Students' commitment reflects the student's motivation to continue the relationship with the university, noting that high reputation and trustable universities have a positive effect on students' commitment [13]. The level of students' commitment rises when students believe they have an opportunity for improvement within the university, as well as when they feel they have become key stakeholders [12]. Here, it is important to distinguish between normative commitment and affective commitment [15]. The affective commitment represents an emotional attachment (feelings of inspiration, pride, belonging, and so on), while normative commitment represents a feeling of obligation [16], [15]. For example, if a student remains with the university because they want to – it denotes affective commitment. Opposite of that, students with strong normative commitment will remain with the university because they feel that they ought to do so [15]. Affective commitment is indeed a meaningful concept within HE since it contributes to a sense of care towards the university and a desire to stay connected [16]. The importance of students' commitment has been recorded long-ago: Tinto [17] stressed that students achieving a higher level of social and academic integration have stronger goal commitment and institutional commitment – resulting in a lower retention rate. Recent research showed that the relationship between students' university commitment and students'

effectiveness could also play an important part in the enrolment, financial planning, and management of the university [18] or, to put it differently, the commitment not only affects individuals' outcomes but also impacts the organizational/university outcomes [12]).

2.2. Attitude Towards University Management

Universities worldwide are facing management problems such as [19]: (1) unbalanced growth in the number of students, (2) infrastructures that cannot keep up with the enrolment growth, (3) increased student/faculty ratios, (4) quality of education, (5) heavy competition for limited funding for research, and (6) heavy competition between the universities. At the same time, university management has a great responsibility as it has to maximize the impact on society through supervision and promotion of knowledge creation and science research [20]. In the literature related to smart universities and smart campuses, the management aspect is often highlighted as one of the main areas where changes are needed [21], [22], [23]. The importance of using technologies for data management to store, manage and use (big) data for providing an accurate basis for university management [24] is another promising research area with more and more evidence from real-life implementations [25]. The improvement in the efficiency of university management, for example resulting from the performance of an integrated information system, can improve various aspects of the educational process, automate administrative and business activities and financial management as well as provide information support to decision-making in all areas of the university [26], and, above all, contribute to better student experiences. The changes in university management can help address the identified challenges, resulting in better performance of the university, and, consequently, in developing feelings of pride in the student population, a sense that can be linked to commitment construct [16]. A hypothesis is formulated:

***H1.** Positive attitude towards university management will have a positive impact on students' university commitment.*

2.3. Perception of Fellow Students

Another aspect deemed important for students' university commitment is the perception of fellow students. As mentioned before, affective commitment is related to emotional attachment [16]. Students find the opinions of close people relevant; for example, the commitment of students and their parents to obtaining a HE degree significantly relates to whether or not the students persist beyond their freshman year [27]. The same has been confirmed in recent years. Opinion about fellow students, such as negative impressions of them, increases the likelihood of first-year students dropping out [28], i.e. disliking them is considered one reason for a voluntary drop out [29]. Academic and social integration were the two most important factors in the retention of students [30]. As a part of social integration, the quality of the individual's relationships with fellow students (regular contacts) and with lecturing staff (especially informal interactions) are considered essential [29]. Nowadays,

communication and regular contact are simplified – students have easy access to information they need, and they are connected 24/7 [7] with different university fellow groups for assistance, sharing and discussion or just staying informed [31]. This includes information about the university and its management structures that could lead to a sense of pride. Here, it is important to note that there is a great deal of research on marketing and mass communications identifying conditions under which group opinions influence individuals [32]. One of the conditions under which group opinions are more likely to persuade individuals is when the audience is younger, a point in the case when considering the student population [33]. Consequently, two hypotheses are formulated:

***H2.** Positive attitude towards university management will have a positive impact on the perception of fellow students of the university.*

***H3.** Perception of fellow students of the university will have a positive impact on students' university commitment.*

2.4. Perceived External Prestige

Analogously, acknowledging the importance of other people's opinions but in a slightly narrower approach, the term perceived external prestige is examined. The concept refers to organizational members' perceptions of how prestigious the organization is in external stakeholders' eyes [34]. It stands for what an individual thinks outsiders view his or her organization (and therefore, him- or herself as a member) [35], [36]. Authors Sung and Yang highlight that perceived external prestige is an individual-level variable [37] primarily because it is based on individual's interpretations and assessments of their organization's prestige, based on their exposure to information about the organization [34]. Due to this personal approach, members of the same organization may have different perceptions of its external prestige [37]. Perceived external prestige answers the question, "what do outsiders think of me because I belong to this organization?" [35]. The higher the organization's prestige, the more likely it is for the individual to identify with the organization because the affiliation to the organization enhances their self-esteem [37]. Many researchers in the field assumed that perceived external prestige influences an individual's behavior due to their identification with the organization and have found, in different contexts, that perceived external prestige leads to individuals' affective commitment [38]. In the university context, specifically, a study showed that perceived external prestige positively affected students' supportive attitudes toward the university [37]. Based on the presented, two hypotheses are formulated:

***H4.** Positive attitude towards university management will have a positive impact on perceived external prestige.*

***H5.** Perceived external prestige will have a positive impact on students' university commitment.*

2.5. Smart Governance

Authors define governance as interaction and collaboration between different stakeholders in decision-making processes [39]. Creating a collaborative environment (smart collaboration) is believed to be a prerequisite for smart governance concepts [40]. Characteristics such as openness and transparency of decision-making and actions, open information sharing, stakeholder participation and collaboration, leveraging operations and services via intelligent and integrated technology use, as well as organization's role of facilitator of innovation, sustainability, competitiveness, and livability are used to define smart and open government [41], and as a subset of it, smart governance. It plays an essential role in providing transparent information-sharing mechanisms, among other benefits [42] and using ICT offers the opportunity to know, understand, and govern problems [43]. Smart universities must implement smart governance solutions with foci on [23]: (1) enabling governance on multiple stakeholder levels, (2) implementing work plans, (3) improving organizational performances and (4) presenting management workflow which supports automated reporting. Good governance in the context of HE refers to the concept of shared governance or distributed leadership, a principle that requires the participation of numerous stakeholders in the decision-making processes of universities [44]. Different stakeholders' expectations are mediated in smart university, ensuring the success of complex but cohesive and co-administered governance [45]. Various aspects of smart governance (for example, transparent communication via the web and mobile applications, resource sharing-booking) are explored in the paper. Four hypotheses are formulated:

H6. Smart governance will have a positive impact on students' university commitment.

H7. Smart governance will have a positive impact on the perception of fellow students of the university.

H8. Smart governance will have a positive impact on the positive attitude towards university management.

H9. Smart governance will have a positive impact on perceived external prestige.

Figure 1 illustrates the hypothesized links between the five proposed constructs.

3. Data and Methods

3.1. Participants and Data Collection

The study participants were the first-year students of the University in Split, Faculty of Economics, Business and Tourism. The respondents come from a relatively homogeneous group (first-year students) and share a similar background in education and economic situations. However, a slight gender imbalance is observed as there are approximately 70% of female respondents and 30% of male respondents, yet this is consistent with the enrolled students' structure.

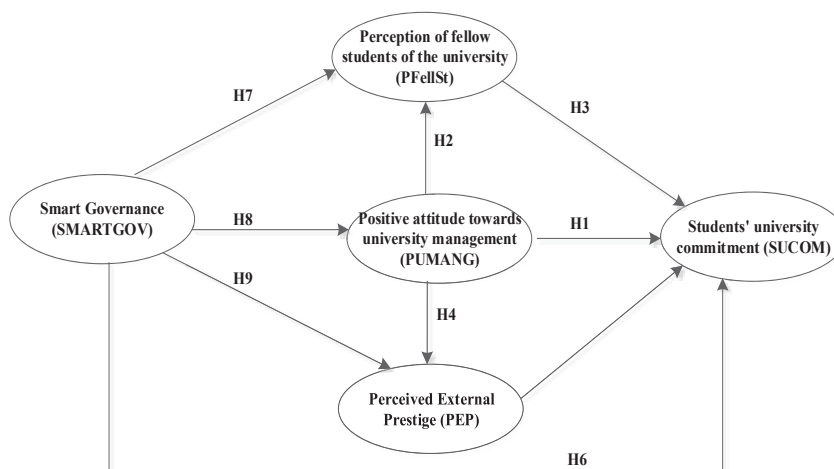


Figure 1. Proposed research model (extended and adapted from Udir Mišič and Podnar [9])

Data was collected in late October 2019 using an online survey tool (Lime Survey). Students completed the questionnaires voluntarily and anonymously, in computer labs and under a teaching fellow's supervision. They were instructed to access the link to the online questionnaire placed in the e-learning system. It took students approximately 15 minutes to complete it, and there were 411 completed questionnaires.

3.2. Instrument

For the survey, two instruments were used to measure students' perceptions of a university and its smart dimensions. The way the instruments were constructed, adapted and tested is presented in detail in another paper [6]. The first instrument measuring students' perceptions was based on construct names and 15 statements that have been contextualized for the university setting, instead of city context as it was originally proposed in the model by Udir Mišič and Podnar [9]. Variables have been contextualized as follows: city = university, resident = student, live = study, people = colleagues, tourists = visiting students and scholars. The second instrument, with 18 statements, was based on smart city characteristics classification by Giffinger *et al.* [10] (3 questions per category). Exploratory factor analysis was used to test the construct validity of new instruments and reliability using Cronbach's Alpha. After removing one item from the first and one item from the second instrument, both presented factor structures are valid. For this paper, from the second instrument, only Smart governance construct and related scales were used as is already presented in the theoretical background.

3.3. Structured Equation Modeling (SEM)

Structural equation modeling (SEM) is a multivariate statistical analysis technique, a combination of factor analysis and path analysis. Part of the model that refers to

measuring is equivalent to factor analysis and interpretation or relationship between latent and manifest variables, while the structural part corresponds to path analysis and interpretation of direct and indirect effects between latent variables [46]. The error related to manifest variables presents measurement error, reflecting the suitability of manifest variable for measuring related latent factors. The structural equation model is flexible and comprehensive, defining the relationship between dependent and independent variables (whether they are manifest or latent). This enables statistical evaluation, including multiple regression weight, factor analysis and multivariate ANOVA (MANOVA) [47]. The convergent and discriminant validity of the model was tested using confirmatory factor analysis and other relevant calculations and coefficients (Cronbach's alpha, Composite reliability, Average variance extracted, square root of AVE). The overall structural model contained 5 latent and 16 manifest variables presented further in the paper.

4. Results

4.1. Descriptive Statistics and Assessment of Normality

Before the reliability and validity testing of the measurement model, a normality test was performed based on skewness and kurtosis values. According to Hair *et al.* [48], if the number is higher than +1 or lower than -1 for skewness or kurtosis, distributions are considered not normal. Following the stated criteria, the variable "PEP4 - The University in which I study is considered reputable" has been excluded from further analysis. Descriptive statistics and assessment of normality are presented in Table 1.

Variable	Min	Max	Mean	SD	Skew	Kurtosis
PEP4	1.00	5.00	4.23	0.875	-1.177	1.360
PEP3	1.00	5.00	4.01	0.942	-.0677	-0.154
PEP2	1.00	5.00	3.92	0.962	-0.691	0.073
PEP1	1.00	5.00	3.58	1.107	-0.524	-0.423
SGOV2	1.00	5.00	3.92	0.814	-0.237	-0.414
SGOV3	1.00	5.00	4.17	0.749	-0.602	0.138
SGOV1	1.00	5.00	3.91	0.948	-0.778	0.453
PUM3	1.00	5.00	3.88	0.861	-0.614	0.635
PUM2	1.00	5.00	3.83	0.848	-0.424	-0.014
PUM1	1.00	5.00	3.90	0.775	-0.195	-0.381
SUC4	1.00	5.00	3.90	0.963	-0.609	0.005
SUC3	1.00	5.00	4.14	0.862	-0.829	0.474
SUC2	1.00	5.00	3.93	0.969	-0.809	0.501
SUC1	1.00	5.00	4.03	0.894	-0.631	-0.014

Variable	Min	Max	Mean	SD	Skew	Kurtosis
PFSU3	1.00	5.00	4.12	0.826	-0.774	0.526
PFSU2	1.00	5.00	3.81	0.893	-0.442	-0.033
PFSU1	1.00	5.00	4.08	0.776	-0.551	0.220

Table 1. Descriptive statistics and assessment of normality

4.2. Reliability and Validity of the Measurement Model

When selecting the number of manifest variables included in the model, the ratio of the sample size and the number of parameters were taken into account. Authors Hair *et al.* [49] suggest that the minimum sample size is 150 respondents for models containing 7 or fewer latent variables – each having 3 or more manifest variables with moderate variance projection on a relevant latent variable (0.5). Since the number of respondents is adequate (N=411), there was no need for reducing the number of latent and manifest variables. Cronbach's alpha coefficient for reliabilities was calculated, showing the internal consistency of items measuring the same construct [47]. There are varying opinions related to the acceptability of constructs based on alpha coefficients – Felder and Spurlin [50] consider $\alpha=0.5$ as a lower limit for acceptance, while [51] suggests it is 0.7. Another criterion, such as a minimum sample size of 300, is emphasized [52], or even 400 respondents required to have a reliable estimation of Cronbach's alpha coefficients. Cronbach's alpha for each construct was above 0.7 (Table 3), indicating high reliability.

Abbrev.	Manifest variables	FL	Corresponding latent variable
SUC1	At the university where I study, I will continue to study, because I love my university.	0.912	Students' university commitment (affective commitment) (SUCOM)
SUC2	I wish to continue to study at this university because I enjoy it.	0.859	
SUC3	I would like to continue to study at the university where I study now because it makes me feel good.	0.875	
SUC4	At the university where I study, I will continue to study, because this is the best place for me and my family.	0.781	
PEP1	Students of other universities think highly of the university where I study.	0.754	Perceived external prestige (PEP)
PEP2	It is believed that it is good to study at the university where I study.	0.882	
PEP3	It is believed that the university where I study is one of the most prestigious in the country.	0.690	
PUM1	University management includes and takes into account various disciplines regarding the development of the university.	0.830	Positive attitude towards university management (PUMANG)
PUM2	University management encourages diverse cultural, artistic and sports activities.	0.757	

Abbrev.	Manifest variables	FL	Corresponding latent variable
PUM3	The university management has a clearly defined vision.	0.755	
PFSU1	At the university where I study, colleagues show solidarity with each other.	0.751	Perception of fellow students of the university (PFellSt)
PFSU2	Students of the university are in favor of and friendly to visiting students and scholars.	0.797	
PFSU3	Students at the university where I study, feel safe.	0.804	
SGOV1	University where I study implements new technology and digital services for common activities (such as communication with student offices, for library services and similar).	0.761	Smart governance (SMARTGOV)
SGOV2	University where I study implements new technology and digital services to increase efficiency and effectiveness for management of public campus infrastructure (e.g. signalization, booking of campus resources and similar).	0.750	
SGOV3	University where I study implements new technology and digital services to achieve transparent and trustworthy communication with all stakeholders (primarily using the web and mobile applications).	0.731	

Table 2. Results of confirmatory factor analysis (manifest and latent variables included in the SEM model and standardized factor loadings from AMOS model)

Convergent and discriminant validity of the scales was tested using confirmatory factor analysis. Convergent validity was checked using three tests (recommended by Anderson and Gerbing as cited in [53]): standardized factor loadings, composite reliabilities and average variance extracted. Standardized factor loadings of manifest variables in the model are obtained based on the confirmatory factor analysis done in AMOS based on the sample of 411 respondents. As presented in Table 2, all items loaded in the range from 0.690 to 0.912 and are statistically significant ($p < 0,01$), indicating a good measurement level of latent variables. Based on the criteria used for estimating composite reliability ($CR \geq 0,7$ and average variance extracted ($AVE \geq 0,5$ [54], there is only one construct (presented in Table 3) – Smart governance, that has $CR=0.684$, deviating slightly from the satisfactory convergent validity scale. Bearing in mind that all other constructs have appropriate values of CR and AVE, and taking into consideration that value of Cronbach's alpha coefficient for the Smart governance construct is satisfactory (which can be used as an alternative measure for CR), and adding that the construct has only three statements – construct was kept in for the purpose of discriminant validity testing.

Constructs	Number of items	Cronbach's alpha	Composite reliability (CR)	Average variance extracted (AVE)
Students' university commitment (SUCOM)	4	0.916	0.918	0.736
Perceived External Prestige (PEP)	3	0.816	0.713	0.608
Positive attitude towards university management (PUMANG)	3	0.822	0.717	0.611
Perception of fellow students of the university (PFellSt)	3	0.826	0.720	0.615
Smart governance (SMARTGOV)	3	0.789	0.684	0.559

Table 3. Results of reliability and convergent validity test

Table 4 presents the square root of AVE diagonally in bold emphasis and the correlation of pairs of latent variables (constructs) below the diagonal. The correlation of latent variables is lower than the square root of AVE for every pair of variables, confirming the discriminant validity of the scale. Consequently, the construct is regarded as distinct from other constructs since the criteria are met.

Constructs	SUCOM	PEP	PUMANG	PFellSt	SMARTGOV
SUCOM	0.858				
PEP	0.537**	0.780			
PUMANG	0.511**	0.520**	0.782		
PFellSt	0.601**	0.616**	0.755**	0.784	
SMARTGOV	0.457**	0.441**	0.619**	0.565*	0.748

** p < 0.001

Table 4. Results of discriminant validity test

4.3. Structural Model Analysis

Several relevant fit indices have been calculated and are presented in Table 5 to determine if the hypothesized model fits the analyzed data. Since there are a number of fit indices available, only the ones that provide enough information for model estimation have been chosen [49].

Fit measure	Model value	Acceptable fit
Comparative Fit Index (CFI)	0.972	≥0.900
RMSEA	0.051	≤ 0.08
AGFI (adjusted goodness-of-fit index)	0.921	≥0.800

GFI (goodness-of-fit index)	0.945	≥ 0.900
Chi-square	195.893	
Degrees of freedom	95	
Probability level	0.000	$P \geq 0.05$
Chi-square/Degrees of freedom	2.062	< 3.00

Table 5. Overall model fit indices for the research model

Given that all values of analyzed indices are within acceptable ranges, it can be concluded that the defined model is suitable for further structural analysis.

Constructs' relationship	Standardized regression weight	Critical Ratio (C. R.)	p values	Hypothesis supported
<i>PUMANG</i> → <i>SUCOM</i>	0.030	0.291	0.771	<i>H1 - Not supported</i>
<i>PUMANG</i> → <i>PFellSt</i>	0.696**	9.295	0.000	<i>H2 - Supported</i>
<i>PfellSt</i> → <i>SUCOM</i>	0.355**	3.765	0.000	<i>H3 - Supported</i>
<i>PUMANG</i> → <i>PEP</i>	0.463**	6.027	0.000	<i>H4 - Supported</i>
<i>PEP</i> → <i>SUCOM</i>	0.270**	4.474	0.000	<i>H5 - Supported</i>
<i>SMARTGOV</i> → <i>SUCOM</i>	0.121	1.792	0.073	<i>H6 - Not supported</i>
<i>SMARTGOV</i> → <i>PFellSt</i>	0.141*	2.140	0.032	<i>H7 - Supported</i>
<i>SMARTGOV</i> → <i>PUMANG</i>	0.621**	9.897	0.000	<i>H8 - Supported</i>
<i>SMARTGOV</i> → <i>PEP</i>	0.164*	2.188	0.029	<i>H9 - Supported</i>

* $p < 0.05$; ** $p < 0.001$

Table 6. Results of the structural model and hypotheses testing

As presented in Table 6 and Figure 2, all of the path coefficients have a positive effect, and seven of them are statically significant with an associated p-value lower than 0.05. Exceptions are the path leading from the Positive attitude towards university management to Students' university commitment and path from Smart governance to Students' university commitment; even though the effects are positive, they are not statically significant (H1 and H6 are not supported by the results). Results show the significant and positive effect of Smart governance on Perception of fellow students (0.141), Positive attitude towards university management (0.621) and Perceived External Prestige (0.164) – H7, H8, and H9 are thus supported. The highest effect is on Positive attitude towards university management, which is significant at level $p > 0.001$. Furthermore, the effect of Positive attitude towards university management on Perceived External Prestige (0.463), as well as on the Perception of fellow students (0.696), is high and significant ($p < 0.001$) – H4 and H2 are also supported. In addition, the effect of the Perception of fellow residents (0.355) and Perceived External Prestige (0.270) on Students' university commitment are moderate

and significant ($p < 0.001$) – H3 and H5 are also supported. On the contrary, the effect of the Positive attitude towards university management on Students' university commitment, with a path coefficient of 0.03 is low, and has no significant effect, the same as the path from Smart governance to Students' university commitment (0.121). Results of the structural model analysis by Udir Mišič and Podnar [9] showed very similar results regarding the path leading from Perception of city management to Citizens' commitment, i.e. the path coefficient was also low and not significant for both cities.

In brief, the results demonstrate that the Perception of fellow students and Perceived External Prestige mediate the correlation between constructs Smart governance and Students' university commitment. Both Perceived External Prestige and the Perception of fellow students are significant drivers of Students' university commitment. Positive attitude towards university management had a significant effect on Perceived External Prestige and Perception of fellow students but, surprisingly, had no significant direct effect on Students' university commitment.

Squared Multiple Correlation is the communality estimate for an indicator variable. The estimated value measures the percent of the variance in a given indicator variable explained by its latent variable (factor); the results are shown in Table 7.

Construct	Estimate
PUMANG	0.377
PEP	0.336
PFellSt	0.627
SUCOM	0.412

Table 7. Squared Multiple Correlations

Figure 2 illustrates the validated research model with path coefficients and the significance of each relationship (* $p < 0.05$; ** $p < 0.001$). The model also includes calculated variances R² (from table 7) for each independent variable.

5. Discussion

This study aimed to examine the antecedents of students' university commitment. Specifically, the intention was to explore the level and the relation of one smart university feature – smart governance to the Positive attitude towards university management, Perception of fellow students, and Perceived External Prestige (PEP) as antecedents of university affective commitment. To the best of our knowledge, a study focusing on these constructs and in this form has not been conducted in the university context. The survey was conducted at the University of Split, the second biggest university in Croatia, composed of eleven faculties, one academy of arts and four university departments.

The study confirmed that, in the given context, Smart governance has positive effects on students' perceptions (Perception of fellow students, Positive attitude

towards university management and Perceived External Prestige). Smart governance is characterized by openness, transparency, participation and collaboration [41].

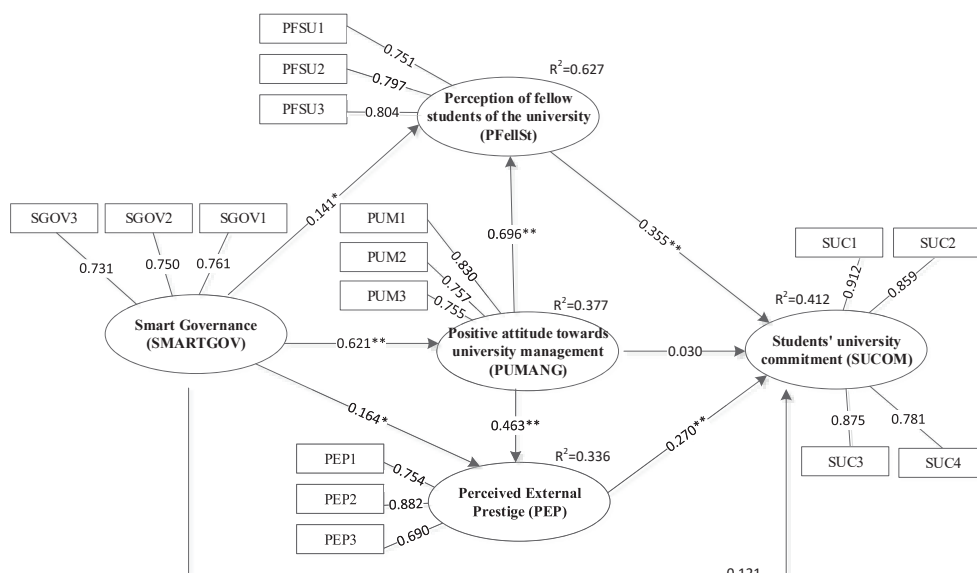


Figure 2. Validated final structural model

The strongest impact is on the Positive attitude towards university management (0.621), reflecting its importance. It is not enough only to use the technology that makes universities smart, but the universities also have to manage and facilitate the creation of smart human social capital and support innovative investments fostering synergies between teaching and research [2]. The same authors acknowledge that the smart university also has less bureaucracy [2], which would surely have a positive impact on students nowadays. Even though previous studies have demonstrated that the level of students' commitment rises when students have more opportunities and when they feel like they have become relevant stakeholders [12]), the results from this study surprisingly show a weak correlation between Smart governance and Students' university commitment. Smart governance does, however, have an indirect impact on Students' university commitment through the Perception of fellow students and Perceived External Prestige. The results are consistent with the theoretical background when explaining the link between the Perception of fellow students and Students' university commitment similar to studies that demonstrate that the opinion of close people influences the decision to maintain the relationship and stay affiliated to the university [29], [16], [30]. Positive and significant effect of Perceived External Prestige on Students' university commitment was expected in line with other studies that indicate that the external prestige leads to individuals' affective commitment [38, 34]. This would mean that students who believe that individuals from outside the university have reasonable opinion about it would develop affective commitment.

In relying on first-year students' feedback when they state, "I wish to continue to study at this university because I enjoy it" or "University management includes and takes into account various disciplines regarding the development of the university", one has to be cautious. It comes as no surprise that the strongest relationship is observed between the Positive attitude towards university management and the Perception of fellow students (0.696) since students form a strong opinion based on their experience (not just from the university but also from school). In that context, it is not surprising that the correlation between the Positive attitude towards university management and Students' university commitment is low and not significant, leaving the gap for future research: more focus has to be put on examining that relationship to see whether any other constructs could contribute to the explanation. University management considers a lot of aspects in order to improve efficiency, increase education quality and satisfy the needs of students, and as a result, it has an impact on student's attitudes towards the university as well as on how prestigious the organization is in the eyes of external individuals. If university management works well, it manifests to both Perception of fellow students (they will be satisfied) and Perceived External Prestige (outside individuals would have a good opinion about the university due to, for example, good university rankings or accreditations and similar). University outputs are the results of university management.

The limitation of this study is that the participants were limited to first-year students. There are plans to survey students from senior years to see how years of study affect their opinions. Also, gender imbalance among participants represents a limitation; however, these results are consistent with the institutional enrolment data. For future research, it would also be interesting to conduct this same study in other universities in Croatia and other European universities and compare the results. Due to the aforementioned limitations, one could not generalize the results without caution.

6. Conclusion

By addressing the relationships across selected constructs, this quantitative research contributes to growing research on smart universities. This paper seeks to contribute an understanding of how university management, using smart technologies, can increase university commitment and students' perceptions. Results showed that Smart governance has a positive impact on the Perception of fellow students of the university, Positive attitude towards university management and Perceived External Prestige. Smart governance also has an indirect impact on Students' university commitment (through Perception of fellow students and Perceived External prestige). Results also confirm that a Positive attitude towards university management positively correlates with Perceived External Prestige and Perception of fellow students of the university. Both Perceived External Prestige and the Perception of fellow students also have a positive impact on Students' university commitment. However, the relationship between a Positive attitude towards university management and Students' university commitment is not significant, so a Positive attitude towards university management influences affective commitment only through the aforementioned constructs. Smart governance has a highly positive and significant effect on students'

perceptions, meaning that interaction, transparency, and inclusion in the decision-making processes and taking into consideration all stakeholders in resource management can be vital for improving students' experiences. Improving experiences for students and staff is one of the reasons why universities tend to become smart [8]. The practical implication of this study would be that finding antecedents of university commitment would help universities to achieve one of their main goals – attract and retain the best students and staff from around the globe [7]. In the process, the issues that universities need to study in-depth are how to use available technologies, improve user experience, optimize teaching methods, and improve teaching efficiency and effectiveness [24]. The role of University management cannot be neglected. For example, there is a lot to improve: introduce frequent and transparent communication on university achievements, projects, and other outputs and more.

Acknowledgements

This research was supported by the Croatian Science Foundation [grant number UIP-2017-05-7625].

References

- [1] E. Smyrnova-Trybulska (ed.), *“E-learning and Smart Learning Environment for the Preparation of New Generation Specialists”*. Seria on E-learning. Katowice-Cieszyn. Vol. 10. 2018.
- [2] M. Coccoli, A. Guercio, P. Maresca, and L. Stanganelli, “Smarter universities: A vision for the fast changing digital era,” *J. Vis. Lang. Comput.*, vol. 25, no. 6, pp. 1003–1011, 2014.
- [3] M. Coccoli, P. Maresca, L. Stanganelli, and A. Guercio, “An experience of collaboration using a PaaS for the smarter university model,” *J. Vis. Lang. Comput.*, vol. 31, pp. 275–282, 2015.
- [4] Ministarstvo, znanosti obrazovanja i sporta, “Strategija obrazovanja, znanosti i tehnologije,” MZOS, Zagreb, Croatia, Oct. 2014.
- [5] Sveučilište u Splitu, “Strategija 2015-2020,” Split, Croatia, Oct. 2015.
- [6] M. Jadrić and M. Čukušić, “Constructing and testing instruments for measuring students' perceptions of a university and its smart dimensions” in for 49th International Scientific Conference on Economic and Social Development “Building Resilient Society”, 2019, pp. 13-14
- [7] O. Akhrif, Y. E. B. El Idrissi, and N. Hmina, “Smart university: SOC-based study,” in *ACM International Conference Proceeding Series*, 2018.
- [8] T. Sutjarittham, H. H. Gharakheili, S. S. Kanhere, and V. Sivaraman, “Realizing a Smart University Campus: Vision, Architecture, and

- Implementation,” *Int. Symp. Adv. Networks Telecommun. Syst. ANTS*, vol. 2018-Decem, 2019.
- [9] K. Udir Mišič and K. Podnar, “Perception of city management, fellow residents, and Perceived External Prestige (PEP) as antecedents of city affective commitment - The city marketing perspective”, *Cities*, vol. 84, pp. 66-74, 2019.
- [10] R. Giffinger, C. Fertner, H. Kramar, R. Kalasek, N. Pichler-Milanovic and E. Meijers, *Smart Cities - Ranking of European medium-sized cities*, Vienna University of Technology, 2007.
- [11] L. C. Strauss and J. F. Volkwein, “Predictors of Student Commitment at Two-Year and Four-Year Institutions,” *J. Higher Educ.*, vol. 75, no. 2, 2004.
- [12] Y. Chen, “The relationships between brand association, trust, commitment, and satisfaction of higher education institutions”, *International Journal of Educational Management*, vol. 31(7), pp. 973-985, 2017.
- [13] B. Nguyen, X. Yu, T. C. Melewar, and J. Hemsley-Brown, “Brand ambidexterity and commitment in higher education: An exploratory study,” *J. Bus. Res.*, vol. 69, no. 8, pp. 3105–3112, 2016.
- [14] M. Jadric, Ž. Garača and M. Ćukušić, “Student dropout analysis with application of data mining methods,” *Management*, vol. 15, no. 1, pp. 31-46, 2010.
- [15] A. Japutra, K. Keni, and B. Nguyen, “What’s in a university logo? Building commitment in higher education,” *J. Brand Manag.*, vol. 23, no. 2, pp. 137–152, 2016.
- [16] F. Cownie, ““What drives students’ affective commitment towards their university?”,” *J. Furth. High. Educ.*, vol. 43, no. 5, pp. 674–691, 2019.
- [17] V. Tinto, “Dropout from higher education: a theoretical synthesis of recent research”, *Review of Educational Research*, vol. 45(1), pp. 89-125, 1975.
- [18] K. G. Love and A. P. Stemer, “Commitment to the University as Defined by the Allen and Meyer Model: Student-Athlete Versus Nonstudent-Athlete Differences,” *J. Coll. Student Retent. Res. Theory Pract.*, p. 152102511987988, 2019.
- [19] Y. Barlas and V. G. Diker, “A dynamic simulation game (UNIGAME) for strategic university management,” *Simul. Gaming*, vol. 31, no. 3, pp. 331–358, 2000.
- [20] I. Chiyón, M. Palma, and A. Cazorla, “An approach of the European Higher Education Framework to the management of higher education at university level in Peru,” *Procedia - Soc. Behav. Sci.*, vol. 15, pp. 586–591, 2011.

- [21] N. Aion, L. Helmandollar, M. Wang, and J. W. P. Ng, "Intelligent campus (iCampus) impact study" in *Proc. 2012 IEEE/WIC/ACM Int. Conf. Web Intell. Intell. Agent Technol. Work. WI-IAT 2012*, pp. 291–295, 2012.
- [22] Du, F. Meng, and B. Gao, "Research on the application system of smart campus in the context of smart city," in *Proceedings - 2016 8th International Conference on Information Technology in Medicine and Education, ITME 2016*, 2017, pp. 714–718.
- [23] W. Muhamad, N. B. Kurniawan, S. Suhardi, and S. Yazid, "Smart campus features, technologies, and applications: A systematic literature review" in *2017 Int. Conf. Inf. Technol. Syst. Innov. ICITSI 2017 - Proc.*, vol. 2018-Janua, no. October, pp. 384–391, 2018.
- [24] M. Xiaocui, L. Peng, and W. Chumin, "Discussion on the Construction of College Smart Campus under the Background of Mobile Internet," *no. Icamei*, pp. 24–29, 2019.
- [25] B. Valks, M. Arkesteijn, and A. Den Heijer, "Smart campus tools 2.0 exploring the use of real-time space use measurement at universities and organizations," *Facilities*, vol. ahead-of-p, no. ahead-of-print, 2019.
- [26] N. Abishov, D. Asan, A. Kanat, and Z. Erkisheva, "Development of an Automated Information System University Management," *Procedia - Soc. Behav. Sci.*, vol. 143, pp. 550–554, 2014.
- [27] J. R. Hackman and W. S. Dysinger, "Commitment to College as a Factor in Student Attrition," *Sociol. Educ.*, vol. 43, no. 3, p. 311, 1970.
- [28] M. McGrath and A. Braunstein, "The prediction of freshmen attrition: an examination of the importance of certain demographic, academic, financial and social factors", *College Student Journal*, vol. 31(2), pp. 396–408, 1997.
- [29] R. Bennett, "Determinants of Undergraduate Student Drop Out Rates in a University Business Studies Department," *J. Furth. High. Educ.*, vol. 27, no. 2, pp. 123–141, 2003.
- [30] V. Tinto, *Leaving College: rethinking the causes and cures of student attrition*,. Chicago, 1993.
- [31] F. Nawaz, S. Shakeel, Z. Nawaz, and M. A. Hamza, "Acceptance of social fellow groups for learning: extension of technology assessment model (TAM)," vol. 13, no. 2, pp. 151–157, 2017.
- [32] C. S. Areni, M. E. Ferrell, and J. B. Wilcox, "The persuasive impact of reported group opinions on individuals low vs. High in need for cognition: Rationalization vs. Biased elaboration?," *Psychol. Mark.*, vol. 17, no. 10, pp. 855–875, 2000.

-
- [33] C. Marsh, "Back on the bandwagon: The effect of opinion polls on public opinion", *Journal of Political Science*, vol. 15(1), pp. 51-74, 1984.
- [34] A. Smidts, A. T. H. Pruyn, and C. B. M. Van Riel, "The impact of employee communication and perceived external prestige on organizational identification," *Acad. Manag. J.*, vol. 44, no. 5, pp. 1051–1062, 2001.
- [35] J. B. Fuller, K. Hester, T. Barnett, L. Frey, C. Relyea, and D. Beu, "Perceived external prestige and internal respect: New insights into the organizational identification process," *Hum. Relations*, vol. 59, no. 6, pp. 815–846, 2006.
- [36] A. Smidts, A. T. H. Pruyn, and C. B. M. Van Riel, "The Impact of Employee Communication and Perceived External Prestige on Organizational Identification" *Acad. Manag. J.*, vol. 44, no. 5, pp. 1051–1062, 2016.
- [37] M. Sung and S.-U. Yang, "Toward the Model of University Image: The Influence of Brand Personality, External Prestige, and Reputation," *J. Public Relations Res.*, vol. 20, no. 4, pp. 357–376, 2008.
- [38] S. K. Mishra, D. Bhatnagar, P. D'Cruz, and E. Noronha, "Linkage between perceived external prestige and emotional labor: Mediation effect of organizational identification among pharmaceutical representatives in India," *J. World Bus.*, vol. 47, no. 2, pp. 204–212, 2012.
- [39] R. G. Alonso and S. Lippez-De Castro, "Technology helps, people make: A smart city governance framework grounded in deliberative democracy" in *Smarter as the new Urban Agenda*, J. R. Gil-Garcia, T. A. Pardo, and T. Nam (Eds.), pp. 333-347. Springer International., 2016.
- [40] G. Viale Pereira, M. A. Cunha, T. J. Lampoltshammer, P. Parycek, and M. G. Testa, "Increasing collaboration and participation in smart city governance: a cross-case analysis of smart city initiatives," *Inf. Technol. Dev.*, vol. 23, no. 3, pp. 526–553, 2017.
- [41] H. J. Scholl and M. C. Scholl, "Smart Governance: A Roadmap for Research and Practice," *iConference 2014 Proc.*, no. 1, 2014.
- [42] S. Alawadhi and H. J. Scholl, "Smart governance: A cross-case analysis of smart city initiatives," *Proc. Annu. Hawaii Int. Conf. Syst. Sci.*, vol. 2016-March, no. January, pp. 2953–2963, 2016.
- [43] M. Azzari, C. Garau, P. Nesi, M. Paolucci, and P. Zamperlin, "Smart city governance strategies to better move towards a smart urbanism," *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 10962 LNCS, pp. 639–653, 2018.
-

- [44] W. Tamrat, "The exigencies of student participation in university governance: Lip services and bottlenecks," *High. Educ. Q.*, no. March, pp. 1–13, 2019.
- [45] C. Bassano, A. Carotenuto, M. Ferretti, Ma. C. Pietronudo, and H. E. Coskun, *Smart University for Sustainable Governance in Smart Local Service Systems*, vol. 787. Springer International Publishing, 2019.
- [46] A. Halmi, *Multivarijantna analiza u društvenim znanostima*. Zagreb: Alineja, 2003.
- [47] R. Ho, *Handbook of univariate and multivariate data analysis and interpretation with SPSS*, Taylor & Francis Group, Chapman & Hall/CRC, Boca Raton, 2006.
- [48] J.F. Hair, G. T. M. Hult, C.M. Ringle and M. Sarstedt, *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*. 2nd Ed. Thousand Oaks, CA: Sage. 2017.
- [49] J. F. Hair, W.C. Black, B.J. Babin, B.J. and R.E. Anderson, *Multivariate Data Analysis*, Pearson Prentice Hall, 2010.
- [50] R.M. Felder and J. Spurlin, "Application, Reliability and Validity of the Index of Learning Styles", *International Journal of Engineering Education*, vol. 21(1), pp. 103-112, 2005.
- [51] R.B Kline, *Principles and practice of structural equation modelling*. Guilford Publications, New York, 2015.
- [52] G. Shiral, M. Shekari and K.A. Angali, "Assessing Reliability and Validity of an Instrument for Measuring Resilience Safety Culture in Sociotechnical Systems", *Safety and Health at Work*, vol. 9(3), pp. 296-307, 2018.
- [53] N.P. Rana, Y.K. Dwivedi, B. Lal, M.D. Williams and M. Clement, "Citizens' adoption of an electronic government system: towards a unified view", *Information Systems Frontiers*, vol. 19., pp. 549-568, 2017.
- [54] C. Fornell and D.F. Larcker, "Evaluating structural equation models with unobservable variables and measurement error", *Journal of Marketing Research*, vol. 18(1), pp. 39–50, 1981.



Queueing Systems with Random Volume Customers and their Performance Characteristics

Oleg Tikhonenko

o.tikhonenko@uksw.edu.pl

Institute of Computer Science

*Cardinal Stefan Wyszyński University in Warsaw,
Warsaw, Poland*

Marcin Ziolkowski

marcin_ziolkowski@sggw.pl

Institute of Information Technology

*Warsaw University of Life Sciences – SGGW,
Warsaw, Poland*

Abstract

In the paper, we consider non-classical queueing systems with non-homogeneous customers. The non-homogeneity we treat in the following sense: in systems under consideration, we characterize each customer by random capacity (volume) that can have an influence on his service time. We analyze a stochastic process having the sense of the total volume of all customers present in the system at given time instant. Such analysis for different queueing systems with unlimited or limited total volume can be used in designing of nodes of computer and communication networks while determining their buffer space capacity. We discuss basic problems of the theory of these systems and their performance characteristics. We also present some examples and results for systems with random volume customers.

Keywords: customer's volume, buffer space capacity, total volume, loss probability, volume unit loss probability, Laplace-Stieltjes transform

1. Introduction

Classical queueing theory was created by Danish engineer and scientist A.K. Erlang in the early years of 20th century. Its first mathematical models were used in designing of telephone networks. Now, they are known as $M/M/n/0$ or Erlang systems. Nowadays, queueing theory contains a set of developed mathematical tools that are widely used as mathematical models of many real objects, such as markets, communication and computer networks, airport traffic, Internet etc. (see e.g. [1], [2], [3], [4], [5]).

Classical queueing models are often used for determination of communication networks' nodes characteristics [6], [7], [8], [9]. One of the most important of them is loss probability or probability of message's losing that depends on messages' arrival process characteristics, buffer space capacity of the node and distributions of message's volume and its service time.

Let $\eta(t)$ be the number of customers present in a system under consideration at time instant t . It is known that, in classical queueing theory, the determination of almost all performance characteristics comes to analysis of a stochastic process $\eta(t)$. But such analysis becomes insufficient, if we want e.g. to determine buffer space capacity of a communication network's node that guarantees small losses of information transmitted in the network. The causes of this fact are the following: 1) different messages (customers) in a network consist, as a rule, of different numbers of bytes, in other words, they have different volumes; 2) service time of a customer can be dependent on his volume; 3) the total (summarized) volume of customers present in the system is limited by some buffer capacity. The factors 1–3 are not be able taken into consideration in classical queueing theory.

To overcome appeared difficulties, we have to introduce the following assumptions: 1) each customer in the system is characterized by random volume ζ , where ζ is a non-negative random variable (RV); 2) service time ξ of a customer can depend on his volume, generally, this dependence can be defined by a joint distribution function (DF)

$$F(x, t) = \mathbf{P}\{\zeta < x, \xi < t\}. \quad (1)$$

Let $\sigma(t)$ be the total volume, i.e. the sum of volumes of all customers present in the system at time instant t . The process $\sigma(t)$ is a generalization of $\eta(t)$ one. Indeed, their values are the same, if $\zeta \equiv 1$. It is clear that changing epochs of both these processes are the same, because their values change at epochs of customers arriving to the system and customers service termination. But it is clear that an analysis of the process $\sigma(t)$ is more complicated, because, at an epoch of service termination, each customer takes away from the buffer the same volume that he brings to it at an arrival epoch. For the process $\eta(t)$, these values are equal 1 and -1 , respectively. We assume that volumes of different customers are independent and do not depend on the customers' arriving epochs.

Note that, from relation (1), we obtain the following formulae for DFs $L(x)$ and $B(t)$ of RVs ζ and ξ , respectively:

$$L(x) = \mathbf{P}\{\zeta < x\} = \lim_{t \rightarrow \infty} F(x, t) = F(x, \infty), B(t) = \mathbf{P}\{\xi < t\} = \lim_{x \rightarrow \infty} F(x, t) = F(\infty, t).$$

In queueing models of real systems, the total volume is usually limited by constant value $V > 0$ that is called buffer space capacity of the system. Below, we assume that inequality $0 \leq \sigma(t) \leq V$ holds (the case of $V = \infty$ is also possible for some models). We also assume that buffer space is occupied by a customer at an epoch he arrives and is released entirely at an epoch he completes service. If the value V is finite, it leads to additional losses of customers. A customer of volume x , which arrives at epoch τ when there are idle servers or waiting positions in the queue, will be admitted to the system, if $\sigma(\tau - 0) + x \leq V$, where $\sigma(\tau - 0)$ is the left-sided limit of the process $\sigma(t)$ at the point of τ . In other words, if τ is an arriving epoch, then $\sigma(\tau - 0)$ is the number of customers present in the system just before τ . Otherwise (if $\sigma(\tau - 0) + x > V$), the customer will be lost. In the first case, we have

$$\eta(\tau) = \eta(\tau - 0) + 1, \sigma(\tau) = \sigma(\tau - 0) + x,$$

where $\eta(\tau - 0)$ is the left-sided limit of the process $\eta(t)$ at the point of τ . In the second case, we obtain:

$$\eta(\tau) = \eta(\tau - 0), \sigma(\tau) = \sigma(\tau - 0).$$

If t is an epoch of service termination of a customer having volume x , we obtain

$$\eta(t) = \eta(t - 0) - 1, \sigma(t) = \sigma(t - 0) - x.$$

2. Classification of Models

Consider firstly a classical queueing system of $GI/G/n/m$ ($1 \leq n \leq \infty, 0 \leq m \leq \infty$) type in Kendall's notation (see e.g. [2]). This system with identical servers $S_1, \dots, S_n$ is shown schematically in Fig. 1.

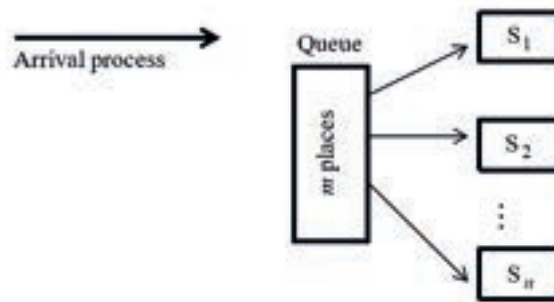


Fig. 1. Classical queueing system $GI/G/n/m$

Denote by $GI/G/n/(m, V)$ a similar system with random volume customers and limited by value V ($V \leq \infty$) total volume. It is shown in Fig. 2.

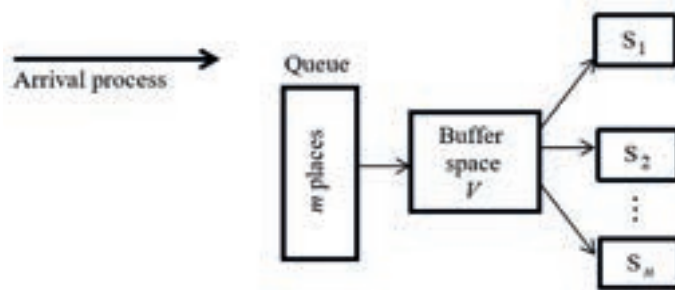


Fig. 2. Queueing system $GI/G/n/(m, V)$ with random volume customers

It is clear that the system shown in Fig. 2 generally differs from classical one, because its loss characteristics at some arrival epoch depend on the volume of arriving customer and the total volume of other customers present in the system at this time. Indeed, compare mechanisms of customers' losing in both systems under assumption that there are no other limitations except those shown in Fig. 1 and Fig. 2.

In both systems, a customer is lost, if, at the epoch τ of his arrival, there are $n + m$ other customers in each of them ($\eta(\tau - 0) = n + m$). In the system $GI/G/n/(m, V)$,

a customer having volume x is lost not only if $\eta(\tau - 0) = n + m$, but also if $\sigma(\tau - 0) + x > V$. It means that an admission or losing of a customer partly or completely depends on his volume and total volume of other customers present in the system.

Classification of models of systems with random volume customers is determined by the type of RVs ζ and ξ dependence and the value V . Then, we can distinguish four following classes of these models: 1) models with $V = \infty$ and independent RVs ζ and ξ ($F(x, t) = L(x)B(t)$); 2) models with $V < \infty$ and independent RVs ζ and ξ ; 3) models with $V = \infty$ and dependent RVs ζ and ξ ($F(x, t) \neq L(x)B(t)$); 4) models with $V < \infty$ and dependent RVs ζ and ξ .

Note that an analysis of models of the first class can be carried out by tools of classical queueing theory.

Consider e.g. a steady-state queueing system $M/G/1/\infty$. Let $L(x)$ be DF of customer's volume ζ , and service time ξ of a customer does not depend on his volume. Denote by $B(t)$ DF of RV ξ and by $\beta(q) = \int_0^\infty e^{-qt} dB(t)$ Laplace-Stieltjes transform (LST) of this DF. Let a and β_1 be parameters of the arrival process and the mean service time of a customer, respectively, then we have $\rho = a\beta_1 < 1$.

It is clear that, in the system under consideration, a distribution of number of customers η present in the system in steady state does not depend on their volumes. Introduce the notation $p_k = \mathbf{P}\{\eta = k\}$. Let $P(z) = \sum_{k=0}^\infty p_k z^k$, $|z| < 1$, be generating function of number of customers present in the system. Then, the Pollaczek-Khinchine formula takes place (see e.g. [1]):

$$P(z) = \frac{(1 - \rho)(1 - z)\beta(a - az)}{\beta(a - az) - z}.$$

Denote by $D(x)$ DF of the total steady-state customers' volume σ . From the fact that volumes of customers are independent and their service times do not depend on their volumes, we obtain the following relations: $\mathbf{P}\{\sigma < x | \eta = k\} = L_*^{(k)}(x)$, where $L_*^{(k)}(x)$ is k -fold Stieltjes convolution of DF $L(x)$, i.e. $L_*^{(1)}(x) = L(x)$, $L_*^{(k)}(x) = \int_0^x L_*^{(k-1)}(x - u) dL(u)$ for $k = 2, 3, \dots$, and $\mathbf{P}\{\sigma = 0\} = p_0 = 1 - \rho$. Then, for DF $D(x)$, we obtain

$$D(x) = p_0 + \sum_{k=1}^\infty p_k \mathbf{P}\{\sigma < x | \eta = k\} = p_0 + \sum_{k=1}^\infty p_k L_*^{(k)}(x).$$

Passing to LST with respect to x in the last relation, we have:

$$\begin{aligned} \delta(s) &= \int_0^\infty e^{-sx} dD(x) = \sum_{k=0}^\infty p_k (\varphi(s))^k = P(\varphi(s)) = \\ &= \frac{(1 - \rho)(1 - \varphi(s))\beta(a - a\varphi(s))}{\beta(a - a\varphi(s)) - \varphi(s)}, \end{aligned} \quad (2)$$

where $\delta(s)$ and $\varphi(s)$ denote LSTs of DFs $D(x)$ and $L(x)$, respectively. I.e. we obtain in this case that a distribution of steady-state total volume σ is completely determined

by distribution of number of customers present in the system η and DF $L(x)$ of customer's volume.

The main characteristics of models from classes 2 and 4 are the distribution of number of customers present in the system at arbitrary time instant or in steady state and some loss characteristics (e.g. steady-state loss probability).

For systems belonging to class 2, we can often use tools of classical queueing theory. Indeed, let $q_k, k = \overline{0, n+m}$, be steady-state probability that k customers present in the classical system $M/G/n/m, n = 1, 2, \dots; m = 0, 1, \dots$. Let $M/G/n/(m, V)$ be a system from class 2 that differs from the classical $M/G/n/m$ system in the following details: 1) each customer is characterized by random volume with DF $L(x)$; 2) the total customers' volume is limited by buffer space capacity $V < \infty$. Assume that DFs of service time for both systems are the same. It was proved (see [14], [15]) that steady-state probabilities p_k of presence of k customers in the system $M/G/n/(m, V)$ can be determined by the following relation: $p_k = C q_k L_*^{(k)}(V), k = \overline{1, n+m}$, where C can be calculated from the normalization condition: $C = \left[\sum_{k=0}^{n+m} q_k L_*^{(k)}(V) \right]^{-1}$. Note that this relation takes place also if $m = \infty$, when steady state exists for the classical system.

The main characteristic of models from class 3 is the distribution of total volume at arbitrary time instant or in steady state. Various models of queueing systems with random volume customers can be found in [10], [11], [12], [13].

3. Simple Examples of Systems with Random Volume Customers

3.1. System $M/M/n/(\infty, V)$ with independent customer's volume and service time.

For this system, we assume that service time does not depend on customer's volume and has an exponential distribution with parameter $\mu > 0$, i.e. $B(t) = 1 - e^{-\mu t}, t > 0$. The system was firstly analyzed in [10]. Let $L(x)$ be DF of customer's volume. Denote by η and σ the number of customers present in the system in steady state and their total volume, respectively. Let a be parameter of the arrival process. For this system were obtained the functions $g_k(x) = \mathbf{P}\{\eta = k, \sigma < x\}, k = 1, 2, \dots, x \in [0; V]$:

$$g_k(x) = \begin{cases} \frac{(n\rho)^k}{k!} p_0 L_*^{(k)}(x), & \text{if } k = \overline{1, n}, \\ \frac{n^n \rho^k}{n!} p_0 L_*^{(k)}(x), & \text{if } k = n+1, n+2, \dots, \end{cases}$$

where $p_0 = \mathbf{P}\{\eta = 0\}, \rho = a/(n\mu)$.

Then, we can easily obtain the following relations for probabilities $p_k = \mathbf{P}\{\eta = k\} = g_k(V)$:

$$p_k = \begin{cases} \frac{(n\rho)^k}{k!} p_0 L_*^{(k)}(V), & \text{if } k = \overline{1, n}, \\ \frac{n^n \rho^k}{n!} p_0 L_*^{(k)}(V), & \text{if } k = n+1, n+2, \dots, \end{cases}$$

where p_0 can be determined from the normalization condition as:

$$p_0 = \left[A_n(V) + \frac{n^n}{n!} B_n(V) \right]^{-1},$$

where

$$A_n(x) = \sum_{k=0}^n \frac{(n\rho)^k}{k!} L_*^{(k)}(x), \quad B_n(x) = \sum_{k=n+1}^{\infty} \rho^k L_*^{(k)}(x).$$

Loss probability P_{loss} for this system is determined by the following relation [10]:

$$P_{\text{loss}} = 1 - (n\rho)^{-1} \sum_{k=1}^{n-1} k p_k - \rho^{-1} \left(1 - \sum_{k=0}^{n-1} p_k \right). \quad (3)$$

Now, we can easily obtain DF $D_V(x)$ of the total volume σ :

$$D_V(x) = p_0 + \sum_{k=1}^{\infty} g_k(x) = p_0 \left[A_n(x) + \frac{n^n}{n!} B_n(x) \right], \quad x \in [0; V]. \quad (4)$$

Let us consider a special case of the system when customer's volume is distributed exponentially: $L(x) = 1 - e^{-fx}$, $f > 0$, $x > 0$. Then, we have

$$A_n(x) = \sum_{k=0}^n \frac{(n\rho)^k}{k!} \left[1 - e^{-fx} \sum_{i=0}^{k-1} \frac{(fx)^i}{i!} \right],$$

$$B_n(x) = \sum_{k=n+1}^{\infty} \rho^k \left[1 - e^{-fx} \sum_{i=0}^{k-1} \frac{(fx)^i}{i!} \right].$$

After some transformations, we can present the relation for $B_n(x)$ in the form that does not contain infinite sums:

$$B_n(x) = \frac{\rho^{n+1}}{1-\rho} \left[1 - e^{-fx} \sum_{i=0}^n \frac{(fx)^i}{i!} \right] - \frac{\rho}{1-\rho} \left[e^{-(1-\rho)fx} - e^{-fx} \sum_{i=0}^n \frac{(\rho fx)^i}{i!} \right].$$

In the case of one-server system ($n = 1$), we obtain (see [13]):

$$p_0 = \begin{cases} \frac{1-\rho}{1-\rho e^{-(1-\rho)fV}}, & \text{if } \rho \neq 1, \\ (1+fV)^{-1}, & \text{if } \rho = 1; \end{cases} \quad (5)$$

$$P_{\text{loss}} = \begin{cases} \frac{1-\rho}{e^{(1-\rho)fV} - \rho}, & \text{if } \rho \neq 1, \\ (1+fV)^{-1}, & \text{if } \rho = 1; \end{cases} \quad (6)$$

$$D_V(x) = \begin{cases} \frac{1-\rho e^{-(1-\rho)fx}}{1-\rho e^{-(1-\rho)fV}}, & \text{if } x \in [0; V], \text{ for } \rho \neq 1; \\ 1, & \text{if } x > V, \end{cases}$$

$$D_V(x) = \begin{cases} \frac{1+fx}{1+fV}, & \text{if } x \in [0; V], \text{ for } \rho = 1. \\ 1, & \text{if } x > V \end{cases}$$

3.2. System $M/G/1/\infty$ with unlimited buffer space and service time generally dependent on customer's volume

Denote by $F(x, t)$ a joint DF of customer's volume ζ and his service time ξ . Let $\alpha(s, q) = \int_0^\infty \int_0^\infty e^{-sx-qt} dF(x, t)$ be double LST of DF $F(x, t)$. Then, $\varphi(s) = \alpha(s, 0) = \int_0^\infty e^{-sx} dL(x)$ and $\beta(q) = \alpha(0, q) = \int_0^\infty e^{-qt} dB(t)$ are LSTs of DFs $L(x)$ and $B(t)$, respectively. Let $\beta_1 = \mathbf{E}\xi$ be the mean value of service time. Assume that $\rho = a\beta_1 < 1$, where a is parameter of arrival process. Then, for the system under consideration, finite steady-state characteristics exist. E.g. we have $\sigma(t) \Rightarrow \sigma$ and $\eta(t) \Rightarrow \eta$ in the sense of a weak convergence, where σ and η are the steady-state total customers' volume and number of customers in the system, respectively. Let $D(x)$ be DF of RV σ . Denote by $\delta(s)$ its LST. Then, we obtain [10], [11], [12], [13]:

$$\delta(s) = \int_0^\infty e^{-sx} dD(x) = \frac{(1-\rho)[\beta(a-a\varphi(s)) - \alpha(s, a-a\varphi(s))]}{\beta(a-a\varphi(s)) - \varphi(s)}. \quad (7)$$

Note that, in the case of independent RVs ζ and ξ ($F(x, t) = L(x)B(t)$, $\alpha(s, q) = \varphi(s)\beta(q)$), relation (2) follows from (7).

Using relation (7), we can calculate moments of RV σ (if they exist). For the first and second ones, we have [12], [13]:

$$\begin{aligned} \delta_1 &= E\sigma = -\delta'(0) = a\alpha_{11} + \frac{a^2\beta_2\varphi_1}{2(1-\rho)}, \\ \delta_2 &= \mathbf{E}\sigma^2 = \delta''(0) = \\ &= a(\alpha_{21} + a\varphi_1\alpha_{12}) + \frac{a^3\beta_2\varphi_1\alpha_{11}}{1-\rho} + \frac{a^2\beta_2\varphi_2}{2(1-\rho)} + \frac{a^3\beta_3\varphi_1^2}{3(1-\rho)} + \frac{a^4\beta_2^2\varphi_1^2}{2(1-\rho)^2}, \end{aligned}$$

where φ_i, β_i are the i th moments of RVs ζ and ξ , respectively, $i = 1, 2, \dots$, α_{ij} is the mixed $(i+j)$ th moment of the random vector (ζ, ξ) , $i, j = 1, 2, \dots$

Assume e.g. that customer's volume ζ has an exponential distribution with parameter f , and service time of the customer is proportional to his volume ($\xi = c\zeta, c > 0$). In this case, we can determine an explicit form of DF $D(x)$ [13]:

$$\begin{aligned} D(x) &= 1 + \frac{\rho^2 e^{-(1-\rho)fx}}{1-2\rho} - \frac{\rho(1-\rho)}{\sqrt{\rho(4+\rho)}} \left(\frac{1-b_1}{1-b_1-\rho} e^{-b_1fx} - \frac{1-b_2}{1-b_2-\rho} e^{-b_2fx} \right), \text{ if } \rho \neq 1/2, \\ D(x) &= 1 + \frac{1}{9} e^{-2fx} - \frac{1}{3} \left(\frac{11}{6} + \frac{fx}{4} \right) e^{-fx/2}, \text{ if } \rho = 1/2, \end{aligned} \quad (8)$$

where $\rho = ac/f$,

$$b_1 = \frac{2+\rho-\sqrt{\rho(4+\rho)}}{2}, b_2 = \frac{2+\rho+\sqrt{\rho(4+\rho)}}{2}. \quad (9)$$

Note that, in the case of independent RVs ζ and ξ when they have exponential distributions with DFs $L(x) = 1 - e^{-fx}$ and $B(t) = 1 - e^{-\mu t}$, respectively, we have:

$$D(x) = 1 - \rho e^{-(1-\rho)fx}, \quad (10)$$

where $\rho = a/\mu$.

Note that, in the case of exponential distribution of RV ζ and the same dependence between ζ and ξ ($\xi = c\zeta$), we can also determine an explicit form of $D(x)$ for the system $M/M/n/m$ with unlimited buffer space, $n = 1, 2, \dots, m = 0, 1, \dots$ [16]. E.g. for $n = 2, m = \infty, \rho = ac/(2f) < 1$, we obtain:

$$D(x) = 1 + \frac{2\rho e^{-(1-\rho)fx}}{(1-\rho)(1-2\rho)} - \frac{2\rho^2 p_0}{\sqrt{\rho(4+\rho)}} \times \left[\frac{1-b_1}{(1-b_1)(1-b_1-\rho)} e^{-b_1 fx} - \frac{1-b_2}{(1-b_2)(1-b_2-\rho)} e^{-b_2 fx} \right],$$

if $\rho \neq 1/2$, and

$$D(x) = 1 - \frac{2}{27} [(3fx + 10)e^{-fx/2} - e^{-2fx}], \text{ if } \rho = 1/2,$$

where $p_0 = (1-\rho)/(1+\rho)$ and b_1, b_2 are calculated by relations (9).

4. Loss Characteristics of Systems with Random Volume Customers

In classical queueing theory, a unique loss characteristic is P_{loss} , i.e. the relative part of number of customers that were lost in steady state during infinite time interval. In terms of our theory, each customer in a classical system has the volume equals 1.

Let $D_V(x)$ be steady-state DF of the total customers' volume in a queueing system with limited (by V) buffer space ($D_V(x) = 1$, if $x > V$).

Generally, P_{loss} can be obtained from the stability conditions, i.e. from the fact that (in steady state) the mean number of customers accepted to the system during some time interval must be equal to the mean number of customers completing their service during the same interval. E.g. by this way, relation (3) were obtained. For the system with Poisson arrival process, in which only buffer space is limited and there are no other limitations, we can determine P_{loss} by the following relation [13], [17]:

$$P_{\text{loss}} = 1 - \int_0^V D_V(V-x) dL(x), \quad (11)$$

where $L(x)$ is DF of RV ζ . It is clear that P_{loss} is also a performance characteristic of systems with random volume customers. But it cannot take into account the fact of difference between loss probabilities for customers of different volumes.

Other (may be more objective) loss characteristic is probability Q_{loss} of volume unit losing [13], [17], i.e. the relative part of total volume of customers that were lost during infinite time interval. For the system with Poisson arrival process and without other limitations except of buffer space one, this probability can be calculated by the following relation:

$$Q_{\text{loss}} = 1 - \frac{1}{\varphi_1} \int_0^V x D_V(V-x) dL(x), \quad (12)$$

where $\varphi_1 = \mathbf{E}\zeta = \int_0^\infty x dL(x)$ is the mean customer's volume. E.g., for system $M/M/1/(\infty, V)$ with independent customer's volume and service time, we obtain from relation (4):

$$Q_{\text{loss}} = p_0 \int_0^V x \left[A_n(V-x) + \frac{n^n}{n!} B_n(V-x) \right] dL(x).$$

It is clear that, for fixed n , we can easily calculate Q_{loss} in the case of exponentially distributed service time (see Section 3).

Generally, Q_{loss} can be also obtained from the stability conditions, i.e. from the fact that (in steady state) the mean total volume of customers accepted to the system during some time interval must be equal to the mean total volume of customers completing their service during the same interval. However, in this case, appropriate calculations are significantly more complicated than in the case of P_{loss} ones.

Denote by $\mathbf{E}(\zeta|A)$ a conditional mean of RV ζ under condition that an event A ($\mathbf{P}\{A\} > 0$) takes place (see e.g. [18, p. 70]).

Using theory of regenerative processes [5], [19], we can prove the following statement.

Theorem. Assume that, for a system under consideration, stochastic processes $\sigma(t)$ and $\eta(t)$ are regenerative with finite mean value of regeneration cycle. Let A be a random event that means a loss of arriving customer. Then, characteristics Q_{loss} and P_{loss} are connected by the relation $Q_{\text{loss}} = \frac{\mathbf{E}(\zeta|A)}{\varphi_1} P_{\text{loss}}$, where $\mathbf{E}(\zeta|A)$ is a conditional mean customer's volume under condition A (i.e. $\mathbf{E}(\zeta|A)$ is a mean volume of losing customers).

Proof. Let n_j be the number of arriving customers during j th regeneration cycle, n_j^* be the number of losing customers during this cycle, $j = 1, 2, \dots, N$, v_{ij}^* be the volume of i th losing customer within this cycle, $i = 1, 2, \dots, n_j^*$, V_j^* be the total losing volume within this cycle: $V_j^* = \sum_{i=1}^{n_j^*} v_{ij}^*$.

As it follows from the theory of regenerative processes [19], we have $N^{-1} \sum_{j=1}^N V_j^* \xrightarrow{a.s.} \mathbf{E}\chi^*$ when $N \rightarrow \infty$, where RV χ^* is the total volume of losing customers within arbitrary regeneration cycle, $N^{-1} \sum_{j=1}^N n_j^* \xrightarrow{a.s.} \mathbf{E}v^*$, where RV v^* means the number of losing customers during a regeneration cycle. It is clear that $\chi^* = \mathbf{E}v^* \mathbf{E}(\zeta|A)$. By similar way, we obtain that $N^{-1} \sum_{j=1}^N n_j \xrightarrow{a.s.} \mathbf{E}v$, where RV v means the number of arriving customers on arbitrary regeneration cycle. Then, $\mathbf{E}\zeta \mathbf{E}v$ is the mean total volume of arriving customers on arbitrary cycle and we obtain:

$$\frac{N^{-1} \sum_{j=1}^N V_j^*}{\mathbf{E}\zeta \mathbf{E}v} \xrightarrow{a.s.} Q_{\text{loss}} = \frac{\mathbf{E}(\zeta|A)}{\mathbf{E}\zeta} \cdot \frac{\mathbf{E}v^*}{\mathbf{E}v} = \frac{\mathbf{E}(\zeta|A)}{\mathbf{E}\zeta} P_{\text{loss}}. \quad \square$$

Hence, $Q_{\text{loss}} \geq P_{\text{loss}}$, if $\mathbf{E}(\zeta|A) \geq \mathbf{E}\zeta = \varphi_1$, i.e. the mean volume of losing customers is equal or greater than the mean volume of arbitrary ones. It is clear that $Q_{\text{loss}} = P_{\text{loss}}$, if the loss of a customer does not depend on his volume.

It was proved [20] that the relation $P_{\text{loss}} = 1 - (1 - p_0)/\rho$ holds for one-server systems when service time does not depend on customer's volume, and the relation $Q_{\text{loss}} = 1 - (1 - p_0)/\rho$ holds when service time is proportional to customer's volume.

We can obtain loss characteristics in explicit form for some queueing systems with random volume customers. E.g. from relation (11), we can calculate probability P_{loss} (see relation (6)) for system $M/M/1/(\infty, V)$ with independent RVs ζ and ξ , when RV ζ is distributed exponentially. The same formula takes place for processor sharing system with exponential customer's length¹ distribution (with parameter μ) and independent exponentially distributed customer's volume (with parameter f). For both these systems, we can obtain the following relation for Q_{loss} (using relation (12)) [17]:

$$Q_{\text{loss}} = \frac{p_0 e^{-fV}}{\rho} [(1 + \rho)e^{\rho fV} - 1], \quad (13)$$

where p_0 is determined by relation (5), $\rho = a/\mu$.

If, in processor sharing system, customer's volume has an exponential distribution with parameter f and customer's length is proportional to his volume ($\xi = c\zeta$, $c > 0$), we obtain [17]:

$$P_{\text{loss}} = p_0 e^{-fV} \cosh(\sqrt{\rho} fV), \quad (14)$$

$$Q_{\text{loss}} = \frac{p_0 e^{-fV}}{\sqrt{\rho}} [\sinh(\sqrt{\rho} fV) + \sqrt{\rho} \cosh(\sqrt{\rho} fV)], \quad (15)$$

where $\rho = ac/f$ and

$$p_0 = \begin{cases} \frac{1 - \rho}{1 - \sqrt{\rho} e^{-fV} [\sinh(\sqrt{\rho} fV) + \sqrt{\rho} \cosh(\sqrt{\rho} fV)]}, & \text{if } \rho \neq 1, \\ \frac{4}{3 + 2fV + e^{-2fV}}, & \text{if } \rho = 1. \end{cases}$$

For systems with $V < \infty$ and dependent RVs ζ and ξ , we, as a rule, cannot exactly determine loss characteristics. An exception are some models without waiting places, e.g. $M/G/n/(0, V)$ or processor sharing systems [22], [23]. But, in this case, we often can estimate these characteristics with the help of models with unlimited buffer space.

Let QS be the system with Poisson arrival process and without any limitations (there are no losses in it). Let QS_V be the system, which differs from QS in limitation (by V , $V < \infty$) of buffer space capacity, only. Assume that steady state exists for both systems. Denote by $D(x)$ and $D_V(x)$ DFs of the steady-state total volume in systems QS and QS_V , respectively.

It can be proved (see e.g. [17]) that inequality $D(x) \leq D_V(x)$ holds for all real x . Then, we obtain the following inequalities:

$$\begin{aligned} P_{\text{loss}} &= 1 - \int_0^V D_V(V - x) dL(x) \leq 1 - \int_0^V D(V - x) dL(x) = P_{\text{loss}}^*, \\ Q_{\text{loss}} &= 1 - \frac{1}{\varphi_1} \int_0^V x D_V(V - x) dL(x) \leq 1 - \frac{1}{\varphi_1} \int_0^V x D(V - x) dL(x) = Q_{\text{loss}}^*. \end{aligned}$$

¹ In a processor sharing system, service time of the customer, under condition that there are no other customers in the system during his service, is called customer's length (see e.g. [20]).

As it follows from these inequalities, the values P_{loss}^* and Q_{loss}^* can be interpreted as upper boundaries for P_{loss} and Q_{loss} , respectively, when DF $D(x)$ is known.

Unfortunately, calculation of these characteristics is often very complicated, because we have function $D(x)$ very rarely in explicit form. For this function approximation, we often can use incomplete Gamma function $\gamma(p, bx)$ and Gamma function $\Gamma(p) = \gamma(p, \infty)$. E.g. in both inequalities, we sometimes can approximate $D(x)$ by the function [13]:

$$D^*(x) = p_0 + (1 - p_0) \frac{\gamma(p, bx)}{\Gamma(p)}.$$

The values of parameters p and b we choose so that the first and second moments of the approximate distribution are equal to the first (δ_1) and second (δ_2) moments of DF $D(x)$. Then, we have:

$$p = \frac{\delta_1^2}{(1 - p_0)\delta_2 - \delta_1^2}, b = \frac{(1 - p_0)\delta_1}{(1 - p_0)\delta_2 - \delta_1^2}.$$

E.g., if RV ζ is absolute continuous, we obtain for Q_{loss}^* the following approximate relation [24]:

$$Q_{\text{loss}}^* \approx 1 - \frac{1}{\varphi_1} \int_0^V x \left[p_0 + (1 - p_0) \frac{\gamma(p, b(V - x))}{\Gamma(p)} \right] l(x) dx,$$

where $l(x)$ is density of RV ζ . To calculate P_{loss}^* and Q_{loss}^* , we can use methods of numerical integration (see e.g. [25]).

5. Analog of Little's Formula

Little's formula $E\eta = \lambda E\nu$, where η is number of customers present in the system in steady state, λ is intensity of (stationary) arrival process, ν is sojourn time of a customer in the system, is one of the most significant results of classical queueing theory. It holds for arbitrary steady-state system without losing of customers.

Consider an arbitrary queueing system with random volume customers. Assume that RV ζ means customer's volume and ξ his service time. Denote by $\alpha_{11} = E(\zeta\xi)$ the mixed moment of (1+1)th order of RVs ζ and ξ . Assume that arrival process is stationary with intensity λ . Let w be queueing time of a customer, hence, $\nu = w + \xi$, where RVs w and ξ are independent. Let σ be the total volume of customers present in the system in steady state. It was proved (see [26], [27]) that the following relation named an analog of Little's formula holds:

$$E\sigma = \lambda(Ew \cdot E\zeta + E(\zeta\xi)). \quad (16)$$

Consider, as an example, two steady-state systems of $M/M/1/\infty$ type: QS_1 and QS_2 . Let a be parameter (intensity) of arrival process in both systems. Assume that customer's volume is distributed exponentially with parameter f in each of them, i.e. $L(x) = P\{\zeta < x\} = 1 - e^{-fx}$. Assume that customer's volume and service time are independent in QS_1 . Denote by μ parameter of service time in it, i.e. $B_1(t) = 1 -$

$e^{-\mu t}$. Assume that, in QS_2 , service time is proportional to customer's volume: $\xi = c\zeta$, $c > 0$. Then, we have for this system:

$$B_2(t) = \mathbf{P}\{\xi < t\} = \mathbf{P}\{c\zeta < t\} = \mathbf{P}\{\zeta < t/c\} = 1 - e^{-ft/c}.$$

Assume that equality $\mu = f/c$ holds. Then, we obtain $B_1(t) = B_2(t)$. It means that the systems QS_1 and QS_2 are identical from classical queueing theory point of view, i.e. distributions of all RVs characterizing these systems (e.g. queueing time, sojourn time, number of customers present in the system) are the same in both systems. But this assertion becomes wrong for mean values $\mathbf{E}\sigma^{(1)}$ and $\mathbf{E}\sigma^{(2)}$ of total volumes for systems QS_1 and QS_2 , respectively.

Indeed, RVs ζ and ξ are independent in QS_1 . Then, for their mixed moment $\alpha_{11}^{(1)}$, we obtain:

$$\alpha_{11}^{(1)} = \mathbf{E}(\zeta\xi) = \mathbf{E}\zeta \cdot \mathbf{E}\xi = (f\mu)^{-1}.$$

Classical characteristic $\mathbf{E}w$ is the same for both systems. It is known [3], [5] that $\mathbf{E}w = \rho/(\mu(1 - \rho))$, where $\rho = a/\mu = ac/f$. Then, for system QS_1 , we have from relation (16):

$$\mathbf{E}\sigma^{(1)} = a \left[\frac{\rho}{\mu(1 - \rho)} \cdot \frac{1}{f} + \frac{1}{f} \cdot \frac{1}{\mu} \right] = \frac{1}{f} \cdot \frac{\rho}{1 - \rho}.$$

For mixed moment $\alpha_{11}^{(2)}$ of the system QS_2 , we have:

$$\alpha_{11}^{(2)} = \mathbf{E}(\zeta\xi) = \mathbf{E}(\zeta \cdot c\zeta) = c\mathbf{E}\zeta^2.$$

For the second moment $\mathbf{E}\zeta^2$ of customers' volume, we easily obtain $\mathbf{E}\zeta^2 = 2/f^2$ and finally have:

$$\mathbf{E}\sigma^{(2)} = a \left[\frac{\rho}{\mu(1 - \rho)} \cdot \frac{1}{f} + \frac{2c}{f^2} \right] = \frac{1}{f} \cdot \frac{\rho(2 - \rho)}{1 - \rho}.$$

Therefore, mean total volume is $2 - \rho$ times greater in the system QS_2 . It is intuitively clear, because customers of a greater volume are served for a longer time in this system.

This simple example shows that we have to take into account the dependence between RVs ζ and ξ , if we want correctly determine buffer space capacity while communication center (router) designing of a computer or telecommunication network.

6. Examples of Calculations of Loss Characteristics

Now, we shall present some exemplary calculations of loss characteristics for the chosen queueing systems with random volume customers.

6.1. Processor sharing system $M/M/1/(\infty, V)$ -EPS

Consider processor sharing system in which customer's volume is distributed exponentially with parameter f . We shall analyze two versions of this system. In first

of them (QS_1), customer's length is independent on his volume and is exponentially distributed with parameter μ . In second one (QS_2), customer's length is proportional to his volume ($\xi = c\zeta, c > 0$) i.e. it is distributed exponentially with parameter f/c . If we assume that $\mu = f/c$, we obtain that the systems QS_1 and QS_2 become identical from the classical queueing theory point of view. But, of course, loss characteristics are not the same for these systems, because the dependence between RVs ζ and ξ has a substantial influence on their values. Indeed, in Sections 3 and 4, we obtained explicit relations for loss characteristics of the systems QS_1 (relations (6) and (13)) and QS_2 (relations (14) and (15)). Now, we present some numerical computations under assumption that $a = 1, f = 2$ for both systems, $\mu = 2$ for QS_1 and $c = 1$ for QS_2 , i.e. $\rho = 0.5$ for both systems. The results of computations are presented in Fig. 3 (for QS_1) and Fig. 4 (for QS_2).

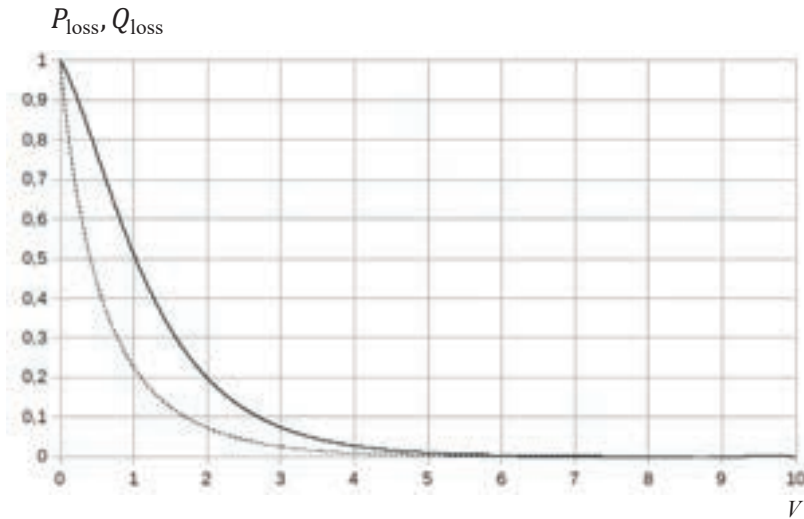


Fig. 3. Loss characteristics for system $M/M/1/(\infty, V)$ -EPS with independent customer's

6.2. System $M/M/1/(\infty, V)$

Consider single-server queueing system in which customer's volume is distributed exponentially with parameter f . We shall also analyze two versions of this system (QS_1 and QS_2). In the first of them, customer's service time is independent of his volume and distributed exponentially with parameter μ . In the second one, service time is proportional to customer's volume ($\xi = c\zeta$). If we assume that $\mu = f/c$, these two models are also equivalent from the classical point of view.

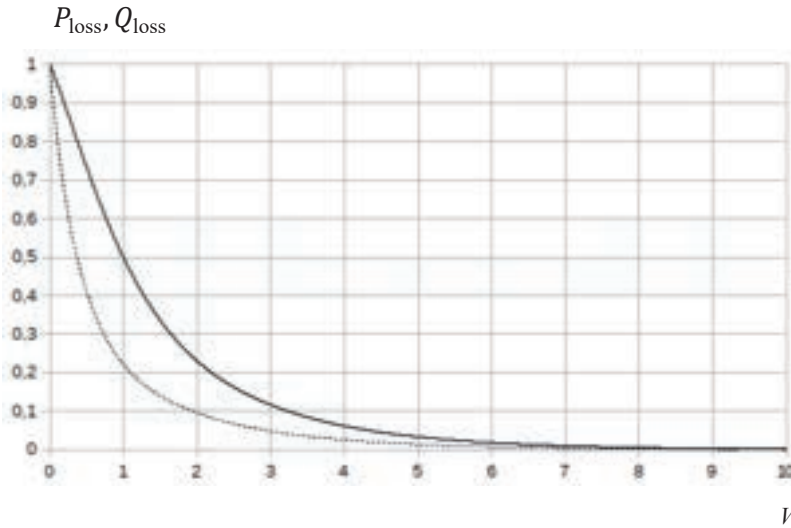


Fig. 4. Loss characteristics for system $M/M/1/(\infty, V)$ -EPS with customer's length proportional to his volume

It is clear that we can't calculate exact loss characteristics for the second version of the system, because its DF $D_V(x)$ is unknown in explicit form. But, for both versions, we can calculate approximations of $D_V(x)$ (see Section 4). These approximations are based on the use of incomplete gamma function with parameters that depend on the values of the first (δ_1) and second (δ_2) moments of analogous system $M/M/1/\infty$ with unlimited buffer space, i.e. $V = \infty$ (see Section 3), under assumption $\rho = a/\mu = ac/f < 1$. For system QS_1 from relation (10), we easily obtain:

$$\delta_1 = \frac{\rho}{f} \cdot \frac{1}{1-\rho}, \delta_2 = \frac{2\rho}{f^2} \cdot \frac{1}{(1-\rho)^2}.$$

For system QS_2 , we have analogously from relation (8):

$$\delta_1 = \frac{\rho}{f} \cdot \frac{2-\rho}{1-\rho}, \delta_2 = \frac{2\rho}{f^2} \cdot \frac{3+\rho^3-\rho^2-2\rho}{(1-\rho)^2}.$$

Now, we present some numerical computations. Assume that $a = 1, f = 2$. Then, $\rho = 0.5$. The results of calculation for system QS_1 are presented in Fig. 5. Proper results for QS_2 are shown in Fig. 6.

Obtained numerical results show that a character of dependency between customer's service time and his volume has substantial influence on estimators of loss characteristics, and we have to take it into account during the process of computer systems designing. E.g. if we want to design computer system having the same input characteristics and want to have maximal volume unit loss probability less than 10^{-4} , then, in the case of QS_1 , we have to set value V at least equal to 10, and, in the case of QS_2 , to set it equal at least to 12. Of course, we can see that Q_{loss} characteristics are

greater than P_{loss} . Numerical computations of loss characteristics and other performance ones for various types of queueing systems with random volume customers (also with non-identical servers) can be found in [23], [28] and [29].

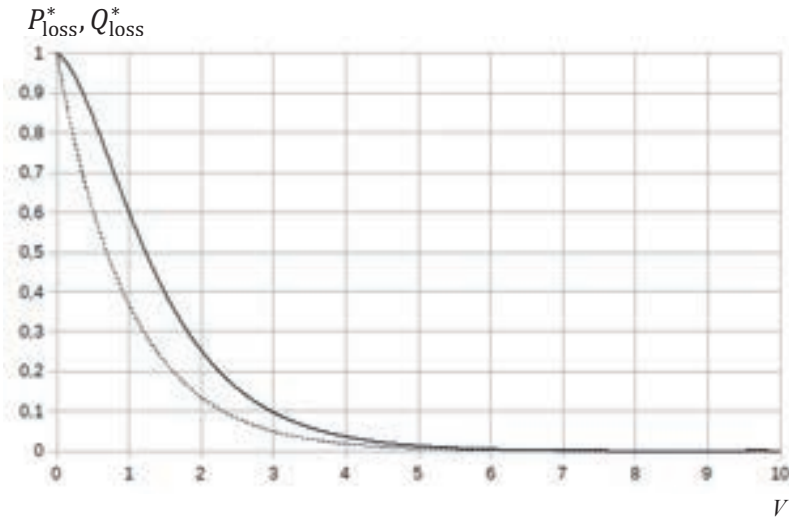


Fig. 5. Loss characteristics for system $M/M/1/(\infty, V)$ with independent customer's volume and his service time (approximation)

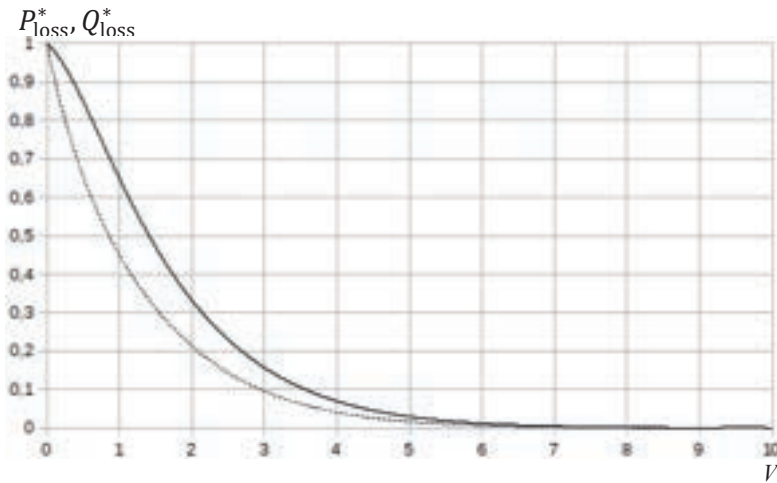


Fig. 6. Loss characteristics for system $M/M/1/(\infty, V)$ with service time proportional to customer's volume (approximation)

7. Conclusion

In the paper, we focus on models of queueing systems with random volume customers. We show that analysis of these models needs some extensions of mathematical tools known from the classical queueing theory.

We also discuss the most important problems that are connected with determining of distribution functions of the customers' total volume in such models and obtaining of their loss characteristics. We additionally present results of investigations for some models of such systems. We point out that the character of dependency between customer's volume and his service time has incontestable influence on performance characteristics of analyzed models that was shown in some numerical examples. Moreover, we present some practical approximation methods of calculating estimators of loss characteristics in the case when it is not possible to obtain explicit formulae.

These methods can be used in computer systems designing, when we determine needed buffer space capacity of the system.

References

- [1] B. V. Gnedenko, I. N. Kovalenko, Introduction to Queueing Theory, Birkhauser, Cambridge, 1989.
- [2] L. Kleinrock, Queueing Systems, Volume 1: Theory, Wiley, New York, 1976.
- [3] P. P. Bocharov, C. D'Apice, A. V. Pechinkin, S. Salerno, Queueing Theory, Utrecht-Boston: VSP, 2004.
- [4] L. Breuer, D. Baum, An Introduction to Queueing Theory and Matrix-Analytic Methods, Springer, Dordrecht, 2005.
- [5] L. Lakatos, L. Szeidl, M. Telek, Introduction to Queueing Systems with Telecommunication Applications, Springer, New York, 2013.
- [6] V. N. Roginsky, A. D. Kharkevich, M. A. Shneps, Communication Networks Theory, Radio i Svyaz', Moscow, 1981 (in Russian).
- [7] M. Schwartz, Computer-Communication Network Design and Analysis, Prentice-Hall, New Jersey, 1977.
- [8] M. Schwartz, Telecommunication Networks: Protocols, Modeling and Analysis, Addison-Wesley Publishing Company, 1987.
- [9] N. B. Zeliger, O. S. Chougreev, G. G. Yanovsky, Design of Networks and Systems of Discrete Messages Transmission, Radio i Svyaz', Moscow, 1984 (in Russian).
- [10] A. M. Alexandrov, B. A. Kaz, Non-homogeneous demands flow service, Izvestiya AN SSSR. Technicheskaya Kibernetika, no. 2, 1973, pp. 47–53 (in Russian).
- [11] B. Sengupta, The spatial requirements of an $M/G/1$ queue, or: how to design for buffer space, In: F. Baccelli and G. Fayolle (eds.) Modeling and Performance Evaluation Methodology, LNCS, vol. 60, Springer, Heidelberg, 1984, pp. 547–562.

- [12] O. M. Tikhonenko, Queueing Models in Computer Systems, Universitetskoe, Minsk, 1990 (in Russian).
- [13] O. Tikhonenko, Computer Systems Probability Analysis, Akademicka Oficyna Wydawnicza EXIT, Warsaw, 2006 (in Polish).
- [14] O. Tikhonenko, M. Kawecka, Queueing Systems with Customers of Random Space Requirements, *Studia Informatica*, vol. 33, no. 3A (107), Gliwice 2012, pp. 19–28 (in Polish).
- [15] O. Tikhonenko, W. M. Kempa, Performance Evaluation of an $M/G/n$ -type Queue with Bounded Capacity and Packet Dropping, *International Journal of Applied Mathematics and Computer Science*, Vol. 26, no. 4, 2016, pp. 841–854.
- [16] O. Tikhonenko, M. Kawecka, Total Volume Distribution for Multiserver Queueing systems with Random Capacity Demands, *Communications in Computer and Information Science*, vol. 370, Springer, 2013, pp. 394–405.
- [17] O. Tikhonenko, Determination of Loss Characteristics in Queueing Systems with Demands of Random Space Requirement, *Communications in Computer and Information Science*, vol. 564, Springer International Publishing Switzerland, 2015, pp. 209–215.
- [18] A. A. Borovkov, Probability Theory, Springer-Verlag, London, 2013.
- [19] S. Asmussen, Applied Probability and Queues, 2d ed., Springer-Verlag, New York, 2003.
- [20] E. Morozov, R. Nekrasova, L. Potakhina, O. Tikhonenko, Asymptotic analysis of queueing systems with finite buffer space, *Communications in Computer and Information Science*, vol. 431, Springer International Publishing Switzerland, 2014, pp. 223–232.
- [21] S. F. Yashkov, A. S. Yashkova, Processor Sharing: a Survey of the Mathematical Theory, *Automation and Remote Control*, vol. 68, no. 9, 2007, pp. 1662–1731.
- [22] O. M. Tikhonenko, Generalized Erlang Problem for Service systems with Finite total Capacity, *Problems of Information Transmission*, vol. 41, no. 3, 2005, pp. 243–253.
- [23] O. M. Tikhonenko, Queueing systems with processor sharing and limited resources, *Automation and Remote Control*, vol. 71, no. 5, 2010, pp. 803–815.
- [24] O. Tikhonenko, M. Ziółkowski, Single-Server Queueing System with External and Internal Customers, *Bulletin of the Polish Academy of Sciences, Technical Sciences*, vol. 66, no. 4, 2018, pp. 539–551.
- [25] Y. L. Luke, Mathematical Functions and their Approximations, Academic Press Inc., New York, 1975.

- [26] O. M. Tikhonenko, An analog of Little's formula for queueing systems with non-uniform customers, *Automation and Remote Control*, vol. 57, no. 1, 1996, pp. 85–88.
- [27] E. Morozov, L. Potakhina, O. Tikhonenko, Regenerative analysis of a system with a random volume of customers, *Communications in Computer and Information Science*, vol. 638, Springer International Publishing Switzerland, 2016, pp. 261–272.
- [28] O. Tikhonenko, M. Ziółkowski, M. Kurkowski, $M/\vec{G}/n/(0, V)$ Erlang Queueing System with Non-Homogeneous Customers, Non-Identical Servers and Limited Memory Space, *Bulletin of the Polish Academy of Sciences, Technical Sciences*, vol. 67, no. 3, 2019, pp. 489–500.
- [29] M. Ziółkowski, $M/\vec{G}/n/0$ Erlang Queueing System with Heterogeneous Servers and Non-Homogeneous Customers, *Bulletin of the Polish Academy of Sciences, Technical Sciences*, vol. 66, no. 1, 2018, pp. 59–66.



UDC 004.738.5:658:354(497.11)

Original Scientific Paper

The Use of E-government from the Perspective of Biggest Business Entities in Serbia

Jasmina Đurašković*jasmina.djuraskovic@pmc.edu.rs**Faculty of Projects and Innovation Management
Educons University, Sremska Kamenica, Serbia***Dejan Viduka***dejan@viduka.info**Faculty for Applied Management, Economics and Finance, Belgrade
University Business Academy, Novi Sad, Serbia***Marina Gajić - Glamočlija***marina.gajic@beogradput.com**College of Management and Economics
Kragujevac, Serbia*

Abstract

The development and use of information and communication technologies (ICTs), and in particular the Internet, have changed the way businesses operate in the last twenty years, providing a number of new opportunities for improving innovation and competitiveness. Today, modern ICT is considered to be the basis for the development of a knowledge society, in which the concept of e-government plays a special role. The main goal of this paper was to examine the perceptions of business users, in terms of perceived barriers and benefits achieved, from the use of electronic public administration services. The survey included 500 companies with the highest business income in Serbia. The data collected were analyzed using Pearson's correlation coefficient, Mann Whitney's test and Kruskal-Wallis test. The results of the research showed that the level of acceptance of electronic services is still lower than expected, given the volume of services offered. Also, this study pointed to the need to raise the level of awareness of businesses about e-government services, as well as the need to improve the quality of electronic services, in terms of complete digitization, alignment with enterprise requirements and regular updating of data.

Keywords: ICT, e-government, business entities, Serbia

1. Introduction

The interest in the modernization of the public sector has grown rapidly in the last ten years, and the introduction of electronic services is a key element of public administration reform. E-government initiatives are present in all democratic systems reform programs in developed Western European countries [1]. According to the OECD [2], e-government represents "the use of information and communication

technologies, and especially the Internet, as a means of achieving better public administration.” The application of information and communication technologies enables greater transparency in the work of state bodies, while reducing corruption [3]. In the first stages of digital governance development, investments have focused on technology that supports the development of electronic communication with stakeholders, and lately, as the problem of low acceptance of e-government becomes increasingly apparent, the focus is shifting to users [4]. Considering the results of previous research, it was concluded that all user groups play a very significant role in ensuring the long-term success of the e-government project [5]. The electronic public service provides a range of benefits to its users (citizens, businesses, the public sector, the non-profit sector). However, the expected benefits for the state administration cannot be materialized immediately, but only at the moment when most interactions with the government are realized through the Internet. One of the obstacles to the development of e-government is the nature of public service, which, with all its obligations, is not in a position to easily and swiftly dispense with paperwork procedures, as soon as the opportunity for the implementation of electronic services becomes available [6]. Lessa et al. [7] point out that the failure rate of e-government implementation is very high, especially in developing countries and transition democracies. According to Heeks [8], 85 percent of e-government projects have experienced partial or complete failure in developing countries. Regardless of the level of development or the form of social ordering, there are numerous benefits that the concept of e-government can provide for any society. First of all, the modernization of public administration and the introduction of modern information and communication technology into the state sector increase the efficiency and effectiveness of all business processes. Another reason, crucial to the necessity of implementing e-government, is democratic reform of the state structure, promotion of democratic practice and transparency in the work of state bodies [9]. For Serbia, the issue of digitalization of public administration is particularly important because of the accession process to the European Union. It is required to align the objectives of the Europe 2020 Strategy and the Digital Plan for Europe initiative [10], one of the priorities of which is to create a single digital market based on high-speed internet and interoperable applications. In the last ten years, some effort has been invested, both in the development of information technologies and in their application in the work of state bodies [11]. However, according to the results of a recent two-year United Nations survey, Serbia has not made progress on the global list when analyzing the performance of state-owned e-services [12]. The paper presents the basic results of the research, which aims to identify the most significant advantages and limitations, detected by business entities in the process of using e-services. The paper is divided into five sections, including introductory notes. The second section provides an overview of the relevant e-government literature, which served as the basis for defining the methodological framework of the research. The third part contains a description of the applied statistical methods of data processing, analysis of the obtained results and comparison with previously published data. Section 4 outlines the limitations of the research conducted, as well as suggestions and recommendations

for future research. Finally, the last section contains concluding considerations and practical implications of the results, which are significant for the further development of e-government in transition countries. The survey was conducted on a sample comprising of 500 largest economic entities, the size of which was measured by the amount of business income generated in 2017, in the territory of the Republic of Serbia (based on data from the Serbian Business Registers Agency (SBRA)). This group of companies is significant for the Serbian economy because it generates more than half of the income of all companies in the country, and also, these companies operate in different sectors and through relationships with suppliers and customers, to some extent, create flows in the Serbian economy [13] and consequently, influence future trends in e-business of Serbian companies.

This paper raises the following research questions:

RQ1: How much has the e-government service been used by the most profitable companies in Serbia in the last six months?

RQ2: What are the reasons for the possible disuse of e-government services?

RQ3: Is there a relationship between the level of use of e-services and the affiliation sector, type of business or size of business?

RQ4: What are the most significant benefits of digitizing the administration, from the perspective of business entities?

RQ5: What are the most significant obstacles to the digitization of government, from the perspective of business entities?

As a result of the aforementioned research questions, the main objective of the study is to analyze the use of an electronic public service and identify the motivating and limiting factors for its adoption from the perspective of business organizations. The information on the extent of use and reasons for not using e-government services, as well as the benefits and barriers that users encounter in the course of electronic communication with public administration, provide a better insight and clearer picture of the current state of e-government development and the information basis for policy making, which will advance the user-focused government and stimulate the adoption of electronic public services. The results of this research are important, first of all, because of the lack of academic papers focused on business users and their use of e-government services in transition countries, as well as because they provide better insight into the possibilities of successful implementation of e-government systems.

2. Literature Overview

The concept of e-government emerged in the late 1990s, but the development of information systems of governmental organizations can be traced back decades, from the beginnings of computer history [14]. The rapid advances and constant changes in the field of information and communication technologies (ICT) have led to the need to innovate communication channels at all levels of government and to modernize the state administration. E-government development projects, due to their complex nature, have had broader political, social, and economic implications for society as a whole [15]. Today, e-government is seen as a means of reducing red tape, increasing

the efficiency and effectiveness of public service, and strengthening democratic structures [16]. Many previous studies have highlighted the existence of a gap between the quality of government supply and the level of use of e-government services [17]. There are a number of factors that impede digital collaboration between government and users and lead to the formation of a communication gap, both on the supply side and on the demand side. Previous research has confirmed the difference between developed and other countries in terms of the spread of electronic public service [18]. Most of the e-government development strategies adopted are based on successful experiences from developed countries, which cannot be directly applied to developing countries. In recent years, significant progress has been made in developed countries in the e-government implementation process [19], which further widens the existing gap and increases the gap between leaders in the digitalization of public administration in less developed countries. According to Azad et al. [20], this inequality is explained by the action of institutional factors, which include: democratic practice, transparency of private sector operations, perception of corruption and freedom of the media, while other authors place this topic in a wider context, taking into account the work of history and culture, infrastructure, citizens and government sector employees, with particular reference to their IT capabilities [21]. The modernization of the public sector and the application of information and communication technologies are an essential part of Serbia's European integration process and accession negotiations. In this context, the current Strategy for the development of electronic communications from 2010 to 2020 sets the implementation of e-government as one of the development priorities for the coming period [22]. Regional cooperation and partnership between the public and private sectors can significantly contribute to the development of the e-government concept, which focuses on the interests of users in the Southeastern Europe region [23]. It is noticeable that more and more private sector companies are cooperating with state institutions on joint projects in the field of ICT, as a basis for digitalization of public administration [24].

3. Research Methodology

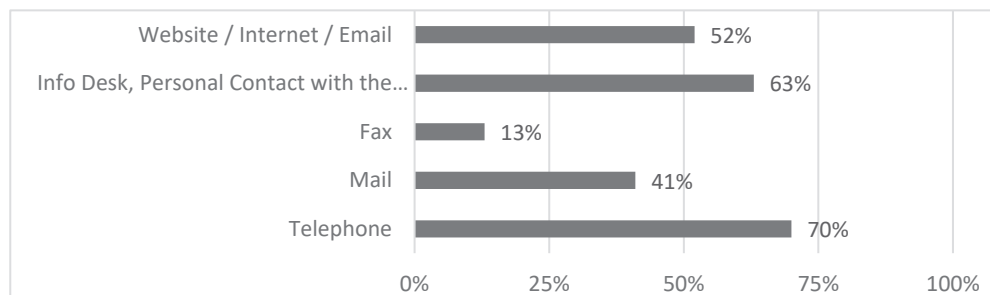
The survey included 500 companies with the highest business income in Serbia. The sample frame consisted of a database of companies registered with the Business Registers Agency, which submitted the annual accounts for the 2017 fiscal year. Enterprises covered by the sample belong to different industries, regions, ownership structures and size. The survey used an online survey as a method of data collection. Twelve companies were excluded from the sample due to the inability to determine their email address, due to the lack of transparency of information regarding their business and the lack of publicly available sources, such as company websites. The invitation to participate in the survey, with a link to the questionnaire, was sent by e-mail to all other listed companies (488 companies in total). The letter also included an explanation of the purpose of the research, instructions for completing the questionnaire, and contact information for further clarification. The online

questionnaire, uploaded in the form of a Google document, was available to businesses for 21 days (from September 24 to October 15, 2018) and one email reminder was sent during that period. Non-delivery messages were returned from 23 email addresses. The questionnaire used in this research partly relies on previous e-government research [25]. However, it has been significantly modified and adapted to the conditions and state of development of e-government in Serbia. In the survey, 37 participants were asked in the decision-making process in the field of e-government. Employees at higher levels of management were interviewed to gain insight into their views regarding the use of e-government services. The questions are divided into four sections, covering four main topics, which are also the subjects of research. The first part of the questionnaire relates to basic data such as: number of employees (size of company), location (region), form of ownership and activity of company. The second part of the questionnaire is aimed at gathering information on the level of representation of various forms of e-commerce among business entities, the level of use of the electronic public administration service, as well as possible reasons for not using it. In the third part of the questionnaire, businesses evaluate the benefits of using e-government services, and the last part deals with the perception of the most important barriers to its adoption by businesses. Both sections contain a set of claims that describe the different benefits or benefits, limitations, and for each claim, respondents rate the degree of their agreement or disagreement, on a six-point scale. All questions asked in the survey are of a closed type, with modalities of answers being offered. Quantitative analysis of the obtained data was carried out with the help of the SPSS software program. The matrix in SPSS was formed based on a questionnaire. Also, the analysis of descriptive statistics was used to edit and group the data, as well as the parametric test Pearson's correlation coefficient, to calculate the correlation of variables (the use of e-government services with the affiliation sector, type of activity and size of enterprise). Non-parametric tests were also used in the study: Mann Whitney test (or Rank sum test) to compare employees in manufacturing and service companies using individual e-government services, and the Kruskal-Wallis test to compare employees in enterprises of different sizes in assessing the benefits use of e-government.

4. Results

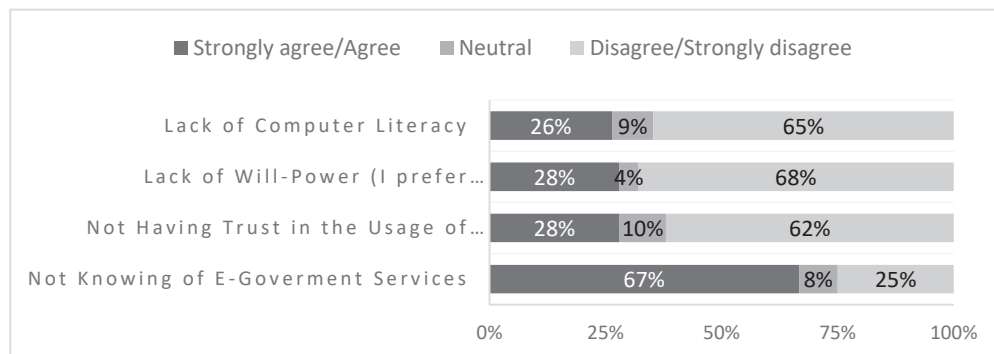
Representatives of 83 companies operating in the Republic of Serbia were surveyed, representing 17% of the total number of companies (488) invited by e-mail to participate in the survey. Considering the size of the surveyed companies (i.e. the number of employees), the representation of small (29%), medium (40%) and large (31%) enterprises is quite balanced. The sample covers enterprises operating within the service (64%) and manufacturing (36%) sectors, the largest percentage belonging to the private sector (85%), while 15% is state-owned. The regional structure of the sample indicates the highest presence of business entities from Belgrade (72%) and Vojvodina (22%), while the least surveyed companies are from Central Serbia (6%). Descriptive statistics were analysed to answer the first two research questions

regarding the level of use of e-government services and the reasons for their possible non-use (in the last six months). Based on the data collected, it was found that the most common channels of communication of the economy with the state administration are: telephone (70%) and personal contact with government officials (63%), while the Internet is most commonly used by 52% of companies surveyed in communication with public administration (Graph 1).



Graph 1. Frequency of responding of the surveyed business entities to the question related to the choice of the most common channels of communication with the state administration, in the last six months (expressed as a percentage). Note: Respondents were given multiple answers.

Of the surveyed businesses, 80% said they had used e-government services in the last six months. Most of the remaining 20% of respondents stated that such a situation is a result of ignorance of the Government's offer of electronic services (67%), while more than half of the surveyed companies disagree with the statement that lack of information literacy (65%), trust in the use of internet services (62%) or lack of will (68%), the reason for not using e-government services (Graph 2).



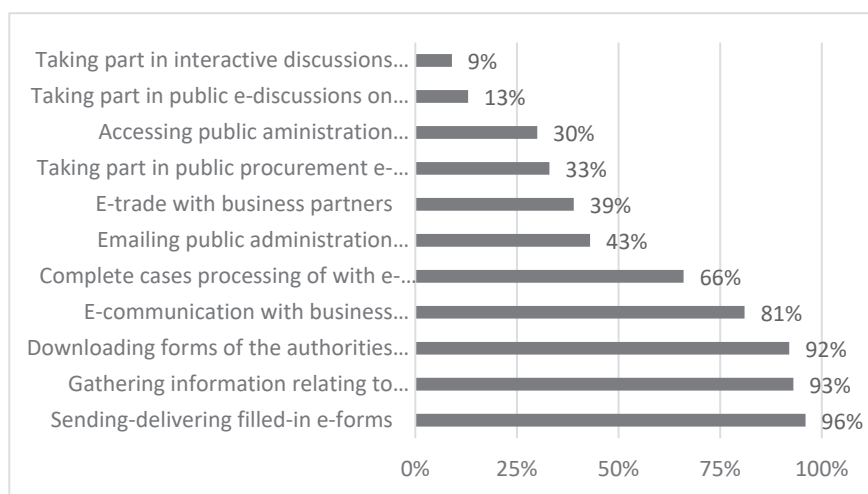
Graph 2. Frequency of responses of the surveyed business entities, indicating the degree of their agreement or disagreement with statements describing the reasons for not using e-government services in the last six months (expressed as a percentage). Note: Respondents were given multiple answers.

According to the Mann Whitney test, a difference was found between respondents employed in manufacturing and service companies, in assessing the claim of "unfamiliarity with e-government services". Respondents employed in the service

sector indicated that at a majority of them were not familiar with e-government services ($Z = -2.134$, $p = 0.033$).

The Mann Whitney test did not identify differences between respondents of employees in public and private companies in evaluating claims regarding the reasons for not using e-government. The Kruskal Wallis test indicated that there were statistically significant differences between employees of enterprises of different sizes, in assessing claims related to lack of will ($\chi^2 = 9,920$, $p = 0.007$) and lack of computer literacy ($\chi^2 = 16,896$, $p = 0.007$), meaning these two items were rated the highest by employees of medium size companies.

In order to answer the third research question, which relates to establishing the connection between the level of use of e-services and the affiliation sector, type of activity and size of the company, a Hi-square test was applied. The use of e-services according to the conventional statistical criterion does not depend on the type of activity ($\Phi = -, 205$, Pearson's $\chi^2 = 3.471$, $p = 0.062$), but this correlation is marginally statistically significant. Also, the use of e-government services does not depend on the size of the enterprise ($C = , 210$, Pearson's $\chi^2 = 3.830$, $p = 0.147$), ownership ($\Phi = , 027$, Pearson's $\chi^2 = 0.061$, $p = 0.804$), or location of the enterprise ($C = , 139$, Pearson's $\chi^2 = 1.624$, $p = 0.139$).



Graph 3. Frequency of responses of business respondents to the question related to the purpose of Internet use, in the last six months (expressed as a percentage). Note: the respondents were given multiple answers.

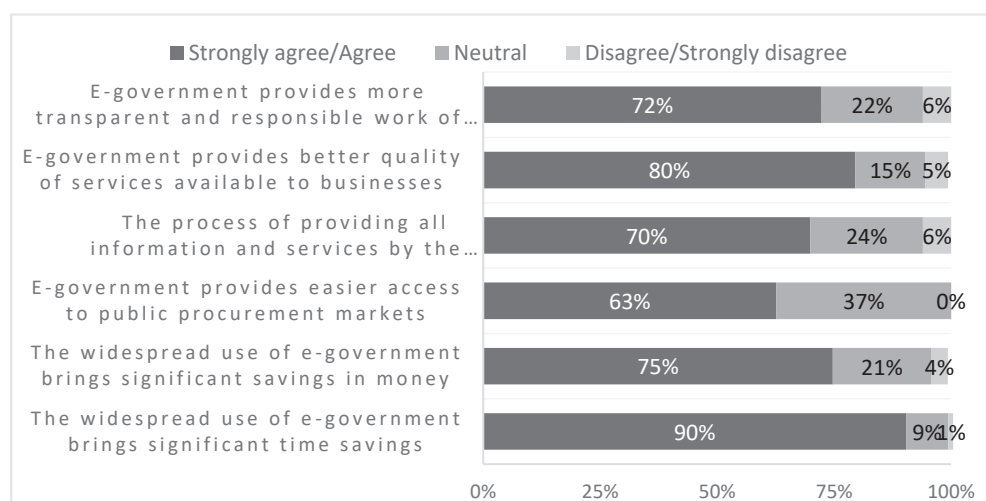
As shown in Graph 3, businesses use the Internet most to send (submit) completed forms electronically (96%), while the smallest percentage of surveyed business representatives use e-participation opportunities, such as participating in interactive discussions on the e-government Portal Forum page (9%) and participation in electronic public discussions (13%).

The analysis of sectoral differences regarding the purpose of internet use by the surveyed companies is based on the Mann Whitney test. According to the rank

averages, it can be concluded that employees of state-owned enterprises used the Internet more to obtain information ($Z = -2,455$, $p = ,014$), download forms ($Z = -1,966$, $p = ,049$) and complete case processing ($Z = -1,858$, $p = ,063$), and employees of private companies for electronic communications with clients ($Z = -1,786$, $p = ,074$).

Also, employees in large companies rated more positively the items related to participation in the electronic public procurement system ($\chi^2 = 8.469$, $p = 0.014$), participation in electronic discussions ($\chi^2 = 10.290$, $p = 0.006$) and the use of public administration services through mobile of devices ($\chi^2 = 7.786$, $p = 0.020$), with respect to SMEs. In general, surveyed business entities use the Internet to a greater extent for accessing e-services ($AS = 11.32$) than for e-participation ($AS = 5.62$).

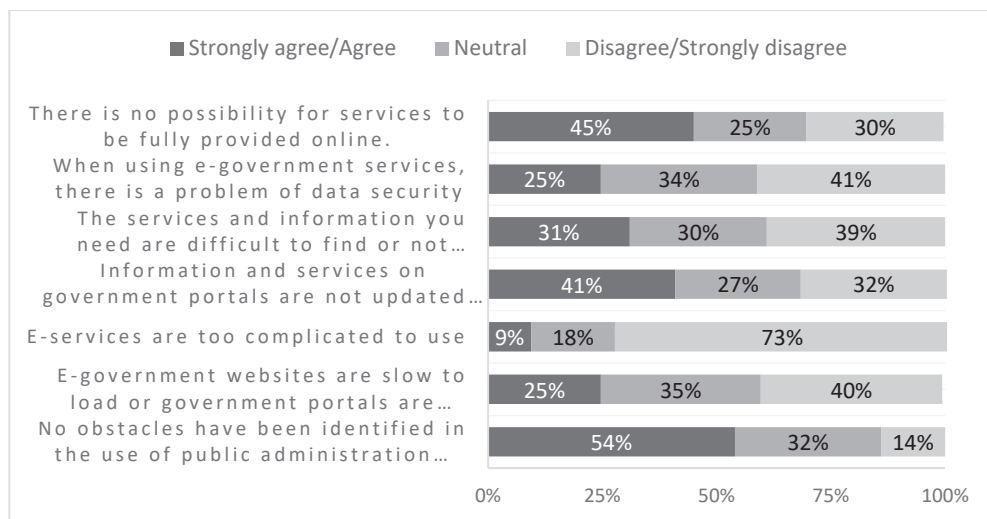
The remaining research questions relate to the assessment of the most significant advantages (Graph 4) and/or limitations (Graph 5) of the use of electronic services of public administration, from the perspective of business entities.



Graph 4. Frequency of responses of the surveyed business entities, indicating the degree of their agreement or disagreement with the statements describing the most significant benefits of using e-government (expressed as a percentage). Note: Respondents were given multiple answers.

The vast majority of businesses are aware of the benefits of the e-government process, benefiting first and foremost in terms of significant savings over time (90% of respondents agree with this statement), then better quality of public administration services for the business sector (80 %), savings in money (75%), more transparent government work (72%), and easier access to digital public service (70%). The benefits of using e-government do not depend on the activity, sectoral affiliation or size of the enterprise.

Chart 5. Frequency of responses of the surveyed business entities, indicating the degree of their agreement or disagreement with statements that describe the most significant restrictions on the use of e-government (expressed as a percentage). Note: Respondents were given multiple answers.



Graph 4. Frequency of responses of the surveyed business entities, indicating the degree of their agreement or disagreement with the statements describing the most significant benefits of using e-government (expressed as a percentage). Note: Respondents were given multiple answers.

More than half of the surveyed companies did not find any significant barriers to the use of public administration electronic services (54%), while the majority of businesses did not find e-government services complicated to use (73%). More than a third of respondents disagree (at all or mostly) with the claims that e-government web sites are slow to load (40%), that the services and information needed are difficult to find (39%) or that a security problem arises and data protection (41%). What worries the surveyed businesses is the inability to provide services completely electronically (45%) and irregular updates of information and services on government portals (41%). With regard to the assessment of a series of claims regarding the barriers to the use of e-government, no difference was observed between respondents from public and private sector employees.

5. Discussion

Representatives of 83 companies accepted to participate in the survey (out of 488 invited companies), corresponding to a response rate of 17%. This response rate may be considered acceptable, given the results of online research by other authors in the social sciences. According to Johnson [26], who analyzed the level of respondents' expected response to electronic customer satisfaction surveys, email surveys generate a response rate of about 9.3%. This rate has been steadily declining since the 1990s, although the number of studies collecting data electronically has increased [27]. In general, most online surveys have significantly lower response rates than traditional (paper-based) surveys [28]. The conducted research has shown that 80% of economic entities belonging to the segment of the most profitable in the Serbian economy have

used the services of e-government in the last six months, while one fifth of the surveyed companies did not have this type of contact with state administration bodies. In conditions of low level of internet penetration, the policy of encouraging the development of electronic public administration service does not provide satisfactory results. A critical mass of internet users is needed to promote digital services with significant effects [29]. According to the latest SORS (2018) survey on the use of information and communication technologies, 100% of companies in Serbia own an Internet connection and use a computer in their business. Although 99.8% of enterprises use the Internet for business purposes, only half of the surveyed businesses (52%) chose the Internet as the most common channel of communication with public administration. This study has shown that the degree of acceptance of e-government services by the most profitable companies does not depend significantly on the type of ownership, location, size of the business or type of business. One explanation may be the fact that the subjects of analysis are the largest economic entities (by operating income), and accordingly have sufficient resources (in terms of financial resources and human resources) as a support for the adoption of e-government services. Also, the study by Al-Zoubi et al. [30] provides empirical evidence for the existence of a significant relationship between e-government acceptance and business performance. Nevertheless, this question requires further research. Although there is a relatively satisfactory degree of use of e-government services by business entities, they mainly relate to obtaining information and downloading and submitting completed forms in electronic form. This is confirmed by the evaluation of various aspects of the regulatory activity of the Government by economic entities, according to which the availability of information on the websites of state bodies is most favorable, while the administrative burden imposed by regulations is most unfavorable [31]. The results of the survey reveal a gap between the use of e-government services and e-participation in web content forms. Of the companies surveyed, the smallest percentage uses the Internet to participate in interactive discussions on the E-Government Web Portal. Although a public discussion was organized for a third of the laws, the effects of these public discussions are not visible [31]. Almost all surveyed companies are aware of the benefits of introducing e-government. This is first of all significant savings in time and money, then better quality of services and easier access to digital services. These findings are consistent with the results of previous studies addressing e-government user perceptions [32], [33], [34], [35]. It is interesting that the assessment of the most significant advantages, from the point of view of economic entities, also, as well as the level of use of electronic services, does not depend on the activity, sectoral affiliation or size of the enterprise. Analyzing and understanding the factors that encourage or constrain businesses in the use of e-government services is the basis for enacting government measures that provide greater customer support [32]. Therefore, it is also necessary to investigate the problems encountered by enterprises in communicating with state administration bodies through the Internet. The lack of knowledge about e-government programs and services is rated as a "very important" barrier in a range of research [36], [37], [38]. These findings were confirmed in the conducted survey as a major obstacle for the business sector in Serbia, in which the

majority of enterprises (67%) most often state that lack of knowledge of the Government's e-services offerings is the most important reason for not using electronic services, while IT literacy and trust in the use of e-services are not a limiting factor for further development. According to the European Commission [39], lengthy and complicated procedures and incomplete digitization of services continue to limit use by a significant proportion of businesses. However, survey results showed that most businesses do not find e-government services complicated to use (73%). What concerns the surveyed companies is the inability to provide services completely electronically and the irregular updating of information on government portals. Unlike previous studies [40], which highlight the issue of data security/privacy as a significant barrier to e-government adoption, confidentiality and data security do not represent a barrier to the surveyed businesses.

6. Conclusion

The development of e-government is one of the biggest challenges in further modernizing the public administration system. The digitalization of the public sector is conditioned by a number of factors, including technical and technological progress, financial resources and political views. The influence of these factors determines the dynamics and direction of ICT development in the modern information society [34]. The implementation of e-government is particularly complex in the political and economic environment of post-communist countries, which are facing reform of the entire public sector. This study has shown that the largest companies have generally recognized the importance and benefits of the Internet as a way of communicating with the state. Although there is a relatively satisfactory level of use of e-government services, the level of development of electronic services is still lower than expected. There was a need to raise the level of information on e-government services, as well as the need to improve the quality of electronic services, in terms of complete digitization, alignment with the requirements of businesses and regular updating of data. In general, there is considerable room for improvement in this area. Although, at first glance, the problem of misinformation may seem minor in relation to other obstacles, it needs to be given greater attention in the coming period. In order for businesses to fully exploit the potential of e-government, and not just use the services provided by law as mandatory, it is necessary for the Government to promote existing e-services as well as the benefits of using them. More broadly, the implementation of innovation policy, and the support of the Government in this context, is one of the important factors for successful digitization of public services [41]. The results of the research have indicated that information literacy is not a limiting factor in the use of electronic services. However, it should be emphasized that the sample was formed on the basis of the 500 most profitable companies in Serbia, which generate more than half of the income of all companies, so their investment in employee literacy is much more likely. It can be assumed that in order to obtain significantly different results, the focus of the research was on companies with a chronic lack of financial resources [42]. The state administration of the Republic of Serbia faces numerous challenges

today, and one of the most important are the requirements that the European Union places before its potential members, within the framework of the tenth negotiating chapter, in the field of electronic communications and information society services. The success of public sector reform and implementation of e-government, as one of the cornerstones of information society development, depends both on the government and the political will of economic policy-makers and on the degree of acceptance of all potential users (citizens, economy, government employees). Viewed from the perspective of the most successful businesses, they are expected to set an example for other companies and become leaders in adopting new technologies and electronic services of public administration, as they occupy a leading position in the market in terms of revenue generated.

Acknowledgements

The work is part of a scientific research project: “Investigating trends in the development of competencies of project managers in the process digitization of society and the industrial revolution 4.0”.

References

- [1] Bonsón, E., Torres, L., Royo, S., & Flores, F. (2012). Local e-government 2.0: Social media and corporate transparency in municipalities. *Government information quarterly*, 29(2), 123-132.
- [2] Organisation for economic co-operation and development (OECD). (2003). *The e-Government imperative*. Paris: OECD e-Government Studies.
- [3] Bertot, J. C., Jaeger, P. T., & Grimes, J. M. (2010). Using ICTs to create a culture of transparency: E-government and social media as openness and anti-corruption tools for societies. *Government Information Quarterly*, 27(3), 264-271.
- [4] Gauld, R., Goldfinch, S., & Horsburgh, S. (2010). Do they want it? Do they use it? The ‘Demand-Side’ of e-Government in Australia and New Zealand. *Government Information Quarterly*, 27(2), 177-186.
- [5] Flak, L. & Nordheim, S. (2006). *Developing Commitment for Horizontal G2G Integration: A Stakeholder Governance Approach*, Proceedings of the 6th European Conference on e-Government (ECEG 2006), April 27 - 28, Marburg, Germany.
- [6] Tung, L. L., & Rieck, O. (2005). Adoption of electronic government services among business organizations in Singapore. *Journal of Strategic Information Systems*, 14, 417-440.
- [7] Lessa, L., Negash, S. and Belachew, M. (2012). *Steering e-Government Projects from Failure to Success: Using Design-Reality Gap Analysis as a*

- Mid-Implementation Assessment Tool, iGovernment Working Paper no. 22, Centre for Development Informatics, University of Manchester, UK
- [8] Heeks, R.B. (2003). Most eGovernment for Development Projects Fail: How Can Risks be Reduced?, i-Government Working Paper no.14, University of Manchester, UK
- [9] Theunissen, C. (2007). Contextual issues surrounding portable and interactive technologies within the contemporary and future environment of e-government and informatisation. Chapter 4. In Prins, J. E. J. (ed.). *Designing e-Government*. Second Edition. Alphen aan den Rijn, The Netherlands: Kluwer Law International.
- [10] European Commission. (2010). *Europe 2020: A strategy for smart, sustainable and inclusive growth: Communication from the commission*. Publications Office of the European Union.
- [11] Todorovic, B. (2015). *Elektronska uprava u Republici Srbiji – Izazovi modernizacije javne uprave*. Fondacija Centar za javno pravo.
- [12] United Nations Department of Economic and Social Affairs (UNDESA). (2018). *UN E-Government Survey 2018: Gearing E-government to Support Transformation towards Sustainable and Resilient Societies*. Department of Economic and Social Affairs, United Nations, New York
- [13] Hypo Alpe Adria bank & Certus Consulting. (2013, December). Top 500 [Special issue]. *NIN magazine*. Belgrade: Ringier Axel Springer.
- [14] Grönlund, Å., & Horan, T. A. (2004). Introducing e-gov: history, definitions, and issues. *Communications of the Association for Information Systems*, 15(2004), 713-729.
- [15] Mishra, A., & Mishra, D. (2012). E-government: exploring the different dimensions of challenges, implementation, and success factors. *ACM SIGMIS Database*, 42(4), 23-37.
- [16] Rowley, J. (2011). E-Government stakeholders - Who are they and what do they want? *International Journal of Information Management*, 31(2011), 53-62.
- [17] Organisation for economic co-operation and development (OECD). (2009). *Rethinking e-Government Services: User-Centred Approaches*, Paris: Organisation for Economic Co-operation and Development
- [18] Brown, D. H., & Thompson, S. (2011). Priorities, policies and practice of e-government in a developing country context: ICT infrastructure and diffusion in Jamaica. *European Journal of Information Systems*, 20(3), 329-342.
- [19] United Nations. (2010). *United Nations E-Government Survey 2010 - Leveraging e-government at a time of financial and economic crisis*. New

- York, United Nations Department of Economic and Social Affairs.
Division for Public Administration and Development Management
- [20] Azad, B., Faraj, S., and Goh J. F. (2010). What Shapes Global Diffusion of eGovernment: Comparing the Influence of National Governance Institutions, *Journal of Global Information Management*, 18(2), 85-104.
- [21] Chen, Y. N., Chen, H. M., Huang, W., and Ching, R. K. (2006). E-government strategies in developed and developing countries: An implementation framework and case study. *Journal of Global Information Management (JGIM)*, 14(1), 23-46.
- [22] Vlada Republike Srbije. (2010). Strategija razvoja informacionog društva u Republici Srbiji do 2020. godine, Službeni glasnik RS, br. 51.
- [23] Vidas-Bubanja, M. (2011). Prednosti i ograničenja izgradnje e-uprave u Srbiji, *Časopis za ekonomiju i tržišne komunikacije*, 1, 73-88.
- [24] Stojanovic, A. (2013). Upravljanje IKT projektima u javnom sektoru. INFOTECH 2013 ICT Conference & Exhibition, Asocijacija za računarstvo, informatiku, telekomunikacije, automatizaciju i menadžment Srbije (JURIT), 12-13. jun, Aranđelovac, Srbija
- [25] Papadomichelaki, X., & Mentzas, G. (2012). e-GovQual: A multiple-item scale for assessing e-government service quality. *Government Information Quarterly*, 29(1), 98-109.
- [26] Johnson, T. C. (2012). Is your 'voice of the customer' shouting as loud as it should? <http://downloads.servicetick.com/ServiceTick-white-paper-response-rates.pdf>
- [27] Sheehan, K. B. (2001). E-mail survey response rates: A review. *Journal of Computer-Mediated Communication*, 6(2).
- [28] Nulty, D. D. (2008). The adequacy of response rates to online and paper surveys: what can be done?. *Assessment & Evaluation in Higher Education*, 33(3), 301-314.
- [29] Fernández Marin, X. (2011). The Impact of e-Government Promotion in Europe: Internet Dependence and Critical Mass. *Policy & Internet*, 3(4), 1-29.
- [30] Al-Zoubi, M. I., Sam, T. L., & Eam, L. H. (2011). Analysis of e-government adoption and organization performance in the Jordan businesses sector. *Academic Research*, 1(3), 334-348.
- [31] Nacionalna alijansa za lokalni ekonomski razvoj (NALED). (2013). Sinergija: kvartalni bilten NALED-a. br. 1, <http://www.naled-serbia.org/> (24.8.2019).

- [32] Gilbert, D., Balestrini, P., and Littleboy, D. (2004). Barriers and benefits in the adoption of e-government. *International Journal of Public Sector Management*, 17(4), 286-301.
- [33] Naz, R. (2009). E-governance for improved public service delivery in Fiji. *The Perceptions of Small Business Owners on Tourism Development in the Blackstone Valley, Rhode Island*, 190.
- [34] Rieger, P., & Toth, P. (2011). Assessing the Successfulness of e-Government on an Example of the Czech Republic. *Research Journal of Economics, Business and ICT*, 1 (1), S. 35–41.
- [35] Russell, T. (2013). *Electronic Government Barriers and Benefits as Perceived by Citizens Who Use Public Services*, Doctoral dissertation, Walden University, Minnesota.
- [36] Alshehri, M., Drew, S., & Alfarraj, O. (2012a). A Comprehensive Analysis of E-government services adoption in Saudi Arabia: Obstacles and Challenges. *Higher education*, 6, 8-2.
- [37] Schwester, R. (2011). Examining the barriers to e-government adoption. *Leading Issues in E-government Research*, 1, 32.
- [38] Nkwe, N. (2012). E-Government: Challenges and Opportunities in Botswana. *International Journal of Humanities and Social Science*, 2(17), 39-48.
- [39] European Commission. (2012). *Digital Agenda for Europe Scoreboard 2012*. Chapter 5. Luxembourg: Publications Office of the European Union
- [40] Kunstelj, M., Jukic, T. & Vintar, M. (2007). Analysing the demand side of e-government: what can we learn from Slovenian users? In: Wimmer, M., A. (Eds.), Scholl, J. (Eds.), Grönlund, Å. (Eds.). *Electronic government: 6th international conference, EGOV 2007 (305-317)*. Regensburg, Germany: Lecture notes in computer science, 4656, Berlin: Springer-Verlag
- [41] Vlačić, E., Dabić, M., & Aralica, Z. (2018). National innovation system: where do government and business diverge?. *Drustvena Istrazivanja*, 27(4), 649-669.
- [42] OECD (2010), “E-Government Case Study”, in Finland: Working Together to Sustain Success, OECD Publishing, Paris.



Trends in the Enterprise Resource Planning Market Landscape

Shadrack Katuu

skatuu@gmail.com

Department of Information Science

University of South Africa, Pretoria, South Africa

Abstract

The purpose of this article is to provide a brief discussion of ERPs, including how they can be defined, their component parts, and the evolution of technologies since the 1940s. The article then offers a general overview of the current ERP vendor market landscape based on academic journals and industry reports. The article's methodological approach is a review of both academic literature and industry expert reports, which the author performed to trace trends within the landscape. Results of the analysis demonstrate that the rapidly evolving market landscape dates back at least six decades, and there are many large, longstanding ERP vendors. Yet, opportunities like cloud computing may result in niche products in existing industry players or through start-ups. These include trends such as the Fourth Industrial Revolution, artificial intelligence, blockchain technology as well as computing. Nonetheless, it remains to be seen how they will impact the ERP market.

Keywords: artificial intelligence, blockchain technology, cloud computing, cloud ERPs, digital disruption, ERP vendor market, Fourth Industrial Revolution, postmodern ERPs

1. Introduction

The enterprise resource planning (ERP) phenomenon has been a reality for many institutions over several decades. ERP is the integrated management of institutional activities mediated by technology [1]. According to Greengard [2], an ERP system is at the centre of an institution, tackling core tasks of managing and integrating business processes in real-time. Not all global institutions have implemented any ERP systems. However, many institutions require integrated enterprise wide functionality in areas such as accounting, sales, order management, customer relationship management (CRM), and supply chain management (SCM). Van Decker, Anderson, and Leiter [3] argued that ERPs continue to be the largest category of enterprise software expenditures in institutions.

Working professionals have endeavoured to ensure disciplinary theories and methodologies are in step with the rapidly evolving realities of the digital environment [4] – [5]. Numerous researchers have examined ERP systems development as well as implementation challenges and future [6] – [10]. However, it is rare to find

publications that give a general landscape of the ERP software vendor industry. Dahlén and Elfsson [11] investigated global ERP in 1999, pointing out eight companies at the time. Almost two decades later, when examining the emergence of the ERP software market, Erkut [12] based the discussions on one company that was a pioneering innovator in the market. Therefore, this article's contribution to academic discourse is to provide an overview of the current ERP vendor market landscape as well as trace current and emerging trends in that landscape.

2. Methodology and Approach

This article's methodological approach is a review of both academic literature and industry expert reports. This review explores relevant sources in order to provide a brief discussion of ERPs, including how they can be defined, their component parts, and the evolution of technologies since the 1940s [6], [13]. The article then offers a general overview of the current ERP vendor market landscape. There are various criteria that institutions could use to categorize ERP vendors, including market share, geographical coverage of their client base, historical background, and expansion patterns. However, this article uses two industry experts: Panorama Consulting and *eWeek* magazine's author, Samuel Greengard. Panorama Consulting is an information technology (IT) service company that specializes in business management and ERP consulting. Samuel Greengard has almost two decades of experience as an IT editor and writer. Together, their reports provide an expansive view rather than a deep analysis of the market. This article then discusses the current and emerging trends in the ERP market, concentrating on cloud computing, Fourth Industrial Revolution, artificial intelligence, and blockchain technology. The article concludes by reflecting on limitations and opportunities in the developing research on ERPs.

3. Defining ERPs

Readers can understand an ERP as both a concept that involves the integration of business processes as well as a system that, at its core, has an integrated database and several modules that cover various functional areas [14], [15]. The ERP may have one or more modules providing cross-organization integration of information, managing, and integrating core business processes in real-time [16]. These modules include the following:

1. Billing
2. Distribution
3. Finance
4. Human Resources
5. Logistics
6. Order Management
7. Procurement
8. Production
9. Project Management
10. Sales

11. Scheduling
12. Shipping
13. Supply Chain Management

For this reason, ERP systems are more than just mere technological artefacts. They are core platforms designed to support and leverage the capabilities of the tools and processes used by an organization [16]. In this sense, they are at the centre of everything an organization does, providing it the opportunity to adopt standardized practices and to have the potential to enhance operational efficiency, accountability, and organizational performance [14]. By managing and coordinating data and workflows between and among these components, it is possible for an organization to improve processes, trim costs, and achieve a more streamlined and effective business framework [2].

ERP platforms and concepts trace their genesis in the early years of computing to the 1940s. They have their immediate precursors as integrated control (IC) packages of the 1960s and the material resource planning (MRP) systems of the 1970s and 1980s. Between the 1990s and 2000s, ERPs and extended ERPs initially had monolithic architecture. They then moved toward multiple platforms in the advanced ERPs of the 2010s [16], [17]. In the 2000s, traditional ERP systems began expanding their footprint to include CRM, human capital management (HCM), enterprise asset management, product lifecycle management, product information management, product data management, quality assurance, manufacturing execution systems, SCM, transportation management systems, and warehouse management systems [18].

In the mid-2010s, Gartner, a global research and advisory firm, coined a new term of postmodern ERPs that they saw as more agile and outward facing than previous ERP iterations [19]. A postmodern ERP is described as a technology strategy that “automates and links administrative and operational business capabilities (such as finance, human resources, purchasing, manufacturing, and distribution) with appropriate levels of integration that balance the benefits of vendor delivered integration against business flexibility and agility” [20]. In this sense, a postmodern ERP is a more federated, loosely coupled environment than previous ERP iterations, with all or most of its functionality sourced as cloud services or business process outsourcers [19]. In a postmodern ERP, institutions can deploy modules or applications as complementary systems to support a postmodern ERP strategy, or embed or integrate them with a core ERP system [18].

The rapid technological development that took place between the 1990s and the 2020s resulted in institutions with ERPs implemented in the 1990s facing a technological crisis. On the one hand, modern institutions, including both multinational companies [21], [22], and small and medium size enterprises [23], increasingly required integrated enterprise applications. On the other hand, traditional ERPs had core legacy systems that were inflexible and unable to keep up with rising demands. Therefore, they were faced with the challenge of upgrading these applications.

According to Møller [24], ERP research prior to 2000 consisted of two strands. The first strand related to ERP success and failure research and ERP implementation [6], [25]. The second strand looked at ERP technology as an enabler of business

process reengineering [26]. A wide array of literature discusses challenges in implementing ERP: technical implementation challenges and organizational implementation challenges [27]. One of the technical implementation challenges is error in the choice of ERP software [27]. The choice of ERP software is a strategic decision that requires a large number of factors to be taken into consideration [28]. One of the considerations is a thorough understanding of the choice of ERP software products available in the market. The next section provides an overview of the modern ERP market landscape.

4. ERP Vendor Market Landscape

According to She and Thuraisingham [29], the ERP market landscape in the early 2000s included a wide variety of vendors. For instance, there were about 50 established vendors and a few more emerging smaller and medium size ERP vendors, including third party developers competing for the ERP market [30]. Due to historic reasons, these vendors had a specialty in a particular module area, such as Baan in manufacturing, PeopleSoft in HR management, SAP in logistics, and Oracle in financials [30].

At that time, some of the most consequential and tectonic changes took place in the market. For instance, in 2004, Oracle acquired PeopleSoft and JD Edwards, gaining approximately 22% of the ERP market share [29], [31]. By 2005, Sage had revenue of \$1.4 billion in the ERP market, claiming a 6% market share as the third largest ERP vendor. In 2005, SAP had 26% of CRM market share, 29% of ERP market share, and 19% of SCM market share by total software revenue [29].

According to Zare Mehrjerdi [32], the major ERP players in 2010 included SAP, Oracle, and Baan. Over the years, several ERP companies have come and gone. Others have maintained or strengthened their positions through mergers and acquisitions. There are different ways of laying out the current landscape. This section outlines two such ways by two industry experts, Panorama Consulting, and *eWeek* magazine's author, Samuel Greengard.

Panorama consulting [18] categorized ERP systems into Tier I, Upper Tier II, Lower Tier II, and Tier III based on factors such as target organization size, vendor revenue, target number of users, and other factors such as functional complexity (Table 1).

In Table 2, Greengard (2019) used varied criteria to identify a list of 10 ERP software providers, their flagship products, deployment, and headquarters. Table 2 also provides ratings based on the assessment of various industry reports.

Tables 1 and 2 demonstrate how vast the ERP industry is by showing at least thirteen current ERP vendors and some of their flagship products. However, the tables remain static illustrations that do not reveal the dynamic changes over time. Therefore, any organization that uses such resources for decision making needs to be cognizant of nuanced dynamism. For instance, regarding the issue of deployment, Panorama Consulting [33] noted 67% of the institutions had on-premises ERP software, 27% had SaaS, and 6% had cloud ERP. Two years later, Panorama consulting [18] noted a disaggregated deployment landscape with 37% of the institutions having on-premises,

	Criteria	Characteristics	Examples
Tier I	Designed for organizations with more than \$750 million in annual revenue	- Designed for large enterprises that have complex processes within their operations or complexity around consolidation and entity management - Tier I applications address multiple industries and scalability	- Infor LN - Oracle Cloud Apps, Infor M3 - SAP S/4/HANA
Upper Tier II	Designed for organizations with \$250 million to \$750 million in annual revenue	Small to medium size organizations that serve multiple industries and have multiple business units to manage	- IFS - Microsoft Dynamics 365 for Finance and Operations - Sage Enterprise Management
Lower Tier II	Designed for organizations with \$10 million to \$250 million in annual revenue	Small to medium size organizations that typically serve one industry and have a single entity to manage	- Infor CloudSuite - IQMS - Microsoft Dynamics 365 Business Central - Oracle NetSuite - Plex - SYSPRO
Tier III	Designed with niche functionality	- Smaller organizations - Used to supplement a larger ERP system	- Aptean - Sage ERP 100 - Sage ERP 300

Table 1. ERP market landscape tiers [18].

21% having cloud ERP (multi-tenant), 20% having SaaS, 14% having cloud ERP (single tenant), 9% having hybrid cloud, and 2% having a different arrangement. This latter report shows a more granular analysis of the choice of deployment in ERP implementation. The next section provides an overview of some current and emerging trends. These are likely to disrupt the market, prompting responses that will spur change.

5. Impact of Technology Trends on the ERP Market Landscape

Gartner predicted that at the dawn of the 21st century, ERP strategies would evolve into a new generation of enterprise systems [34]. As the ERP industry enters the 2020s, on-going disruptions in the digital world have also affected the ERP landscape. Kuula [35] describes digital disruptions as changes that occur when new digital technologies that are usually accompanied by new business models “affect the value proposition of existing goods and services.” These include current digital disruptions,

Vend- or	Flag- ship Product	Product Features	Deploymen t	Scor e	Headquart ers/ Global Presence
Epicor	Epicor ERP	HCM tools, sophisticated MRP functionality, and powerful financial tools like being a multi-company, accounting, and consolidation and allocation.	On-premises or in the cloud	4.2	Austin, Texas (USA); 150 countries
IFS		- Engineer-to-order processes in asset management features, along with HR, project management, and multi-site planning. - Designed for medium and large enterprises in construction and engineering, aerospace, and multimode manufacturing.	Service oriented architecture	4.1	Itasca, Illinois (USA); /50 countries
Infor		- A two tiered ERP approach that focuses both on the front office business needs of an enterprise and the back end operational requirements of manufacturing. - A shared services model for a wide range of tasks, including accounts payable, accounts receivable, HCM, SCM, and customer management. - Incorporates artificial intelligence and machine learning functions, powerful analytics, and reporting functions. - Focuses on specific industry segments and verticals such as manufacturing, consumer goods, services, public sector, and energy.	Cloud based platform	4.3	New York, NY (USA)
Micro soft	Microso ft Dynamics 365	- Mainly for finance and operations incorporated CRM features. - Strengths in business intelligence (BI) and real-time multi-dimensional analytics that can be used in demand forecasting and product change management tools with granular tracking of products and serial numbers.	On-premises or SaaS	4.5	Redmond, Washington (USA), 118 countries
Oracle	Oracle ERP NetSuite	- Considered a top tier provider of ERP solutions with both flagship products, delivering powerful embedded reporting and analytics tools and capabilities to manage assets across their lifecycle. - Oracle ERP leads in breadth and depth of features and functionality. - NetSuite focused on financial services and financial management with integration with Salesforce and other business software platforms.	SaaS	4.8	Redwood City, California (USA)
QAD		Integrated platform that connects various tasks, such as engineering, customer service, supply chain, and finance, without various add-ons and third party additions.	Cloud based framework to create an Anything-as-a-Service (XaaS) business environment	4.3	Santa Barbara, California (USA)

Vend- or	Flag- ship Product	Product Features	Deploymen t	Scor e	Headquart ers/ Global Presence
Rootstock		Integrated approach to sales, sales order processing, engineering, supply chain, production, inventory, logistics, and financials. Works with other leading business and financial applications using APIs (e.g., Salesforce).	Cloud based	4.3	Rootstock, California (USA)
Sage	Sage 300 ERP Sage 100c Sage Intacct	- Offers payroll and HR products and tools with integration tools to products like Salesforce. - Focuses on construction, manufacturing, chemicals, food and beverage, professional services, and non-profits. - Three products with a different emphasis: - Sage 300 ERP: a business management platform for large global enterprises; - Sage 100c: small and medium businesses; - Sage Intacct: delivers financial tools.	Cloud based	4.4	Atlanta, Georgia (USA)
SAP	SAP ERP SAP S/4HANA SAP Business One	- Pioneered the ERP space and continues to be a top vendor. - Has more than three dozen products and solutions for treasury and financial risk management tools, HR components, procurement, logistics, and SCM capabilities. - Offers solutions for predictive analytics, data management, machine learning, Internet of things, cyber security, and governance risk and compliance.	On-premises and cloud solutions	4.7	Waldorf (Germany)
SYSPRO		- Offers a comprehensive set of tools and features aimed at managing manufacturing with an end to end approach focused on production, distribution, and inventory management. - Offers industry specific software for automotive, electronics, food and beverage, industrial machinery and equipment, fabricated metals, packaging, plastics, and rubber, etc.		4.5	Costa Mesa, California (USA)

Table 2. ERP market landscape [2].

like cloud computing, process robotics, and visualization, as well as emerging digital disruptions, such as advanced analytics, blockchain, and cognitive computing [36]. For instance, visualization helps in presenting data generated within ERPs in ways that ensure they can be easily leveraged in decision-making. This may include external tools, such as Tableau Desktop or Microsoft's Power BI, which give users new options for data processing and consumption [15]. This section will discuss several technological trends, namely, the Fourth Industrial Revolution, cloud computing, artificial intelligence, and blockchain technology.

5.1. Fourth Industrial Revolution

In order to understand the Fourth Industrial Revolution, also known as *Industry 4.0* or *4IR*, one has to understand the preceding industrial revolutions. The First Industrial Revolution lasted between mid-18th century to mid-19th century and was marked by a transition in an agrarian society from hand production methods to machines through the use of steam and water power, the distinguishing principle being machine productivity [37], [38]. The Second Industrial Revolution lasted between the mid-19th century to the early 20th century and was marked by the extensive installation of railroad and telegraph networks, the distinguishing principle being scientific management [37], [38]. The Third Industrial Revolution occurred from the mid-20th century until the early 21st century and characterised by the development and ubiquity of digital technologies and decentralized networks. ERPs were among those technologies that emerged during the Third Industrial Revolution. The phrase *Fourth Industrial Revolution* is attributed to the Klaus Schwab, who introduced it in 2015 [39], [40]. This fourth phase has been characterised by automation of traditional manufacturing and industrial practices as well as the increasing use of smart technology, including large scale machine to machine communication and the Internet of Things that improve communication, self-monitoring, and the product of smart machines [41].

While the 4IR is increasingly being adopted by governments in their technology development strategies, some researchers have also noted that ERPs will form a key part of the 4IR agenda. For instance, in manufacturing processes, ERPs dominated other types of information systems [42] while in the health sector, ERPs were increasingly being used to integrated hospital management operations [43], [44].

5.2. Artificial Intelligence

Artificial intelligence (AI) is a discipline that has existed since the 1950s and is described as intelligence demonstrated by machines in contrast to natural intelligence displayed by humans or animals [37], [45]. It has most recently received heightened interest with the technological developments seen in cloud computing and the platform created in the 4IR. An example of increased interest is seen with the proliferation of an increasing amount of digital content that is difficult to search. AI is seen as a means of enhancing search mechanisms [46]. Girasa [37] argues that there are three categories of artificial intelligence: artificial narrow intelligence (ANI), artificial general intelligence (AGI), and artificial super intelligence (ASI). These are seen as progressive, with ANI being limited to performing singular tasks such as making sales predictions or autonomously driving vehicles. AGI is considered human level, in which machines are able to imitate human reasoning. ASI is considered futuristic, in which machines will surpass human creativity, social skills, and ability to make complex decisions [37].

Basl and Marketa [47] conducted research amongst ERP system supplies and found that while most indicated that artificial intelligence was at the core of their systems, less than a quarter were actively expanding their ERP systems with artificial

intelligence. In their research, most responding institutions used AI in predictive inventory management with two thirds of those in decision support as well as data analysis and processing [47]. Other common AI applications include conversational AI platforms that include virtual assistants and chatbots, as well as predictive analytics models [48]. This demonstrates that most ERPs were involved in ANI and not AGI or ASI.

5.3. Cloud Computing

Mell and Grance [49] define *cloud computing* as a model “for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.” At the most fundamental level, there are three cloud computing service models [49]:

1. **Software as a Service (SaaS):** Delivers software applications through a thin client interface so that users do not manage or control underlying infrastructure.
2. **Platform as a Service (PaaS):** Delivers middleware used by developers to build and configure SaaS applications.
3. **Infrastructure as a Service (IaaS):** Delivers computing power such as storage, network, and provision processing, used to deploy and run software.

The ERP market has been undergoing a generational technology shift driven by the advent of cloud computing [3]. Cloud based ERPs emerged by the mid-2000s due to two perceived benefits: using closely coupled systems and moving away from managing on-premises ERPs [50].

5.3.1. Close Coupling Vs. Cloud Based ERPs

Martinez [51] argued that ERP vendors built traditional ERP tools to be comprehensive, meaning they were full suites that combined BI, CRM, general ledger accounting, and HR applications that are tied directly to preconceived, specific business use cases and devices. In contrast, cloud-based ERP vendors built apps that are broken into separate modules that can seamlessly connect. This means that if an institution needs BI and CRM apps (but do not need HR management and point of sale [POS]) apps, it is a matter of toggling apps on or off [51]. In this way, cloud delivered apps allow customized and feature relevant modules, enabling institutions to rapidly respond to internal integration and workflow needs [52].

5.3.2. On-Premise Systems Vs. Cloud Based ERPs

Most ERP vendors build everything on the same digital architecture. This means that one is getting the same user interface (UI) across every module—from CRM to e-commerce to general ledger. This also means that one is only using one security protocol to monitor and protect the data within this architecture. The more apps that

one combines, the more security adjustments need to be made. In addition, at the core, most work uses a general ledger core. Therefore, combining ERPs from different vendors means duplicating the core [51].

Initially, traditional ERPs were built as on-premises apps. Like all enterprise systems, IT professionals in institutions must update them regularly to fix bugs, tighten security, extend current functionalities and modules, convene market and legal regulations, update processes, and meet the evolving organizations [50]. However, these processes, when conducted on-premises, have been cumbersome considering the granular nature of each activity and the need to monitor the technical change processes.

In contrast, cloud implementations allow information technology professionals to update apps when new features and security patches become available [51], [53]. However, this also means that cloud ERP users are no longer in control of the updates and upgrades and maintenance decisions. As Bjelland and Haddara [50] stated, “maintenance and update decisions and efforts are solely triggered and conducted on chosen dates by ERP vendors.”

5.4. Blockchain Technology

Blockchain technology, which was first implemented in 2009, was the underlying platform designed to solve a problem with the cryptocurrency, Bitcoin, to transfer digital value without relying on a trusted third party [54]. The terminology is still confusing because the technology is evolving. For regulators in the financial world, the rapidly shifting and contested vocabulary is difficult to understand and govern [55]. Nonetheless, Lemieux, Hofman, Batista, and Joo [56] described this “technology of trust” as a type of distributed ledger comprised of confirmed and validated blocks cryptographically chained together.

Researchers see blockchain technology as a solution to a global crisis of trust. Therefore, some advocates argue that the technology’s unique capabilities serve to negate the need for trust, calling it a trust-less technology [57], [58]. However, Lemieux, Hofman, Batista, and Joo [56] argued that in practice, blockchain does not obviate the need for trust. Instead, it replaces more traditional, and often inefficient or flawed, means of obtaining information and establishing trust, such as traditional legal contracts, with a new, more efficient source of information. The substitution does not negate the need for trust. It is an evolution based on incentive mechanisms, record creation, recordkeeping, and decentralization [56]. Blockchain has three interacting trust layers in technology (Figure 1).

According to Lemieux, Hofman, Batista, and Joo [56], the social layer “is where social actors interact with one another and determine how much information they need, and in what form (e.g., by social convention, how much from the blockchain system and how much from other sources external to the system) in order to be able to trust and take action on the basis of trust.” The data or record layer “supplies the information that social actors have decided they need to obtain from the blockchain system to give them confidence to act” [56]. Finally, the technical layer “technical

means by which social actors interact and create, store, and obtain information about those interactions as tamper resistant and non-reputable proof of facts about acts” [56].



Figure 1. Three layer trust model for blockchain technology [56].

This final layer blockchain is a data structure that is technically implemented in a decentralized peer to peer network. It offers the possibility to define and hold both data and functions in single blocks [59].

Since the mid-2010s, there have been various efforts to develop enterprise blockchain that will eventually roll out blockchain as infrastructure [60]. According to George, Peterson, Yaros, Beam, Dibbell, and Moore [54], many current supply chain processes rely on non-standardised paper and digital records held among various parties. This often results in difficulties pinpointing problems in the chain. With blockchain, an ERP system can provide an integrated platform across partners and stakeholders, providing data that cannot be manipulated (i.e., true record) and an audit trail for transactions that happen within the extended ERP network [54], [61]. For this reason, several ERP vendors are developing blockchain platforms and protocols, such as SAP Cloud Platform Blockchain and Oracle Blockchain [60]. Pelz-Sharpe [60] expects that ERP vendors, such as SAP, Oracle, and Microsoft, will eventually be major infrastructure vendors for blockchain as a service (BaaS).

In general terms, the ability of ERPs to provide network solutions is typically limited to implementation within the boundaries of an enterprise [62]. Therefore, only a truly decentralized blockchain implementation must operate outside this limitation. For this reason, there are efforts to integrate information technology landscapes and disparate ERP systems to ecosystems of blockchains. For instance, Schmidt et al. [59] used a unified framework for blockchain based business integration, Unibright Connector, to connect separate ERP systems, as illustrated in Figure 2.

Figure 2 illustrates the ability to encapsulate communication technologies of two different ERPs (SAP and Oracle) with different blockchain platform channels using an Unibright Connector. It is also possible to use blockchain to orchestrate multiple workflows in both public and private blockchains for products such as smart contracts. Additionally, this is possible in integrated scenarios, including an ERP system, as illustrated in Figure 3 [59].

Figure 3 illustrates how an institute with access to a public blockchain environment tries to institute a smart contract that is connected to the institution’s ERP

system. This will undergo internal processing within the ERP; then it is delivered to a private blockchain for completion of the second and final workflow process [59].

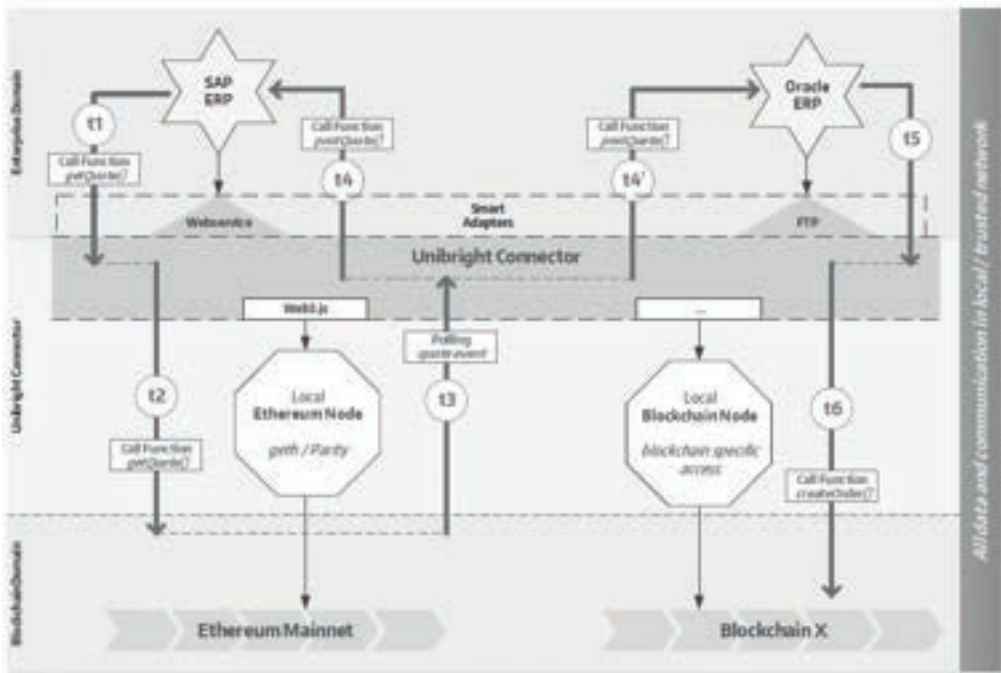


Figure 2. Unibright Connector architecture [59].

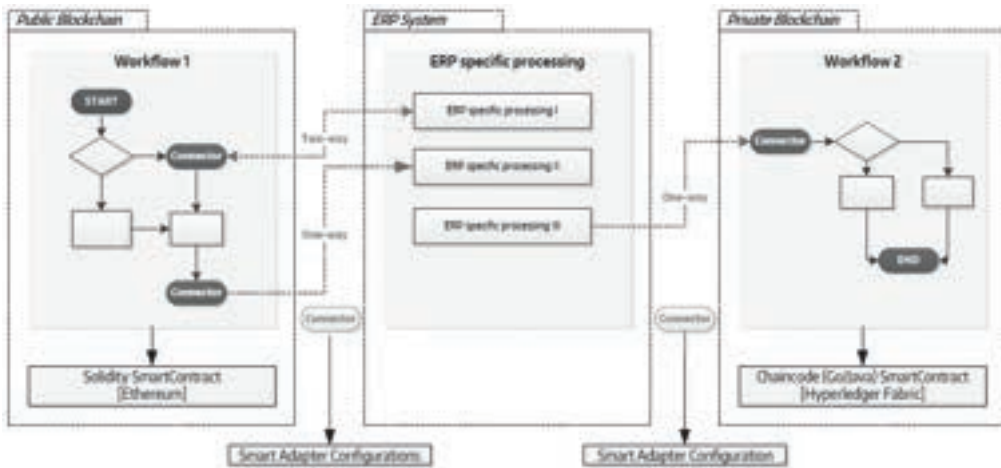


Figure 3. Orchestrating workflows [59].

6. Discussion and Conclusion

Of the four trends discussed in the paper, cloud computing is the one most frequently reported because it is seen as a drastic gateway to modernization compared to previous ERP solutions [47]. Nonetheless, 4IR platforms, particularly the opportunities to connect ERPs to smart devices, open up huge opportunities to harness real-time data and support decision making within institutions [45], [47].

Figure 4 illustrates how ERP innovations are possible with a digital core and cloud PaaS from vendors that support varied technologies [36]. On the outer core of the illustration are various technologies discussed in this article. Starting clockwise from the top, these technologies are networking platforms, machine learning, blockchain, android devices, SAP Leonardo, wearable devices, technology in scientific research, mobile devices, industrial robotics, artificial intelligence, and Apple devices [63] – [67].

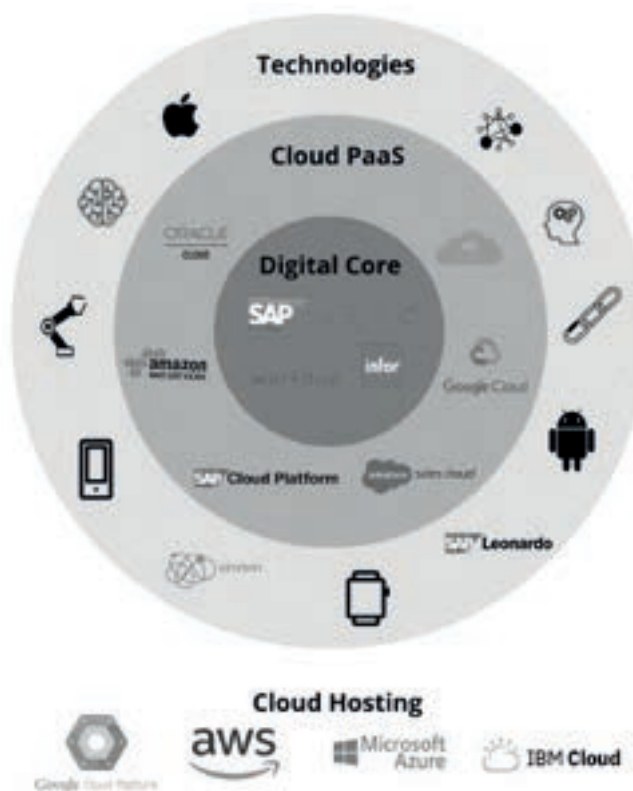


Figure 4. ERP innovation [36].

As Figure 4 demonstrates, cloud computing makes it easy for institutions to use ERPs on mobile devices [68].

In 2019, Gartner stated that ERP systems were one of the largest categories of enterprise software spending and added that by 2022, 30% of large enterprises will have moved to a platform and product-centric approach with standardized ERP

capabilities at the platform core [69]. This continued growth partly illustrates why ERP systems remain vital enabling technologies within institutions. This article has provided a brief overview of the ERP market landscape. While there have been many ERP vendors since its start in the 1940s, some have disappeared through mergers/acquisitions, while others have emerged [30].

Since the early 2000s, new digital innovations have impacted the ERP landscape, including advanced analytics, cognitive computing, and visualization [36]. The digital revolution has been characterised by the convergence of technologies that improve the efficiency and effectiveness of business processes [70]. This article examined how four trends, 4IR, AI, cloud computing, and blockchain technology, have impacted and continue to impact the trajectory of developments within the ERP market. While the discussion was limited to these technologies, there are many other trends, including open source ERP models as well as machine learning [71], [72]. These discussions are necessary for the current ecosystems within ERP systems because it is easy to get lost in the complexity of the rapidly evolving market landscape. The impact of external influences from such technologies requires working outside an ERP's ecosystem. Therefore, this fundamentally challenges how future ERPs will be built and used [73]. All these considerations are critical for information management professionals in their quest to fulfil their institutional mandates, particularly since discussions on ERPs systems and current developments may not be included in formal education and training [74],[75].

Acknowledgements

Research leading to this article was funded by South Africa's National Research Foundation Grant Number 114856. The views expressed herein are those of the author and should neither be attributed to their current employer nor to any of their previous employers.

References

- [1] P. Parmar, "Managing electronic supply chains," *Managing Operations Throughout Global Supply Chains*, J. C. Essila, Ed. Hershey, PA: IGI Global, 2019, pp. 181–197.
- [2] S. Greengard, *Top 10 Enterprise Resource Planning Software Providers*. City, 2019.
- [3] J. E. Van Decker, R. P. Anderson, and G. Leiter, "Magic Quadrant for Cloud Core Financial Management Suites for midsize, large and global enterprises," Gartner [Online]. Available: <https://b2bsalescafe.files.wordpress.com/2019/09/gartner-magic-quadrant-for-cloud-core-financial-management-suites-for-midsize-large-and-global-enterprises-may-2019.pdf> [Accessed: Aug. 22, 2020].

- [4] S. Katuu, "Enterprise Architecture—A Value Proposition for Records Professionals," In 2019 IEEE International Conference on Big Data, Los Angeles, CA, C. Baru, J. Huan, L. Khan, X. Hu, R. Ak, Y. Tian, R. Barga, C. Zaniolo, K. Lee, and Y. F. Ye, Eds. IEEE, 2019, pp. 3116–3125.
- [5] R. Marciano, V. Lemieux, M. Hedges, Y. Tomiura, S. Katuu, J. Greenberg, W. Underwood, K. Fenlon, A. Kriesberg, M. Kendig, G. Jansen, P. Piety, D. Weintrop, and M. Kurtz, "Establishing an international computational network for librarians and archivists," University of Maryland, College Park [Online]. Available: https://www.ideals.illinois.edu/bitstream/handle/2142/103139/Marciano_et_al_BlueSky2.pdf?sequence=4&isAllowed=y, [Accessed: Aug. 22, 2020].
- [6] M. Ali and L. Miller, "ERP system implementation in large enterprises: A systematic literature review," *Journal of Enterprise Information Management*, vol. 30, no. 4, pp. 666–692, 2017.
- [7] M. A. A. Elmonem, E. S. Nasr, and M. H. Geith, "Benefits and challenges of cloud ERP systems: A systematic literature review," *Future Computing and Informatics Journal*, vol. 1, no. 1–2, pp. 1–9, 2016.
- [8] V. M. Khaparde, "Barriers of ERP while implementing ERP: A Literature Review," *Journal of Mechanical and Civil Engineering*, vol. 3, no. 6, pp. 49–91, 2012.
- [9] Y. Moon, "Enterprise resource planning (ERP): A review of the literature," *International Journal Management and Enterprise Development*, vol. 4, no. 3, pp. 235–264, 2007.
- [10] S. Ranjan, V. K. Jha, and P. Pal, "Literature review on ERP implementation challenges," *International Journal of Business Information Systems*, vol. 21, no. 3, pp. 388–402, 2016.
- [11] C. Dahlén and J. Elfsson, *An Analysis of the Current and Future ERP Market*. Sweden: The Royal Institute of Technology, 1999.
- [12] B. Erkut, "The emergence of the ERP software market between product innovation and market shaping," *Journal of Open Innovation: Technology, Market, and Complexity*, vol. 4, no. 3, pp. 1–23, 2018.
- [13] S. Katuu, "Conducting research: Graduate level literature reviews," University of South Africa, Pretoria, South Africa [Online]. Available: https://www.researchgate.net/publication/343725059_Conducting_research_-_graduate_level_literature_reviews/ [Accessed: Aug. 22, 2020].

- [14] J. T. F. Callejas and C. Terzi “Review of enterprise resource planning (ERP) systems in United Nations organizations: JIU/REP/2012/8,” Joint Inspection Unit: United Nations, Geneva [Online]. Available: https://www.unjiu.org/sites/www.unjiu.org/files/jiu_document_files/products/en/reports-notes/JIU%20Products/JIU_REP_2010_6_English.pdf [Accessed: Aug. 22, 2020].
- [15] O. Rist and J. Martinez, “5 enterprise resource planning (ERP) trends to watch in 2019” [Online]. Available: <https://www.pcmag.com/article/351807/5-enterprise-resource-planning-erp-trends-to-watch-in-2019> [Accessed: Aug. 22, 2020].
- [16] E. Nazemi, M. J. Tarokh, and G. R. Djavanshir, “ERP: A literature survey,” *International Journal of Advanced Manufacturing Technology*, vol. 61, no. 9–12, pp. 999–1018, 2012.
- [17] S. Katuu, “Enterprise resource planning: Past, present and future,” *New Review of Information Networking*, vol. 25, no. 1, pp. 37–46, 2020.
- [18] Panorama Consulting “2019 ERP report: People, process, technology” [Online]. Available: <https://cdn2.hubspot.net/hubfs/4439340/2019-ERP-Report-3.pdf> [Accessed: Aug. 22, 2020].
- [19] M. Guay, “Postmodern ERP strategies and considerations for midmarket IT leaders,” Gartner [Online]. Available: <http://proyectos.andi.com.co/camarabpo/Webinar%202016/Postmodern%20ERP%20strategies%20and%20considerations%20for%20midmarket%20IT%20leaders-%20Gartner.pdf> [Accessed: Aug. 22, 2020].
- [20] Gartner, “Gartner Glossary: Postmodern ERP” [Online]. Available: <https://www.gartner.com/en/information-technology/glossary/postmodern-erp> [Accessed: Aug. 22, 2020].
- [21] H. L. Meghana, A. O. Mathew, and L. L. R. Rodrigues, “Prioritizing the factors affecting cloud ERP adoption: An analytic hierarchy process approach,” *International Journal of Emerging Markets*, vol. 13, no. 6, pp. 1559–1577, 2018.
- [22] B. Molnár, “The country-specific organizational and information architecture of ERP systems at Globalised Enterprises,” *Business Systems Research*, vol. 2, no. 2, pp. 39–50, 2011.
- [23] Y. Xie, C. J. Allen, and M. Ali, “An integrated decision support system for ERP implementation in small and medium sized enterprises,” *Journal of Enterprise Information Management*, vol. 27, no. 4, pp. 358–384, 2014.
- [24] C. Møller, “ERP II: A conceptual framework for next-generation enterprise systems?” *Journal of Enterprise Information Management*, vol. 18, no. 4, pp. 483–497, 2005.

-
- [25] E. Chan and A. Mills, "Implementation of enterprise resource planning (ERP) software in a major construction contracting organization in Hong Kong," *International Journal of Managing Projects in Business*, vol. 4, no. 1, pp. 168–178, 2011.
- [26] N. A. Panayiotou, S. P. Gayialis, N. P. Evangelopoulos, and P. K. Katimertzoglou, "A business process modeling-enabled requirements engineering framework for ERP implementation," *Business Process Management Journal*, vol. 21, no. 3, pp. 628–664, 2015.
- [27] G. Capaldo and P. Rippa, "A planned-oriented approach for EPR implementation strategy selection," *Journal of Enterprise Information Management*, vol. 22, no. 6, pp. 642–659, 2009.
- [28] E. Yontar, "A comparative study to evaluate of SAP and LOGO ERP software's for SMEs and big businesses," *Turkish Journal of Engineering*, vol. 3, no. 1, pp. 1–8, 2019.
- [29] W. She and B. Thuraisingham, "Security for enterprise resource planning systems," *Information Systems Security*, vol. 16, no. 3, pp. 152–163, 2007.
- [30] M. A. Rashid, L. Hossain, and J. D. Patrick, "The evolution of ERP systems: A historical perspective," *Enterprise Resource Planning: Solutions and Management*, IGI Global, 2002, pp. 35–50.
- [31] C. Jones, *The Technical and Social History of Software Engineering*. Upper Saddle River, NJ: Addison-Wesley, 2013.
- [32] Y. Zare Mehrjerdi, "Enterprise resource planning: Risk and benefit analysis," *Business Strategy Series*, vol. 11, no. 5, pp. 308–324, 2010.
- [33] Panorama Consulting, "2017 Report on ERP systems and enterprise software" [Online]. Available: <https://www.panorama-consulting.com/wp-content/uploads/2017/07/2017-ERP-Report.pdf> [Accessed: Aug. 22, 2020].
- [34] N. Wood, B. Bond, Y. Genovese, B. Zrimsek, N. Rayner, and D. Miklovic, "ERP is dead—Long live ERP II," New York: Gartner Group [Online]. Available: <https://www.gartner.com/en/documents/314701/erp-is-dead-long-live-erp-ii> [Accessed: Aug. 22, 2020].
- [35] S. Kuula and H. Haapasalo, "Continuous and co-creative business model creation," in *Service Business Model Innovation in Healthcare and Hospital Management*, M. A. Pfannstiel and C. Rasche, Eds. Springer, 2017, pp. 249–268.
- [36] M. Stallard, "ERP and enabling technologies," Deloitte [Online]. Available: <https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/public-sector/deloitte-uk-matt-stallard-erp-and-enabling-technologies.pdf> [Accessed: Aug. 22, 2020].
-

- [37] R. Girasa, *Artificial Intelligence as a Disruptive Technology*. Pleasantville, NY: Palgrave Macmillan, 2020.
- [38] Ž. Stojkić, I. Veža, and I. Bošnjak, "Concept of information system implementation (CRM and ERP) within Industry 4.0," In 26th DAAAM International Symposium on Intelligent Manufacturing and Automation, Vienna, Austria, B. Katalinic, Ed. DAAAM International, 2016, 0912–0919.
- [39] K. Schwab, "The Fourth Industrial Revolution: What it means and how to respond," *Foreign Affairs* [Online]. Available: <https://www.foreignaffairs.com/articles/2015-12-12/fourth-industrial-revolution> [Accessed: Aug. 22, 2020].
- [40] M. Xu, J. M., David, and S. H. Kim, "The Fourth Industrial Revolution: opportunities and challenges. *International Journal of Financial Research*, 9, 2 (2018), 90–95.
- [41] S. P. da Costa and N. Costa, "Industrial occupational safety: Industry 4.0 upcoming challenges," *Safety and Security Issues in Technical Infrastructures*, D. Rehak, A. Bernatik, Z. Dvorak, and M. Hromada, Eds. IGI Global, 2020, pp. 152–172.
- [42] Y. Liao, L. F. P. Ramos, M. Saturno, F. Deschamps, E. d. F. R. Loures, and A. L. Szejka, "The role of interoperability in the Fourth Industrial Revolution era," *IFAC–PapersOnLine*, vol. 50, no. 1, pp. 12434–12439, 2017.
- [43] S. Katuu, "Transforming South Africa's health sector: The eHealth strategy, the implementation of electronic document and records management systems (EDRMS) and the utility of maturity models," *Journal of Science and Technology Policy Management*, vol. 7, no. 3, pp. 330–345, 2016.
- [44] M. Lee, Y. Yoon, G. H. Ryu, H. S. Bok, K. Yoon, S. Park, and K.-S. Lee, "Innovative distribution priorities for the medical devices industry in the Fourth Industrial Revolution," *International Neurourology Journal*, vol. 22, Supplement 2, pp. 83–90, 2018.
- [45] M. Helmold, *Lean Management and Kaizen: Fundamentals From Cases And Examples In Operations And Supply Chain Management*. Berlin, Germany: Springer, 2020.
- [46] A. Pelz-Sharpe, "Oracle Intelligent Track and Trace," *Deep Analysis* [Online]. Available: <https://www.oracle.com/a/ocom/docs/blockchain/deep-analysis-oracle-intelligent-track-and-trace-2020.pdf> [Accessed: Aug. 22, 2020].

- [47] J. Basl and M. Novakova, "Analysis of selected ERP 4.0 features and proposal of an ERP 4.0 maturity model," In *Research and Practical Issues of Enterprise Information Systems: 13th IFIP WG 8.9 International Conference, CONFENIS 2019, Prague, Czech Republic, December 16–17, P. Doucek, J. Basl, A. M. Tjoa, M. Raffai, A. Pavlicek, and K. Detter, Eds. Springer Nature, 2019, pp. 3–11.*
- [48] A. Krishnamoorthy, "How to leverage AI technology for a winning ERP strategy," *Acumatica* [Online]. Available: <https://www.acumatica.com/blog/how-leverage-ai-technology-for-winning-erp-strategy-gartner-research-note/>, [Accessed: Aug. 22, 2020].
- [49] P. Mell and T. Grance, *The NIST Definition of Cloud Computing*. Gaithersburg, MD: National Institute of Standards and Technology, 2011.
- [50] E. Bjelland and M. Haddara, "Evolution of ERP systems in the cloud: A study on system updates," *Systems*, vol. 6, no. 22, pp. 1–26, 2018.
- [51] J. Martinez, "Is enterprise resource planning (ERP) software dead?" [Online]. Available: <https://www.pcmag.com/article/353591/is-enterprise-resource-planning-erp-software-dead> [22nd August, 2020].
- [52] C. Saran, "Can cloud-based ERP buy you business agility?" [Online]. Available: <https://www.computerweekly.com/feature/Can-cloud-based-ERP-buy-you-business-agility> [Accessed: Aug. 22, 2020].
- [53] B. M. Shabou, M. Guercio, S. Katuu, E. Lomas, and A. Grazhenskayas, "Strategies, methods and tools enabling records governance in a cloud environment," in *Trusting Records in the Cloud: The creation, Management, and Preservation of Trustworthy Digital Content*, L. Duranti and C. Rogers, Eds. London, UK: Facet Publishing, 2019, pp. 97–116.
- [54] R. P. George, B. L. Peterson, O. Yaros, D. L. Beam, J. M. Dibbell, and R. C. Moore, "Blockchain for business," *Journal of Investment Compliance*, vol. 20, no. 1, pp. 17–21, 2019.
- [55] A. Walch, "The path of the blockchain lexicon (and the law)," *Review of Banking and Financial Law*, vol. 36, pp. 713–765, 2016.
- [56] V. Lemieux, D. Hofman, D. Batista, and A. Joo, "Blockchain technology and recordkeeping," ARMA International Educational Foundation [Online]. Available: https://www.researchgate.net/profile/Victoria_Lemieux/publication/333659272_Blockchain_Technology_Recordkeeping/links/5cfadaaf299bf13a3845866e/Blockchain-Technology-Recordkeeping.pdf [Accessed: Aug. 22, 2020].

- [57] M. Klems, J. Eberhardt, S. Tai, S. Härtlein, S. Buchholz, and A. Tidjani, "Trustless intermediation in blockchain-based decentralized service marketplaces," in *International Conference on Service-Oriented Computing, ICSOC 2017*, M. Maximilien, A. Vallecillo, J. Wang, and M. Oriol, Eds. Cham, Switzerland: Springer, 2017, pp. 731–739.
- [58] Q. Xia, E. B. Sifah, K. O. Asamoah, J. Gao, X. Du, and M. Guizani, "MeDShare: Trust-less medical data sharing among cloud service providers via blockchain," *IEEE Access*, vol. 5, pp. 14757–14767, 2017.
- [59] S. Schmidt, M. Jung, T. Schmidt, I. Sterzing, G. Schmidt, M. Gomm, K. Tschirschke, T. Reisinger, F. Schlarb, D. Benkenstein, and B. Emig, "Unibright: The unified framework for blockchain based business integration" [Online]. Available: <https://neironix.io/documents/whitepaper/3d4c0f5db2e4c6ffff57a281b26afe08.pdf> [Accessed: Aug. 22, 2020].
- [60] A. Pelz-Sharpe, "Enterprise blockchain market forecast and scenarios 2019–2024," *Deep Analysis* [Online]. Available: <https://www.deep-analysis.net/wp-content/uploads/2019/08/DA-190812-Ent-Blockchain-forecast.pdf> [Accessed: Aug. 22, 2020].
- [61] A. Banerjee, "Blockchain technology: Supply chain insights from ERP," *Advances in Computers*, vol. 111. P. Raj and G. C. Deka, Eds. Elsevier, pp. 69–98, 2018.
- [62] R. Cole, M. Stevenson, and J. Aitken, "Blockchain technology: Implications for operations and supply chain management," *Supply Chain Management: An International Journal*, vol. 24, no. 4, pp. 469–483, 2019.
- [63] Getty Images, "Artificial intelligence" [Online]. Available: <https://www.gettyimages.com/detail/illustration/simple-set-of-artificial-intelligence-royalty-free-illustration/1185273300> [Accessed: Aug. 22, 2020].
- [64] Getty Images, "Industry 4.0" [Online]. Available: <https://www.gettyimages.com/detail/illustration/simple-set-of-industry-4-0-related-vector-royalty-free-illustration/1187860522> [Accessed: Aug. 22, 2020].
- [65] Getty Images, "Internet of Things" [Online]. Available: <https://www.gettyimages.com/detail/illustration/internet-of-things-icon-set-royalty-free-illustration/1156691042> [Accessed: Aug. 22, 2020].
- [66] Getty Images, "Internet of Things infographic design" [Online]. Available: <https://www.gettyimages.com/detail/illustration/internet-of-things-related-line-infographic-royalty-free-illustration/1141680060> [Accessed: Aug. 22, 2020].

- [67] Getty Images, “Technology and devises” [Online]. Available: <https://www.gettyimages.com/detail/illustration/internet-of-things-icon-set-royalty-free-illustration/1156691042> [Accessed: Aug. 22, 2020].
- [68] K. Omar and J. M. Gómez, “A selection model of ERP system in mobile ERP design science research: Case study—Mobile ERP usability,” In Proceedings of the 13th International Conference of Computer Systems and Applications (AICCSA), Agadir, Morocco, November 29 – December 2. IEEE, 2016.
- [69] F. D. Capua, S. Tan, and A. Wilkins, “Magic Quadrant for SAP S/4HANA application services,” Gartner [Online]. Available: <https://www.pwc.com/gx/en/about-pwc/analyst-relations/assets/magic-quadrant-sap-s4hana-may-20-2019.pdf>, 2019, [31st August, 2020].
- [70] A. Banerjee, “Blockchain with IOT: Applications and use cases for a new paradigm of supply chain driving efficiency and cost,” *Advances in Computers*, vol. 115, pp. 259–292, 2019.
- [71] E. Labonte-LeMoine, P.-M. Leger, J. Robert, G. Babin, P. Charland, and J.-F. Michon, “Business intelligence serious game participatory development: Lessons from ERPsim for big data,” *Business Process Management Journal*, vol. 23, no. 3, pp. 493–505, 2017.
- [72] D. L. Olson, B. Johansson, and R. A. D. Carvalho, “Open source ERP business model framework,” *Robotics and Computer-Integrated Manufacturing*, vol. 50, pp. 30–36, 2015.
- [73] M. Guay, “State of North Carolina JLOC on IT,” Gartner [Online]. Available: <https://www.ncleg.gov/DocumentSites/committees/JLOCIT//03-08-2018/State%20of%20NC%20ERP%20Briefing-Ver-3.pdf> [Accessed: Aug. 22, 2020].
- [74] P. C. Franks, *Records and Information Management*. Chicago: American Library Association, 2013.
- [75] S. Katuu, “Exploring the challenges facing archives and records professionals in Africa: Historical influences, current developments and opportunities. *The UNESCO Memory of the World Programme: Key aspects and recent developments*, R. Edmondson, L. Jordan, and A. C. Prodan, Eds. Switzerland: Springer Nature, 2020, pp. 275–292.



Application of Fuzzy Set Theory in the Distribution of Information Flows of a Network Information System

Alexander V. Rubtsov

rubtsov.lpi@mail.ru

Department of Basic Disciplines

Lesosibirsk Pedagogical Institute – branch of Siberian Federal University, Lesosibirsk, Russia

Violetta V. Levshina

levshina.rssust@rambler.ru

Department of Quality Management, Standardization, Documentation Management

Reshetnev Siberian State University of Science and Technology, Krasnoyarsk, Russia

Svetlana V. Mamaeva

mamaeva.lpi@rambler.ru

Department of Basic Disciplines

Lesosibirsk Pedagogical Institute – branch of Siberian Federal University, Lesosibirsk, Russia

Ludmila N. Khramova

khramova.lpi@rambler.ru

Department of Higher Mathematics, Computer Science and Natural Science

Lesosibirsk Pedagogical Institute – branch of Siberian Federal University, Lesosibirsk, Russia

Igor V. Khramov

khramov.lpi@rambler.ru

Department of Basic Disciplines

Lesosibirsk Pedagogical Institute – branch of Siberian Federal University, Lesosibirsk, Russia

Abstract

This study's subject represents the processes of functioning of information flows in a network information system through the use of fuzzy sets. It considers the possibilities of fuzzy sets in the information flows distribution problems of the Network Information System by the development of mathematical tools. In the theoretical part of the study, the main issue was the description of the fuzzy approach. In the empirical part of the study, the main concern was finding out the reasons for the fuzzy approach's advantages. The main results of the study: proof of the identity between the functioning of the analytical data; held the solution of the optimization problem based on the formulated analytical models; comparison of the usage of fuzzy logic with a different statistical method; demonstrated the advantage of fuzzy

approach in modeling processes network information system. The results can be applied in the field of information systems and technologies.

Keywords: information systems, network information systems, information flows, fuzzy sets, mathematical modeling

1. Introduction

Any organization is characterized by a constant change process, explained by the creation and application of new methods in all areas of human activity. The rise of pervasive information and communication technologies seen in cyber-physical systems, the internet of things, and blockchain services has been accompanied by a tremendous growth in the size and complexity of systems [1]. At present, most various organizations' work is mainly associated with the use of information systems. The organization's success depends on the functioning of the latter and on the degree of correspondence between the problems they solve.

The primary function of the information network system is to provide integrated information space. Therefore, the primary vector of development in this area is studying the mechanisms of distribution and competition of information. The story of the information space largely depends on a quantitative change in the amount of data and increasing the complexity of the processes included in it [2].

By information network system (INS) is usually understood as a complex hardware and software structure that includes ergatic, technical, or hardware elements and is included directly in a computer system or computing machine for data transmitting, storing, and processing [3]. The INS has many advantages from modularity, reduced complexity, and memory requirements [4].

Considering modern sources of INS modeling, we can say that the most widely used technology for providing a set of computing resources or their logical combination is implementing user operations on a PC. Currently, researchers have identified many systems that consist in the ability of a particular type of signs to be replaced by characters concerning another class, the capabilities of which are focused on identifying many parameters and not just solving the problem of analyzing the configuration of the studied system [5].

The set of methods and techniques for organizing information processes in the INS is the content of forming an information resource. The INS's structural composition and its direct impact on creating and maintaining an integrated information space indicate an incredibly important component that provides all the fundamental processes of a network information system - the information flow.

The information flow is a tool of the logistics system. A few measures of information flow have been proposed previously in the literature, and actions of directed causal influence are currently being used as a heuristic proxy for information flow. However, there is no rigorous treatment of the problem with formal definitions and clearly stated assumptions. The process of defining information flow is often conflated with the issue of estimating it [6]. A modern way of solving the above problem is to make it language-based. That is: to enrich a programming language with features that specify or control the flow of data so that

the programs we write are correct [7]. The determining area of importance of information flows mainly to the management domain. It is impossible to build an effective management system without a well-ordered flow of information through its transmission channels. Information flows are the basis of the information system of any organization. Information flows of a course represent the functional and structural organization of the studied object in terms of decision-making mechanisms within the system.

Since any organization's information system refers to the totality of subjects and means of transmitting various types of data, the INS, given the vector of technological exchange of information, is one of the main elements of the structure of the information system. In the INS process, the main difficulties arise when the need for analyzing and monitoring changes in information flows increases. Information resources are dynamic by nature. Changes in external conditions that border the INS's functioning and the untimely receipt of the information lead to several negative consequences. In particular, this is a significant problem for production facilities, which use network systems as a basis for their computer-aided data management. "In those cases, when the requirements for the process of functioning of information flows inside the INS are forced to change constantly, the efficiency of the INS rapidly decreases" [1]. This idea explains the relevance of the search for solutions for a more effective solution to the distribution of information flows in the INS.

The object of this article is the functioning of the information network system.

The study's subject is the presentation of the processes of functioning of information flows in the INS through the use of fuzzy sets.

This article's purpose is to consider the possibilities of fuzzy sets in information flows distribution problems of the INS by the development of mathematical tools.

2. Literature Review

Researchers study the distribution of information flows from different points of view. Thus, Gromov considers the process of distribution of information flows in a network information system [4]. Minchenko highlights the streaming networks' performance parameter [8]. Many authors also consider the principle of building structures for the distribution of information flows; in particular, Osin highlights methods for modeling network information systems and the usage of fully polynomial approximation schemes for solving multi-product flow problems [5]. Other authors present a presheaf theoretic approach to the construction of fuzzy sets, which builds on Barr's description of fuzzy sets as sheaves of monomorphisms on a locale [9] and propose definitions of limits of sequences of fuzzy sets, and limits and derivatives of fuzzy set-valued mappings [10]. Jezewski, Czabanski, and Leski defined the real possibilities of describing fuzzy sets and operations on them [11]. Also, other researchers, such as Andrew J. Blumberg and Michael Lesnick when establishing homotopy-theoretic foundations for topological data analysis (TDA), introduced and study homotopy interleavings between filtered topological spaces using fuzzy sets' method as a basic [3].

Previously, the distribution of INS information flows using fuzzy set methods was not considered in detail. Moreover, the usage of fuzzy logic is currently limited to modeling linguistic variables and is not widely used in the field of information systems [12]. However, the distribution of INS information flows refers to optimization tasks in conditions of uncertainty.

When characterizing the work of INS, most researchers also highlight an element of uncertainty, which appears due to the following reasons:

- the impossibility of accurate measurements of information flow parameters;
- the use of values close to average in the qualitative and quantitative measurement of information flows;
- a significant difference in the values of the transmitted flows from the average of their values;
- a constant change in the bandwidth capacities of the elements of the INS structure caused by the influence of external factors.

The above-listed explains that the INS parameters cannot be determined under predetermination conditions since the requirements imposed by the user on the transmission of information flows are initially unknown [11]. Moreover, these factors determine the specifics of modeling the distribution of information flows in the INS. Thus, the researchers found that "the use of graph theory in conjunction with the theory of fuzzy sets" seems to be the most accurate way to build analytical models of INS functioning that can reflect the non-determinism of ongoing processes [11].

Information properties of a large set of distributed objects differ from the model object's properties, both quantitatively and qualitatively [13]. Considering the functioning of information flows in the INS, the information resource itself acquires many properties, which should be reflected in the mathematical model of processes. The main difficulty in distributing information flows is the existing feature of the basic model for the analysis of functioning information flows, which includes two different levels: low and high, which means, respectively, open and classified information. The information should not be allowed to flow from high to low variables. Also, before direct modeling of INS information flows, it is necessary to monitor procedures with high information complexity. So, it becomes possible to identify the following problems:

- The procedure has more than one function.
- The procedure is a stress point in the system (with information traffic).
- The procedure has excessive functional complexity.

High informational complexity implies possible advanced testing or redesign procedures. These parameters must be taken into account when modeling, which complicates the use of traditional logic.

In terms of INS, it is worth noting that "one of INS's main properties is their topological dimension D_c " [13]. Many of INS properties depend on the dimension measurement D_c , which is expressed in a standard form as a functional relation of the type "network quality = $f(D_c)$ ". When considering "the functioning of information flows in the INS in a topological dimension, it becomes possible to

quantitatively express the properties of the network and find the general information laws of the movement of data flows" [13].

In addition to considering information flows in the dimension determined by the most important invariant of the INS topological space (coverage), there are entirely polynomial approximation schemes used as a group of effective methods computing schemes. A completely polynomial approximation scheme is considered an algorithm for solving combinatorial problems. The option differs from the optimal one by no more than an individual tolerance, at which the level of accuracy acts as a new parameter [5].

Linear programming methods, albeit with significant labor costs, can solve the problems of distributing information flows in the INS. However, in the practical application of such a methodology, it becomes impossible to consider many parameters, which, in turn, leads to enormous miscalculations. Thus, the importance of using methods that could be characterized by the ability to find close to optimal values of variables in a given accuracy is growing.

Human thinking is often associated with fuzzy information originating from initially inaccurate concepts formulated by a human being. Moreover, diversity measures can be computed over different types of data and in a multitude of contexts. Access to data contracts or representations of different real phenomena has allowed for an explosive extension of quantitative studies' reach in many disciplines [14]. The abilities of traditional computational methods developed based on the classical theory of sets, and two-valued logic cannot cope with unreliable and incomplete information. They cannot give expert conclusions on these parameters. In particular, this is a problem in the mathematical modeling of decision-making processes based on various data types.

Today, the managers of production facilities, where the functioning of the INS is the main technical parameter, are in search of flexible IT solutions for managing information circulating within the facility. Thus, today it is customary to use additional modules of already established planning systems. However, in the absence of such an opportunity, computer programs for quick calculations are taken as the basis [10]. Nevertheless, greater interest in the top management of facilities is observed towards the use of fuzzy logic methods in distributing information flows in the INS of a facility since it is impossible to obtain accurate measurements of the values of information flows. The importance of the volumes of transmitted the information flows obtained in this way instantly differs significantly from the average cost.

The advantage of using fuzzy logic methods is justified by interpreting the concept of "truth." So, by "truth," it is customary to understand any linguistic variable that takes the meaning of phrases from natural or artificial languages [10]. So, when creating a mathematical model of any process, it becomes possible to consider more accurate indicators, which is especially important when solving problems with information flows. The accuracy then determines compliance with all the main parameters and principles of the functioning and distribution of information flows.

3. Research Methods

We specified the linguistic variable (x, T, U, G, M) . Where x is the name of the variable; T is a term set, each element of which (term) represents as a fuzzy set on a universal stage U ; G - syntax rules, often in the form of grammar, generating the name of the terms; M - semantic rules defining membership functions of fuzzy terms generated by the syntactic rules G [10]. Using a linguistic variable in modeling makes it easier to implement the decision-making process.

Unlike classical sets, fuzzy sets do not have a clear boundary. The transition from a state of membership to a group to going beyond its borders is characterized by membership functions that allow using fuzzy logic methods to observe flexibility in modeling the linguistic expressions used. Moreover, fuzziness arises not because of the set's constituent element's randomness but because of the uncertain and inaccurate nature of abstract thoughts and concepts [15].

The fuzzy approach does not intend to replace the most straightforward analysis in search of reasonable accuracy; on the contrary, it facilitates the problem of formulating inaccurate restrictions [16]. This fact is why as a result of the integration of approaches from the point of view of set theory and approaches from the point of view of classical programming, it becomes possible to create new methods in managing information flows.

The forms of fuzzy description of information “at input” in management and decision-making problems may vary. It indicates significant differences in the mathematical formulations of the fuzzy mathematical programming problems.

Before moving on to fuzzy modeling of the distribution of information flows in the INS, it is necessary to explain the main concepts and operations inherent in problems solved within fuzzy sets. It is customary to denote any arbitrary set X . A fuzzy set is A defined by using the form's membership function as follows: $X \rightarrow [0,1] \mu_A$. The value $\mu_A(x)$ is a number whose value satisfies the interval $[0,1]$.

The equality $\mu_A(x) = 1$ indicates the exact membership of x to the set A ; the equality $\mu_A(x) = 0$ shows the exact non-membership of x to A . For a standard set, the membership function takes the form as follows:

$$\mu_Y = \begin{cases} 0, & x \notin Y, \\ 1, & x \in Y \end{cases} \quad (1)$$

Provided that the fuzzy set A is normalized, i.e., there exists an element x such that $\mu_A(x) = 1$ [17].

Let's take two arbitrary fuzzy sets for A and B . Membership functions, by definition, will give the result of the operations of combining, intersecting, and complement A on fuzzy sets, which we can express as follows:

$$\mu_{A \cup B}(x) = \max(\mu_A(x), \mu_B(x)), \quad (2)$$

$$\mu_{A \cap B}(x) = \min(\mu_A(x), \mu_B(x)), \quad (3)$$

$$\mu_{\bar{A}}(x) = 1 - \mu_A(x) \quad (4)$$

Before implementing fuzzy information about the ratio of the limiting number (bandwidth capacity) of structural elements, the volume of transmitted information flows. Several requirements for them in the INS, according to the theory of fuzzy

sets, fuzzy LR [11] numbers of the form $ALR = (AM, AL, AR)$ are used, where AM – mode and AL, AR are the fuzziness coefficients of the LR -number ALR .

When performing operations on fuzzy numbers of the form LR , it is necessary to note the identity between the functioning analytic representations of the fuzzy number forms $L(y)$ and $R(y)$. Thanks to them, it becomes possible to bring the membership functions (5) as close as possible to the observed values of the INS parameters [18], where $L(y)$ and $R(y)$ are analytical models for representing the shape of a fuzzy LR number:

$$\mu(x, A_{LR}) = \begin{cases} L\left(\frac{A_M - x}{A_L}\right) & \text{at } x \leq A_M \\ R\left(\frac{x - A_M}{A_R}\right) & \text{at } x \geq A_M \end{cases} \quad (5)$$

To find as close as possible to the optimal values of the variables in a given accuracy as functions $L(y)$ and $R(y)$ Osin proposed an analytical model for representing the form of a fuzzy LR -number of the type indicated later in this study as – (6), which allows one to build numbers that have many ways of membership functions; besides, the model proposed by Osin can replace other used functions [5]:

$$F(x, p1, p2) = (\max(0, 1 - |x|^{p1}))^{p2} \quad (6)$$

where $p1, p2$ – function parameters, at $p1 > 0, p2 > 0$.

When distributing information flows in the INS, it is necessary to consider that each output and input pair has many methods that can identify the maximum transmission efficiency [11]. The INS structure, in this case, will become supreme. Since it is precisely on this parameter that the dependence of the methods for fulfilling each pair's requirements at different levels will be determined, thereby ensuring conflict-free transmission when an increase in one pair's transmitted information flow does not reduce that for the other pair. To determine these levels, Osin proposed to “consistently solve the optimization problem” [5], the author's analytical model of which has the following form $F(\tilde{f}) \rightarrow \max$:

$$F(\tilde{f}) = k_1 F1(\tilde{f}) + k_2 F2(\tilde{f}) + k_3 F3(\tilde{f}) + k_4 \theta(7)$$

in accordance with the restrictions:

$$\begin{aligned} F1(\tilde{f}) &= \frac{\sum_{i=\overline{1,p}} (N \max_i - |\tilde{f}_i|)}{\sum_{i=\overline{1,p}} (N \max_i - 1)}, \\ F2(\tilde{f}) &= \sum_{i=\overline{1,p}} \left(L \max_i - \frac{\sum_{j=\overline{1,|\tilde{f}_i|}} L(\tilde{f}_{i,j})}{|\tilde{f}_i|} \right), \\ F3(\tilde{f}) &= \frac{\sum_{i=\overline{1,p}} \sum_{j=\overline{1,|\tilde{f}_i|}} \tilde{f}_{i,j}}{\sum_{i=\overline{1,p}} \tilde{d}_i}, \forall e: \sum_{P:e \in P} \tilde{f}(P) \leq \tilde{c}(e), \\ 0 &\leq F1(\tilde{f}) \leq 1, 0 \leq F2(\tilde{f}) \leq 1, 0 \leq F3(\tilde{f}) \leq 1 \end{aligned}$$

where $k_1 - k_4$ – weighting factors set by the decision maker;

$k_1 + k_2 + k_3 + k_4 = 1$;

$F1(\tilde{f}), F2(\tilde{f})$ are estimated $\tilde{f}$ by the number of information flows and nodes in them;

$N \max_i$ and $L \max_i$ – the maximum possible number of components and the path length for the information flow i ;

$|\tilde{f}_i|$ – a number of components for i flow in distribution $\tilde{f}$;

$L(\tilde{f}_{i,j})$ – a path length of j component;

$F3(\tilde{f})$ – the total fulfilment of the requirements of gravitating pairs;

θ assesses the lower limit of security requirements;

$\tilde{c}(e)$ – the capacity of arc e ;

P – the information flow transmission path;

$\tilde{f}(P) \sim$ – a volume of information flow transmitted along the path P [18].

The analytical models for representing the type of a fuzzy LR number shown in formulas (6) and (7) of this article can formalize non-deterministic data on the parameters of information flows in the INS in the form of LR numbers and then determine the degree of efficiency of their distribution. It considers all the parameters formalized by the model based on fuzzy logic's concepts and properties [19]. Namely, the structure of information flows, which means managing complex problems, such as load balancing, processor synchronization, and access to information, are taken into account.

Since fuzzy sets are a generalization of the classical ones known to us, the operations should be reduced to the ones we are familiar with in particular cases. Functions must be defined outside of the theory of fuzzy mathematics itself and, therefore, its adequacy cannot be verified by means of the approach itself. Based on the essence of subjective evaluations, the function can only be constructed based on expert assessment. In our task evaluating the distribution's effectiveness as a fuzzy composite option is based on the work by Geske [20]. The transition to formulas suitable for fuzzy sets is made using the expansion principle. Applying the extension principle to arithmetic operations and trapezoidal fuzzy numbers, we get the following rules for addition and subtraction (Figure 1).

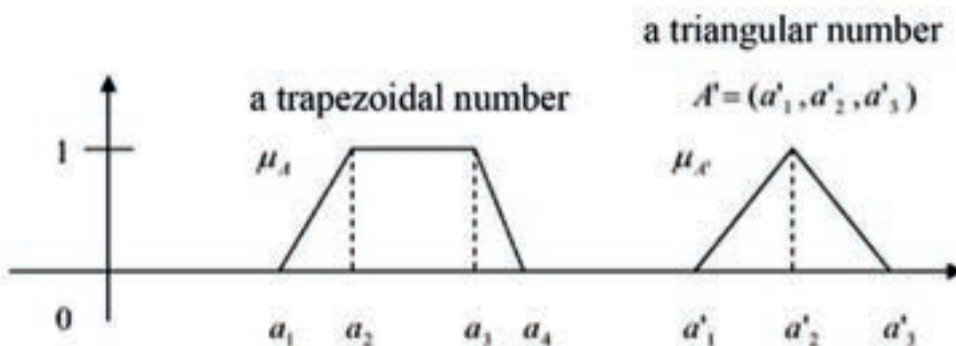


Figure 1. Trapezoidal and triangular numbers.

$$(a_1, a_2, a_3, a_4) + (b_1, b_2, b_3, b_4) = (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4) \quad (8)$$

$$(a_1, a_2, a_3, a_4) - (b_1, b_2, b_3, b_4) = (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1) \quad (9)$$

The use of fuzzy logic elements in calculus tools is not limited to the values "true" and "false." Here we see the main advantage of fuzzy logic in creating an empirical knowledge model that determines which control actions should be performed for a given input data set.

To determine the effectiveness of using fuzzy sets, consider distributing the information flow of a network information system in three stages. In this problem, unlike the previous calculations, the fuzzy set method will be used as an auxiliary method since this type of situation is optional (Figure 2).

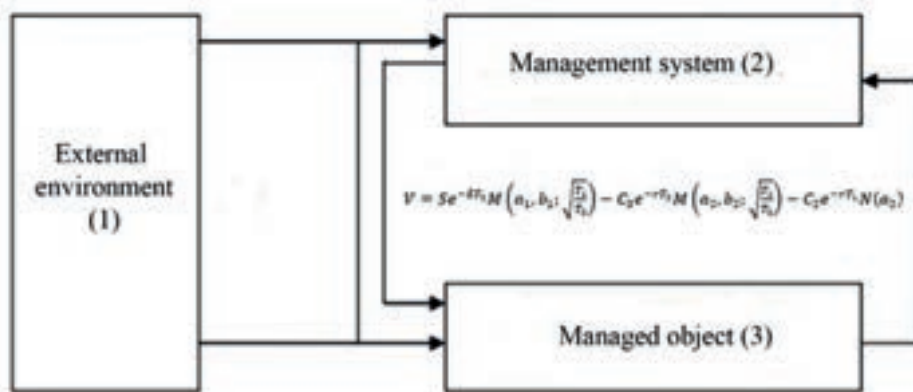


Figure 2. The illustration of the problem.

It is assumed that at the beginning of each stage, an absolute return of information is made (costs); we denote the value of the return of information at each stage $C1, C2, C3$, respectively. In addition to distributing existing data, the information flow receives an additional data set during each stage. This condition is vital when moving to each next step. Let S denote the receipt of information leading to the beginning of the third stage of distribution. It is assumed that $C1, C2, C3, S$ are fuzzy numbers obtained by expert analysis. The fuzzy variables must be centered to perform calculations. It makes it possible to reduce operations to addition, subtraction, and multiplication. When switching to operations for fuzzy sets, this property is of great importance for further visualization of the obtained data under homotopy topology conditions [17]. Let $T1, T2$ be the time for passing the first and second stages, and r be the parameter that determines the information flow's efficiency.

Now we should move on to make formulas for solving the problem. Based on the above analysis of the issues, it is necessary to distinguish the following properties: the identity between functioning analytical representations (5); the INS structure parameter determines how to fulfill the flow requirements at different levels, thus ensuring conflict-free transmission (7). We consider the following task as the task of effective distribution the information flow of a network information system. Thus, we calculate the INS information flow distribution efficiency using our formula based on the real option's method. Using the real options method, it becomes possible to consider improving specific parameters at the stage of evaluating the effectiveness of a particular technology. Thus, we calculate the efficiency of the INS information flow distribution using our formula, which is based on the real option's method, where we are going to estimate an evaluating the current distribution of information flow:

$$V = S e^{-\delta T_2} M\left(a_1, b_1; \sqrt{\frac{T_1}{T_2}}\right) - C_3 e^{-r T_2} M\left(a_2, b_2; \sqrt{\frac{T_1}{T_2}}\right) - C_2 e^{-r T_1} N(a_2) \quad (10)$$

where:

$$a_1 = \frac{\ln[E(S)/S^c] + (r - \delta + \frac{\sigma^2}{2})T_1}{\sigma\sqrt{T_1}}, \quad a_2 = a_1 - \sigma\sqrt{T_1}, \quad (11)$$

$$b_1 = \frac{\ln[E(S)/E(C_3)] + (r - \delta + \frac{\sigma^2}{2})T_2}{\sigma\sqrt{T_2}}, \quad b_2 = b_1 - \sigma\sqrt{T_2}, \quad (12)$$

$$\sigma = \frac{\sqrt{\text{Var}(S)}}{E(S)} - \text{a statistical indicator that characterizes variability,}$$

$$\delta = \frac{E(C_1)}{E(S)} - \text{the amount of information received at each of the three stages,}$$

$N(a)$ – the standard normal distribution function,

$E(S)$ – the expected value of the distribution efficiency of information flow,

$M(a, b; \rho)$ – is the cumulative function of the double normal distribution with the correlation coefficient ρ (that is, the cumulative function of a pair of standard normally distributed random variables, the correlation between which is equal to ρ), and the critical value of the information flow distribution INS S^c is the root of the following equation:

$$S^c e^{-\delta(T_2 - T_1)} N(c_1) - E(C_3) e^{-r(T_2 - T_1)} N(c_2) - E(C_2) = 0, \quad (13)$$

where:

$$c_1 = \frac{\ln[S^c/E(C_3)] + (r - \delta + \frac{\sigma^2}{2})(T_2 - T_1)}{\sigma\sqrt{T_2 - T_1}}, \quad (14)$$

$$c_2 = c_1 - \sigma\sqrt{T_2 - T_1}, \quad (15)$$

Thus, it becomes possible to calculate the efficiency of the INS information flow distribution that passes through the three stages of the problem condition. Let $C_1 = (40, 50, 60)$, $C_2 = (280, 300, 320)$, $C_3 = (630, 700, 770)$, $S = (2000, 2500, 3000)$, these are estimates of the return of information from all three stages as a result of the distribution of the information flow INS by means of fuzzy numbers. Let $T_1 = 3$, $T_2 = 5$, $r = 5\%$.

Then

$$\begin{aligned} E(S) &= 2500, \\ \text{Var}(S) &= 41666.7, \\ E(C_3) &= 700, \\ \text{Var}(C_3) &= 816.7, \\ E(C_1) &= 50. \end{aligned}$$

where $\sigma = 0.082$, $\delta = 0.02$.

The critical value is approximately equal to $S^c = 971.47$.

Therefore, we have:

$$\begin{aligned} a_1 &= 7.39, \\ a_2 &= 7.25, \\ b_1 &= 7.89, \\ b_2 &= 7.7. \end{aligned}$$

As a result, we get the following estimate of the information flow distribution INS:

$$V = (934.57, 1458.72, 1982.87).$$

As a validation of the proposed model, solved using the fuzzy set methodology, it is proposed to use the following scheme (Figure 3).

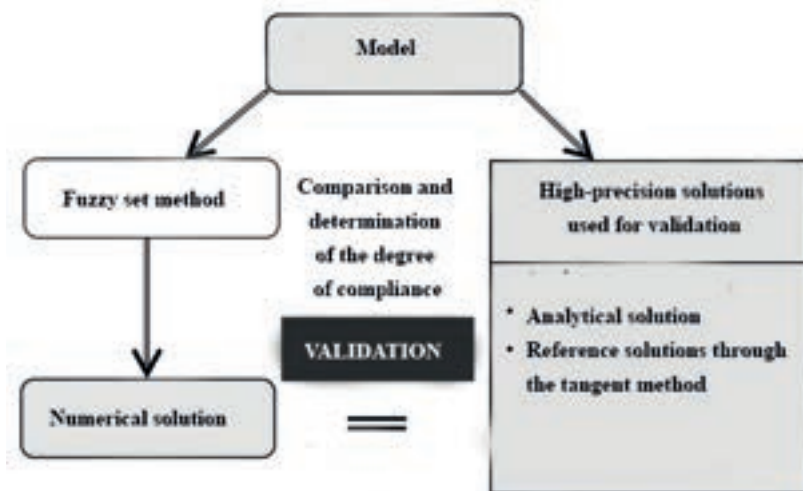


Figure 4. Validation scheme.

Thus, the model's representation and its solution via the fuzzy set method are reflected in the formulas (10-15). It should be noticed that the following process requires analytical analysis when choosing the solution result. We can also note that the solution involves many conditions to be met, which makes it difficult to make changes to the parameters' values, which, due to their fuzziness, can significantly complicate the process of finding solutions.

To compare the results' accuracy, we do the calculation through a numerical solution without introducing fuzzy numbers. Thus, the evaluation of the efficiency of the INS information flow distribution by calculating the efficiency depending on the expected addition of quality data at the end of the third stage is equal to:

$$V = (850, 1450, 2050).$$

As for high-precision solutions the tangent method is used (Figure 5). In this method the calculation is performed by using the approximate numbers.

According to Figure 6, we have:

a – the left border of the section

b – the right border of the section

ε – given accuracy

i_{max} – a maximum number of iterations

x – the approximate value of the root

f_x – the value of the function at x

δ – the achieved accuracy

i – a number of iterations

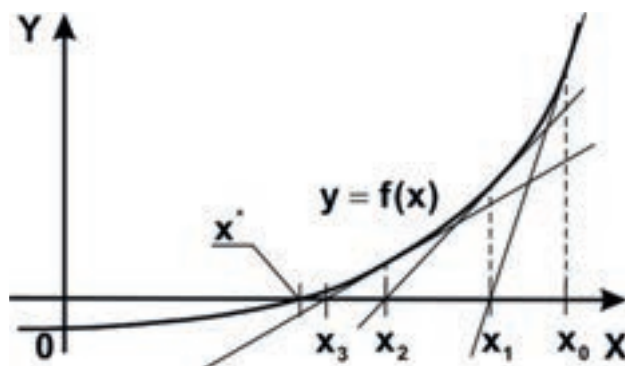


Figure 5. Geometric illustration of the tangent method.

The following algorithm for finding variables is applied to Figure 6.

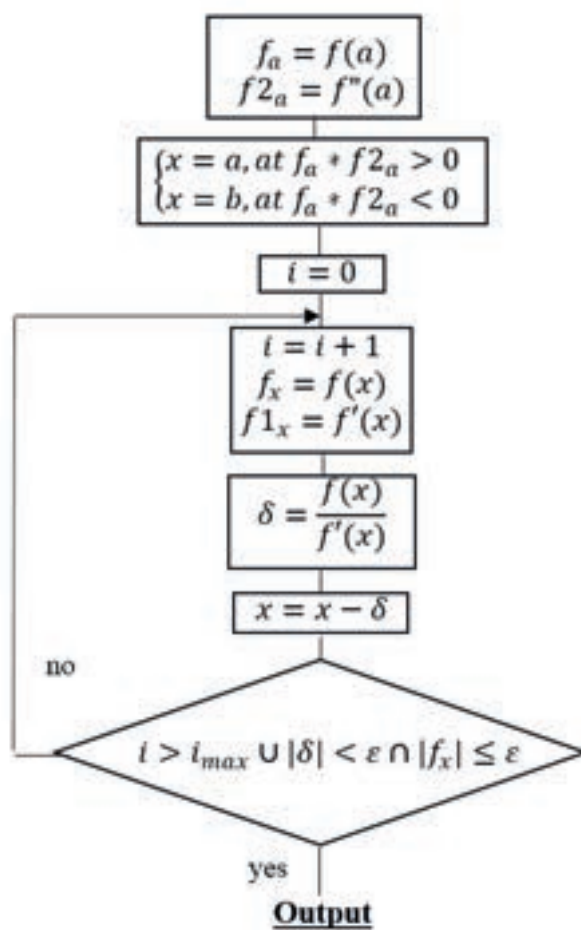


Figure 6. The algorithm of the tangent method.

According to our problem, we get the following equation:

$$Sc = V + C_3 e^{-rT_2} + C_2 e^{-rT_1} \quad (16)$$

It is necessary to present the found parameter V – an indicator of the efficiency of information flow distribution as a function. By entering all the necessary notation, we get the following equation:

$$f(V) = V + C_3 e^{-rT_2} + C_2 e^{-rT_1} \quad (17)$$

We use the previous calculations to enter the values of known variables. Using Figure 3, we assume that the separation of the roots is made and there is one root located on the interval $[a, b]$, which must be specified with the error ε .

So, we have $f(a)f(b) < 0$.

Define half of the segment $c = 1/2(a + b)$ and calculate $f(c)$. We check the following conditions:

1. If $|f(c)| < \varepsilon$, then c is the root. Here ε is the specified accuracy;
2. If $f(c)f(a) < 0$, then the root lies in the interval $[a, c]$;
3. If $f(c)f(b) < 0$, then the root lies on the segment $[c, b]$.

Continuing the process of half division in the selected subintervals, you can reach an arbitrarily small segment containing the root ξ .

Since the interval where the root is located is halved for each iteration, then after n iterations the interval will be equal to:

$$b_n - a_n = 1/2(b - a).$$

As the root of ξ . take $1/2(a_n + b_n)$. Then the error in determining the root will be equal to $(b_n - a_n)/2$. If the condition is met: $(b_n - a_n)/2 < \varepsilon$.

Then the search process ends and $\xi = 1/2(a_n + b_n)$.

The number of steps required to achieve the specified accuracy is determined by the inequality:

$$h \geq \left(\log_2 \frac{b-a}{\varepsilon} \right) + 1.$$

Calculating the efficiency of information flow distribution, we get the following results (Table 1).

No.	c	a	b	$f(c)$	$f(V)$	ε
1	0	0	10	-4510	2500	10
2	-5	-5	0	2500	-1005	5
3	-2.5	-2.5	0	-1005	747.5	2.5
4	-3.75	-3.75	-2.5	747.5	-128.75	1.25
5	-3.125	-3.125	-2.5	-128.75	309.375	0.625
6	-3.4375	-3.4375	-3.125	309.375	90.3125	0.3125
7	-3.5938	-3.5938	-3.4375	90.3125	-19.2188	0.1563

Table 1. The iterations of the root.

The estimate calculated without introducing fuzzy numbers was more general: the lower bound of the corresponding fuzzy number differs by 10%, the most

possible value – by 0.5%, and the upper bound-by 3%. This confirms the idea that using the fuzzy set method in information flow distribution problems allows us to see the most accurate data with an accuracy of 0.01.

4. Findings

Considering the problem of distributing the INS information flows, we highlight the primary definition of the possible efficiency of distribution, implying that specific parameters can change. Using our formula based on calculating cash flows, we were able to get more accurate estimates when using operations with fuzzy sets to obtain numerical values.

The above analysis of the use of fuzzy models in the distribution of information flows in the INS allows us to highlight the following advantages:

- modeling of dynamic problems, the results of various studies, as well as operations on them;
- fuzzy presentation of the formalization of evaluation and comparison criteria;
- the use in the calculation of not only data values, but also their parameters, and the subsequent distribution in the system based on productive models;
- reduction of time and labor costs when modeling complex dynamic systems and comparing them for a given degree of accuracy.

As a result of the research, we have found that fuzzy set methods can form the basis for solving problems of distribution of INS information flows and can be used in conjunction with other methods. In the comparison of traditional technique and fuzzy logic, we have proved the effectiveness of fuzzy methods. Using fuzzy logic and conventional statistical methods in combination, we introduced the variability parameter values and the volume of information. Using centered variables in the solution of the problem to perform further operations inherent in fuzzy sets, we refer to the perspectives of programming these problems in the context of homotopy type theory. Using fuzzy set methods allows getting more accurate results due to the above properties, taking into account all the parameters and restrictions typical for such a phenomenon. Based on international experience, we have determined a way to find the variables that are as close as possible to the optimal values in a given accuracy. Thus, by adding mathematical tools to the study of the distribution of information flows INS, it becomes possible for the expert to see more accurate data on the organization's distribution of information. In the future, these indicators can serve as a basis for improving the organization's information support, thereby ensuring the correct operation of the network. Our method provides a refinement relation and a composition operation that supports both the quality of information and implementation ability. We develop a basic theory for better results. We illustrated the applicability of our idea with an example of information flows' distribution.

Consistent with earlier research, the study supported the hypothesis that using the fuzzy approach is effective. Thus, considering the solution of the problem based on the models proposed by Osin, who pointed attention to the question of matching

the data under consideration [5], we can prove the identity between the analytical data, as well as the ability to most accurately reflect the parameters in mathematical modeling.

It is also worth mentioning the contributions of other authors, particularly Jezewski, Czabanski, and Leski, who defined the real possibilities of describing fuzzy sets and operations on them [11]. Based on the propositions put forward by these authors, we found that the properties of fuzzy sets can be used as an auxiliary parameter for optional problems. After investigating the issue, we concluded that fuzzy set methods are not widely used to solve the distribution of INS information flows.

Since we were faced with identifying the advantages of using fuzzy set methods in the distribution of information flows of an INS, we first turned to the primary source of theoretical material - the work of Osin [5]. As a result of reviewing the mathematical tools of this methodology, based on the formulas and definitions proposed by Osin [5], we identified the advantages in the conciseness of procedures and opportunities for modeling fuzzy information by description. Further, we assumed that the processing of the essential mathematical tools for solving information flow distribution problems in the INS would not be rational due to subsequent computer modeling problems and presenting more accurate results.

Based on this point of view, we decided to implement the fuzzy set method in conjunction with the main functioning tools. At this stage of the study, we found that using a fuzzy approach is rational when modeling the main variables, which we reflected when solving our problem. The main problem of the distribution of information flows in the INS is the inability to recall many modeling parameters. Our proposed approach, reflected in the problem, removes these limitations and allows us to get more accurate values.

Unlike other researchers, we make it the key to improving the quality of the distribution information. We use the example of our problem to discover that using the fuzzy set method in conjunction with other calculus types helps to get more accurate estimates. Accordingly, we consider this approach to be practical and easy to implement.

In the present study, we confirm the effectiveness of using fuzzy set methods in the distribution of INS information flows by using this method as the main one and as an auxiliary one. Thus, we consider it necessary to improve this field's mathematical tools based on the proposed approach. We suggest integrating already proven methods in conjunction with fuzzy logic methods, which in the future presents the possibility of modeling such problems in modern and accessible programming languages. Thus, in the course of the study, we concluded developing mathematical tools by using fuzzy sets in solving problems of distribution of information flows of INS.

Therefore, we highlight possible prospects for the development and application of the theory of fuzzy sets, which is suitable for different software structures. Summing up the calculations, we can conclude that fuzzy modeling is optimal when the technological processes are of some complexity when analyzing using generally accepted quantitative methods. According to our idea, fuzzy logic provides for the

availability of mathematical tools to reflect the source information's fuzziness. Also, it allows you to build a model that is as close as possible to reality since, in some cases, the use of fuzzy models makes it possible to formalize the source data with less error.

5. Conclusion

Summarizing all the above, the advantage of fuzzy modeling of the processes of distribution of information flows in the INS becomes evident since the determinism requirement present in the INS's functioning is formalized in this particular method. Since, like all electronic streams, electronic information is determined through difference and is also characterized by parameters of variability, interdependence, and time dependence, necessary to organize the distribution of information flows in the INS by taking into account the uncertainty of information (its display in a mathematical model). The importance of observing the INS uncertainty parameter is explained by the possibility of constructing a model that is most closely approximated to reality, which, in turn, is not difficult to perform operations on models. Failure to comply with the uncertainty parameter in the classical theory of probability is a gross omission of any processes' real properties. Many uncertainty factors characterize any of them, particularly the investment project, the research base, the workflow process, and other types of information.

Thus, in this paper, when considering the INS' distribution of information flows, we highlight the following opportunities for applying this technique in management. The results we highlight as the formation of mathematical tools allow us to expand industrial automation capabilities. This idea makes it possible to use existing knowledge to improve technological processes and perform various tasks. For example, for:

- controls (closed or open systems, one or more variables in linear or nonlinear systems);
- configuration parameters of the system in online or offline mode;
- classification and image recognition;
- real-time decision making;
- help operators in making decision or when adjusting the parameters;
- detection and diagnostics of system failures.

A wide range of application options and a natural approach based on the acquired experience make this method the primary mathematical tool that should become the standard for decision-makers.

Due to its relevance, the fuzzy approach provides a broad base for further research of feasible processes without introducing additional software. This idea greatly simplifies the consumption of resources and uses the existing means of information technology as an element of any organization's information system in full.

References

- [1] E. Bartocci, T. Ferrère, T. A. Henzinger, D. Nickovic, and A. O. da Costa, "Information-flow interfaces," *Computer Science*, vol. 1, pp. 1–33, 2020. [Online]. Available: <http://arxiv.org/abs/2002.06465>
- [2] C. Shi, and P. S. Yu, *Heterogeneous information network analysis and applications*. 2017, doi: 10.1007/978-3-319-56212-4.
- [3] A. J. Blumberg, and M. Lesnick, "Universality of the homotopy interleaving distance," *Cornell University Press*, pp. 1–29, 2017. [Online]. Available: <http://arxiv.org/abs/1705.01690>
- [4] Yu. Yu. Gromov, Yu. V. Minin, A. B. Bakhsh, A. V. Klishina, and M. A. Shakhov, "Determination of groups of negative external influences on the network information system that maximize the value of the damage function," *Information Security*, vol. 2, pp. 269–272, 2014.
- [5] V. N. Osin, "Effective distribution of information flows in a network information system based on fuzzy models," Ph.D. dissertation, Tambov, 2014.
- [6] P. Venkatesh, S. Dutta, and P. Grover, "Information flow in computational systems," *IEEE Transactions on Information Theory*, vol. 66, no. 9, pp. 5456 – 5491, 2020, doi: 10.1109/TIT.2020.2987806.
- [7] G. A. Kavvos, "Modalities, cohesion, and information flow," *Proceedings of the ACM on Programming Languages*, vol. 3(POPL), pp. 1–29, 2019, doi: 10.1145/3290333.
- [8] L. V. Minchenko, and N. P. Yakovleva, "Application of fuzzy logic in food industry enterprise management," *Scientific Journal of ITMO Research Institute. Series 'Economics and Environmental Management*, vol. 4, pp. 270–279, 2015.
- [9] J. F. Jardine, "Fuzzy sets and presheaves," *Compositionality*, vol. 1, no. 3, 2019, doi: 10.32408/compositionality-1-3.
- [10] M. Kon, and H. Kuwano, "On sequences of fuzzy sets and fuzzy set-valued mappings," *Fixed Point Theory and Applications*, vol. 2013, no. 1, pp. 327, 2013, doi: 10.1186/1687-1812-2013-327.
- [11] R. Czapanski, M. Jezewski, and J. Leski, "Introduction to fuzzy systems," in *Theory and applications of ordered fuzzy numbers: A tribute to professor Witold Kosiński*, P. Prokopowicz, J. Czerniak, D. Mikołajewski, Ł. Apiecionek, and D. Ślęzak (Eds.), pp. 23–43, 2017, doi: 10.1007/978-3-319-59614-3_2.
- [12] C. Shi, Y. Li, J. Zhang, Y. Sun, and P. S. Yu, "A survey of heterogeneous information network analysis," *IEEE Transactions on Knowledge and*

- Data Engineering*, vol. 29, no. 1, pp. 17–37, 2017, doi: 10.1109/TKDE.2016.2598561.
- [13] B. Bogaerts, and D. Surinx, J. Van den Bussche, H. Aamer, and E. Ternovska, “Executable first-order queries in the logic of information flows,” *Cornell University Press*, vol. 3, pp. 1–23, 2019.
- [14] P. Ramaciotti Morales, R. Lamarche-Perrin, R. Fournier-S’niehotta, R. Poulain, L. Tabourier, and F. Tarissan, “Measuring diversity in heterogeneous information networks,” *Computer Science*, pp. 3–31, 2020.
- [15] A. A. Baichenko, “Application of fuzzy logic in the management of food industry enterprises,” *Scientific Journal of ITMO Research Institute. Series 'Economics and Environmental Management*, vol. 3, pp. 35–69, 2014. [Online]. Available: https://openbooks.itmo.ru/ru/article/10476/primeneniye_nechetkoy_logiki_v_upravlenii_predpriyatiem_pischevoy_promyshlennosti.html
- [16] A. Yu. Shatalova, and K. A. Lebedev, (2015). “Fuzzy linear programming in the problem of optimal financing of investment projects,” *Fundamental Research*, vol. 9, pp. 35–38, 2015.
- [17] G. Allwein, and W. L. Harrison, “Information flow and homotopy theory,” *Elsevier*, vol. 1, pp. 1–38, 2019.
- [18] R. E. Kent, “Semantic integration in the information flow framework,” *Cornell University Press*, vol. 1, pp. 1–12, 2018. [Online]. Available: <http://arxiv.org/abs/1810.08236>
- [19] H.-C. Wu, “Duality in fuzzy sets and dual arithmetics of fuzzy sets,” *Mathematics*, vol. 7, no. 1, pp. 11, 2018, doi: 10.3390/math7010011.
- [20] R. Geske, “The valuation of compound options,” *Journal of Financial Economics*, vol. 7, no. 1, pp. 63–81, 1979, doi: 10.1016/0304-405X(79)90022-9.



UDC 339.138:634:316.77(594)

Preliminary Communication

Use of WhatsApp Application on Fruit Marketing Communication: A Traders' Experience

Heri Akhmadi*heriakhmadi@umy.ac.id**Department of Agribusiness**Universitas Muhammadiyah Yogyakarta, Indonesia***Susanawati***susanawati@umy.ac.id**Department of Agribusiness**Universitas Muhammadiyah Yogyakarta, Indonesia***Nindia Putri Utami***nindiaputripratiwi98@gmail.com**Department of Agribusiness**Universitas Muhammadiyah Yogyakarta, Indonesia***Aris Slamet Widodo***aris.sw@umy.ac.id**Department of Agribusiness**Universitas Muhammadiyah Yogyakarta, Indonesia*

Abstract

WhatsApp is mobile messaging application which is widely used in communication. However, its use in marketing communication is relatively new. This study investigates WhatsApp user profile, factors that influence the use of WhatsApp and relationship between the factors with WhatsApp usage level in fruit marketing communication. Respondents were selected using census method by taking all fruit wholesalers in Giwangan Fruit Central Market, the largest fruit market in Yogyakarta, Indonesia. Data were analyzed using descriptive methods and Spearman Rank correlation. The results showed that majority of WhatsApp users among traders are male in millennial age, with high school education. Furthermore, the convenience in use and economical reason were the most influential factors in the use of WhatsApp on marketing communication. Moreover, this study found that there was a strong and positive correlation between benefits factors and the use of WhatsApp on fruit marketing communication.

Keywords: WhatsApp adoption, digital marketing communication, fruit trading

1. Introduction

Social media has become a popular and effective platform of communication in the digital world [1]. One of the most popular social media platform is WhatsApp. Recently, WhatsApp as a social media applications shows an increasing trend of being

used as a new communication platform [2] and the most widely used social media for sending messages with a total of 1.6 billion global users in 2019 [3].

The popularity of WhatsApp as a social media base messaging application is may driven by the increasing use of the internet in various aspects of life [4]. The International Telecommunication Union (ITU), an UN agency which is responsible for issues that concern on the development of information and communication technology, in its recent report states that global internet users in 2019 are estimated to reach 53.6 percent of the global population, or 4.1 billion people as the Internet users [5]. In Indonesia alone, according to a national survey on Penetration and Behavior Profile of Indonesian Internet User, it was stated that out of a total of 264.16 million Indonesians population, there were around 64.8% or 171.17 million people who used the internet in their daily lives in 2018. This data showed a growth of around 10% from 2017 in the amount of 143.26 million people or 54.86% of the population [6].

Mobile messenger and social media applications are the most widely used internet-based applications with a total number of users reaching 89.35% in Indonesia [7]. Mobile messenger and social media services are growing rapidly since they provide convenience and lower costs [8] compared to previous messaging platforms such as short message services (SMS) [9]. Online messaging applications such as WhatsApp, LINE, Facebook Messenger, Blackberry Messenger (BBM) and WeChat are among the most widely used applications. Furthermore, WhatsApp is the most popular message sending application in Indonesia where 83% of internet users use the WhatsApp platform as their message sending application, far surpassing LINE or FB Messenger which is only used by 59% and 43% of users [10].

Ultimate features in sending messages, such as the ease of sending pictures and videos makes WhatsApp offer many advantages compared to the previous message service application [11] [12]. Moreover, WhatsApp also provides calling service both voice call and video call for "free", this indeed making WhatsApp more popular [13]. All these advantages are certainly very supportive for trading activities, especially in marketing communication between sellers and buyers [14]. The use of the WhatsApp application could make it easier for merchants to communicate with consumers in providing goods and services using mobile technology or communication devices such as smartphones, tablets, computers or laptops.

Moreover, in case of trading of perishable products such as fresh fruit, the presense of internet-based communication application such as WhatsApp could be an effective communication tool to deliver messages to consumers or other stakeholders [15]. Fruit trade, for instance, is one sector that has an important role in Indonesian economy. Data shows that in 2015 Indonesia exported 354,508.9 tons of fruit valued at USD \$ 368.68 million. This number increased compared to the previous year which only reached 299,104.3 tons or valued at USD \$ 302.2 million [16]. Not only the number of exports of fruit products has increased, the number of Indonesian fruit production has also increased. Indonesia's total fruit production in 2017 was 19.64 million tons, an increase of 7.1% from 2016 which was only 18.34 million tons [17].

The increase in fruit production is in line with the increase in Indonesian people's per capita fruit consumption. The level of fruit consumption per person per year has

increased in 2015 from 0.349 kg per capita per week to 0.405 kg in 2016 and most recently in 2018 to 0.480 kg per capita [18]. According to Indonesian Food Security Monitoring data, there are three provinces that have reached the level of consumption recommended by the government of 400 grams per capita per day, namely Yogyakarta, Bali and Sulawesi. While other provinces have not reached the level of consumption recommended by the government [19].

Horticultural commodities, especially fruits have an important role in the Indonesian economy. Data shows that in 2015 Indonesia exported 354,508.9 tons of fruit valued at USD \$ 368.68 million. This number increased compared to the previous year which only reached 299,104.3 tons or valued at USD \$ 302.2 million [16]. Not only did the number of exports of fruit products increase, the amount of Indonesian fruit production also increased. Indonesia's total fruit production in 2017 was 19.64 million tons, an increase of 7.1% from 2016 which was only 18.34 million tons [17].

The increase in fruit production is in line with the increase in Indonesian people's per capita fruit consumption. The level of fruit consumption per person per year has increased in 2015 from 0.349 kg per capita per week to 0.405 kg in 2016 and the last year in 2018 to 0.480 kg per capita. The increase was found in oranges, apples, salak, bananas, papayas and watermelons [18], [19]. According to Indonesian Food Security Monitoring data, there are three provinces that have reached the level of consumption recommended by the government of 400 grams per capita per day, namely Yogyakarta, Bali and Sulawesi. While other provinces have not reached the level of consumption recommended by the government [19].

Increasing trend of fruit production and consumption in Indonesia opens up opportunities for fruit trading activities to expand its marketing activities. Especially with the development of information and communication technology which is a strategic tool to improve the efficiency and effectiveness of marketing communication activities [20]. ICT base social media such as WhatsApp could provide benefits for marketing communication activities such as promoting products, marketing products, communicating with consumers, communicating with suppliers, providing services needed by consumers to improve collaboration, new products or services and allowing for opening market opportunities [21].

WhatsApp is widely known as one of the most popular internet-based messaging platforms. Previous research related to the use of WhatsApp has been done a lot, however, research on its use in marketing communications, especially marketing of fresh fruit has not been found. Several previous studies regarding the use of WhatsApp for instance explore the role of WhatsApp in interactions between consumers and companies [22], WhatsApp as a communication medium [4] and learning exchange [23] as well as study on the ability of WhatsApp application to disseminate information to become "viral" [24] and making it as a marketing tool [14]. WhatsApp as social media could also be used as a gathering place (group) and can be used to spread information [25] with one click to many people (broadcast message) so that it becomes an effective advertising medium [26] and coordinating information trade [27]. However, although a lot of research has been done on WhatsApp, research on using WhatsApp as a marketing communication medium has not yet been found.

The variety of functions and features possessed by WhatsApp application and the growing dominance of this application as a medium for sending messengers and social media is interesting to investigate its use in marketing communications, especially fresh fruit marketing. Therefore this study aims to examine whatsapp application usage profile, the level of use of WhatsApp application and the factors that influence the use of this application by fruit marketing communication traders. This study provides insight into the baviour of trader on using WhatsApp as marketing communication tools in fresh fruit trading.

2. Literature Review

2.1. Marketing Communication

Many researchers have defined marketing communication with various definitions. In order to understand the concept of marketing communication, it is necessary to figure out the meaning of communication itself. A communication is an activity of exchanging ideas [28] where there is meaning or value conveyed by individuals to other individuals or groups [29]. While marketing communication or in other term called integrated marketing communication is an effort of traders to persuade, inform regarding the brand [30] and provide information related to products directly through traditional media such as radio and television or using new media such as Youtube, Facebook, Instagram, WhatsApp, Line and other social media application. Trough online communication, trader and producer could build relationships with consumers effectively [31] and consumers can understand about the product being sold, who makes the product, the purpose of the product is made so that consumers can buy as needed.

The main purpose of marketing communication is to provide information from merchants to consumers about product or service information, introduce products and establish relationships with consumers or providers of goods and services using various media available such as Instagram, WhatsApp and Facebook [32]. There are several forms of marketing communication:

a. Sales promotion

Promotion is part of integrated marketing communication with the objectives to boost sales so that consumers can see and buy products directly sold by merchants so that traders can increase sales. Through promotion, consumers can get to know the products or services offered, sell, have the opportunity to buy more often and more [33].

b. Personal Sales

Personal selling involves two parties between the trader and the buyer which is carried out either face to face, telephone, video call and website. Applications that are used vary depending on the needs desired by the trader, personal selling also functions as a way to find consumer demand for the products offered by the merchant [34].

c. Public relations

Public relations serves to build and maintain a mutually beneficial relationship between traders and consumers to get the desired results. The main objective of public relations is to introduce and maintain perception and image of products sold by traders and the traders organization/company [35].

2.2. WhatsApp Adoption

Use of information technology such as WhatsApp, and other social media is relatively new. As a new technology, before it was used massively as it is today, it underwent the adoption process. Adoption of technology is a common process in using new technologies such as information and communication technology. One well-known theory of technology adoption model is the Technology Acceptance Model (TAM), which was first developed by Davis 1985 [36]. This technology adoption model is a model to find out the influential factors in the technology adoption process such as ease of use, benefits, anxiety, business owner's innovation power, consumer demands and competitor pressure.

There are several factors according to Theory of Technology Acceptance Model that are considered by researchers as supporting factors of technology adoption including variable of usefulness and ease of use [37]. On the contrary, factors that hinder the adoption process including security and privacy issue, cost of technology and incompatibility of the technology with business processes so that the technology does not provide benefits [38]. In addition, another factor is that not all businesspeople such as traders understand on using information technology (3). Many do not trust information technology because they believe that there is a lack of security in interacting with consumers using information technology or social media, (4). Costs incurred in maintaining electronic systems and facilities that do not yet support the utilization of the technology, (5) and there is no definite law in the use of technology for business [39].

Adoption of social media innovation is one of the important things since it could expand and improve business competitiveness and can improve the ability to communicate with others and establish relationships with customers [40]. With rapid change requires traders inevitably have to use technology in order to compete. In adopting information technology, there are benefits to its use such as social media technology that includes younger traders in communicating with consumers and suppliers, building relationships with new people so that expanding friendships and marketing, making it easier to share ideas or information with others and information technology as well make me more creative in increasing sales [41].

Adoption of technology is the final result obtained from the process of utilizing information and communication technology by traders and the ease of using the technology so as to produce behavior and attention to existing technology for use in daily activities [42]. There are several models for technology adoption [43]:

a. Technology Acceptance Model (TAM)

TAM is a theory developed by Fred Davis in 1985 [36] that explains the acceptance of technology that someone will use. In this case there are several variables that influence the use of the system carried out by previous studies mention there are

two determinants that have an important role, namely the perceived usefulness (Perceived usefulness) is defined by the extent to which someone uses information technology at work and has benefits in its use and perceived ease (Perceived ease of use) is defined by the extent to which a person believes using information technology makes it free from difficulties or major obstacles [37].

b. Theory of Planned Behavior (TPB)

This theory is a theory of attitude models that predict a person's interest or intention to take action by being influenced by three main factors namely attitude toward behavior (attitude toward behavior) is defined as a person's negative and positive feelings towards the achievement of a behavior. Subjective norms (subjective norms) are defined as a person's perception by seeing for most someone who is considered important, he must or not in carrying out an action or behavior and control the behavior. The last factor is behavior control or behavior control to guard behavior against things that are not in accordance with the norm [44].

c. Theory of Reasoned Action (TRA)

The theory that was successfully developed by Fishbein and Ajzen in 1979 [45] states that a person's perception and reaction to a thing determines the person's attitude or behavior. This theory chooses behavioral goals as a function and indicates that behavior can be predicted from the intensity of behavior (behavior intention) is a combination of attitude factors (attitude) and subjective norms (subjective norm) in shaping a person's behavior. So that a person's attitude or behavior about information technology will have an effect on his attitude in the acceptance of the use of information and communication technology because someone will use something if there are benefits and ease of use. (Permana, Astuti, & Suydi, 2012).

3. Methodology

This study is a survey research using descriptive analytical method. The survey research was conducted by conducting a structured interview with respondents chosen using questionnaires to obtain the facts, opinions and behavior of respondents [47]. The descriptive method is a method for examining the status of a group, object, condition or event in the present with the aim of obtaining a systematic and accurate description and description of the facts and phenomena studied [48].

Yogyakarta city was chosen as a research location with consideration that in addition to being a large city (the provincial capital), the city of Yogyakarta was one of the cities that showed growth in per capita fruit consumption above the national average [19]. Giwangan Fruit and Vegetable Market was chosen with consideration because it is the largest fruit market in Yogyakarta. The respondents in the study were selected using census method from all wholesalers in Giwangan Market. Based on field visits and research criteria there are 45 wholesalers who are willing and meet the research criteria, so the total number of respondents is 45 traders.

The Whatsapp user profile including variable of gender, age, education and trading experience was analyzed using descriptive statistic, while the level of use of the WhatsApp application in marketing communication is measured using three indicators, namely: sales promotion, personal sales and public relations [49], [50].

Furthermore, the indicators were analyzed by descriptive method using the help of tables and average scores. The category intervals in this study are as follows:

$$\text{Interval Score} = \frac{\text{maximum score} - \text{minimum score}}{\text{number of category}}$$

$$\text{Interval} = \frac{(5 - 1)}{5} = 0,8$$

Based on the formula, the resulting score interval is presented on Table 1:

Score	Response
1,00 – 1,80	Strongly Disagree
1,81 – 2,60	Disagree
2,61 – 3,40	Doubtful
3,41 – 4,20	Agree
4,21 – 5,00	Strongly Disagree

Table 1. Score Interval and Response

After the measurement is done by calculating the average score of each indicator, then classified according to the achievement of scores to determine the level of use of the WhatsApp application and determine how much the factors influence the use of WhatsApp applications in fruit marketing communication. The formula for calculating each variable score is as follows:

$$\text{Achievement Score} = \frac{\text{Total score} - \text{Minimum score}}{\text{Maximum score} - \text{Minimum score}} \times 100\%$$

Moreover, the WhatsApp app usage level categories based on achievement scores per variable are as follows:

Achievement Score	Usage Perception
0% - 19,99%	Very Low
20% - 39,99%	Low
40% - 59,99%	Medium
60% - 79,99%	High
80% - 100%	Very High

Table 2. Achievement Score and Usage Perception

Furthermore, to determine the relationship between the level of use of the WhatsApp Application with the factors that influence the use of the WhatsApp Application, the Spearman Rank correlation test is used. This study proposed four factors including education, convenience, benefit, reference group, and economic factors that influence the use of the WhatsApp Application [51] [52].

The Spearman rank correlation test is used to look for relationships or test the significance of associative hypotheses if each of the linked variables in the form of an ordinal and the source of data between the variables is not the same [53], [54]. This analysis performed by statistical calculation using the following formula [55]:

$$rs = 1 - \frac{6\sum d^2i}{n(n^2 - 1)}$$

Note:

rs = Rank Spearman correlation coefficient

d = ranking difference between variables

n = number of samples or data

After determining the correlation coefficient value from the above formula, the result value can be set into the value interval to determine the relationship that will be generated. The relationship between the factors that influence WhatsApp usage with the level of use of the WhatsApp can be seen in Table 3 [56].

Interval Score (+/-)	Relationship Strength
0,0	None
0,1	Negligible
0,2	Weak
0,3	Moderate
0,4 - 0,6	Strong
0,7 – 0,9	Very Strong
1,0	Perfect

Table 3. Interval Score and Usage Perception

4. Result and Discussion

4.1. Respondents Profile

The respondents of this study were all fruit wholesalers in Giwangan Fruit and Vegetable Market in Yogyakarta City. There are 73 traders registered at the Giwangan Market Management Office, however only 45 people are eligible and are willing to become respondents. Several traders have more than one shop with different names, and others no longer trade even though they are still registered in the Giwangan Market Office. Based on the data, the profile of fruit wholesaler is then arranged. There are several indicators to describe the profile of traders, namely: gender, age, level of education and trading experience, as presented in Table 4.

No	Variable	Range	Respondent	
			Number	%
1	Gender	Male	38	84.4
		Female	7	15.6
2	Age (Year)	≤ 18	0	0,0
		19 – 35	29	64,4
		36 – 55	14	31,1

		> 54	2	4,4
3	Education	Elementary	6	13.3
		Junior High School	6	13.3
		Senior High School	27	60.0
		Graduate	6	13.3
4	Trading Experience (Year)	≤ 5	15	33,3
		6 – 10	4	8,9
		11 – 20	21	46,7
		> 20	5	11,1

Table 4. Socio-demographic Characteristics of Traders

Table 4 shows that the majority of fruit traders in Yogyakarta's Giwangan Fruit and Vegetable Centr Market are male with a percentage of 84.4%. Men dominate the merchant population for the reason that most of the work done has started early in the morning so that men are more free to work with these situations and conditions than women. However, in the context of using WhatsApp, gender has no significant effect [57].

Furthermore regarding the age of traders, the majority of traders aged between 19-38 years or covering 64.4% of the total trader population. Age between 19-38 years in 2019 is the age range of millennial generation. Some studies mention that millennial generation is the generation born between 1980-2000 [58], [59]. Among the characteristics of millennial generation is their closeness to digital technology and the internet [60]. This is certainly an important finding that the majority of fruit traders are already familiar with digital technology to support their work.

Finally in the trader's profile is the factor of experience or length of trading. The data shows that 46.7% of traders have experience of 10 to 20 years, and there are even 11.1% who have traded for more than 20 years. Nevertheless there are still a third or 33.3% of traders who only have experience of between 0 and 5 years. This is likely for young traders, especially the previous data states that the majority of traders (64%) are between 19-38 years. Experience in business is expected to support the adoption of new technologies [61].

4.2. The Level of Use of WhatsApp Application

The usage level of WhatsApp in marketing communications of fruit wholesalers was analyzed from several marketing communication indicators which include the use in sales promotion, personal sales and public relations [62]. Each indicator was analyzed its average score and then classified according to the category of achievement score, which starts from the category of very low to very high. This research shows that the overall level of use of the WhatsApp application in marketing communication by wholesalers was relatively high as presented in Table 5.

Indicator	Average Score	Score	
		(%)	Category
Sales Promotion	4.24	80.93	Very High
Personal Sales	4.19	79.81	High
Public Relation	3.41	60.28	High
Total	3.95	73.67	High

Table 5. Usage Level of WhatsApp Application

Table 5 indicates that three indicators of the level of use of WhatsApp application are at the very high and high score category level. The sales promotion indicator shows a very high category with an achievement score of 80.93% and an average value of 4.24. The promotion indicator shows a very high category in the use of the WhatsApp application by traders perhaps because promotion is the main activities in marketing of fruit, and WhatsApp provides facilities to spread information [63] in order to support sales promotions [64] easily and inexpensively.

Moreover, the level of use WhatsApp in personal sales indicators shows high category with an achievement score of 79.81% with an average score of 4.19. This is in line with previous research which states that some features and services in the WhatsApp application can support sales activities [65]. Another reason is may because the use of WhatsApp provide interactivity between sellers and buyers, allows connecting with other marketing channels, and personalize the customers [66].

The last variable is public relations which shows a high category with a score of 60.28% and average score of 3.41. Public relations has an important meaning in marketing communication since it could build a good image to consumers and other trading stakeholders. WhatsApp offers several features that support public relations activities such as being able to share photos, videos and also create groups [67]. Communication and image building could be carried out through the WhatsApp group.

4.3. Factors that Influence the Use of WhatsApp Application

WhatsApp as a technology that has not been so long known, launched in 2009, has been widely used by people and not just utilized as a sender of messages, but also a tools of networking [68]. Its use in marketing communication is also the development of use as a message sender application.

There are several factors that are likely to influence the use of the WhatsApp application by traders in fruit marketing communication. Based on previous studies [69], [70], this study proposes educational factors, convenience factors, benefit factors, reference group factors and saving factors as factors that influence the use of WhatsApp on marketing communication by fruit traders. Furthermore, these factors were analyzed its scores and categories of influence as presented in Table 6.

Variable	Average Score	Score	
		(%)	Category
Education	3.73	68.33	High
Convenience	4.56	88.89	Very High
Benefit	4.01	75.14	High
Reference group	3.57	64.26	High
Economic	4.32	83.06	Very High
Total	4.04	75.94	High

Table 6. The Level of Use of WhatsApp Application

Table 6 shows that factors that influence the use of the WhatsApp application have several indicators with different categories, from high to very high. The difference in the level of use of WhatsApp is influenced by the level of merchant approval in the selection of existing variables. There are 2 variables that show a very high category, namely convenience variable and economic variable. Convenience variable has a very high category with the score obtained by 88.89% and the average score of 4.56. This shows that WhatsApp as an application does not provide difficulties for traders in using it. Another thing that might be the reason is because most traders (64.5%) are millennials generation whith aged between 19 to 38 years old who are very familiar with new technology such as WhatsApp [71], [72].

The next variable that shows a very high category is the economic variable with an achievement score of 83.06% and an average score of 4.32. Reasons for economical view in using WhatsApp can be understood since in business the cost factor is very important [73]. Traders feel that using WhatsApp can save costs because they do not need to pay more for mobile service in order to contact suppliers or consumers. Another reason is that it can save time in buying fruit to suppliers since they do not have to go to see and buy the fruit but just to share the pictures using WhatsApp.

Moreover the other variables, namely education variable, benefit variable and reference group variable, show high category. Educational variables get a high category with a score of 68.33% with an average score of 3.37. It shows that the education factor has a significant role in the merchant's decision to use WhatsApp in marketing communication. Educational factors have an influence in facing difficulties in using new technologies and applications such as WhatsApp [74].

While the benefit variable gets a high category with a score of 75.14% and an average score of 4.01. Traders feel the benefits after using WhatsApp such as promoting fruit, knowing information about the price of fruit in the market so that traders can make decisions faster in order to increase sales. The last variable is reference group shows a high category with a score of 64.26% and an average score of 3.57. This indicates that reference groups such as family, other traders and consumers have an influence on the use of the WhatsApp to communicate. This can be understood since in Indonesia WhatsApp is the most popular mobile messaging application which was used by the majority of the population, with penetration of 83% of the population in 2018 [75].

4.4. Relationship Between the Level of Use of WhatsApp Application with Factors That Influence the Use of WhatsApp Application

The next analysis is about the relationship between the level of use of WhatsApp application with the factors that influence the use of WhatsApp application on fruit marketing communication. This relationship can be positive or negative. The positive sign indicates that the stronger the relationship of the factors that influence the use of the WhatsApp application with the factors that influence the use of the WhatsApp application, the higher the level of use of the WhatsApp application by traders. While the negative sign illustrates the weaker relationship of factors affecting WhatsApp usage. The detail of the results can be seen in Table 7.

Variable	The Level of the Use of WhatsApp on Marketing Communication Activity					
	Sales Promotion	Category	Personal Sales	Category	Public Relation	Category
Education	0,180	Week	-0,045	Week	-0,074	Week
Easy to use	0,268	Week	0,429	Strong	0,555	Strong
Benefit	0,541	Strong	0,520	Strong	0,623	Strong
Reference group	0,247	Week	0,281	Week	0,360	Moderate
Economic view	0,059	Week	0,176	Week	0,265	Week

Table 7. Coefficient of Correlation of Factors that Influence the Use of WhatsApp Application

Table 5 shows that there are several number of variables that have been shown to have a strong positive relationship. The easy to use variable is proven to have a positive and strong relationship with public relations and quite strong relationship with personal sales with a correlation coefficient of 0.555 and 0.429 respectively. This shows that the easier it is to use WhatsApp, the more it is used in public relations and personal sales activities in fruit marketing communication. The ease of use of mobile technology applications such as WhatsApp has indeed become an important factor in its use [73].

Furthermore, the benefit variable has a strong and positive relationship with all indicators of marketing communication including sales promotion, personal sales and public relations with correlation coefficients of 0.541, 0.520 and 0.623, respectively. This results indicate that the higher the benefits of using WhatsApp, the higher its use in marketing communication activities including sales promotion activities, individual sales and public relations. The benefit of using WhatsApp is one of the reasons for its popularity [76]. In the context of usage for public relations which is also has strong relationship, it may because WhatsApp could bring an intimate relationship compare to another social media such as Facebook [77].

4.5. Conclusion

Based on the results and discussion, it can be concluded that the majority of whatsapp users among traders are male from millennial generation with high school education. Furthermore the level of use of Whatsapp application in marketing communications by fruit wholesalers at a high level. This is indicated by Whatsapp usage level variables such as sales promotions which is shows in a very high category, and variable of personal sales and public relations at high categories. The high level of use of the WhatsApp application among traders is supported by the profile of the majority of them with a young age and a good level of education.

Furthermore, regarding the factors that influence the use of the WhatsApp application, this study concludes that convenience and economic reasons are the most influential factors in the use of the WhatsApp application by traders, compare to other factors such as education, benefits and reference groups with lower influence. Finally the relationship between the level of use of WhatsApp and the factors that influence the use of WhatsApp on fruit marketing communication by traders, this study found that there is a significant strong relationship between the benefits factor and the use of WhatsApp in marketing marketing communication activities that include sales promotion activities, personal selling and public relations. The easy to use factor is proven to have a moderate relationship but only on personal selling activities and public relations.

Acknowledgements

This study was financially supported by Institute of Research, Publication and Community Service, Universitas Muhammadiyah Yogyakarta. The author thanks all colleagues from the Department of Agribusiness who provided insight and expertise that greatly assisted in conducting the research, although they may not fully agree with all the interpretations/conclusions of this paper.

References

- [1] Y. K. Dwivedi, K. K. Kapoor, and H. Chen, "Social media marketing and advertising," *Mark. Rev.*, vol. 15, no. 3, pp. 289–309, 2015.
- [2] Wearesocial.com, "Global Digital Report 2019: Global Internet Use Accelerates," 2019.
- [3] Statista, "Most popular global mobile messaging apps 2019," 2019.
- [4] T. Akinlosotu, "Predictors of WhatsApp 'Consumption' among undergraduate students of Economics in Ambrose Alli University, Ekpoma," *African Res. Rev.*, vol. 10, no. 3, p. 290, 2016.
- [5] ITU, "Individual using internet 2005-2019," 2019.
- [6] APJII, "Laporan Survei Penetrasi & Profil Perilaku Pengguna Internet

- Indonesia 2018 (Survey Report: Penetration & Behaviour Profile of Indonesian Internet User 2018),” Jakarta, Indonesia, 2018.
- [7] APJII, “Penetrasi & Perilaku Pengguna Internet Indonesia 2017 (Penetration & Behaviour Profile of Indonesian Internet User 2017),” Jakarta, Indonesia, 2017.
- [8] G. Resende and M. Vasconcelos, “(Mis) Information Dissemination in WhatsApp: Gathering, Analyzing and Countermeasures,” in *2019 IW3C2 (International World Wide Web Conference Committee)*, 2019, pp. 818–828.
- [9] S. L. Bairwa, M. Kumari, and L. K. Meena, “Developing mobile based agri retailing (mbar) model for high value agricultural and livestock products,” *Int. J. Agric. Sci. Res.*, vol. 5, no. 6, pp. 125–130, 2015.
- [10] Hootsuite, “DIGITAL 2019: Indonesia,” 2019.
- [11] I. Riadi, A. Fadlil, and A. Fauzan, “Evidence Gathering and Identification of LINE Messenger on Android Device,” *Int. J. Comput. Sci. Inf. Secur. (IJCSIS)*, vol. 16, no. June, pp. 201–205, 2018.
- [12] R. Shambare, “The Adoption of WhatsApp: Breaking the Vicious Cycle of Technological Poverty in South Africa,” *J. Econ. Behav. Stud.*, vol. 6, no. 7, pp. 542–550, 2014.
- [13] Y. S. Tawiah, H. E. Nondzor, and A. Alhaji, “Usage of WhatsApp and voice calls (phone call): Preference of polytechnic students in Ghana,” *Sci. J. Bus. Manag.*, vol. 2, no. 4, pp. 103–108, 2014.
- [14] N. Fouad, “Viral marketing effect on digital knowledge acquisition: WhatsApp as a model,” *Alexandria J. Natl. Int. Libr. Inf. Issues*, vol. 27, no. 1, 2017.
- [15] C. Lombart, E. Millan, J. Normand, A. Verhulst, B. Labbé-pinlon, and G. Moreau, “Journal of Retailing and Consumer Services Consumer perceptions and purchase behavior toward imperfect fruits and vegetables in an immersive virtual reality grocery store,” *J. Retail. Consum. Serv.*, vol. 48, no. July 2017, pp. 28–40, 2019.
- [16] BPS, “Exports of Fruit by Major Countries of Destination, 2002-2015,” Jakarta, 2017.
- [17] Kementan, “Statistik Pertanian - Agricultural Statistics 2018,” 2018.
- [18] BPS, “Konsumsi Kalori dan Protein Penduduk Indonesia dan Provinsi - Consumption of Calorie and Protein of Indonesia Population and Province,” 2019.
- [19] WFP, BMKG, and BPS, “Food Security Monitoring Bulletin: Special Focus: Fruit and vegetable consumption and production trends,” 2017.

- [20] H. Akhmadi, "Use of Information and Communication Technology (ICT) on Agricultural Marketing in Indonesia a Brief Literature Review," in *Proceedings of the International Conference on Food, Agriculture and Natural Resources (FANRes 2018)*, 2018.
- [21] F. Lashgarara, R. Mohammadi, and M. O. Najafabadi, "Identifying appropriate information and communication technology (ICT) in improving marketing of agricultural products in Garmsar City, Iran," *African J. Biotechnol.*, vol. 10, no. 55, pp. 11537–11540, 2011.
- [22] A. Priyono, "Improving Quality of Interactivity Between Organisation And Customers With The Support Of Whatsapp," in *Global Marketing Conference 2016*, 2016.
- [23] M. S. Nain, R. Singh, and J. R. Mishra, "Social networking of innovative farmers through WhatsApp messenger for learning exchange: A study of content sharing," *Indian J. Agric. Sci.*, vol. 89, no. March, pp. 556–558, 2019.
- [24] C. W. Yu and Y. Kamarulzama, "Viral Marketing via the New Media: The Case of Communication Behaviour in WhatsApp," in *Proceedings of 3rd International Conference on Marketing, IBAICM 2016.*, 2016, vol. 3, pp. 82–102.
- [25] M. S. Ansari and A. Tripathi, "Use of WhatsApp for Effective Delivery of Library and Information Services," *DESIDOC J. Libr. Inf. Technol.*, vol. 37, no. 5, pp. 360–365, 2017.
- [26] K. D. Gonte, "Application of Social Media in Advertising Fresh Fruit and Vegetable Products In Ahmednagar District," *Int. J. Mod. Trends Bus. Res.*, vol. 1, no. 5, pp. 16–27, 2018.
- [27] J. Hanlon, "Working Paper Series 2018 The Uberization of Mozambique's heroin trade," London, 2018.
- [28] I. A.. Abuarqoub, "Language barriers to effective communication/Barreras del lenguaje para una comunicacion efectiva," *Utopía y Prax. Latinoam.*, vol. 24, no. S6, p. 64+, 2019.
- [29] S. Kusniadji, "Strategi Komunikasi Pemasaran Dalam Kegiatan Pemasaran Produk Consumer Goods (Studi Kasus Pada PT Expand Berlian Mulia Di Semarang)," *J. Komun.*, vol. 8, no. Studi Kasus Pada PT. Expand Berlian Mulia Di Semarang, pp. 83–98, 2016.
- [30] M. J. Valos, V. L. Maplestone, and M. J. Polonsky, "Integrating social media within an integrated marketing communication decision-making framework," *J. Mark. Manag.*, vol. 33, no. 17–18, pp. 1522–1558, 2017.
- [31] G. C. Shen, J. Chiou, C. Hsiao, C. Wang, and H. Li, "Effective marketing communication via social networking site: The moderating role of the social tie," *J. Bus. Res.*, vol. 69, no. 6, pp. 2265–2270, 2016.

- [32] O. Adesanoye, "Integrated Marketing Communication Tools and Customers' Perception and Attitudes to the Brands of Selected Nigerian Banks," *Communicatio*, vol. 13, no. 2, pp. 26–40, 2019.
- [33] V. N. O. Aghara, I. C. Nwaizugbo, P. C. Oparah, and C. D. Ifeanyichukwu, "Sales Promotion as A Leverage Strategy for Improving Sales and Profitability in Alcohol Beverage Industry (A study of Nigeria)," *Int. Res. J. Manag. IT Soc. Sci.*, vol. 5, no. 4, pp. 18–25, 2018.
- [34] M. Stros, Ě. David, Ě. Elena, and L. L. K. Lim, "PERSONAL SALES SUCCESS FACTORS IN A WEALTHY AUTOMOTIVE MARKET ENVIRONMENT," *J. East. Eur. Cent. ASIAN Res.*, vol. 6, no. 1, 2019.
- [35] L. Naumovska and D. Blazeska, "Public relation-based model of integrated marketing communications," *UTMS J. Econ.*, vol. 7, no. 2, pp. 175–186, 2016.
- [36] F. D. Davis, "A technology acceptance model for empirically testing new end-user information systems: Theory and results," Massachusetts Institute of Technology, 1985.
- [37] R. Matikiti, "Application of the Technology Acceptance Model and the Technology – Organisation – Environment Model to examine social media marketing use in the South African tourism industry," *South African J. Inf. Manag.*, vol. 20, no. 1, pp. 1–12, 2016.
- [38] N. Siamagka, G. Christodoulides, N. Michaelidou, and A. Valvi, "Determinants of social media adoption by B2B organizations," *Ind. Mark. Manag.*, vol. 51, no. November, pp. 89–99, 2015.
- [39] Febrianty, "Faktor-Faktor Adopsi Teknologi Informasi Akuntansi Terhadap Peningkatan Kinerja UKM," *Semin. Nas. Teknologi Informasi, Bisnis dan Desain*, pp. 63–73, 2016.
- [40] S. Kwayu, B. Lal, and M. Abubakre, "Enhancing Organisational Competitiveness Via Social Media - a Strategy as Practice Perspective," *Inf. Syst. Front.*, vol. 20, pp. 439–456, 2018.
- [41] S. Kosasi, "Inovasi Teknologi Media Sosial : Keberhasilan Proses Adopsi Meningkatkan Kelincahan Organisasi Inovasi Teknologi Media Sosial : Keberhasilan Proses Adopsi," *Konf. Nas. Sist. Inform. 2017*, no. STMIK STIKOM Bali, 10 Agustus 2017, pp. 131–136, 2017.
- [42] D. Fatmasari and S. Wulandari, "Analisis Faktor-Faktor Yang Mempengaruhi Minat Mahasiswa Dakam Penggunaan APMK," *Anal. Fakt. Yang Mempengaruhi Minat Mhs. Dakam Pengguna. APMK*, pp. 93–103.
- [43] S. S. Zabukovšek, R. Picek, and I. Š. Klančnik, "Technology Acceptance Model Based Study of Students' Attitudes Toward Use of Enterprise Resource Planning Solutions," *J. Inf. Organ. Sci.*, vol. 43, no. 1, pp. 49–71,

2019.

- [44] I. Ajzen, "The Theory of Planned Behavior," *Organ. Behav. Hum. Decis. Process.*, vol. 50, pp. 179–211, 1991.
- [45] M. Fishbein, "A theory of reasoned action: Some applications and implications," *Nebraska Symp. Motiv.*, vol. 27, pp. 65–116, 1979.
- [46] W. Permana, E. S. Astuti, and I. Suyadi, "Faktor-Faktor Yang Mempengaruhi Intensitas Kelanjutan Pengguna Layanan Mobile," *J. Profit*, vol. 6, no. 1, pp. 1–18, 2012.
- [47] C. McDaniel and R. Gates, *Marketing Research*, Ninth Edit. John Wiley & Sons Singapore Pte. Ltd., 2013.
- [48] M. Nazir, *Metode Penelitian (Research Method)*, 9th ed. Jakarta: Ghalia Indonesia, 2014.
- [49] P. Turner, "Implementing integrated marketing communications (IMC) through major event ambassadors," *Eur. J. Mark.*, vol. 51, no. 3, pp. 605–626, 2017.
- [50] N. P. Kartikasari, "Pengaruh Komunikasi Pemasaran Terpadu terhadap Ekuitas Merek," *Interak. J. Ilmu Komun.*, vol. 3, no. 2, pp. 162–167, 2014.
- [51] S. A. Razak, D. Nor, A. Bin, and M. Latip, "Factors That Influence the Usage of Social Media in Marketing," *Quest Journals J. Res. Bus. Manag.*, vol. 4, no. 2, pp. 2347–3002, 2016.
- [52] K. Church and R. De Oliveira, "What's up with WhatsApp? Comparing mobile instant messaging behaviors with traditional SMS," in *MobileHCI 2013 - Proceedings of the 15th International Conference on Human-Computer Interaction with Mobile Devices and Services*, 2013, pp. 352–361.
- [53] P. Schober and L. A. Schwarte, "Correlation coefficients: Appropriate use and interpretation," *Anesth. Analg.*, vol. 126, no. 5, pp. 1763–1768, 2018.
- [54] D. W. M. Chan, A. P. C. Chan, P. T. I. Lam, J. F. Y. Yeung, and J. H. L. Chan, "Risk ranking and analysis in target cost contracts: Empirical evidence from the construction industry," *Int. J. Proj. Manag.*, vol. 29, no. 6, pp. 751–763, 2011.
- [55] O. Shirokikh, G. Pastukhov, V. Boginski, and S. Butenko, "Computational study of the US stock market evolution: A rank correlation-based network model," *Comput. Manag. Sci.*, vol. 10, no. 2–3, pp. 81–103, 2013.
- [56] H. Akoglu, "User's guide to correlation coefficients," *Turkish J. Emerg. Med.*, vol. 18, no. 3, pp. 91–93, 2018.
- [57] Ramakrishnan, "USE OF WHATSAPP FOR ENGLISH LANGUAGE PROFICIENCY AMONG B.ED. TRAINEES," *Int. J. Res. -*

- Granthalayah*, vol. 5, no. September, pp. 1–6, 2017.
- [58] S. A. Devaney, “Understanding the Millennial Generation,” *J. Financ. Serv. Prof.*, vol. 69, no. 6, pp. 11–15, 2015.
 - [59] A. Kuhns and M. Saksena, “How Millennial Food Purchase Decisions Compare to Previous Generations,” in *Agricultural and Applied Economics Association.*, 2016.
 - [60] A. Hall, N. Towers, and D. R. Shaw, “Understanding how Millennial shoppers decide what to buy Digitally connected unseen journeys,” *Int. J. Retail Distrib. Manag.*, vol. 45, no. 5, pp. 498–517, 2017.
 - [61] I. Romero and J. A. Martínez-Román, “Determinants of technology adoption in the retailtrade industry – the case of SMEs in Spain,” *Amfiteatru Econ.*, vol. 17, no. 39, pp. 646–660, 2015.
 - [62] G. Todorova, “Marketing Communication Mix,” *Trakia J. Sci.*, vol. 13, no. 1, pp. 368–374, 2015.
 - [63] D. Thakur, M. Chander, and E. C. Author, “Use of Social Media in Agricultural Extension: Some Evidence From India,” *Int. J. Sci. Environ.*, vol. 7, no. 4, pp. 1334–1346, 2018.
 - [64] S. Jose, “Strategic use of digital promotion strategies among female emigrant entrepreneurs in UAE,” *Int. J. Emerg. Mark.*, vol. 13, no. 6, pp. 1699–1718, 2018.
 - [65] Y. Hamdan, A. Ratnasari, and A. Julia, “Online digital media in supporting product sales,” *J. Phys. Conf. Ser.*, vol. 1375, no. 012090, 2019.
 - [66] K. A. Prihatna, R. Ayal, M. Sistarani, and Y. Christanti, “What Whatsapp Status Enables Reseller to Do as Channel,” *Int. J. Innov. Technol. Explor. Eng.*, vol. 8, no. 9, pp. 44–55, 2019.
 - [67] K. Garimella and G. Tyson, “WhatsApp, Doc? A First Look at WhatsApp Public Group Data,” in *The Twelfth International AAAI Conference on Web and Social Media (ICWSM 2018)*, 2018, no. June, pp. 511–517.
 - [68] P. Naruka, S. Verma, S. Sarangdevot, C. Pachauri, S. Kerketta, and J. Singh, “A Study on Role of WhatsApp in Agriculture Value Chains,” *Asian J. Agric. Extension, Econ. Sociol.*, vol. 20, no. 1, pp. 1–11, 2017.
 - [69] A. Y. Adilah, M. N. Fadhiha, and S. Kalsitinoor, “Cost, Security and Features Influencing Baby Boomers Behavioral Intention On Adopting WhatsApp Application,” *Int. J. Accounting, Financ. Bus.*, vol. 4, no. 18 (March), pp. 67–77, 2019.
 - [70] F. A. Abdullah and B. A. Samah, “Factors Impinging Farmers’ Use of Agriculture Technology,” *Asian Soc. Sci.*, vol. Vol. 9, no. No. 3, pp. 120–124, 2017.

- [71] D. Suhartanto, D. Dean, G. Leo, and N. N. Triyuni, "Millennial experience with online food home delivery: A lesson from Indonesia," *Interdiscip. J. Information, Knowledge, Manag.*, vol. 14, pp. 277–279, 2019.
- [72] M. W. Allen and M. L. Spialek, "Young millennials, environmental orientation, food company sustainability, and green word-of-mouth recommendations," *J. Food Prod. Mark.*, vol. 24, no. 7, pp. 803–829, 2018.
- [73] P. Chopra and M. Bedi, "Understanding Determinants of User Acceptance of WhatsApp: An Empirical Study," *J. Serv. Res.*, vol. 18, no. 2, 2019.
- [74] D. Balkrishan, A. Joshi, C. Rajendran, N. Nizam, and C. Parab, "Making and Breaking the User-Usage Model: WhatsApp Adoption Amongst Emergent Users in India," in *IHCI '16: Proceedings of the 8th Indian Conference on Human Computer Interaction*, 2016, no. Desember.
- [75] Statista, "Penetration of leading social networks in Indonesia as of 3rd quarter 2018," 2019.
- [76] N. Kumar and S. Sharma, "Survey Analysis on the usage and Impact of Whatsapp Messenger," *Glob. J. Enterp. Inf. Syst.*, vol. 8, no. 3, p. 52, 2017.
- [77] E. Karapanos, P. Teixeira, and R. Gouveia, "Need fulfillment and experiences on social media: A case on Facebook and WhatsApp," *Comput. Human Behav.*, vol. 55, pp. 888–897, 2016.



Re-examination and expanding the EUCS Model on Cloud-based ERP system

Weli Weli

weli.imbiri@atmajaya.ac.id

Faculty of Economics and Business

Atma Jaya Catholic University of Indonesia, Jakarta

Abstract

The end-user computing satisfaction model (EUCS) has been widely used in previous studies, and Enterprise Resource Planning. Therefore, Enterprise Resource Planning (ERP) System, need to be developed in accordance with cloud computing that dominate current information technology devices. This study was carried out to test the expansion of the EUCS model in a cloud-based ERP system. Therefore, the purpose of this research is to re-examine the validity and reliability of the computer application satisfaction model and its relationship with user performance in cloud-based ERP system. The overall satisfaction variable is added as a mediation between the satisfaction model and user performance. Data was collected through snowball sampling with a questionnaire distributed to the cloud-based ERP users. Additionally, data processing was conducted using the Second-order concept in structural equation modeling with the Partial Least Square approach. Since data processing using WarpPLS confirmed the validity and reliability of the model and all relationships between variables, this research contributes theoretically to the study of end-user satisfaction from information technology applications. Its final section describes the limitations and opportunities for future research.

Keywords: ERP, Cloud-based, EUCS, end-user satisfaction, performance

1. Introduction

The end-user computing satisfaction (EUCS) was initially developed to measure the satisfaction level of end-user computers in the early 1980s. EUCS is a measurement of affective attitudes towards specific computer-based applications by someone directly interacting with the applications [1]. According to the EUCS concept, user satisfaction is measured based on the perception of content, accuracy, format, ease of use, and timeliness. With these 5 dimensions, satisfaction shows the excellent quality and acceptance level of the system application used. Until now, EUCS has been widely applied in various types of computer internet-based applications studies, including the ERP application.

Previous studies have shown adequate consistency and validity in measuring the satisfaction of end-user information systems [1]–[7]. Previous research showed that the EUCS instrument is consistent in measuring user satisfaction for conventional

ERP systems [6]. ERP users are delighted with the system's accuracy, and they provide the highest rank for the timeliness. The ease of use and user-friendliness was ranked the lowest. The psychometric properties of EUCS appear strong in all studies and user groups. However, some studies stated that EUCS could not be used as a final model in explaining the end-user satisfaction of computer applications [6], [7]. Furthermore, research suggested to improve by re-validating and extending the EUCS Model [6]. Subsequently, this study validates the EUCS model concerning cloud-based Enterprise Resource Planning (ERP) users.

According to Zhong & Rhode [8], cloud-based ERP applications is a new domain, with little research conducted on their adoption. The EUCS instrument has not been validated on ERP cloud. This research examines the ERP application and its relation to the computing domain separately. The prospects for future developments that allow migration from conventional to cloud-based ERP, the EUCS model is re-evaluated on cloud-based ERP users.

Cloud-based ERP testing was performed because there is much anecdotal evidence pointing to its benefits, especially in organizations. For instance, there is increased efficiency with high application scalability, lower hardware costs, information integration, and faster response time to customers. This leads to improved customer satisfaction and company image [9].

ERP is an interesting research topic, though its implementation is expensive [10], [11]. However, the factors of globalization, centralization, and performance improvement make large and small-scale companies implement ERP [12]. Reports from several application supervisors support the increase in the number of companies investing in the ERP sector. For instance, Oracle claims that there has been a massive investment in cloud-based ERP systems. This is in line with the report from the global ERP Software Market, published by KBV Research in 2019 [13]. The report predicts a substantial increase in the ERP market in 2025. Therefore, it is challenging to assess the benefits of this substantial investment. The challenge is whether a substantial investment in implementing the ERP application is beneficial to the company in terms of value.

1.1. End-User Satisfaction Model in ERP Systems

The concept of user satisfaction was initially intended to assess the success of information system implementation. Satisfaction is closely related to the success of the system in fulfilling user needs [2], [14]. Furthermore, user satisfaction shows whether the implemented system is effective [1]. Overall individual satisfaction towards information systems is evaluated cognitively. Measurements should be conducted to determine whether the system has fulfilled user needs. Based on the overall satisfaction, this study adopts the concept proposed in [1]. It expands the EUCS model towards overall user satisfaction. This variable serves as a mediation between the EUCS model and individual performance in using ERP cloud system, especially SaaS with Oracle vendors.

The relationship between user satisfaction and individual performance is based on interaction with the system. Previous research focused on ERP impact at the

organizational level, with very few examinations on how it influences individual users [15]. When the use of an ERP system is beneficial to the organization, the end-users also indirectly benefit from using it. This is possible because the end-user always interacts with the system. Furthermore, when the end-users feel the benefits, their productivity positively affects the organization. Therefore, successful implementation of the system should be measured based on user satisfaction. The study confirmed the relationship between satisfaction and individual performance in using ERP systems [8]. This was supported by similar studies in various application groups, such as e-learning [16], customer information systems [17], e-government systems [18], and m-banking [19].

Based on the description above, this study confirms and extends the End User Computing Satisfaction (EUCS) model. Confirmation is conducted in the domain of cloud-based ERP systems, especially for SaaS with Oracle vendors. Furthermore, the satisfaction model is related to end-user performance [8], [9], [12], [15], [17]. Based on the model developed, expansion is conducted by adding the overall satisfaction variable [1]. Although the EUCS model has been widely used in various studies with different information system applications, this research contributes to cloud-based ERP systems. Furthermore, the user satisfaction instrument is tested with the second-order variable concept.

1.2. Research Model

The research model predicts that a higher user satisfaction level of ERP cloud system increases performance, as shown in Figure 1. The user satisfaction model is based on the ease of use, content, timeliness, accuracy, and format. Furthermore, the model is extended towards overall satisfaction and related to individual performance. Hence, it follows the concept of the ERP User Satisfaction as the second-order latent variable. The indicators of this variable are ease of use, content, timeliness, accuracy, and format, which is the first-order latent variable.

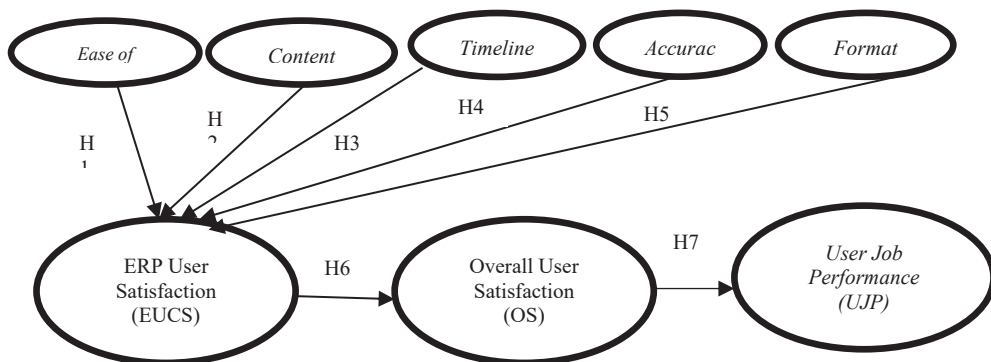


Figure 1 The Research Model

Based on the EUCS concept designed by Doll & Torkzadeh [20], user satisfaction is defined as the extent to which application users believe that the available system meets their requirements. The user satisfaction component is their interaction experience when using the application. This is reflected in the affective attitude of satisfaction towards measurable applications through 5 dimensions, namely 1) ease of use that reflects user-friendliness, 2) content that meets user expectations, 3) timeliness of information presentation, 4) accuracy of the information and 5) presentation format of information under user expectations, [5]

The previous studies results [1], [2], [6], [7] provide empirical evidence and confirmation of the 5 dimensions that establish EUCS. Ease of use is a subjective perception by users. It reflects user-friendliness [6] in browsing, finding, and editing content provided by the system [17]. An easy-to-use system provides satisfaction to users because they do not experience operational problems. Furthermore, the easier the access to the system, the more users feel the benefits.

Similarly, the good content design tends to generate useful information for its users and increase their trust [21][17]. Information content that meets user expectations impacts on their satisfaction ability to carry out their job. The more appropriate the content presented by the application, the better the response given by the user.

This is not less important than other dimensions, whereby the timeliness and accuracy of presenting information also play an important role in determining system user satisfaction because it is related to their accuracy in solving problems [1]–[3]. Inaccurate information leads to errors in the decision-making process, with the format defined as the presentation of information in a form that matches user expectations. Application users can use the system, browse the site, find and edit content according to an information presentation format and help others understand information clearly [21][17].

Furthermore, the relationship between end user satisfaction and individual performance is explained through the successful implementation of the system, which is described as the level of acceptance by users willing to voluntarily use it to meet their various needs [22]. Successful system implementation reflects on their acceptance, which is manifested from the level of use and increased individual performance [1], [5].

Therefore, based on the description above, the research hypothesis is formulated as follows:

- H1: Ease of Use is a forming element in cloud ERP user satisfaction
- H2: Content is a forming element in cloud ERP user satisfaction
- H3: Timeliness is a forming element in cloud ERP user satisfaction
- H4: Accuracy is a forming element in cloud ERP user satisfaction
- H5: Format is a forming element in cloud ERP user satisfaction
- H6: ERP Cloud User Satisfaction is related to overall Satisfaction
- H7: Overall satisfaction is related to user performance.

The next section explains the research methods consisting of data collection, variable operationalization, and data processing methods. This is followed by the analysis section and discussion of the data processing results, as well as conclusions.

2. Research Method

The following diagram explains the approach used in this research



Figure 2. Research Method

This study used primary data by distributing questionnaires from October to November 2019. Respondents were end-users of the Cloud-based SaaS ERP system in Jakarta, especially with Oracle vendors. Data were collected using the snowball sampling technique with Google Form and sent via social media using Whatsapp, Line, or e-mail. The data collection obtained 100 responses. Furthermore, the questionnaire was compiled based on the EUCS model, which had been translated into Indonesian. It was modified by measuring the overall satisfaction of the research adoption results [1]. The modification of previous studies [8], [9], [12], [15], [17] was used to measure individual performance according to the use of ERP cloud system. The following sections describe each instrument.

2.1. Variable Operationalization

The following are the dimensions and constructs used in this study.

End-User Computing Satisfaction (EUCS)

Based on the measurement Doll and Torkzadeh model[20], EUCS is formed from the following 5 dimensions:

1. *Ease of Use*. This is the user satisfaction level due to interaction with the system easily understood without much effort. It is measured using following 5 questions:
 - ERP cloud is easy to operate.
 - The interaction with ERP cloud system is flexible.
 - ERP cloud is easy to understand.
 - There is no difficulty using ERP cloud.
 - ERP cloud is user friendly.
2. *Content*. This is the extent to which the system output is available according to user needs, measured using 3 questions:

- ERP cloud helps provide the right information/according to the requirements.
 - ERP cloud displays the report as desired.
 - ERP cloud helps generate accurate information.
3. *Timeliness*. This is how timely the information should be presented. It is measured using 3 questions:
- ERP cloud helps provide up to date information.
 - ERP cloud supports the provision of information for a fast and precise time.
 - ERP cloud helps to release report results on time.
4. *Format*. This is related to the application's appearance as presented and used by the user. This variable is measured using 3 questions:
- ERP cloud helps display output in a useful format.
 - ERP cloud helps to present information more clearly.
 - ERP cloud display formats are easy to understand.
5. *Accuracy*. Refers to the degree of correctness of the information presented by technology, measured using 3 questions:
- ERP cloud provides accurate information.
 - ERP cloud helps display the appropriately presented output.
 - ERP cloud helps reduce mis served in compiling reports.

Overall satisfaction (OS)

Overall satisfaction is an attitude towards the use of a cloud-based ERP system, measured using 6 questions:

- I am satisfied with the convenience provided by ERP cloud.
- I am satisfied with the content of ERP cloud.
- I am satisfied with the timeliness of information available in ERP cloud.
- I am satisfied with the format presented by ERP cloud.
- I am satisfied in using ERP cloud.
- Overall, I am satisfied in using ERP cloud.

User Job Performance (UJP)

This describes the user's performance achievement based on their experience in using a cloud ERP system. This variable is measured based on the IS Success Model with several adjustments:

- Using ERP cloud allows me to accomplish tasks faster.
- Using ERP cloud increases my productivity.
- Using ERP cloud improves the performance of my job.
- Using ERP cloud enables me to get more done.
- Using ERP cloud enhances the results of my job.

The indicators used in this study were measured using a 5-point Likert scale, where 1 represented strongly disagree and 5 strongly agree. A higher score indicated a high acceptance level for each statement.

2.2. Data Processing Methods

Data were processed using the Structural Equation Model (SEM) method, with the Partial Least Square (PLS) or the Variance Based approach. The PLS method utilizes two interactive procedures that use least squares estimation for single and multi-component models. PLS is a powerful analytical method because, with bootstrapping facilities, data is processed without considering assumption problems, such as multi-collinearity, and normality. Moreover, data is processed with certain scale measurements, even with a small number of samples [18]. However, it is only used to predict models and assess the relationship between constructs [18]. The program used for data processing was WarpPLS 7.0, developed by Professor Ned Knock in 2010 [23].

In line with the PLS approach, the data were processed in stages consisting of:

1. Testing the research model with second-order latent variables by evaluating the measurement model (Outer Model).
2. Evaluating the structural model (Inner Model).
3. Testing the model fit (Model Fit).

2.3. Evaluation of the Measurement Model (Outer Model)

The measurement model was evaluated to determine the effect of indicators in explaining the latent variables. This test was performed in 3 stages, including [23]

1. *Convergent Validity*
Convergent validity was assessed by comparing the correlation between the indicator and construct (loading factor) values. When the loading factor value is greater than 0.5, the indicator fulfills the Convergent Validity criteria.
2. *Discriminant Validity*
Discriminant Validity was assessed in 2 approaches. In the first approach, the cross-loading table between constructs was examined. When the correlation value of a construct in the same indicator is greater than other constructs, a latent construct predicts the indicator of each construct more than the other indicators. The second approach involved looking at the Average Variance Extracted (AVE) value, which should be greater than 0.5.
3. *Composite Reliability*
It was assessed by looking at the Composite Reliability and Cronbach's Alpha value. When the value of a construct is greater than 0.7, it fulfills the Composite Reliability criteria.

2.4. Evaluation of Structural Model (Inner Model)

The structural model was evaluated to test the significance of the relationship between the constructs. The evaluation was conducted in 3 stages [23], including:

1. Evaluation of the R^2 value was used to measure the degree of variation change in the independent variable towards the dependent variable. The higher the R^2 value, the better the prediction of the proposed research model.

2. Evaluation of the path coefficient value was used to assess the relationship between constructs. It is conducted by looking at the path coefficient score indicated by the p-value at $p < 0.05$.
3. Effect Size evaluation was performed to assess the effect of predictor latent variables from a practical perspective. When the value of the effect size is > 0.35 , the variable has a strong influence, and for a value < 0.15 has a moderate and weak effect when it is less than 0.02.

2.5. Evaluation of Fit Goodness Model

At this stage, the assessment was performed by evaluating the suitability of the model towards the data collected. The evaluation was conducted using the fit index model provided in the output of WarpPLS version 7.0, as summarized in Table 1 [23].

Indeks	Criteria
Adjusted R ²	$\geq 0.70 \Rightarrow$ Strong, $\geq 0.45 \Rightarrow$ Moderate, $\leq 0.25 \Rightarrow$ Weak
Average Path Coefficient (APC)	$p < 0.05 \Rightarrow$ acceptable
Average R-Squared (ARS)	$p < 0.05, \Rightarrow$ acceptable
Average Adjusted R-Squared (AARS)	$p < 0.05, \Rightarrow$ acceptable
Average Block VIF (AVIF)	$\leq 5 \Rightarrow$ acceptable, $\leq 3.3 \Rightarrow$ ideally
Average Full Collinearity VIF (AFVIF)	$\leq 5 \Rightarrow$ acceptable, $\leq 3.3 \Rightarrow$ ideally
Tenenhaus GoF (GoF)	$\geq 0.1 \Rightarrow$ small, $\geq 0.25 \Rightarrow$ medium, $\geq 0.36 \Rightarrow$ large
Sympson's Paradox ratio (SPR)	$\geq 0.70 \Rightarrow$ acceptable, $1 \Rightarrow$ ideally
R-squared Contribution Ratio (RSCR)	> 0.90 , acceptable, $1 \Rightarrow$ ideally
Statistical Suppression Ratio (SSR)	$\geq 0.70 \Rightarrow$ acceptable
Nonlinear Bivariate Causality Direction Ratio (NLBCDR)	$\geq 0.70 \Rightarrow$ acceptable

Table 1. Model fit criteria

3. Result

General Description of Respondents and Research Variables

The information in Table 2. illustrates that most respondents were women below the age of 30, with undergraduate education. Furthermore, the majority of respondents had less than 3 years of work experience in Financial & Accounting with staff positions.

Description	Total		Description	Total	
Age			Department		
< 30 year	66	66%	Sales & Marketing	16	16%
30-40 year	33	33%	Financial & Accounting	67	67%
> 40 year	1	1%	Operating	4	4%
Gender			Production	3	3%
Male	26	26%	Supporting	4	4%
Female	74	74%	Purchasing	6	6%
Experiences			Position		
<1 year	14	14%	Supervisor	8	8%
1-3 year	61	61%	Staff	89	89%
3-5 year	16	16%			
5-10 year	6	6%	Education		
>10 year	3	3%	Undergraduate	100	100%

Table 2. Characteristics of respondents

According to Table 3, characteristics of research variables describe the overall condition perceived as high, which is above 4 out of 5, except for ease of use, with a score of 3.64. This indicates a reasonably high satisfaction level for all variables. However, the items about ease of use on a cloud-based ERP system are still problematic.

Variabel	Total items	Mean
Ease of Use	5	3.64
Content	3	4.20
Timeliness	3	4.16
Accuracy	3	4.18
Format	3	4.15
Overall Satisfaction	6	4.05
User Job Performance	5	4.05

Table 3. Characteristics of latent variables

3.1. Measurement Model Evaluation (Outer Model) of First-Order

Based on the first-stage evaluation results, all the first-order indicators forming the EUCS variable display the loading factor value greater than 0.7, except for the AC3 indicator at 0.680. However, this value is still useful because it is above 0.5 [23]. The values of Cronbach Alpha, Composite Reliability (CR), and Average Extracted

Variance (AVE) are all greater than 0.7, as summarized in Table 4. Therefore, based on these results, all indicators have good convergent validity, and effectively explain latent variables.

The next evaluation assessed the discriminatory validity of the construction by looking at the cross-loading value. The values in Table 5. show that all indicators have a higher correlation on the latent variable than the other variables. This is evidenced by the Average Extracted Variance (AVE) score. From Table 4, all indicators have AVE values greater than 0.5. Therefore, all indicators explain each latent variable well, as indicated by high correlation values. Subsequently, the First-order outer model was evaluated using composite reliability values and Cronbach's Alpha. As presented in Table 4, the values of the two measures for all latent variables show a score higher than 0.7. Therefore, the constructs have high reliability.

The first-order model test results show that the cloud-based ERP user satisfaction measurement model has fulfilled the concepts of convergent validity, discriminant validity, and composite reliability. Therefore, the first-order of EUCS instrument used has good validity and reliability.

Indicator/ Variable/ Items		Loading Factors
Ease of use (Cronbach Alpha = 0.929, CR= 0.947, AVE = 0.784)		
EOU1	ERP cloud is easy to operate	0.747
EOU2	The interaction with the ERP cloud system is flexible	0.919
EOU3	ERP cloud is easy to understand	0.907
EOU4	There is no difficulty using ERP cloud	0.921
EOU5	ERP cloud is user friendly	0.919
Content (Cronbach Alpha = 0.875, CR= 0.923, AVE = 0.800)		
CN1	ERP cloud helps provide the right information/according to the requirements	0.918
CN2	ERP cloud displays the report as desired	0.878
CN3	ERP cloud helps generate accurate information	0.887
Timeliness (Cronbach Alpha = 0.875, CR= 0.923, AVE = 0.800)		
TM1	ERP cloud helps provide up to date information	0.918
TM2	ERP cloud supports the provision of information for a fast and precise time	0.878
TM3	ERP cloud helps to release report results on time	0.887
Accuracy (Cronbach Alpha = 0.798, CR= 0.884, AVE = 0.721)		
AC1	ERP cloud provides accurate information	0.923
AC2	ERP cloud helps display the appropriately presented output	0.921
AC3	ERP cloud helps reduce misserved in compiling reports	0.680
Format (Cronbach Alpha = 0.860, CR= 0.916, AVE = 0.784)		

FM1	ERP cloud helps display output in a useful format	0.915
FM2	ERP cloud helps to present information more clearly	0.936
FM3	ERP cloud display formats are easy to understand	0.799

Table 4. Test result for first-order outer model



Figure 3. First-order laten variable

3.2. Measurement Model Evaluation (outer model) of Second-Order

After the first-order latent variables evaluation showing good validity and reliability, the second-order latent variables were tested. The summary results in Table 6 illustrates the acceptable values for all indicators because it has a loading factor greater than 0.7. Similarly, the Cronbach Alpha, Composite Reliability (CR), and Average Extracted Variance (AVE) values were greater than 0.7. Furthermore, the evaluation of discriminant validity, as seen from the loading factor value, shows adequate results. As presented in Table 7, all indicators have a higher correlation or loading factor value for the latent variable than the other variables. Therefore, all measurement models for first-order and second-order have good discriminant validity, convergent validity, and composite reliability.

	EOU	CN	TM	AC	FM	SE	P value
EOU1	0.747	0.235	0.000	0.054	0.082	0.082	<0.001
EOU2	0.919	-0.279	0.000	-0.074	0.132	0.078	<0.001
EOU3	0.907	0.139	0.000	-0.191	0.014	0.078	<0.001
EOU4	0.921	-0.140	0.000	0.164	-0.094	0.078	<0.001
EOU5	0.919	0.091	0.000	0.055	-0.119	0.078	<0.001
CN1	-0.062	0.918	0.000	0.204	0.010	0.078	<0.001
	EOU	CN	TM	AC	FM	SE	P value
CN2	0.067	0.878	0.000	-0.260	0.155	0.079	<0.001
CN3	-0.002	0.887	0.000	0.046	-0.164	0.079	<0.001
TM1	-0.062	0.787	0.918	0.204	0.010	0.078	<0.001
TM2	0.067	0.914	0.878	-0.260	0.155	0.079	<0.001
TM3	-0.002	0.986	0.887	0.046	-0.164	0.079	<0.001
AC1	0.150	0.158	0.000	0.923	-0.208	0.078	<0.001
AC2	-0.077	0.108	0.000	0.921	0.100	0.078	<0.001
AC3	-0.099	-0.361	0.000	0.680	0.148	0.083	<0.001

FM1	-0.226	0.069	0.000	-0.056	0.915	0.078	<0.001
FM2	-0.202	-0.074	0.000	0.057	0.936	0.078	<0.001
FM3	0.495	0.008	0.000	-0.003	0.799	0.080	<0.001

Table 5. Cross loading first-order

Indicator/ Variable/items		Loading Factors
ERP User Satisfaction (Cronbach Alpha = 0.924, CR= 0.944, AVE = 0.773)		
EOU	Ease of Use	0.730
CN	Content	0.934
TM	Timeliness	0.934
AC	Accuracy	0.873
FM	Format	0.909
Overall Satisfaction (Cronbach Alpha = 0.954, CR= 0.963, AVE = 0.813)		
US1	I am satisfied with the convenience provided by ERP cloud.	0.934
US2	I am satisfied with the content of ERP cloud.	0.925
US3	I am satisfied with the timeliness of information available in ERP cloud.	0.916
US4	I am satisfied with the format presented by ERP cloud.	0.852
US5	I am satisfied in using ERP cloud	0.899
US6	Overall, I am satisfied in using ERP cloud	0.881
User Job Performance (Cronbach Alpha = 0.948, CR= 0.960, AVE = 0.829)		
UJP1	Using ERP cloud allows me to accomplish tasks faster	0.912
UJP2	Using ERP cloud increases my productivity	0.943
UJP3	Using ERP cloud improves the performance of my work	0.930
UJP4	Using ERP cloud enables me to get more done	0.869
UJP5	Using ERP cloud enhances the results of my work	0.895

Table 6. Test result for second-order outer model

	EUCS	OS	UJP	SE	P value
EOU	0.73	0.925	-0.263	0.082	<0.001
CN	0.934	-0.25	0.09	0.078	<0.001
TM	0.934	-0.25	0.09	0.078	<0.001
AC	0.873	-0.258	-0.028	0.079	<0.001
FM	0.909	0.018	0.054	0.078	<0.001
US1	-0.002	0.934	-0.103	0.078	<0.001
US2	-0.073	0.925	0.052	0.078	<0.001
US3	-0.049	0.916	0.115	0.078	<0.001

US4	-0.12	0.852	0.07	0.079	<0.001
US5	0.02	0.899	-0.159	0.078	<0.001
US6	0.225	0.881	0.03	0.079	<0.001
UJP1	0.043	0.235	0.912	0.078	<0.001
UJP2	0.192	-0.232	0.943	0.077	<0.001
UJP3	0.151	-0.189	0.93	0.078	<0.001
UJP4	-0.369	0.156	0.869	0.079	<0.001
UJP5	-0.044	0.05	0.895	0.078	<0.001

Table 7. Cross loading second-order

3.3. Structural Model Evaluation (Inner Model)

After obtaining validity and reliability results for all constructs, the structural model (Inner Model) was evaluated with second-order latent variables. The data analysis results for the Inner Model were presented in Figure 4. These results show that the R^2 value for Overall Satisfaction (OS) and User Job Performance (UJP) is 0.71 and 0.75, respectively, indicating high explanatory power. The R^2 value shows that the various changes in the dependent variable of Overall Satisfaction (OS) are explained by 71% of the independent variable of satisfaction towards cloud-based ERP (EUCS). The rest is explained by other variables outside the proposed model. Similarly, the User Job Performance (UJP) variable is explained by 75% of the EUCS and OS variables. Therefore, this study fulfills the R^2 criteria.

3.4. Mediation Testing

Based on the research model, the effect testing towards individual performance is conducted directly or indirectly through overall satisfaction. The WarpPLS output program results were used to test the mediation effect. The results of the WarpPLS output in Table 8 show that user satisfaction of cloud-based ERP plays a mediating role in individual performance. The mediation's role is indicated by the coefficient, p-value, and effect size on the indirect and total effect tables [23]. As a requirement, all path coefficients should be significant in both model 1 (direct effect) and model 2 (indirect effect) to fulfill the mediation effect. The analysis results in Figure 4 show that all pathways are significant. In model 1, user satisfaction with cloud-based ERP produces a coefficient value of 0.84 and significant at $p < 0.01$. Also, in the second model, all pathways produced significant results with a p-value of < 0.01 . Table 8 shows that the indirect effect size is $0.28 > 0.15$, which indicates a sufficient, as well as the total effect [24].

The next assessment evaluated the effect size value. Practically, the output of the WarpPLS effect size of 0.70 indicates a strong influence of the predictor latent variable (> 0.35) [24].

Indirect effects				P values for total effects			
	ES	OS	UJP		ES	OS	UJP
UJP	0.333			OS	<0.001		
p	<0.001			UJP	<0.001	<0.001	
SE	0.065			Standard errors for total effects			
Effect Size	0.28				ES	OS	UJP
				OS	0.08		
				UJP	0.08	0.09	
Total effects				Effect sizes for total effects			
	ES	OS	UJP		ES	OS	UJP
OS	0.841			OS	0.707		
UJP	0.833	0.396		UJP	0.701	0.327	

Table 8. Indirect and Total Effects

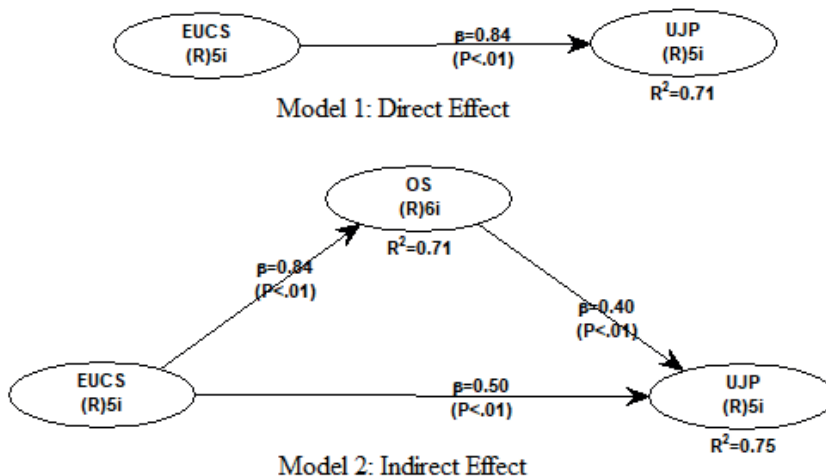


Figure 4. Full Model

3.5. Testing of Fit Model

The structural model testing showed a strong relationship between user satisfaction with cloud-based ERP systems and performance. Moreover, there is a mediating effect of ERP satisfaction. The fit model was then tested. Based on the results in Table 9, the model proposed in this study shows an acceptable fit level. The Average Path Coefficient (APC) and Average R-squared (ARS) criteria provide significant value at $p < 0.001$. The Average Full Collinearity VIF (AFVIF) gives a value of 3,381, meaning that the proposed model is fit with the data collected.

Based on the data in table 9, this research model has fulfilled the goodness of fit criteria. The p-value of APC and ARS, which is less than 0.05, is significant. Therefore, this research model is acceptable.

Index	Value	Result
Adjusted R ²	0.705	> 0.7 => Strong
Average Path Coefficient (APC)	0.001	p < 0.05 => Acceptable
Average R-Squared (ARS)	0.001	p < 0.05 => Acceptable
Average Adjusted R-Squared (AARS)	0.001	p < 0.05 => Acceptable
Average Full Collinearity VIF (AFVIF)	3.381	p <= 5 => Acceptable
Tenenhaus GoF (GoF)	0.753	> 0.36 => Large
Sympson's Paradox ratio (SPR)	1	Ideally
R-squared Contribution Ratio (RSCR)	1	Ideally
Statistical Suppression Ratio (SSR)	1	Ideally
Nonlinear Bivariate Causality Direction Ratio (NLBCDR)	1	Ideally

Table 9. Inner model dan model fit result

The analysis results of the first-order show that all items explain each of the latent variables. These results support the validity and reliability of the EUCS instrument, which was adopted to assess system user satisfaction in a cloud-based ERP system. Therefore, it can be concluded that Hypothesis 1, which states that Ease of Use is a forming element in cloud ERP has empirical support as indicated by the loading factor value of its latent variable which is greater than 0.7, namely 0.730. This means that the user satisfaction measurement remains consistent using the ease of use dimension that reflects user-friendliness. The system used can easily provide satisfaction to users, despite showing the smallest value among other dimensions.

Hypothesis 2 which states that Content is a forming element in cloud ERP user satisfaction, that gets empirical support from the loading factor value of its variable by 0.934. Therefore, it can be concluded that the content presented by a cloud-based ERP system influences user satisfaction, while a high loading factor value indicates a strong explanatory level of satisfaction. Furthermore, the same loading factor value is also found in the Timeliness dimension, by 0.934, therefore, it can be concluded that Hypothesis 3 which states that Timeliness is a forming element in cloud ERP user satisfaction is supported empirically. This means that timeliness is still an important factor in determining user satisfaction when using cloud-based ERP systems. The test results for Hypothesis 4 which states that Accuracy is a forming element in cloud ERP user satisfaction is accepted by analyzing the loading factor value on the latent variable of 0.873. The accuracy of the information presented in a cloud-based ERP system contributes to user satisfaction. The last dimension in hypothesis 5, states that the format is a forming element in cloud ERP, with user satisfaction empirically as

shown by the loading factor value towards the latent variable of 0.909. The results confirm that these five hypotheses are in accordance with the previous studies in different applications [1], [2], [6], [7]. Therefore, this research adds confirmation of the EUCS validity and reliability in measuring user satisfaction for various computer applications or information technology, which continues to develop and influence the growth of various cloud-based applications.

The next is Hypothesis 6 which states that ERP Cloud User Satisfaction is related to the overall Satisfaction, which also has empirical support as shown on the full model test results in Figure 4. The WarPLS output results indicate a P-value of < 0.1 , which means that the relationship is significant and the hypothesis is empirically accepted. In the same way, the information in Figure 4 also provides empirical support for hypothesis 7 which states that the Overall satisfaction level is related to user performance. These results support the previous studies of [1], [5][22], which mean that individual satisfaction in their interactions with the system has a good impact on their work results. High satisfaction shows that user expectations in completing their work have been fulfilled and adequate in carrying out their tasks.

The dimensions with the greatest contribution to this satisfaction model are content, accuracy, timeliness, and format. The ease of use dimension gets the smallest average value, especially for the operation of the ERP Cloud. These results confirm [6] where ease of use factor needs to be developed for both conventional and cloud-based ERP systems. ERP systems are highly complex and require more effort and time to implement. Therefore, when the ERP becomes implemented, end-users should attend a series of training on how to use it.

Another item with the lowest loading factor value is ERP Cloud that reduces errors in compiling reports. Users perceive cloud ERP systems as not sufficiently reducing errors in compiling reports. It is understood that accountants have a significant role in compiling financial reports sourced from the ERP system. The information is sufficiently available in the ERP system. However, it is not directly used or withdrawn from the system without going through a special process by the accountant. For instance, there is a justification process for certain accounts at the end of the period.

4. Discussion

The test results on the structural model confirm previous studies about the validity and reliability consistency of the EUCS instrument. This study has shown that the EUCS instrument remains consistent in measuring user satisfaction for cloud-based ERP systems. The validity and reliability of the instrument are still maintained despite undergoing several modifications. In line with the modifications made on the EUCS instrument by [2]–[4], [6], this study provides the same results regarding the EUCS consistency in measuring user satisfaction in this information age.

The instrument is modified because it adjusts the nature of the computer or internet-based system used. The ease of use, content, timeliness, accuracy, and format dimensions are consistently used to measure end-user satisfaction of an information system or technology. In this research, the ease of use dimensions of a cloud-based

ERP system has the lowest score. However, this condition is in line with daily practice. Due to the relatively new nature of cloud-based ERP applications [4], end-users should attend a series of training on how to use it. Furthermore, because of the integrated context, cloud-based ERP systems are not used individually with conventional accounting applications. ERP systems require coordination and collaboration with other related departments.

There is a relationship between the end-user satisfaction model proposed in this study, both direct and indirect, with user performance. This relationship has empirical support showing the system's usefulness in daily business processes from the end-user perspective. High satisfaction in using Cloud ERP systems is greatly correlated with increasing individual performance. This study confirms the expansion of general user satisfaction measures. It provides an understanding of the dimensions as the assessment of user satisfaction with cloud-based ERP systems for their daily work. Furthermore, these results confirm previous studies on the relationship between end-user satisfaction and individual performance within the framework of the IS Success model [5], [8], [12], [16]. Therefore, the construct variations of the EUCS and the IS Success Model are examined to show various aspects of the system's success from its users' perspective.

According to [8], individual performance is evidenced by their interaction with the ERP system used in their daily work. Individual performance is measured by the time efficiency to complete quality work. End-users are assisted in obtaining the required information in the decision-making process, and how to identify the potential problems. Application development needs to pay attention to various aspects that affect individual performance improvement. As one of the implications of cloud computing technology development, applications should consider the ease or convenience in using applications in the future. Therefore, it is possible to expand the EUCS instrument.

5. Conclusion

This section provides an overall outline of all the research. The first section introduced the research, with various examples on the knowledge gap, work motivation, and research model. The explanation covers the concepts and conditions in the field of information systems using the EUCS model. Previous studies were analyzed using the EUCS model, which motivated the opening of opportunities to confirm and expand the EUCS model on the Cloud-based SaaS ERP system. In addition, the research also examines the relationship between ERP user satisfactions with their performance. Therefore, the first research model explains the confirmation towards the forming factors of EUCS, such as ease of use, content, timeliness, accuracy and format. Secondly, the model explains the relationship between EUCS with Overall user satisfaction and the third analyzes the relationship between Overall user satisfactions with User Job Performance.

The research method in the second part describes all operational variables, data collection methods, and analysis techniques. The first variable used in this study was

EUCS, which was measured using the concept proposed by Doll and Torkzadeh[20] consisting of 5 dimensions, which were treated as second-order latent variables. Secondly, the overall satisfaction variable is measured using 6 question items, while the last is the performance variable measured by 5 question items. Furthermore, for data processing, this study uses a structural equation model with a partial least square approach to carry out data testing in stages, such as the outer, inner and fit models. The third part is to explain the data processing results descriptively for each variable or analysis of hypothesis testing to examine the relationship between variables. Furthermore, discussions on data processing results are also presented in this section, along with conclusions.

This study confirmed end-user computing satisfaction with cloud-based ERP in the currently developing environment. The system user satisfaction is tested for its relationship with individual performance using the IS Success Model concept. Testing using the second-order latent variable model on the EUCS variable shows that all dimensions consistently form user satisfaction. Almost all dimensions provide high mean values, except for ease of use. These results indicate that end-users do not feel the ease of using cloud-based ERP systems. The low score for the ease of use is due to the complexity of the cloud-based ERP system, which is slightly different from conventional models or other accounting applications. The use of information technology infrastructure that differs from conventional ERP makes end-users initiate various adjustments in its implementation. This research indicates that most users are not familiar with cloud-based ERP systems. However, they give a high enough score for the content, accuracy, timeliness, and format of the cloud-based ERP system.

The expansion of the model revealed a mediating effect of the overall user satisfaction in the relationship between the EUCS satisfaction model and individual performance. The relationship between system end-user satisfaction and individual performance, either directly or indirectly obtained empirical support. These results indicate that the features of a cloud-based ERP system have impacted user performance improvement. A system with appropriate content, timeliness, accuracy, and a format that fulfills user expectations promotes efficiency and effectiveness in performance.

The model's expansion in measuring the overall end-user satisfaction is possible in developing applications, such as cloud computing. The use of IT infrastructure becomes more straightforward in cloud computing because of lower investment costs for companies. Therefore, the implementation cost is lower than conventional ERP because there is no license fee. Therefore, further research should add instruments related to comfort, flexibility, and efficiency to the user satisfaction component. This study focused on the end-user. Therefore, all results obtained are based on the user's experience and perceptions. Future research should extend focus to additional analysis, such as the impact on managerial performance and the company as a whole. Furthermore, task fit and productivity testing need to be prioritized for the satisfaction of end-user information systems. Finally, considering that cloud-based ERP is under the control of the service provider, then its use needs to be extended to the security of the company's internal control system.

References

- [1] A. Ilias and M. Z. A. Razak, "End-User Computing Satisfaction (EUCS) towards Computerised Accounting System (CAS) in Public," *J. Internet Bank. Commer.*, vol. 16, no. 2, pp. 1–17, 2011.
- [2] L. Xiao and S. Dasgupta, "Measurement of user satisfaction with web-based information systems: An empirical study," *Proc. Eighth Am. Conf. Inf. Syst. Human-Computer Interact. Stud. MIS*, pp. 1149–1155, 2002, doi: 10.1287/isre.3.1.60.
- [3] S. F. Abdinnour-Helm, B. S. Chaparro, and S. M. Farmer, "Using the End-User Computing satisfaction (EUCS) instrument to measure satisfaction with a Web Site," *Decis. Sci.*, vol. 36, no. 2, pp. 341–364, 2005, doi: 10.1111/j.1540-5414.2005.00076.x.
- [4] N. Mohamed, H. Hussin, and R. Hussein, "Measuring users' satisfaction with Malaysia's electronic government systems," *Electron. J. e-Government*, vol. 7, no. 3, pp. 283–294, 2009, [Online]. Available: <http://irep.iium.edu.my/552/>.
- [5] C. K. Hou, "Examining the effect of user satisfaction on system usage and individual performance with business intelligence systems: An empirical study of Taiwan's electronics industry," *Int. J. Inf. Manage.*, vol. 32, no. 6, pp. 560–573, 2012, doi: 10.1016/j.ijinfomgt.2012.03.001.
- [6] T. Somers, K. Nelson, and J. Karimi, "Confirmatory factor analysis of the end-user computing satisfaction instrument: Replication within an ERP domain," *Decis. Sci.*, vol. 34, no. 3, pp. 595–621, 2004, doi: 10.1111/j.1540-5414.2004.02437.x.
- [7] V. P. Aggelidis and P. D. Chatzoglou, "Hospital information systems: Measuring end user computing satisfaction (EUCS)," *J. Biomed. Inform.*, vol. 45, no. 3, pp. 566–579, 2012, doi: 10.1016/j.jbi.2012.02.009.
- [8] F. Zhong and M. E. Rohde, "Cloud computing and ERP: A framework of promises and challenges," *Proc. 25th Australas. Conf. Inf. Syst. ACIS 2014*, 2014.
- [9] D. Jain and Y. Sharma, "Cloud Computing with ERP - A Push Business Towards Higher Efficiency," *SSRN Electron. J.*, vol. 4, no. March, pp. 140–155, 2017, doi: 10.2139/ssrn.2755457.
- [10] P. Hanafzadeh, R. Gholami, S. Dadbin, and N. Standage, "The core critical success factors in Implementation of Enterprise Resource Planning systems," *Int. J. Enterp. Inf. Syst.*, vol. 6, no. 2, pp. 82–111, 2010, doi: 10.4018/jeis.2010040105.
- [11] A. Shatat, "Critical success factors in enterprise resource planning system implementation: An analysis," *ProQuest Diss. Theses*, vol. 18, no. 1, p.

- 139, 2010, [Online]. Available:
https://search.proquest.com/docview/759240980?accountid=15297%5Cnhttp://bs8lz6ys5q.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info:ofi/enc:UTF-8&rft_id=info:sid/ABI%2FINFORM+Global&rft_val_fmt=info:ofi/fmt:kev:mtx:dissertation&rft.genre=diss.
- [12] K. S. Wei, A. C. Y. Loong, Y.-M. Leong, and K.-B. Ooi, "Measuring ERP System Success: A Respecification of the Delone and McLean's IS Success Model," *Symp. Prog. Inf. Commun. Technol.* 2009, pp. 7–12, 2009, [Online]. Available: http://spict.utar.edu.my/SPICT-09CD/contents/pdf/SPICT09_A-1_2.pdf%5Cnhttp://130.203.133.150/viewdoc/summary?doi=10.1.1.160.5014.
- [13] A. D'Souza, "ERP Software Market to Reach a Market Size of \$70.3 Billion by 2025," *KBV Research*, 2019.
<https://www.prnewswire.com/news-releases/erp-software-market-to-reach-a-market-size-of-70-3-billion-by-2025--kbv-research-300966731.html>
 (accessed Mar. 31, 2020).
- [14] G. E. Heilman, J. Brusa, and A. Texas, "Validating the End User," pp. 84–96, 2006.
- [15] Oracle, "Emerging Technologies : Driving Financial and Operational Efficiency," 2020.
- [16] W. A. Cidral, T. Oliveira, M. Di Felice, and M. Aparicio, "E-learning success determinants: Brazilian empirical study," *Comput. Educ.*, vol. 122, pp. 273–290, 2018, doi: 10.1016/j.compedu.2017.12.001.
- [17] G. Norfazlina, A. S. S. Akma, S. N. Adrina, and M. M. Noorizan, "Customer Information System Satisfaction and Task Productivity: The Moderating Effect of Training," *Procedia Econ. Financ.*, vol. 37, no. 16, pp. 7–12, 2016, doi: 10.1016/s2212-5671(16)30085-5.
- [18] D. Stefanovic, U. Marjanovic, M. Delić, D. Culibrk, and B. Lalic, "Assessing the success of e-government systems: An employee perspective," *Inf. Manag.*, vol. 53, no. 6, pp. 717–726, 2016, doi: 10.1016/j.im.2016.02.007.
- [19] C. Tam and T. Oliveira, "Understanding the impact of m-banking on individual performance: DeLone & McLean and TTF perspective," *Comput. Human Behav.*, vol. 61, pp. 233–244, 2016, doi: 10.1016/j.chb.2016.03.016.
- [20] W. J. Doll and G. Torkzadeh, "The Measurement of End-User Computing Satisfaction End-User Satisfaction The Measurement of End-User Computing Satisfaction Professor of MIS and Strategic Management The

University of Toledo Gholamreza Torkzadeh Assistant Professor of Information Systems,” *MIS Q.*, vol. 12, no. 2, pp. 259–274, 1988, [Online]. Available:

<http://www.jstor.org/stable/248851><http://www.jstor.org/page/info/about/policies/terms.jsp><http://www.jstor.org>.

- [21] G. M. Ling, Y. S. Fern, L. K. Boon, and T. S. Huat, “Understanding Customer Satisfaction of Internet Banking: A Case Study In Malacca,” *Procedia Econ. Financ.*, vol. 37, no. 16, pp. 80–85, 2016, doi: 10.1016/s2212-5671(16)30096-x.
- [22] W. H. DeLone and E. R. McLean, *Information Systems Success Measurement*, vol. 2, no. 1. 2016.
- [23] N. Kock, “WarpPLS 7.0 user manual,” 2020.
- [24] N. Kock, “Advanced Mediating Effects Tests, Multi-Group Analyses, and Measurement Model Assessments in PLS-Based SEM,” *Int. J. e-Collaboration*, vol. 10, no. 1, pp. 1–13, 2014, doi: 10.4018/ijec.2014010101.



UDC 658.8:004.738.5:338.48(497.115+496.5)

Original Scientific Paper

The E-Marketing Strategy Process in the Tourism Industry - Case Study Kosovo and Albania

Behrije Ramaj-Desku*behrije.ramaj@unhz.eu**University "Haxhi Zeka", Kosovo**Faculty of Management in Tourism, Hospitality and Environment***Fatos Ukaj***fatosukaj@gmail.com**University of Prishtina, Kosovo**Faculty of Economic*

Abstract

The E-marketing strategy is developed as a process of several stages that need to be well analyzed and constantly reviewed. The first stage of this process is situational analysis (internal and external factors). The research was focused on identifying internal and external factors. The Delphi technique was used in combination with the AHP method to answer the research questions. The research was conducted in three stages, according to the Delphi technique. In order to process the data in all three phases of the research Excel, SPSS, and the AHP-ON system were used. 36 experts of tourism industry from Kosovo and Albania took part in this study. Ranked based on the significance, of all factors and sub-factors the following indicated the highest influence: entrepreneurial attitudes and knowledge, management support, customer and supplier relationships, IT cost, competitor identification, competitor analysis, and innovation. Based on the scientific literature and the primary results, the conclusion and recommendations were drawn and a model was proposed by the author based on the contingency theory and the TEO framework.

Keywords: E-marketing, strategies, external and internal factors, tourism industry, Kosovo, Albania, Delphi techniques, AHP method, contingency theory.

1. Introduction

Nowadays, tourism unites people in ways that were not thought of decades ago, and also has a high influence on the national and regional economy growth. The information technology (IT) applications have a huge impact on the marketing process. The application of IT creates strong competitive advantages in the areas of sales and marketing. Also, through the use of electronic broadcasting channels, social media platforms, and other innovations, suppliers connect to new and different markets [1]. Modern technology is expected to play an even more important role in the tourism industry in the years to come, given the fact that tourist expectations have recently increased in terms of service delivery. For tourism enterprises the application of information technology has influenced the increase of quality in service delivery,

the possibility of securing market existence, improvement of forms of communication with tourists, selling of tourism products, increasing the possibility of cooperation with other enterprises, increasing of income and cost reduction [2] .

In recent years, within the framework of different marketing strategies, due to the benefits it offers, the attention is on e-marketing strategy. The E-marketing offers new marketing communication opportunities through the leading platform called Internet. Businesses that apply E-marketing achieve higher efficiency, greater return on investment, also through online campaigns, sales and the opportunity to attract potential customers are increased [3].

1.1. Purpose of the study and research questions

This paper aimed to answer the research questions related to the factors influencing the E-marketing strategies in the tourism industry, analysis of the existing situation in our country, as well as giving recommendations for improving this situation. The main objective of this paper was to present which factors have the greatest influence on the design and implementation of E-marketing strategy in the tourism industry to hotel companies, airlines, and tour operators.

The research was focused on the most important factors, such as:

- Internal factors
- External factors

In addition, the objective of this research was to address the theoretical part of scientific theories, the **marketing environment, and the factors influencing the E-marketing strategy.**

1.1.1. Research Questions:

Based on the objectives and aims of the research, the following questions were answered:

1. What are the internal factors that influence the E-marketing strategy in the tourism industry in Kosovo and Albania?
2. What are the external factors that influence the E-marketing strategy in the tourism industry in Kosovo and Albania?
3. Are there differences of opinion between the experts of the two countries about the importance of external and internal factors?
4. Which of the external factors is most important in the E-marketing strategy of the tourism industry in Kosovo and Albania?
5. Which of the internal factors is the most important in the E-marketing strategy of the tourism industry in Kosovo and Albania?

2. Methodology

Based on the research models, this research is exploratory and descriptive. The qualitative and quantitative approach assisted to identify the most important aspects of the issue addressed. The descriptive method describes the external and internal factors that influence the process of E-marketing strategy. The research was conducted in three phases, the Delphi method was applied in all three stages, but in the third phase of research AHP (Analytical Hierarchy Process) method was applied in order to rank which of the factors are the most significant in the E-marketing strategy in the tourism industry. The three phases of this research are outlined in Figure 1.

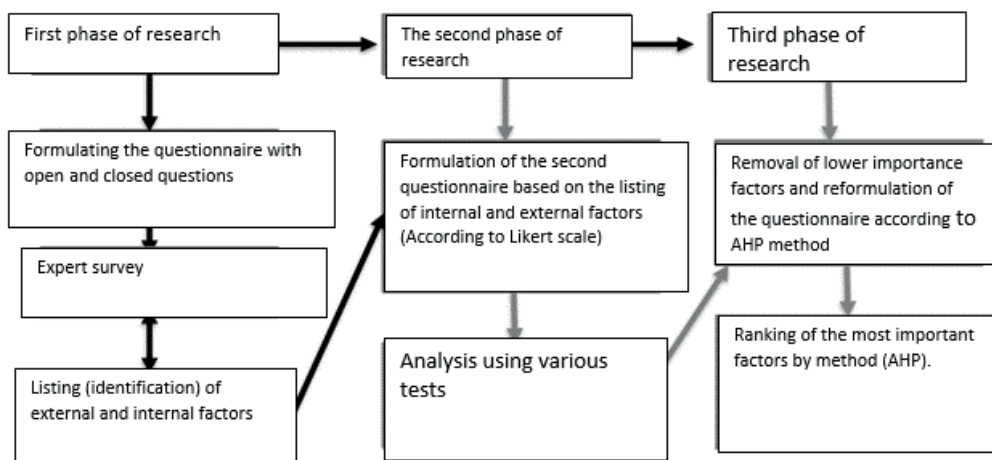


Figure 1. Stages of the research process. Source: Author.

In the the first phase of the research was identified the group of experts with management and decision-making positions to be part of the open-ended questions survey, and to answer the first and second research questions using the Delphi method. In the second phase of the research, the second questionnaire was implemented, from which the answers to the third, fourth and fifth research questions came out. At this stage, various tests were used to analyse the second questionnaire:

- *Frideman Test (Ranking)*
- *Alpha coefficient model (Correlation matrix)*
- *Independent Samples t Test to compare Kosovo and Albania.*

The main focus of the research was to create a common list of influencing factors in three groups of entities: Hotels, airlines, tour operators, and agencies. Initially, the responses of the expert-decision-makers of the field of study to the questions posed by the researcher were analysed. In the second phase of the research, from the sub-factors selected from the first questionnaire, a second questionnaire was created where these sub-factors were included. The questionnaire was structured, completed by questions that were predefined (using the Likert scale). The SPSS and Exel were used for this phase. In the third phase of the research, the AHP (Analytical Hierarchy Process) method was applied in order to rank the most important factors in the E-

marketing strategy in tourism. The method consisted of the main goals of the research then defined the criteria and sub-criteria if any, and at the end of the structure, the alternatives were located. Initially, the two countries Kosovo and Albania were set as alternatives, but [4] suggests that for these research questions the structure of the hierarchical model can be structured without alternatives. He has presented similar examples in his research.

The structure of the hierarchical research model according to the AHP method.

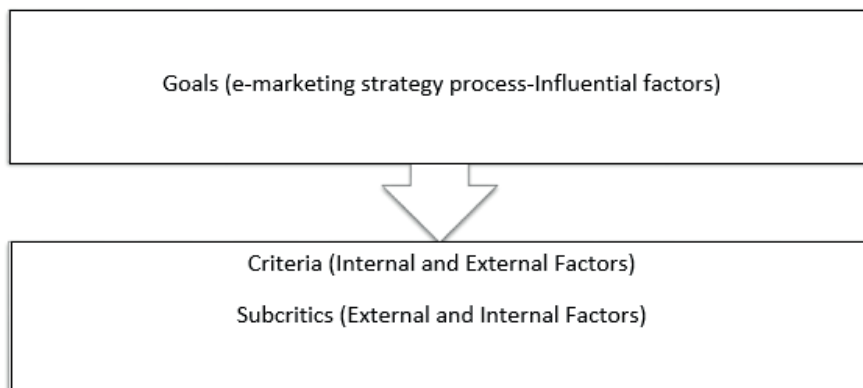


Figure 2. The presentation of research hierarchy (AHP). Source: Adapted according to the author, based on [5].

In Figure 2 the main goals such as the focus on the influencing factors in the E-marketing strategy were presented, the external and internal factors were defined as a criterion, as well as the external and internal sub-factors. The research was based on primary data, original data. As mentioned above, the research was divided into three phases according to the Delphi technique, so in Figure 3 the instruments used to collect the primary data were outlined.

In the first phase of the research, combined techniques for primary data collection were used. For data collection, a self-administered survey form and e-mail survey were selected for the experts' group. In the second and third phases of the survey, the online panel survey was applied. At this stage, the experts' group has responded to the online questionnaire, created at <https://my.survio.com/>. In the second phase, the questionnaire is structured with closed-ended questions according to the Likert scale. While in the third phase the questionnaire was structured according to the AHP method, also created at <https://my.survio.com/>.

3. Scientific theories of strategy building

The E-marketing is considered as the new high-impact discipline in the field of tourism. The main focus of this paper was to identify the determinant factors in the adoption of E-marketing by different businesses, with the specific focus being on the tourism industry businesses. According to the literature review [6]–[10], the following

theories are presented that were used to explain the adoption of information technology and the factors influencing E-marketing:

- Theory of Reasoned Action (TRA)
- Theory of Planned Behavior (TPB)
- Innovation Diffusion Theory (IDT)
- Theory of Technological, Organizational and Environmental Framework (TOE)
- Technology Acceptance Model (TAM) and
- The Common Theory of Technology Acceptance and Use (UTAUT)
- Contingency Theory

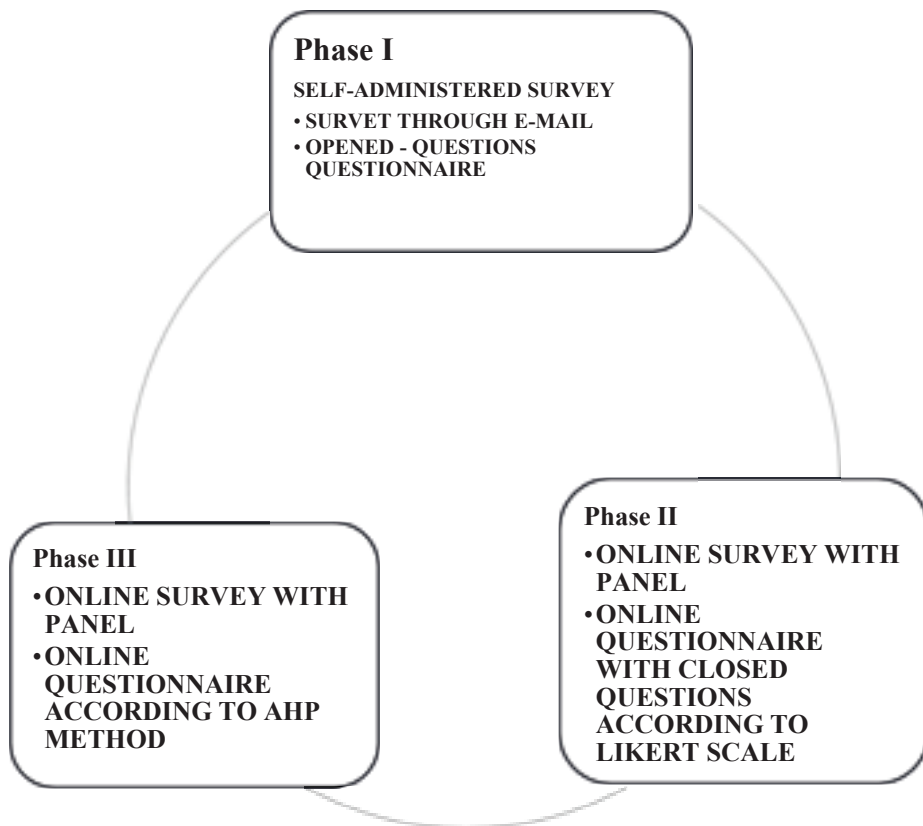


Figure 3. Techniques of primary data collection. Source: Author.

Theory of Reasoned Action (TRA)

The Theory of Reasoned Action (TRA) was proposed by Ajzan and Fishbein, (1980). This theory provides explanations for consumer actions both in the online and offline contexts. Consumer behavior is the result of attitudes that are shaped by perceptions and norms. Attitude toward a behavior is a function of perceived statements related to the behavior and the value to the person, while subjective norms

can be presented as one's perceptions of normative societal pressure to do or not to perform a particular behavior. Introducing behavioral intention through attitudes and social norm components are considered the best predictors of actual behavior [11]–[13].

Theory of Planned Behavior (TPB)

The Theory of Planned Behavior was proposed by the author Ajzen. According to this theory, conducting a behavior is conceived as a common function of goals and perceived behavioral control. The theory of planned behavior deals with antecedents of attitudes, subjective norms, and perceived behavioral control, antecedents which in the final analysis determine goals and actions. The Theory of Planned behavior provides a useful conceptual framework for dealing with the complexities of human social behavior [14]. In the following figure is illustrated the Theory of Planned Behavior (TPB):

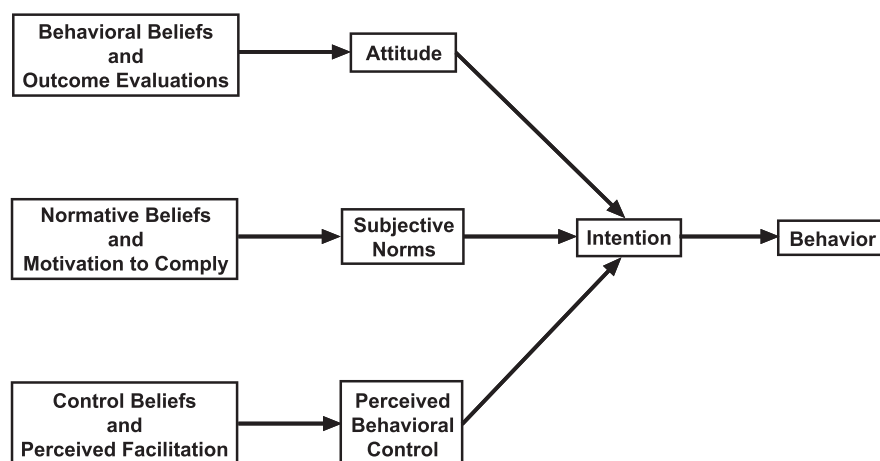


Figure 4. Planned Behavior Theory. Source: Mathieson, (1991)

According to Azjen, (1985) cited in [16], an attitude towards a behavior is a positive or negative assessment of the conduct of that behavior. The attitudes are informed by beliefs, the norms are informed by normative beliefs and motivation to be fulfilled, while the perception of behavioral control is informed by beliefs about mastering the possibilities of individuals and resources needed to engage in a behavior (Azjen, 1991 cited in [16]).

Innovation Diffusion Theory (IDT)

According to [17] "Diffusion" is the process by which an innovation is communicated through certain channels in time between members of a social system. Communication is a process in which participants create and share information in order to reach a mutual understanding."

Technological, Organizational and Environmental Context (TOE)

The TOE identifies the three most important aspects that influence the process of an enterprise to adopt and implement a technology. This framework was developed in 1990 by Tornatzky and Fleischer. According to them, the most important aspects

are: technological context, organizational context and environmental context [18]. In Figure 5 is shown the technological, organizational, and environmental structure:

- The technological context encompasses all technologies that are in use by the firm, and in this context is also included the technology available in the market. So, it is available to the firm but does not currently use it due to different reasons [18], [20].
- The organizational context refers to firm characteristics and resources, including organizational structure, the connection of structures between employees, firm size, and quantity [18], [20].

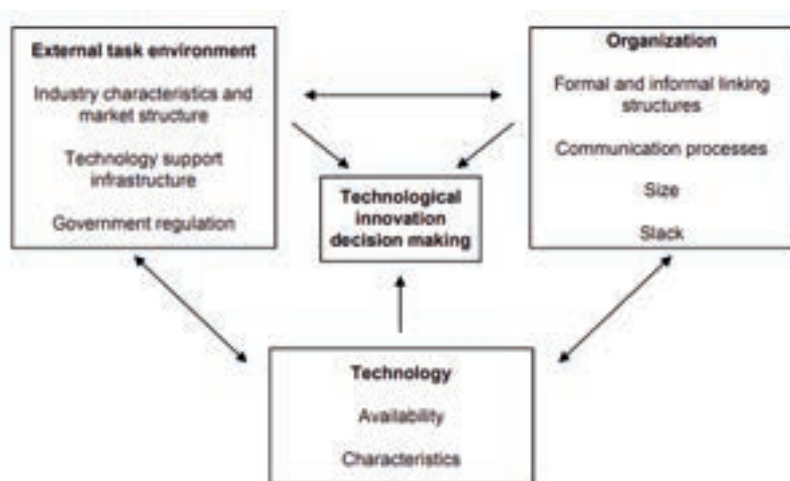


Figure 5. TOE Structure. Source: (Tornatzky dhe Fleischer, 1990) [19].

- The environmental context includes the industry structure, presence or absence of technology service providers, and the regulatory environment. The environmental context, which refers to the arena in which a firm conducts its business; it can be linked to surrounding elements such as industry, competitors, and the presence of technology service providers [18], [20].

Technology Acceptance Model (TAM) and Common Technology Acceptance and Use Theory (UTAUT)

Concerning the literature review, many researchers who have aimed to elucidate how technology is accepted by consumers, organizations, various businesses belonging to the tourism industry and the factors that have influenced the technology adoption, the E- marketing adoption, have used the Technology Acceptance Model (TAM) and the Common Technology Acceptance and Use Theory (UTAUT) [6]–[8], [11], [21]–[34].

Technology Acceptance Model (TAM) and Common Technology Acceptance and Use Theory (UTAUT).

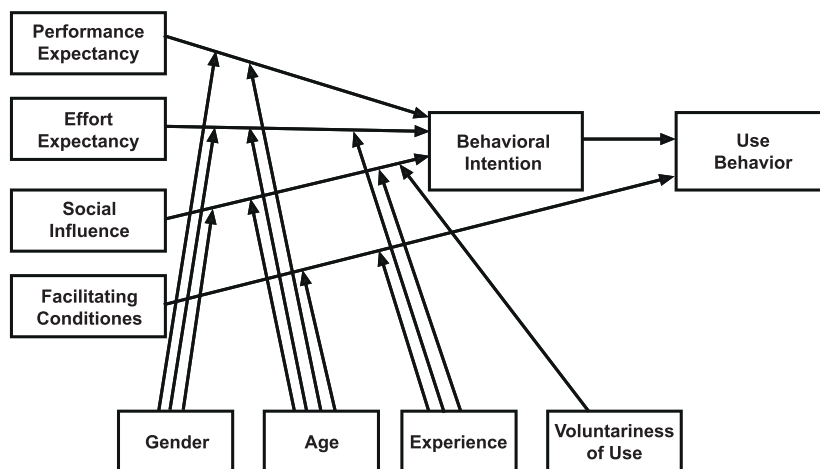


Figure 6. UTAUT Model. Source: [35], [36] .

The UTAUT model is used to explain the goals of the use of information systems in the context of the acceptance and use of technology by the customer. These goals are identified through the four main constructs and mediating factors. The four main constructs are: (performance expectancy, effort expectancy, social influence and facilitating conditions), while the mediating factors are: (gender, age, experience, and voluntariness of use) [6], [7], [33], [37].

Contingency Theory

The contingency theory is conceptually rooted in the fact that strategies to achieve goals and be effective depend heavily on the collision between strategy, organization, and the environment.

This theory has been used in the 70s and 80s, but it still offers important opportunities for SI researchers [38]. The primary focus of contingency theory, therefore, has traditionally been on the relationship between organizational factors, environmental characteristics, and the strategic response of the organization [39] The contingency theory is constructed on the basis of several steps involving three types of variables: contingency variables, performance variables, and response variables [40]. According to Lages & Jap, (2002) the coordination between strategy and enterprise context (eg organizational characteristics and external environment) has a positive impact on performance. The contingent approach emphasizes that a good strategy does not exist for all cases, but should be adapted based on the contingent variables [41]. Figure 7 shows the structure of the contingency theory.

In figure 7 is presented the conceptual scheme of contingency theory, where it is worth noting that external and internal contingent factors result in the decision-making process for strategy determination. This scheme was used to propose a model, with determinants, as explained in detail in the recommendation section.

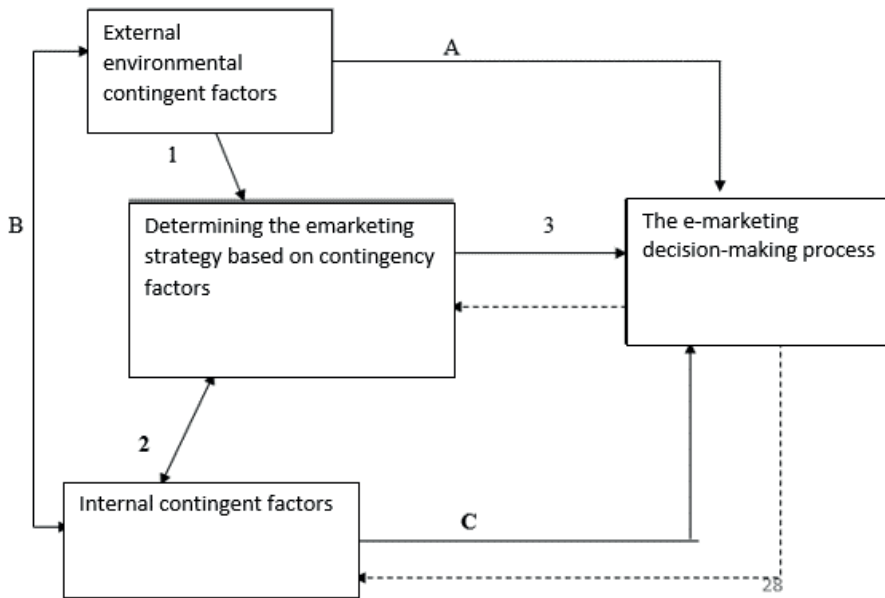


Figure 7. Conceptual scheme on contingency theory. Source: Adapted by author [38].

3.1. Influential factors on E-marketing, internet marketing and E-tourism

The influence of external and internal factors on the application of information technology has been researched by many scholars. In Table 1 is included a summary of some of the authors who have analyzed the influential factors on IT, E-marketing, internet marketing, and E-tourism. In particular, the factors that influence a company's attitude towards E-marketing, when defining E-marketing strategy as part of the marketing strategy within the overall strategy.

<i>FACTORS / VARIABLES / CHARACTERISTICS:</i>
<i>Factors influencing the penetration of E-tourism in organisations:</i> • The cost of purchasing the hardware, software and communication package, the cost of training users, designing and building an online presence, the cost of keeping the site on a reliable server, ongoing maintenance and regular updating, developing treatment procedures of online presence, commissions for online purchases from intermediaries, advertising fees for representation in search engines and other countries, and interconnectedness with travel intermediaries [42]
<i>Factors influencing tourism and e-tourism are classified into two groups:</i> • Indigenous factors include: (economic factors, technological factors, political factors, demographic factors, cultural factors, environment and weather/climate) • Exogenous factors include: (consumer behavior and travel purpose) [43]

Factors influencing E-marketing strategy:

- Influential elements of the environment (IT and the cost of telecommunications infrastructure, IT general knowledge and culture in society, market (skills, potential, turbulence, orientation), competitiveness and competitors' strategies, availability of resources and environmental opportunities, the human resource market (IT & E-Marketing Specialists), IT and e-commerce government policies, laws, regulations, systems standards of IT and technology, innovation, skills, changes in business and marketing models (Time & Process);
- Company elements (products, service quality and varieties, Web marketing mix strategy, Resource availability (Finance, Technology, etc.), brand and its strategy, strategic relationships and alliances, customer segmentation and targeting, restructuring and reorganization processes, IT infrastructure of firm, station and orientation, strong competitive advantages in e-marketing, support for innovation and knowledge management, increased internet traffic and sensitivity,)
- Influential elements in customer satisfaction (web and brand reliability, security, privacy and trust, website (attraction, design, availability and quality), transmission speed and conversion rate, tourist needs, experience and market expectations , support and structure of purchase, products and quality of service, variety and innovation, flexibility and individualization of products and services, price advantage and cost for customers, adaptation (Service and level of CRM coverage), added value perceived by customers [44].

The main organizational variables and motives (reasons) of e-business:

- Firm characteristics (size, age, scope of industry and market),
- Business strategy (strategic orientation and new product strategy),
- Owner characteristics (age, education and leadership style) [45]

The main environmental factors on Internet success:

- Resourceful and essential information should be presented to customers, the website should be well designed, and the design of the website should pay attention to e-trust/reliability because the content of the website can attract the customer and convince them to purchase [46] .

Individual characteristics that affect ICT approval:

- Gender, age, level of education, computer and Internet skills [9].

Dimensions of e-marketing skills:

- IT resources (e-commerce websites that offer sales, intranet, extranet, customer relationship management system, etc.).
- Human resources;
- Business resources [47]

Factors influencing the application of Online Marketing in SMEs:

- Internal factors (owner, characteristics of the organization/enterprise);
- External factors (technological, governmental factors)
- Demand factors [48].

<i>The main stakeholders that have a role in the introduction of IT from SMEs to hotels; Driving factors (education & training, European Union, government & public agencies, strategic partners, strategic shift)</i> • Attractive factors (customer demand, interconnection, intranet, extranet, internet, travel trade, accounting systems [49]).
<i>Internal and external factors that affect small businesses in the use of electronic marketing:</i> • Internal factors (owners' skills, resources, culture and size); • External factors (competition and market trends) (El-Gohary, 2012 cited in [50])
<i>Factors affecting the adaptation of technology by small businesses:</i> • The support of senior management, product features organizational readiness (size, cost, access, technical and financial resources), information intensity, industry pressure (competition), national infrastructure, safety, readiness and pressure, support of technology vendors, the international orientation of the enterprise and the skills of the owner (El-Gohary, 2012).
<i>Factors affecting the current and future level of a firm in the approval of e-business:</i> • Being able to understand the potential benefits of e-business, being able to respond to the practices, customers and competitors, trying to develop staff skills and knowledge of Internet-based technologies [51].
<i>Key factors for effective internet marketing:</i> • Factors related to marketing strategy, websites-related factors, factors related to the global dimension, internal factors, external factors [22].
<i>The main factors influencing social media strategy</i> • Leadership, social media recognition as a powerful marketing tool and a champion in the organization to promote this marketing medium[52] .
<i>The main factors influencing the rapid recognition and approval of social media</i> • Consumer perception that WEB 2.0 is a source of empowerment for users as participants in the market process, the fact that for a growing number of Internet users WEB 2.O has become an indispensable element in their social environment[53].
<i>Characteristics that affect the use of internet-based marketing:</i> • Technological characteristics (security and privacy, convenience and use); • Organizational characteristics (attitude and knowledge of entrepreneurs, suitability of use and technical availability of the firm); • Environmental characteristics (consumer pressure, competitor pressure and government support [23], [54].

Table 1. Summary of influential factors. Source: Adapted by the author

At the general level of the enterprise, it is important to clearly define the strategy in a comprehensive aspect. The marketing department should have, operate, implement, and monitor clear E-marketing policies. To what extent a company applies E-marketing, it affects the cost and resources an organization has and whether it is

part of the E-marketing culture. Similarly, infrastructure, competitive pressures, market trends, and government policies are considered external factors with a high impact on E-marketing adaptation. It is important to analyze the characteristics of the owner (manager) especially variables such as level of education, age, and general knowledge in the technological aspect of the manager. Whereas, the characteristics of the property are emphasized in what size or type the enterprise is, the ways of management, the organizational structure, and it is important how much the application of ICT in the hospitality industry finds support from the management. In order to support ICT, one must know the benefits and barriers that may be encountered with the application of ICT. Various authors have pointed out that the elements of the environment, company, customer satisfaction, IT characteristics, marketing functioning within the company, factors related to marketing strategy, and clear strategy definition are the factors that should be considered as priorities when the E-marketing strategy is defined.

4. Analysis and presentation of results

In the introductory part, the research questions were specified, but in this part they are presented and detailed under the questions, in order to achieve authentic results. In the following, the results of the first, second and third phase will be presented.

4.1. First phase results

In this section, the answers to the opened research questions are shown, which are also divided into other sub-questions:

1. *What are the internal factors that influence the E-marketing strategy in the tourism industry in Kosovo and Albania?*
2. *What are the specific environmental factors that influence the E-marketing strategy in the tourism industry in Kosovo and Albania?*
3. *What are the general environmental factors that influence the E-marketing strategy in the tourism industry in Kosovo and Albania?*

The general environmental factors were addressed more specifically through the four other questions:

1. *What are the technological factors that influence the E-marketing strategy in the tourism industry in Kosovo and Albania?*
2. *What are the economic factors that influence the E-marketing strategy in the tourism industry in Kosovo and Albania?*
3. *What are the political and legal factors that influence the E-marketing strategy in the tourism industry in Kosovo and Albania?*
4. *What are the cultural and social factors that influence the E-marketing strategy in the tourism industry in Kosovo and Albania?*

Internal Factors		
Specific environmental factors		
Convenience of use and technical availability; Cooperation between firms, firm characteristics; Owner / manager characteristics; Management support; Operation of marketing and E-marketing activities; Attitudes and knowledge of entrepreneurs and Human resources skills in E-marketing	Competitor identification and competitor analysis; Relationships with customers and suppliers and Partners/associates	General environmental factors Technological factors: Innovations; IT cost; IT systems standards; Human resources market and Application Convenience Economic factors: The cost of E-marketing adaptation; The cost of purchasing the software package; The cost of maintaining a website (reliable server); Advertising fees for representation in search engines; The cost of installation or service and The cost of hiring specialists Political and legal factors: National government policies on IT and e-commerce; Laws and regulations; Government influence and support; Security and privacy; Adaptation of international policies; Lack of cyber laws and Government investments Cultural and social factors: The general culture of the organisation; Cultural orientations towards e-marketing by the organisation's clients; General knowledge of society in information technology; Role and status in society University quality program level.

Figure 8. List (identifying) of internal and external factors from the first phase of research.
Source: Author

4.2. The second phase of research

In the first phase, the factors that emerged from the opened questions from the first questionnaire are summarized. These above-mentioned factors served to create the second questionnaire with closed questions according to the Likert scale.

In this part were given answers to the following questions that were outlined in the introduction section:

1. *Are there any differences in the opinions of experts from both countries about the importance of external and internal factors?*
2. *Which of the internal factors is the most important in the E-marketing strategy in the tourism industry in Kosovo and Albania?*
3. *Which of the external factors is the most important in the E-marketing strategy in the tourism industry in Kosovo and Albania?*

Also, at this stage, the external factors in specific and general environmental factors were analyzed as addressed in the first phase of the research.

The data collected from the second phase were subjected to statistical tests such as: Alpha Coefficient, Independent Samples t-Test, and Frideman Test.

Factors	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No. of Items
<i>Internal factors</i>	.745	.781	8
<i>Special environmental factors</i>	.649	.	3
<i>Technological factors</i>	.805	.804	5
<i>Economic factors</i>	.839	.842	6
<i>Political and legal factors</i>	.777	.765	7
<i>Cultural and social factors</i>	.764	.762	5

Table 2. Alpha Coefficient Results (Cronbach Alpha Coefficient). Source: Author.

The alpha coefficient of 0.745 indicates that the mean used for the internal factors significance is very reliable. The alpha coefficient of 0.649 indicates that the mean used for the specific factors significance is very reliable. The alpha coefficient of 0.850 indicates that the mean used for the significance of technological factors is highly reliable. The alpha coefficient of 0.839 indicates that the mean used for the significance of economic factors is highly reliable. The alpha coefficient of 0.777 indicates that the mean used for the significance of political and legal factors is reliable. The alpha coefficient of 0.764 indicates that the mean used for the significance of cultural and social factors is reliable.

Independent Samples t-Test

Through this test were given answers to the question: *Are there any differences in the opinions of experts of the two countries about the importance of internal factors?*

The research was focused on the group of experts in Kosovo and Albania. Based on this, the hypotheses were confirmed by this test, such as:

Ho: There are no differences between internal influencing factors on E-marketing strategy

Ha: There are differences between internal influencing factors on E-marketing strategy

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Firm characteristics	Equal variances assumed	10.113	.003	-.439	34	.664	-.222	.507	-1.252	.807
	Equal variances not assumed			-.439	29.672	.664	-.222	.507	-1.257	.813
Owner / manager characteristics	Equal variances assumed	.036	.851	2.007	34	.053	.556	L.277	-.007	1.118
	Equal variances not assumed			2.007	33.634	.053	.556	L.277	-.007	1.118
Management support	Equal variances assumed	.000	1.00	-.213	34	.832	-.056	.260	-.584	.473
	Equal variances not assumed			-.213	33.998	.832	-.056	.260	-.584	.473
Operation of marketing and e-marketing activities	Equal variances assumed	.040	.843	-.867	34	.392	-.222	.256	-.743	.299
	Equal variances not assumed			-.867	33.934	.832	-.222	.256	-.743	.299
Entrepreneurs' attitudes and knowledge	Equal variances assumed	.399	.532	.000	34	1.000	.000	.246	-.500	.500
	Equal variances not assumed			.000	33.610	1.000	.000	.246	-.501	.501
Human resources skills in e-marketing	Equal variances assumed	.102	.751	-.766	34	.449	-.222	.290	-.812	.368
	Equal variances not assumed			-.766	33.839	.449	-.222	.290	-.812	.368
Cooperation between departments	Equal variances assumed	.531	.471	.000	34	1.000	.000	.291	-.592	.592
	Equal variances not assumed			.000	33.800	1.000	.000	.291	-.593	.593
Convenience of use and technical availability	Equal variances assumed	2.109	.156	-.200	34	.843	-.056	.278	-.620	.509
	Equal variances not assumed			-.200	31.528	.843	-.056	.278	-.622	.511

Table 3. Independent sample t-test for internal factors. Source: Author.

Based on the results of the t-test for Equality of Means, we were based on Sig. (2-tailed), to prove the hypothesis raised above. The points are (.664, .832, .392, 1.000, .449, 1.00 .843), have a value greater than 0.05 except for one question that has a

value of 0.053. With a level of 95% reliability, it can be said that there are no significant differences in the significance of internal factors in Kosovo and Albania.

H₀ = $\mu_K = \mu_{Sh}$ (There is no significant difference in the opinions of experts in Kosovo and Albania about the importance of internal factors)

Independent sample test for specific environmental factors

Through this test was given the answer to the question: *Are there any differences in the opinions of experts from both countries about the importance of specific external factors?*

H₀: There are no differences between specific external influencing factors in the E-marketing strategy

H_a: There are differences between specific external influencing factors in the E-marketing strategy

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Competitor Identification and Competition Analysis	Equal variances assumed	.073	.788	-.913	34	..367	-.222	.243	-.717	.272
	Equal variances not assumed			-.913	33.873	..367	-.222	.243	-.717	.272
Relationships with customers and suppliers	Equal variances assumed	.377	..543	.190	34	..851	.056	.293	-.540	.651
	Equal variances not assumed			.190	33.746	..851	.056	.293	-.540	.651
Associates	Equal variances assumed	.325	..572	.413	34	..682	.111	.269	-.435	.657
	Equal variances not assumed			.413	33.914	..682	.111	.269	-.435	.657

Table 4. Independent sample t-test for specific environmental factors. Source: Author.

Based on the results of the t-test for Equality of Means, we were based on Sig. (2-tailed) to confirm the hypothesis raised above. The points are (.367, .851, .682,) have a value greater than 0.05. With a level of 95% reliability, it can be said that there are no significant differences in the importance of specific external factors in Kosovo and Albania.

H₀ = $\mu_K = \mu_{Sh}$ (There is no significant difference in the opinions of Kosovar and Albanian experts on the importance of specific external factors).

Independent sample test for specific environmental factors

Through this test were given the answers to the question: *Are there any differences in the opinions of experts from both countries about the importance of technological factors?*

Ho: There are no differences between the influential technological factors in E-marketing strategy

Ha: There are differences between the influential technological factors in E-marketing strategy

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Innovations	Equal variances assumed	.325	.572	.413	34	.682	.111	.269	-.435	.657
	Equal variances not assumed			.413	33.914	.682	.111	.269	-.435	.657
IT system standards	Equal variances assumed	1.030	.317	-1.116	34	.272	-.278	.249	-.783	.228
	Equal variances not assumed			-1.116	33.895	.272	-.278	.249	-.783	.228
Human resources market (IT and e-marketing specialists)	Equal variances assumed	2.028	.164	.484	34	.631	.111	.229	-.355	.577
	Equal variances not assumed			.484	32.778	.631	.111	.229	-.356	.578
Convenience of application	Equal variances assumed	.728	.399	-.968	34	.340	-.222	.229	-.689	.244
	Equal variances not assumed			-.968	32.778	.340	-.222	.229	-.689	.245

Table 5. Independent sample t-test for specific environmental factors. Source: Author.

Based on the results of the t-test for Equality of Means, we were based on Sig. (2-tailed) to prove the hypothesis raised above. The points are (.682, .272, .631, .340), have a value greater than 0.05. With a reliability level of 95%, it can be said that there are no significant differences in the importance of technological factors in Kosovo and Albania.

Zero hypothesis is accepted and alternative hypothesis is rejected:

Ho= $\mu_K = \mu_{Sh}$ (There is no significant difference in the opinions of Kosovo and Albania experts on the importance of technological factors).

Independent Samples t-test for economic factors

Through this test were given the answers to the question: *Are there any differences in the opinions of experts from both countries about the importance of economic factors?*

Ho: There are no differences between influential economic factors in E-marketing strategy

Ha: There are differences between influential economic factors in E-marketing strategy

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
The Cost of adopting e-marketing	Equal variances assumed	3.314	.078	.406	34	.687	.111	.273	-.445	.667
	Equal variances not assumed			.406	29.737	.687	.111	.273	-.448	.670
The cost of buying software package and hardware	Equal variances assumed	4.748	.036	.169	34	.867	.056	.328	-.611	.722
	Equal variances not assumed			.169	29.453	.867	-.056	.328	-.615	.726
The cost of maintaining a web site(trusted server)	Equal variances assumed	2.136	.153	.853	34	.400	.222	.261	-.307	.752
	Equal variances not assumed			.853	29.397	.401	.222	.261	-.310	.755
Advertising fees for representation on search engines	Equal variances assumed	1.761	.193	-1.014	34	.318	-.278	.274	-.834	.279
	Equal variances not assumed			-1.014	32.426	.318	-.278	.274	-.835	.280
Cost of installation or service	Equal variances assumed	4.784	.036	.496	34	.623	.167	.336	-.516	.849
	Equal variances not assumed			.496	28.896	.623	.167	.33	-.520	.854
The cost of specialized persons employment	Equal variances assumed	3.134	.086	.415	34	.680	.111	.267	-.432	.655
	Equal variances not assumed			.415	32.095	.681	.111	.267	-.434	.656

Table 6. Independent Samples t-test for economic factors. Source: Author.

Based on the results of the t-test for Equality of Means, we were based on Sig. (2-tailed) to confirm the hypothesis raised above. The points are (.687, .867, .400, .381, .623, .680), and have a value greater than 0.05. With a 95% reliability level, it can be

said that there are no significant differences in the importance of economic factors in Kosovo and Albania.

Zero hypothesis is accepted and alternative hypothesis is rejected:

$H_0 = \mu_K = \mu_{Sh}$ (There is no significant difference in the opinions of Kosovo and Albania experts on the importance of economic factors).

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
National government policy on IT and e-commerce	Equal variances assumed	.040	.844	.238	34	.814	.056	.234	-.420	.531
	Equal variances not assumed			.238	33.835	.814	.056	.234	-.420	.531
Laws and regulations	Equal variances assumed	.000	1.000	.678	34	.502	.167	.246	-.333	.666
	Equal variances not assumed			.678	33.778	.502	.167	.246	-.333	.666
Influence and support	Equal variances assumed	1.022	.319	1.939	34	.061	.556	.286	-.027	1.138
	Equal variances not assumed			1.939	32.647	.061	.556	.286	-.028	1.139
Security and privacy	Equal variances assumed	6.760	.014	-1.379	34	.177	-.333	.242	-.825	.158
	Equal variances not assumed			-1.379	29.854	.178	-.333	.242	-.827	.161
Adapting international policies	Equal variances assumed	.000	1.000	.000	34	1.000	.000	.205	-.417	.417
	Equal variances not assumed			.000	34.000	1.000	.000	.205	-.417	.417
Lack of cybernetic laws	Equal variances assumed	5.798	.022	-.833	34	.411	-.222	.267	-.764	.320
	Equal variances not assumed			-.833	31.434	.411	-.222	.267	-.766	.322
Government investment	Equal variances assumed	.043	.837	.528	34	.601	.167	.316	-.475	.808
	Equal variances not assumed			.528	33.918	.601	.167	.316	-.475	.808

Table 7. Independent Samples t-test for political and legal factors. Source: Author.

Based on the results of the t-test for Equality of Means, we were based on Sig. (2-tailed) to prove the hypothesis raised above. The points are (.814, .502, .061, 1.00, .601) and have a value greater than 0.05, except for the two questions that in Levene's

Test for Equality of Variance of Significance are .014 and .022, however sig values (2-tailed) are .177 and .411.

With a 95% reliability level, it can be said that there are no significant differences in the importance of political and legal factors in Kosovo and Albania. $H_0 = \mu_K = \mu_{Sh}$ (There is no significant difference in the opinions of experts in Kosovo and Albania about the importance of political and legal factors).

Independent Samples t Test for cultural and social factors

Through this test was given the answer to the question: *Are there any differences in the opinions of experts of the two countries about the importance of political and legal factors?*

H₀: There is no difference between influential political and legal factors in E-marketing strategy

H_a: There are differences between influential political and legal factors in E-marketing strategy

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
The general culture of the organization	Equal variances assumed	.003	.958	.699	34	.489	.167	.238	-.318	.651
	Equal variances not assumed			.699	33.922	.489	.167	.238	-.318	.651
Cultural orientation towards e-marketing by organization customers	Equal variances assumed	.002	.962	-.433	34	.667	-.111	.256	-.632	.410
	Equal variances not assumed			-.433	33.934	.667	-.111	.256	-.632	.410
General knowledge of society in Information Technology	Equal variances assumed	.080	.778	.246	34	.807	.056	.226	-.403	.515
	Equal variances not assumed			.246	33.733	.807	.056	.226	-.404	.515
Role and status in society	Equal variances assumed	1.516	.227	1.917	34	.064	.444	.232	-.027	.916
	Equal variances not assumed			1.917	33.975	.064	.444	.232	-.027	.916
The level of quality of university programs in this regard	Equal variances assumed	.284	.597	.206	34	.838	.056	.270	-.493	.604
	Equal variances not assumed			.206	33.798	.838	.056	.270	-.493	.604

Table 8. Independent Samples t- test for cultural and social factors. Source: Author.

Based on the results of the t-test for Equality of Means, we were based on Sig. (2-tailed) to prove the hypothesis raised above. The points are (.489, .667, .807, .064, .838) and have a value greater than 0.05. With a reliability level of 95%, it can be said that there are no significant differences in the importance of cultural and social factors in Kosovo and Albania. $H_0 = \mu_K = \mu_{Sh}$ (There is no significant difference in the opinions of experts in Kosovo and Albania about the significance of cultural and social factors)

Frideman Test

It is a non-parametrical test that tests the difference between several related samples[55].

This test confirmed the hypotheses as follows:

1. H_0 : There is no difference between the eight internal factors
 H_a : There is a difference between the eight internal factors
2. H_0 : There is no difference between the three separate external factors
 H_a : There is a difference between the three separate external factors
3. H_0 : There is no difference between the five technological factors
 H_a : There is a difference between the five technological factors
4. H_0 : There is no difference between the six economic factors
 H_a : There is a difference between the six economic factors
5. H_0 : There is no difference between the seven political and legal factors
 H_a : There is a difference between the seven political and legal factors
6. H_0 : There are no differences between cultural and social influential factors on E-marketing strategy
 H_a : There are differences between cultural and social influential factors on E-marketing strategy

Test Statistics ^a				
Factors	N	Ch-Square	Df	Asymp.Sig
Internal factors	36	20.715	7	.004
Specific factors of environment	36	.740	2	.691
Technological factors	36	2.647	4	.618
Economic factors	36	12.997	5	.023
Political and legal factors	36	20.876	6	.002
Cultural and social factors	36	2.739	4	.602

Table 9. Frideman Test. Source: Author.

Frideman Test Results:

Zero hypothesis rejected, accepted – H_a : There is a difference between the eight internal factors

The H_0 hypothesis is accepted: There is no difference between the three specific external factors

The H_0 hypothesis is accepted: There is no difference between the five technological factors

Zero hypothesis is rejected – H_a accepted: There is a difference between the six economic factors

Zero hypothesis is rejected – H_a accepted: There is a difference between the seven political and legal factors

Hypothesis accepted: H_0 : There is no difference between the five cultural and social factors.

Also, this test was done in the second phase to rank which of the internal, special environmental, technological, economic, political and legal factors, and cultural and social factors is more significant according to experts of Kosovo and Albania.

Factors	Ranks	
		Mean Rank
INTERNAL FACTORS	1. Firm characteristics	3.17
	2. Cooperation between departments	2.88
	3. Human resources skills in e-marketing	2.86
	4. Appropriateness of use and technical availability	2.92
	5. Owner / manager characteristics	3.18
	6. Attitudes and knowledge of entrepreneurs	4.92
	7. Management support	5.01
	8. Operation of marketing and e-marketing activities	5.03
ENVIRONMENT SPECIAL FACTORS	1. Competitor Identification and Competition Analysis	2.04
	2. Relationships with customers and suppliers	2.04
	3. Associates/Partners	1.92
TECHNOLOGICAL FACTORS	1. Innovations	2.97
	2. TI cost	2.97
	3. Standards of IT systems	2.86
	4. Human resources market and, IT and e-marketing specialists	2.92
	5. Convenience of application	3.28
ECONOMIC FACTORS	1. The cost of adapting e-marketing	3.54
	2. The cost of purchasing software and hardware packages	3.11
	3. The cost of maintaining a reliable web server	3.68
	4. Advertising fees for representation in search engines	3.56
	5. The cost of service installation	3.08
	6. The cost of hiring specialists	4.03
POLITICAL AND LEGAL FACTORS	1. National government policy on IT and e-commerce	3.60
	2. Laws and regulations	3.57
	3. Influence and support	3.64
	4. Security and privacy	4.88
	5. Adaptation of international policies	4.60
	6. Lack of cybernetic laws	3.96
	7. Government investment	3.76
CULTURAL AND SOCIAL FACTORS	1. The general culture of the organization	3.17
	2. Cultural orientation towards E-marketing by organization customers	2.888
	3. General knowledge of society on information technology	2.86
	4. Role and status in society	2.92

	5. The level of quality of university programs in this regard	3.18
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Table 10. Frideman Tests Ranking. Source: Author.

According to the opinions of Kosovo and Albania experts, it turns out that the operation of marketing and E-marketing activities is one of the most important internal factors that influence the E-marketing strategy. Regarding the significance, two distinct external factors are ranked at the same level, such as competitor identification and competitor analysis and customer and supplier correlations as the most important and influential in the e-marketing strategy. All five technological factors have a rough ranking in terms of importance and influence on the e-marketing strategy, so they were reviewed and analyzed in the third phase of the research to see if there is any change in the ranking. The cost of hiring specialized people is the most important economic and influential factor in the e-marketing strategy. Among the political and legal factors of higher importance, it turns out that security, privacy, and adaptation of international policies by experts in Kosovo and Albania, are of higher significance. According to the experts in Kosovo and Albania, the level of quality of university programs for E-marketing management is considered to be the most important cultural and social factor. The overall culture of the organization influences the E-marketing strategy in the tourism industry as well.

4.3. The third phase of research

In the third phase, an online questionnaire from the results of the second phase was used, according to the scale of the report, based on the AHP method. So, the third questionnaire was sent again to the same group of experts from Kosovo and Albania, to reconsider their opinions, but now in a different form, according to the scale of the report from the paired comparisons. This scale is derived from the main vector, Eigen. For the processing of the results the AHP-OS system was used, a system created by Goepel, K.D., (2018), also, from this system, there was the possibility of sending the online questionnaire through the link to the experts. However, being a bit complicated to complete, the questionnaire was created via <https://my.survio.com/>, however, according to the same form that this system offers. Subsequently, the answers of each expert were transferred to this system by the author of this paper.

Presentation of results according to AHP method

- The goal is: Factors influencing E-marketing strategy
- The criteria are: Internal factors, special environmental factors, technological factors, economic factors, political and legal factors, and cultural and social factors.
- The sub-criteria:
 - Sub-Internal-Factors (Operation of marketing and e-marketing activities, Management support, Attitudes and knowledge of entrepreneurs);
 - Sub-Specific Environmental Factors (Competitor Identification and Analysis, Customer and Supplier Relationships);
 - Technological Sub- Factors (Innovations, IT Cost, IT System Standards);

Economic Sub-Factors (Cost of Employment of specialists, Cost of Maintaining a Reliable Server Website, Advertising Fees for Representation in Search Engines);
 Political and Legal Sub-Factors (Security and Privacy, Adaptation of International Policies, Lack of Cyber Laws);
 Cultural and Social Sub-factors (Level of quality of university programs in this regard, General culture of the organization, Role and status in society).

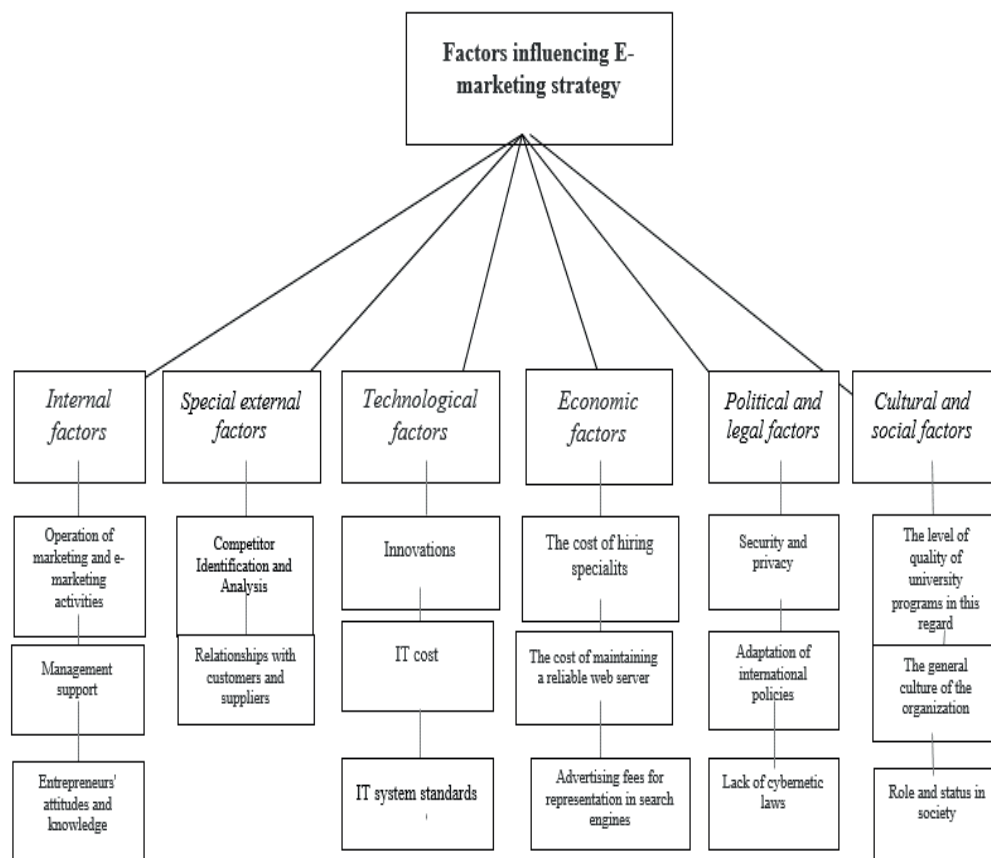


Figure 9. Hierarchical structure of research according to AHP method. Source: Author.

Table 11 summarized the overall results in percentages for all influential E-marketing strategy factors and sub-factors. The overall ratio (CR-consistency ratio) is: $CR = 1.3\% < 10.0$. The consistency ratio is less than 10%, so the matrix is consistent and can be continued with the decision-making process. The consensus within the group is 71.5%, for values below 50%, it is said that there is no consensus within the group of participants and there is a high variety of judgments. However, in our case,

there is a moderate consensus between the participating groups and there is no high variety of judgments.

Decision Hierarchy			
Objectives	Criteria	Sub-criteria	Glb Prio.(The weight of importance)
Factors influencing e-marketing strategy	Internal factors 0.269	Operation of marketing activities and e-marketing 0.253	6.8%
		Management support 0.363	9.8%
		Relationships with customers and suppliers 0.384	10.3%
	Special external factors 0.158	Competitor Identification and Analysis 0.488	7.7%
		Relationships with customers and suppliers 0.512	8.1%
	Technological factors 0.192	Innovations 0.387	7.4%
		IT cost 0.406	7.8%
		IT system standards 0.207	4.0%
	Economic factors 0.150	The cost of hiring specialists 0.312	4.7%
		The cost of maintaining a reliable web server 0.325	4.9%
		Advertising fees for representation in search engines 0.362	5.4%
	Political and legal factors 0.125	Security and privacy 0.365	4.6%
		Adaptation of international policies 0.376	4.7%
		Lack of cyber laws 0.259	3.2%
	Cultural and social factors 0.106	The level of quality of university programs in this regard 0.383	4.1%
		The general culture of the organization 0.370	3.9%
		Role and status in society 0.247	2.6%
			1.0

Table 11. Consolidated Priorities Hierarchy. Source: Author.

In the second column of the table above, the results are presented in percentages for the criteria (internal factors, special environmental factors, technological factors, economic factors, political and legal factors, and cultural and social factors). Also, in the third column, are the percentage results for the sub-criteria (internal sub-factors, special environmental sub-factors, technological sub-factors, economic sub-factors, political and legal sub-factors, and cultural and social sub-factors). Whereas, in the fourth column are presented the consolidated results according to the weight of importance of the factors that influence the e-marketing strategy, in the tourism industry in Kosovo and Albania. As shown, the attitudes and knowledge of entrepreneurs have a higher weight of significance 10.30%, management support 9.80%, customer and supplier correlation 8.10%, IT cost 7.80, competitor

identification and analysis 7.70%, and innovation 7.40%. The other set of factors has a lower weight in correlation to the factors mentioned above.

5. Conclusion

Based on the literature review it can be concluded that the scientific theories that need to be analyzed to determine the adaptation of IT and the factors influencing the E-marketing strategy are: Reasoning Action Theory (TRA), Planned Behavior Theory (TPB), Innovation Dissemination Theory (IDT), Technological, Organizational and Environmental Framework (TTOM) Theory, Technology Acceptance Model (TAM), Common Technology Acceptance and Use Theory (UTAUT) and Contingency Theory. The TRA and TPB should be studied in cases where consumer behavior is analyzed because it provides clarification on how consumers act online and offline. IDT makes a contribution when it is intended to know the reactions of individuals to an innovation, ie to understand how this idea is perceived. This theory consists of a process by which an innovation is communicated through certain channels between members of a society over time. It is considered one of the theories through which the factors that influence individuals to adopt an innovative technology can be identified. Also, through the TOE structure, the three most important aspects that influence an enterprise to implement technology are identified. Decision making for technological innovation is done by analyzing the environmental context (industry characteristics and organizational structure, technological infrastructure support, government rules), organizational context (formal and informal structure, communication process, and size) and the technological context (technology availability and its features). Also, to clarify the reasons why technology is used and accepted by users, as well as by consumers, the TAM and UTAUT theory is used. We have considered the theory of contingency as the basic theory of this paper because according to this theory, the definition of strategy depends on environmental variables, organizational factors, and strategic response. This theory includes three types of variables, such as unforeseen variables, performance variables, and response variables, which are considered quite important in formulating the strategy of an enterprise. In the theoretical aspect, the factors that influence e-marketing strategy are: clear e-marketing policies, cost, resources, cultural orientation towards marketing, infrastructure, competition, owner characteristics, level of education, age, general technological knowledge, enterprise size, management style, organizational structure, application of technology, IT characteristics, marketing department, customer satisfaction, etc.

In the study of E-marketing strategy and E-strategy process in the tourism industry, it was used the sample of 36 experts, who are experts of the tourism industry in Kosovo and Albania, individuals who have university qualifications and work in the positions of marketing managers and sales at hotel enterprises, travel agencies, tour operators and airlines. Based on the results of the third phase, it can be concluded that the internal factors are the most important factors of the six criteria. Among the internal factors (attitudes and knowledge of entrepreneurs), special environmental factors (relationships with customers and suppliers), technological factors (innovations and cost of IT), economic factors (advertising fees for representation in

search engines), political and legal factors (adaptation of international policies), cultural and social factors (the general culture of the organization), are the most influential factors in the E-marketing strategy according to the AHP method analysis. Whereas of all the factors and sub-factors, according to the importance, attitudes, and knowledge of entrepreneurs, management support, customer relations, and suppliers, IT cost, competitor identification, competitor analysis, and innovation have the highest influence.

Recommendations

Based on the contingency theory, and also in the TEO framework, the model in Figure 10 has been proposed. It is recommended to be analyzed by tourism industry sectors, as it can help in defining proper E-marketing strategy. The factors presented in this model are determined based on the findings of this research.

From the proposed model the following recommendations have been derived:

- Every entrepreneur should be knowledgeable of the benefits offered by E-marketing and have a positive attitude since the role of e-marketing on the tourism industry is pivotal. Businesses that have shifted from traditional marketing to online forms have had better success compared to businesses that have not followed this trend.
- It is recommended that senior management should support marketing activities by allocating sufficient budget for these activities and not to consider unnecessary expenses. It is not given enough importance to marketing in Kosovo and Albania, particularly, E-marketing.
- In cases of the lack of E-marketing specialized staff, it is necessary to hire or collaborate with specialized/professional E-marketing agencies.
- To be on track with the trends of technological development concerning developed countries, because only in this way they keep up with the competition. The cost of technology should not be a hindrance to businesses, because it results in high profits.
- Train staff in the area of E-marketing because human resources are a strong pillar for an institution.
- The importance of consumers to the marketing concept lies at the forefront, so more advanced services should be offered, especially in the tourism industry where the tourist travels to the country he or she wants to see and there is no possibility of going to the destination in advance. Based on this, everyone makes a decision based on recent online information.
- Establish continuous contacts with customers. It is recommended for all businesses to create online ways where customers can express their satisfaction and dissatisfaction because only in this way they can make continuous improvement in all the services they offer. Work more on security and privacy issues, because in Kosovo, as well as in Albania, many businesses and clients fear that their data may be misused and used for other purposes.

- Review the policies and laws of developed countries regarding consumer rights to let them know that there is a well-controlled system in these countries in order to make use of the goods and services offered online.
- For public and private universities to work towards quality in the field of E-marketing, offering more professional programs in this field, as it is a segment that needs to be emphasized. Specialists should be in the right positions, as it turns out that non-specialized staff is employed in the e-marketing position. This was proved by the fact that it was difficult to find experts in this field.
- Researchers should focus more on the role of technology and, especially E-marketing, in the field of tourism.

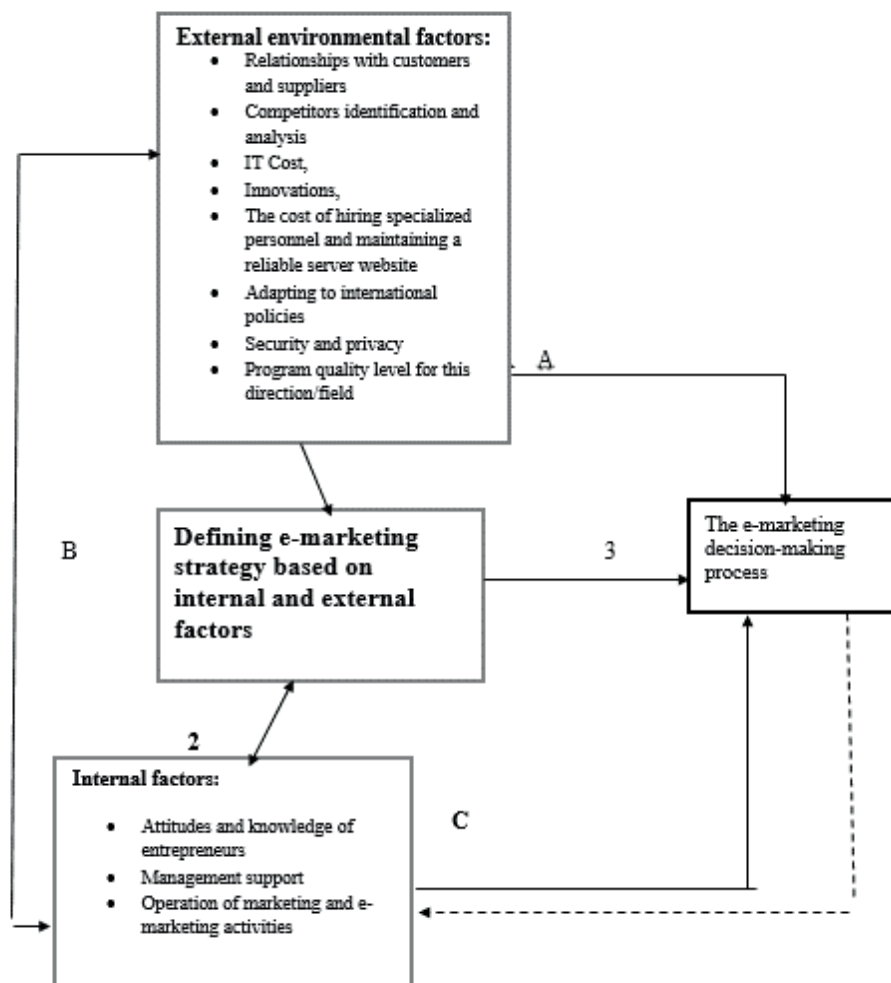


Figure 10. The model recommended by the author on contingent factors based on contingency theory. Source: Author, based on [38].

References

- [1] P. J. Benckendorff, Z. Xiang, and P. Sheldon, *Tourism Information Tecnology*, Third. Boston, Massachusetts, CABI, 2019.
- [2] I. Ilić and A. Nikolić, "Implications of modern technology development for the tourism sector of the Republic of Serbia," *Ekonomika*, vol. 64, no. 1, pp. 37–52, 2018, doi: 10.5937/ekonomika1801037i.
- [3] N. Shabani, A. Munir, and A. Hassan, "E-Marketing via Augmented Reality: A Case Study in the Tourism and Hospitality Industry," *IEEE Potentials*, vol. 38, no. 1, pp. 43–47, 2019, doi: 10.1109/MPOT.2018.2850598.
- [4] K. D. Goepel, "Implementing the Analytic Hierarchy Process as a Standard Method for Multi-Criteria Decision Making in Corporate Enterprises – a New AHP Excel Template with Multiple Inputs," pp. 1–10, 2013, doi: 10.13033/isahp.y2013.047.
- [5] T. L. Saaty and L. G. Vargas, *Models, Methods, Concepts Sc Applications of the Analytic Hierarchy Process*. 2000.
- [6] M. I. Dahnil, K. M. Marzuki, J. Langgat, and N. F. Fabeil, "Factors Influencing SMEs Adoption of Social Media Marketing," *Procedia - Soc. Behav. Sci.*, vol. 148, pp. 119–126, 2014, doi: 10.1016/j.sbspro.2014.07.025.
- [7] H. El-Gohary, "Factors affecting E-Marketing adoption and implementation in tourism firms: An empirical investigation of Egyptian small tourism organisations," *Tour. Manag.*, vol. 33, no. 5, pp. 1256–1269, 2012, doi: 10.1016/j.tourman.2011.10.013.
- [8] T. Iqbal and E. El-Gohary, "An attempt to understand E-Marketing : An information technology prospective department of business administration," *Int. J. Bus. Soc. Sci.*, vol. 5, no. 4, pp. 234–256, 2014.
- [9] B. Khalil Moghaddam and A. Khatoon-Abadi, "Factors affecting ICT adoption among rural users: A case study of ICT Center in Iran," *Telecomm. Policy*, vol. 37, no. 11, pp. 1083–1094, 2013, doi: 10.1016/j.telpol.2013.02.005.
- [10] R. Rahayua and John Daya, "Determinant Factors of E-commerce Adoption by SMEs in Developing Country: Evidence from Indonesia," *Procedia - Soc. Behav. Sci.*, vol. 195, pp. 142–150, 2015.
- [11] N. Delafrooz and A. Khatibi, "Developing an Instrument for Measurement of Attitude Toward Online Shopping," *Eur. J. Soc. Sci.*, vol. 7, no. 3, pp. 166–177, 2009, doi: 10.1007/s00418-007-0354-y.
- [12] P. A. L. C. Pavlou, "WHAT DRIVES ELECTRONIC COMMERCE ACROSS CULTURES? A CROSS-CULTURAL EMPIRICAL

- INVESTIGATION OF THE THEORY OF PLANNED BEHAVIOR,” *J. Electron. Commer. Res.*, vol. 3, no. 4, pp. 1–14, 2002, doi: 10.1016/B978-1-78242-103-0.00001-1.
- [13] E. Yoh, M. L. Damhorst, S. Sapp, and R. Lacznia, “Consumer Adoption of the Internet: The Case of Apparel Shopping,” *Psychol. Mark.*, vol. 20, no. 12, pp. 1095–1118, 2003, doi: 10.1002/mar.10110.
- [14] I. Ajzen, “The Theory of Planned Behavior,” *Organ. Behav. Hum. Decis. Process.*, vol. 50, no. 2, pp. 179–211, 1991, doi: 10.15288/jsad.2011.72.322.
- [15] K. Mathieson, “Comparing The Technology Acceptance Model with The Theory of Planned Behaviour,” *Inf. Syst. Res.*, vol. 2, 3, no. 3, pp. 173–191, 1991.
- [16] J. F. George, “The theory of planned behavior and Internet purchasing,” *Internet Res.*, vol. 14, no. 3, pp. 198–212, 2004, doi: 10.1108/10662240410542634.
- [17] E. M. Rogers and M. Everett, *DIFFUSION OF INNOVATIONS*, Third. Communication of Innovations: A Cross-Cultural Approach., 1991.
- [18] J. Baker, “The Technology–Organization–Environment Framework,” *Inf. Syst. theory, Springer*, pp. 231–245, 2012, doi: 10.1007/978-1-4419-6108-2.
- [19] T. Oliveira *et al.*, “Literature Review of Information Technology Adoption Models at Firm Level,” *Rev. Adm.*, vol. 45, no. 1, pp. 110–121, 2010, doi: 10.1017/CBO9781107415324.004.
- [20] Y. Alshamaila, S. Papagiannidis, and F. Li, “Cloud computing adoption by SMEs in the north east of England: A multi-perspective framework,” *J. Enterp. Inf. Manag.*, vol. 26, no. 3, pp. 250–275, 2013, doi: 10.1108/17410391311325225.
- [21] L. Oshlyansky, P. Cairns, and H. Thimbleby, “Validating the Unified Theory of Acceptance and Use of Technology (UTAUT) tool cross-culturally,” *Proc. 21st Br. HCI Gr. Annu. Conf. People Comput. HCI... but not as we know it*, vol. 2, pp. 83–86, 2007, doi: 10.1515/zntw.1907.8.1.1.
- [22] R. Eid and M. Trueman, “Factors affecting the success of business-to-business international Internet marketing (B-to-B IIM): An empirical study of UK companies,” *Ind. Manag. Data Syst.*, vol. 104, no. 1–2, pp. 16–30, 2004, doi: 10.1108/02635570410514061.
- [23] A. Omar, T. Ramayah, L. B. Lin, O. Mohamad, and M. Marimuthu, “Determining Factors for the Usage of Web-Based Marketing Applications by Small and Medium Enterprises (SMEs) in Malaysia,” *J. Mark. Dev. Compet.*, vol. 5, no. 2, pp. 70–86, 2011, doi: 10.1111/j.1468-3083.2005.01297.x.

- [24] K. Nusair, M. Erdem, F. Okumus, and A. Bilgihan, "Users' Attitudes Toward Online Social Networks in Travel," in *Social Media in Travel, TouriSM and HoSpiTaliTy: Theory, Practice and Cases*, M. Sigala, E. Christou, and U. Gretzel, Eds. 2012, pp. 207–221.
- [25] H. El-Gohary, "E-Marketing - A Literature Review From A Small Businesses Perspective," *Int. J. Bus. Soc. Sci.*, vol. 1, no. 1, p. n/a, 2010, [Online]. Available: http://dq4wu5nl3d.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info:ofi/enc:UTF-8&rft_id=info:sid/ProQ:abiglobal&rft_val_fmt=info:ofi/fmt:kev:mtx:journal&rft.genre=unknown&rft.jtitle=International+Journal+of+Business+and+Social+Science&rft.a.
- [26] H. Celik, "Customer online shopping anxiety within the Unified Theory of Acceptance and Use Technology (UTAUT) framework," *Asia Pacific J. Mark. Logist.*, vol. 28, no. 2, 2016, doi: 10.1108/APJML-05-2015-0077.
- [27] E. Abu-Shanab and S. Haider, "Major factors influencing the adoption of m-government in Jordan," *Electron. Gov.*, vol. 11, no. 4, pp. 223–240, 2015, doi: 10.1504/EG.2015.071394.
- [28] K. I. Al-Qeisi, "Analyzing the Use of UTAUT Model in Explaining an Online Behaviour: Internet Banking Adoption A," 2009.
- [29] E. Tarcan and E. S. Varol, "Role of the demographic factors in the process of hotel information systems adoption," *Turiz. međunarodni Znan. časopis*, vol. 58, no. 2, pp. 127–144, 2010.
- [30] I. S. Pantelidis, "Technology acceptance of hotel web sites," in *Pantelidis, Ioannis S Technology acceptance of hotel websites 2006*, 2006.
- [31] A. Giovanis, C. Assimakopoulos, and C. Sarmaniotis, "Adoption of mobile self-service retail banking technologies: The role of technology, social, channel and personal factors," *Int. J. Retail Distrib. Manag.*, 2018, doi: 10.1108/IJRDM-05-2018-0089.
- [32] N. Dlodlo and M. Dhurup, "Drivers of E-Marketing Adoption among Small and Medium Enterprises (SMEs) and Variations with Age of Business Owners," *Mediterr. J. Soc. Sci.*, vol. 4, no. 14, pp. 53–66, 2013, doi: 10.5901/mjss.2013.v4n14p53.
- [33] V. Venkatesh, J. Y. L. Thong, and X. Xu, "CONSUMER ACCEPTANCE AND USE OF INFORMATION TECHNOLOGY: EXTENDING THE UNIFIED THEORY OF ACCEPTANCE AND USE OF TECHNOLOGY," *MIS Q.*, vol. 36, no. 1, pp. 157–178, 2012, doi: 10.1042/bst0120672.
- [34] K. S. Tan, S. C. Chong, and B. Lin, "Intention to use internet marketing: A comparative study between Malaysians and South Koreans," *Kybernetes*,

- vol. 42, no. 6, pp. 888–905, 2013, doi: 10.1108/K-12-2012-0122.
- [35] V. Venkatesh, M. G. Morris, G. B. Davis, and F. D. Davis, “User Acceptance of Information Technology: Toward a Unified View,” *MIS Q.*, vol. 27, no. 3, pp. 425–478, 2003, doi: 10.1016/j.inoche.2016.03.015.
- [36] Y. S. Wang and Y. W. Shih, “Why do people use information kiosks? A validation of the Unified Theory of Acceptance and Use of Technology,” *Government Information Quarterly*, vol. 26, no. 1, pp. 158–165, 2009, doi: 10.1016/j.giq.2008.07.001.
- [37] H. San Martín and Á. Herrero, “Influence of the user’s psychological factors on the online purchase intention in rural tourism: Integrating innovativeness to the UTAUT framework,” *Tour. Manag.*, vol. 33, no. 2, pp. 341–350, 2012, doi: 10.1016/j.tourman.2011.04.003.
- [38] J. Reinking, “Contingency Theory in Information Systems Research,” in *Information Systems Theory*, Springer, Y. K. Dwivedi, M. R. Wade, and S. L. Schneberger, Eds. 2012, pp. 247–263.
- [39] A. Ginsberg and N. Venkatraman, “Contingency Perspectives of Organizational Strategy: A Critical Review of the Empirical Research,” *Acad. Manag. Rev.*, vol. 10, no. 3, pp. 421–434, 1985, doi: 10.5465/amr.1985.4278950.
- [40] C. J. Tarter and W. K. Hoy, “of Decision Making,” no. 1998, 2005.
- [41] L. F. Lages and S. D. Jap, “A CONTINGENCY APPROACH TO MARKETING MIX ADAPTATION AND PERFORMANCE IN INTERNATIONAL MARKETING RELATIONSHIPS,” pp. 1–46, 2002.
- [42] W. Schertler and D. Buhalis, *Information and communication technologies in tourism 1999 : proceedings of the international conference in Innsbruck, Austria, 1999*. 1999.
- [43] M. Hasan, M. Jabiullah, I. Ahamed, and N. Chakma, “Prospects of E-Tourism Ecosystem in Bangladesh: Services and Infrastructure,” *DIU J. Sci. Technol.*, vol. 10, no. 1, pp. 10–20, 2016.
- [44] S. S. Mousavi, “Effective Elements on E-Marketing strategy in Tourism Industry (Case study Germany and Iran Airlines, Tour Operator and Chain Hotels),” University Trier Faculty VI, 2012.
- [45] N. Levenburg, S. Magal, and P. Kosalge, “An Exploratory Investigation of Organizational Factors and e-Business Motivations Among SMFOEs in the US,” *Electron. Mark.*, vol. 16, no. 1, pp. 70–84, 2006, doi: 10.1080/10196780500491402.
- [46] F. Rahimnia and J. F. Hassanzadeh, “The impact of website content dimension and e-trust on e-marketing effectiveness: The case of Iranian commercial saffron corporations,” *Inf. Manag.*, vol. 50, no. 5, pp. 240–247,

2013, doi: 10.1016/j.im.2013.04.003.

- [47] K. J. Trainor, A. Rapp, L. S. Beitelspacher, and N. Schillewaert, "Integrating information technology and marketing: An examination of the drivers and outcomes of e-Marketing capability," *Ind. Mark. Manag.*, vol. 40, no. 1, pp. 162–174, 2011, doi: 10.1016/j.indmarman.2010.05.001.
- [48] B. Achieng, "How SMEs are using Online Marketing to Improve their Competitiveness in Kenya: A Case Study of Tembea East Africa Safaris," *United States Int. Univ. - Africa*, no. Fall, 2016, [Online]. Available: http://erepo.usiu.ac.ke/bitstream/handle/11732/3093/BILHA_ACHIENG_2016.pdf?sequence=1&isAllowed=y.
- [49] D. Buhalis and H. Main, "Information technology in peripheral small and medium hospitality enterprises: Strategic analysis and critical factors," *Int. J. Contemp. Hosp. Manag.*, vol. 10, no. 5, pp. 198–202, 1998, doi: 10.1108/09596119810227811.
- [50] R. Law, D. Buhalis, and C. Cobanoglu, "Progress on information and communication technologies in hospitality and tourism," *Int. J. Contemp. Hosp. Manag.*, vol. 26, no. 5, pp. 727–750, 2014, doi: 10.1108/IJCHM-08-2013-0367.
- [51] E. Ramsey and P. McCole, "E-business in professional SMEs: The case of New Zealand," *J. Small Bus. Enterp. Dev.*, vol. 12, no. 4, pp. 528–544, 2005, doi: 10.1108/14626000510628207.
- [52] S. Hays, S. J. Page, and D. Buhalis, "Social media as a destination marketing tool: Its use by national tourism organisations," *Curr. Issues Tour.*, vol. 16, no. 3, pp. 211–239, 2013, doi: 10.1080/13683500.2012.662215.
- [53] E. Constantinides, "Social Media / Web 2.0 as Marketing Parameter: An Introduction," *Media*, no. March, pp. 0–25, 2017.
- [54] M. Sigala, "Developing and Benchmarking Internet Marketing Strategies in the Hotel Sector in Greece," *J. Hosp. Tour. Res.*, vol. 27, no. 4, pp. 375–401, 2003, doi: 10.1177/10963480030274001.
- [55] S. B. Green and N. Salkind, *Using SPSS for Windows and Macintosh ANALYZING AND UNDERSTANDING DATA*, Seventh., vol. 66. Pearson Education, Inc., 1 Lake St., Upper Saddle River, NJ 07458., 2014.



UDC 004.93'1:81'37=111=411.21

Original Scientific Paper

New Synonyms Extraction Model Based on a Novel Terms Weighting Scheme

Ahmad Hussein Ababneh*ahmad.ababneh@aum.edu.jo**Computer Science Department**American University of Madaba, Madaba, Jordan***Joan Lu***J.Lu@hud.ac.uk**School of Computing and Engineering**University of Huddersfield, Huddersfield, UK***Qiang Xu***Q.Xu2@hud.ac.uk**School of Computing and Engineering**University of Huddersfield, Huddersfield, UK*

Abstract

The traditional statistical approach in synonyms extraction is time-consuming. It is necessary to develop a new model to improve the efficiency and accuracy. This research presents a new model in synonyms extraction called Noun Based Distinctive Verbs (NBDV). During the documents' numerical representation phase, the NBDV replaces the traditional tf-idf weighting scheme with a novel weighting scheme called the Orbit Weighing Scheme (OWS). The OWS links the nouns to their semantic space by examining the singular verbs in each context. The weight of the term is determined by considering the three parameters: Verb_Noun Frequency, Verb_Noun Distribution, and Verb_Noun Distance. The Verb_Noun Distribution parameter is mathematically formulated to depict the semantic relation between the noun and a certain set of verbs that only appear in the context of this noun. We compared the new models with important models in the field, such as the Skip-Gram, the Continuous Bag of Words, and the GloVe model. The NBDV model was tested on both Arabic and English languages, and the results showed 47% recall and 51% precision in the dictionary-based evaluation and 57.5% precision in the human experts' evaluation. Comparing with the synonyms extraction based on tf.idf, the NBDV obtained 11% higher recall and 10% higher precision. Regarding the efficiency, we found that on average, the synonyms extraction of a single noun requires the process of 186 verbs, and in 63% of the runs; the number of singular verbs was less than 200. It is concluded that the developed method is efficient and processes the single run in linear time.

Keywords: Automatic Synonyms Extraction, Cosine Similarity, Orbit Weighting Scheme, Semantic Context Analysis, Vector Space-based Extraction.

1. Introduction

The languages are rich in synonyms or semantically related words. This merit gives the writer the ability to describe the same entity using different words and yields interesting and more vivid text [1]. However, the existence of synonyms confuses the text mining systems that employ the exact matching approaches such as the Boolean models or the statistical models [2]. Therefore, in the text mining fields, it is necessary to develop Automatic Synonyms Extraction (ASE) systems to identify the synonyms for the text mining applications.

In many Natural Language Processing (NLP) and Information Retrieval (IR) publications, the semantic investigation of the text contents was improved by hiring a semantic dictionary (such as the synonyms dictionary) in the investigation process [3], [4], [5]. The semantic dictionaries, with what they contain of synonyms, are valuable tools. These tools improve the precision and the recall of the NLP and IR applications, for example, in the field of text categorization, Barak et al. in [3] used the synonyms investigation to increase the recall from 71% to 92%, and in the field of Information retrieval, Dinh and Lynda [4] showed that the synonyms investigation participated in increasing the Main Average Precision (MAP) by 5.61%. Also, The ASE supports the term weight which is necessary to determine the importance of the word in a particular context [5]

1.1. OWS Importance

Recently, important publications in the field of ASE used the statistical approach and gained significant precision [6], [7], and [8], but they did not consider the efficiency and the time required for their systems tends to be long. For example, Leeuwenberga et al. in [7] used a bag of word model called relative cosine similarity to extract the term synonyms. In their work, the construction of the terms-terms weighted matrix is expensive in terms of space and time, and the repetitive computations add more delay. Minkov and Cohen [6] used a path constrained graph, and the problem with this graph is the high time required to construct the graph and the space needed to store the graph. The graph stores each term in the corpus with all existing edges that link this term to the other terms found in the corpus, add to this the time needed to follow all the paths that lead to the terms. Henriksson et al. [9] manipulated two efficient distributional hypothesis models over two large corpora to investigate more semantic relations between the terms, but even that the recall was reasonable (47%), it was obtained in a very low precision (8%). In this case, the low precision means that the size of the answer set was large, and only 8% of the answer was correct. Henriksson et al. used the random permutation and random indexing to construct the required semantic spaces, and those two techniques do not have the accuracy of more advanced statistical techniques such as the Latent Semantic Analysis (LSA). The LSA comes under the Global Matrix Factorization methods [10]; it maps the terms-documents space to a terms-concepts space or a concepts-documents space. The time complexity of the LSA is high because the LSA captures the meaning of the term by creating a sophisticated network in different contexts and huge datasets [11].

In the literature of synonyms extraction, the Pointwise Mutual Information (PMI) mathematical model is used to measure the association between two terms [12, 13, 14, 15]. The PMI of x and y considers the number of times x and y occurred together, $f(x, y)$, and the frequency of x , $f(x)$, and the frequency of y , $f(y)$. The PMI is computed using the following equation:

$$PMI(x, y) = \log_2 \frac{f(x, y)}{f(x) * f(y)}$$

Where $f(x, y)$, $f(x)$, and $f(y)$ are normalized by the number of terms (N) in the whole corpus.

$$PMI(x, y) = \log_2 \frac{\frac{f(x, y)}{N}}{\frac{f(x)}{N} \frac{f(y)}{N}}$$

$$PMI(x, y) = \log_2 \frac{f(x, y) * N}{f(x) * f(y)}$$

The PMI does not demand the adjacency of x and y , and the researchers used the PMI with different window sizes, for example, Inkpen in [15] used a content window of size 2, whereas, Yu et al. in [14, 16] used a content window of size 4.

The PMI is a normalized frequency, which inflates for the low frequency of $f(x, y)$. And, the PMI does not consider the semantic association between x and y . In addition, with the plain definition of the PMI, how the PMI distinguishes between the verbs, nouns, or any other parts of speech, and how the PMI finds the relation between the different parts of speech that establish the semantic context of the text. All the standard techniques (such as the PMI and Chi-square [17]) that examine the co-occurrences of the terms see the terms as random variables without any semantic meaning. Therefore, measuring the co-occurrence of two terms is not sufficient to find a true relationship between two terms and to distribute the terms over their semantic contexts.

To solve the problem of the PMI and the similar techniques, and to link the terms to their context, the researchers adapted the Vector Space Model (VSM) to be applicable for the synonyms extraction. For example, the VSM model was used to build two synonyms extraction models, the skip-gram (SG) model and the Continuous Bag-of-Words (CBOW) model [18]. Besides considering the frequency of the examined terms, the VSM measures the distribution of the terms over the text segments by using the inverse term frequency in the tf.idf weighting scheme. However, the traditional VSM model in synonyms extraction is time-consuming, especially in real applications such as query expansions and text mining [6], [11], [19]. In traditional tf.idf models, a vector of weights is created for each term in the text. This vector consists of the weights of every term in the corpus with respect to the term being processed, which yields several weighting processing steps equals the square number of the terms. Mikolov et al. in [18] proposed hierarchical softmax and negative sampling approaches to prevent quadratic time.

Pennington et al. in [20] combined the matrix factorization methods with the shallow window-based methods to produce the pioneering GloVe model. The GloVe model produces global vectors for the corpus terms, and through these vectors, the similarities between the terms can be determined. This model can be used in the field of synonyms extraction because it can give accurate similarity between two words, as the authors showed in table 2 in [20]. In Addition, the GloVe model is considered efficient because it processes only the non-zero elements in the co-occurrence matrix. However, the basic assumption of the GloVe model requires the process of the term i with respect to every term that occurs in the context of i . To avoid $O(|V|^2)$ time complexity, where V is the number of vocabularies, Pennington et al. placed a tight bound on the number of nonzero elements in the co-occurrence matrix.

Excluding the stopwords, the vector space models equalize the importance of the verbs, adjectives, and nouns in determining the weights of a specific term and in exploring the relationship between two terms. From our point of view, this is not accurate and may disperse the extraction process. For example, it is hard to find a set of adjectives that are associated with a specific set of nouns, and the vast majority of the adjectives appear with objects that belong to different semantic contexts, whereas, we can find a set of verbs that normally appears in a specific semantic context, think about the verb “*park*” for the context that talks about the vehicles, and the verb “*bark*” that directly link the picture toward certain kind of animals (dogs or wolves). The design of the OWS weighting scheme addresses this critical issue. The OWS is based on the claim that processing the verbs increases the efficiency because it neglects the processing of the other parts of speech, and increases the precision because it will not process the text’s parts that disperse the extraction process.

The use of verbs as a semantic relation investigator between two concepts was used by Imsombut in [17], Imsombut experienced the semantic relations extraction for the Thai language. Imsombut used the standard definition of the tf.idf to find the weights of the verbs in which, the tf is the frequency of the verb v in the collection, and the idf is the distribution of the verb v over the text segments. The standard definition of tf.idf does not correlate the verbs with the nouns (or concepts); it correlates the verbs with their statistical context. We found two problems of the tf.idf used in [17], (1) the processing of all the verbs found in the corpus, and as we know that some verbs are general verbs and can be used with a verity of objects and subjects in different domains (think about the verbs buy, walk,...), and (2) the inverse verb frequency did not consider the concept (the number of concepts appeared with the verb v); it considered the document or the text segment (the number of documents the verb v appeared in).

1.2. Research Aims and Contributions

This research aims to enhance the weighting scheme in a way that processes the meaningful units and correlates the verbs with the nouns in semantic and robust relations. The paper contributions are summarized in the following points:

- Orbit Weighting Scheme: the paper discusses the efficiency and accuracy enhancement of the synonyms extraction through the amendment of the

traditional weighting schemes in the VSM-based text extraction. The enhanced weighing scheme or the Orbit Weighting scheme represents a developed version of the traditional tf-idf that remedies the time penalty of weighing the contents of text and investigates the semantic context of the verbs and nouns. The OWS computes the term weight based on the semantic investigation that uses clear parameters and robust procedure.

- Semantic Context Investigation: the OWS links a group of nouns or semantically related nouns with a set of verbs that are only used with these nouns. This linking transfers the extraction of the noun synonyms from the traditional statistical context (tf.idf model) to the semantic context space. The nouns' co-occurrences are represented by semantic relations instead of simply counting their occurrences.
- Efficiency and precision improvement: the use of the OWS will reduce the number of processed terms in every single run of the synonyms extraction, which will participate in enhancing the efficiency (see Table 7, and Figure 15, 16). And, the semantic investigation of the text contents will participate in increasing the precision and provide more accurate synonyms (see Figure 9, 10, 11, 12 and Table 4, 5, 6).

The paper sections are organized as follows: Section 2 surveys the research in the field of statistical synonyms extraction. Section 3 describes the NBDV method of extraction with the weighting schemes and the similarity model. Section 4 depicts the experimental environment and presents the results. Section 5 evaluates the relevancy and efficiency of the NBDV results, and section 6 discusses the factors that affected the extraction process and mentions the advantages and disadvantages of the NBDV method. Finally, section 7 draws the conclusions and future work.

2. Related Work

2.1. Synonyms Sets Appearance and their Influence

The idea of constructing a lexical database came from a group of psychologists and linguists who aimed to find an informative way to search the English dictionary [21]. They manually collected the synonyms and stored them in a lexical database. The produced databases grouped words based on their meanings (the synonym relation), and the grouped words are called synsets. The synsets linked together via super-subordinate relation in which the general objects that belong to a certain synset were linked to a more specific object that belongs to another synset. Also, the relation was transitive and allowed the link of the general synsets with the parts of the specific synsets [22].

Researchers in Computational linguistics are interested in investigating the synonyms of the words, and they arranged them in a special kind of dictionaries called WordNets [23]. The WordNet is an extensive database that stores the words together with their synonyms. It is a concepts dictionary that groups words based on their meanings to produce the synsets. The first appearance of the WordNets was at

Princeton University, and it was performed manually for the English language [21]. According to Miller et al., the WordNet aimed to facilitate the searching in the dictionary and to substitute the regular word searching (which is typically done by the alphabetical ordering of words) by the concepts searching.

The EuroWordNet was developed for eight European languages [24]. EuroWordNet employed the same model used to construct the Princeton WordNet and added two new contributions, the hiring of the Base Concept, and the addition of new relations with a precise way to clarify the relations among the synsets [24]. AWN is the WordNet that was developed for the Arabic Language [25]. Elkateb in [25] benefited from the model used in Princeton WordNet and EuroWordNet, but they faced a real challenge related to the morphological structure of the Arabic Language. To solve this challenge, Elkateb combined the Interlingual Index used in EuroWordNet with a suggested upper merged ontology [25].

In many NLP publications, the semantic investigation of the text contents was improved by hiring a semantic dictionary such as the synonyms dictionary [26], [27], [28], and [29]. The term weight of a given term was computed based on its parameters (for example, term frequency and inverse term frequency) and the parameters that can be obtained from its synonyms. In the field of text classification, Scott and Matwin in [26] used the WordNet and computed the weight of a term by dividing the number of occurrences of the term's synset (taken from WordNet) in the document over the document length. Bloehdorn and Hotho in [27] used WordNet to generalize the terms to their concepts and employ them in the classification process instead of individual terms. Bloehdorn et al. in [30] mapped the terms to their super concept using the WordNet. Another semantic text repository used to improve the semantic text classification was Wikipedia [31] and the Open Direct Project [32].

Text Categorization is another field of text mining that utilized the WordNet semantic dictionary, in [28] the authors used WordNet to build training data and in [3] the authors supplemented the Latent Semantic Analysis with the concepts that were extracted from the WordNet. In [29] Luo et al. proposed a weighting scheme that considers the semantic similarity value between the term and the interpretations of the name of the category, and the interpretations are taken from the WordNet. The major benefit they gained was the smaller training data required to distribute the uncategorized documents over their categories.

In the field of Information retrieval (IR), the semantic investigations of the term synonyms and the generalization of the terms to concepts during the weighting and indexing process were addressed by many researchers [4]. Dinh and Tamine used the semantic meaning to solve the ambiguities that are generated from the regular tf.idf weighting. They mapped the terms to specific concepts taken from MeSH (semantic dictionary for medical data) and then correlated the concept to the correct domain. In this case, the IR system can capture the correct meaning of the term because it knows the concept underlying the term and to which domain the term belongs. Dinh and Tamine built an IR system to implement their idea, and they gained a noticeable improvement in the relevancy of their system comparing with two tf-idf IR systems. However, Dinh and Tamine used specific domain knowledge (biomedical documents),

which enabled them to reduce the problem space (a small number of concepts and a small number of domains).

2.2. Synonyms Extraction Techniques

In the literature of the ASE, three main extraction techniques can be derived from the published research:

- The statistical techniques over monolingual corpora, such as the Point Mutual Information [14], the Vector Space Model with cosine similarity or relative cosine similarity [7], [33], [34], [35], and [36].
- The translation techniques among different languages over the bilingual or multilingual dictionaries (the words that share the same interpretations are synonyms) [37], [38], and [39].
- The linguistic analysis techniques that syntactically and semantically parse the corpus or the dictionary to extract synonyms [6], [9], [8], [40], and [41].

In general, the VSM based models in text mining and information retrieval process the whole corpus and make detailed computations for every term [19]. These computations include the weighting of the terms which requires two things: (1) Specifying the required parameters such as the term frequency (tf) and the inverse term frequency (idf). (2) Applying a weighting scheme such as the log frequency and the tf-idf weighting schemes. The best-known formula used in the information retrieval or text mining of the tf-idf scheme was the one proposed by Salton and McGill [42]:

$$w_{t,d} = (1 + \log f_{t,d})(\log \frac{N}{dft})$$

Where $w_{t,d}$ is the weight of the term t in text d , $f_{t,d}$ is the frequency of the term t in text d , dft is the number of text segments contains t , N is the number of text segments in the corpus, text segment could be document, query, paragraph, or sentence.

After specifying the weight for each term, the vector space model computes the similarity between the vectors. The vectors represent the weights of the terms in the text (if it was a text mining application) or the weights of the terms in the user query and in the set of documents (if it was an information retrieval application). The cosine similarity is computed by using the following equation [2]:

$$\begin{aligned} \text{sim}(\vec{v1}, \vec{v2}) &= \cos(\vec{v1}, \vec{v2}) = \frac{\vec{v1} \cdot \vec{v2}}{|\vec{v1}| \cdot |\vec{v2}|} \\ \text{sim}(\vec{v1}, \vec{v2}) &= \frac{\sum_{i=1}^t wv1_i \cdot wv2_i}{\sqrt{\sum_{i=1}^{|\vec{v1}|} wv1_i^2} \cdot \sqrt{\sum_{i=1}^{|\vec{v2}|} wv2_i^2}} \end{aligned}$$

Where $\vec{v1}$ is the vector of text segment $v1$, $\vec{v2}$ is the vector of the text segment $v2$, $wv1_i$ is the weight of the term i in $v1$, $wv2_i$ is the weight of the term i in $v2$, t is the number of terms in the whole corpus.

The cosine similarity measures the angle between the vectors; if the angle is small (high cosine value), then the similarity is high which implies high resemblance between the two text segments (two documents, document and query, document and summary, two lists of synonyms).

Many research publications employed the VSM model in the synonyms extraction [7], [33], [34]. The tf-idf weighting scheme and the cosine similarity are adapted to reflect the terms to terms relations instead of the query to documents relations in the IR [7]. Analog to the VSM model in IR, the CBoW and SG model were developed in the field of synonyms extraction and hired the cosine similarity to find the similarity between specific term and all the terms found in the corpus [18].

Chen and Lynch [34] used the Vector Space Model to extract the synonyms by computing the cosine similarity between the terms found in a large corpus. They collected the nouns (called the descriptors) and computed the cosine similarity between all the descriptors that have a frequency greater than 3. Before Chen and Lynch, Crouch [33] built an automatic thesaurus dictionary to expand the user query in IR research. Crouch used the VSM and represented the terms as dimensions, and the documents were vectors in the term dimension space. The author built thesaurus classes by combining similar documents in one cluster. Then, Crouch extracted the terms that had low document frequencies from each cluster to form the thesaurus classes. The aim was not the synonyms by themselves, but to expand the user query terms by supporting terms found in a similar document.

Leeuwenberga et al. in [7] emphasized the idea that the simple cosine similarity hurt the precision because it combines synonyms, hypernyms, and hyponyms in the synonym set. Leeuwenberga et al. proposed to consider the top ten similar words and included them in the calculation of the similarity to obtain more accurate similarities. They divided the simple cosine similarity between w and w_q words by the summation of the cosine similarities of the top ten words similar to w . Leeuwenberga et al. obtained 12% precision value (for both English and German).

To solve the problem of computation penalty, Zhang and Wang [43] used the Word2Vec model based on CBoW and SG model to map the relations among the corpus terms, and they used the cosine similarity to find the similarity and spectral clustering to identify the synonyms. Henriksson et al. [9] developed a model for extracting synonyms in biomedical data, and they aimed to enhance the distributional hypothesis model that is deeply used to extract the related meaning words. Henriksson et al. enlarged the scale of the semantic relations among the terms by incorporating two distributional models (instead of one as usual in the distributional hypothesis) and two corpora instead of one large corpus. The aggregation of multiple models and corpora enabled the authors to create more semantic spaces which enriched the relations between the terms [9].

In [35], Lakshmi and Baskar presented two novel term weighting schemes TF-RTF and TF-RFST. The shared idea between the TF-RTF and TF-RFST was to combine the term frequency and the frequencies of the terms that share the same meaning. The set of semantically related words was determined by the Fuzzy C-Means clustering algorithm. Alsmadi and Hoon [36] proposed a new supervised term

weighting scheme (called SW) for weighting the terms that appear in short text messages.

Recently, to build an ontology for the Arabic Language, Benabdallah et al. depended on automatically extracted patterns (called them markers) to find the semantic relations between statistically selected terms [8]. AlMaayah et al. in [5] produced a synonym set for the terms of AL Quran AL Kareem (the holy book for Muslims). AlMaayah et al. produced the synsets by linking the Quran's terms with their meanings that were obtained from a traditional dictionary. The authors successfully improved the recall of the semantic search by 27% compared with a baseline system. Table 1 shows the list of references that use the statistical methods with their models and some accuracy results that were collected from their publication.

All the mentioned publications in this section either require heavy access to terms or relations database or require massive computational operations over all the terms found in a huge corpus. In this paper, the weighting and extracting of the terms and synonyms are not based on a store dictionary, and the extraction of the semantic relations between the nouns is accomplished by only considering the verbs. Also, not all the verbs will be processed. The verbs that have a large term frequency or appeared with a large number of nouns will be neglected.

3. NBDV Synonyms Extraction Method

The NBDV is developed in this investigation. It is a vector space-based synonyms extraction method that considers three aspects during the synonyms extraction process:

- Making the synonyms extraction completely statistical. This means that during all the phases of extraction, the NBDV does not use a database of stored synonyms, meanings, or patterns. The database approach is language-dependent, and it restricts the synonyms extraction process with the contents of the database without having the ability to gain more information from the huge text found on the internet. Also, it requires a huge effort and a lot of time, which may long for years, to build a database that contains all the nouns' synonyms.
- Processing the nouns as meaningful units, not as a bag of words (as in the CBoW and SG models) and capturing the noun's meaning by precisely collecting the verbs that are specific to a group of nouns (the parameters used to identify the verb uniqueness is described in section 3.1).
- Reducing the problem domain by weighting the parts of the corpus that are related to the noun being processed.

The NBDV method uses unsupervised learning to extract nouns synonyms. Definition1 gives a simple interpretation of the NBDV method:

Definition 1: assume that S_{n_1} and S_{n_2} (Verb_Noun adjacent lists) are the sets of verbs adjoin the nouns n_1 and n_2 such that: $\bar{S}_{n_1} = \{n_1v_1, n_1v_2, n_1v_3, \dots, n_1v_i\}$, and $S_{n_2} = \{n_2v_1, n_2v_2, n_2v_3, \dots, n_2v_j\}$. Where n_1v_1 is the first verb adjacent to the noun n_1 , and n_2v_1 is the first verb adjacent to the noun n_2 . Both i and j are positive

integers greater than 1. Then, n_1 and n_2 are synonyms if $|S_{n_1} \cap S_{n_2}| \geq c$ (Threshold value)

Example: if n_1 is “سيارة” (car) and n_2 is “مركبة” (vehicle),
 and $S_{سيارة} = \left\{ \begin{array}{l} \text{تسير, ينتج, يشتري, يقطع, يصندم, يركن, يركب, يصلح, يقود} \\ \text{... يبيع, يدهس, يسلك,} \end{array} \right\} \Rightarrow S_{car}$
 $= \left\{ \begin{array}{l} \text{drive, repair, ride, park, bump, take off, buy,} \\ \text{produce, walk, walk, tread, sell, ...} \end{array} \right\}$
 and $S_{مركبة} = \left\{ \begin{array}{l} \text{ينتج, يقطع, يحلق, يبحر, يطير, يصندم, , يركب, يصلح, يقود} \\ \text{... يسقط, يغرق, يرسو, يهبط, يركن} \end{array} \right\} \Rightarrow S_{vehicle}$
 $= \left\{ \begin{array}{l} \text{drive, repair, ride, bump, fly, sail, fly, crash,} \\ \text{produce, park, land, land, sink, fall ...} \end{array} \right\}$

Assume that $c = 5$, then

سيارة and مركبة are synonyms because $|S_{سيارة} \cap S_{مركبة}| = 7 > c$

Definition 1 presents the basic and simple idea of the NBDV method. It considers two nouns as synonyms if they share more than c verbs. But, the selection of the verbs that can group the nouns into semantically related groups is more complicated. The verbs such as “buy”, “produce”, and “walk” are general verbs and can be found with a wide range of nouns, so they cannot be used as distinguishing verbs. Section 3.1 depicts the criteria that have been used to select the distinctive verbs and explains how these criteria have been employed to weight the verbs in the proposed NBDV method.

Two aspects should be mentioned before proceeding to detail the NBDV model.

- The nouns targeted by the NBDV method are the common nouns, not the proper or the entity nouns because the latter mostly do not have synonyms.

Project Name	Ref	Statistical Model	Recall	Precision
Knowledge base creation based on automatic creation of a semantic network	[34]	Cosine similarly (CBoW and SG model) Cluster Algorithm	27% CBoW 35% SG	62% CBoW 66% SG
Minimally Supervised Approach for Automatic Synonym Extraction	[7]	Relative cosine similarity model	7% German 12% English	12% German 12% English
Automatic synonym extraction using Word2Vec and spectral clustering	[43]	Word2Vec model/ CBoW and SG model/ Cosine Similarity/ Spectral Clustering	74% Manual evaluation	80% Manual evaluation

Synonym extraction and abbreviation expansion with ensembles of semantic spaces	[9]	Enhanced distributional hypothesis model	47%	8%
Extraction of terms and semantic relationships from Arabic texts for automatic construction of an ontology	[8]	Learning Extraction Markers TF-idf weights	84%	76%
			Manual judgment of synonyms, domain-specific corpus	
Graph-based similarity measures for synonym extraction from parsed text	[6]	Path Constrained Graph model	MAP = 59%	
Finding Synonyms Using Automatic Word Alignment and Measures of Distributional Similarity	[38]	Distributional Similarity model	13%	23%
Towards an automatic extraction of synonyms for Quranic Arabic	[5]	TF-idf weights (VSM)	35%	33%

Table 1. Summary Of The Statistical Models With Their Accuracy Found In The Related Work

- The NBDV model can be seen as a synonyms extraction or more generally as a collector of the semantically related words because it combines the terms that normally share one semantic context. This point is important to mention because, in the evaluation of the relevance of the output set, the evaluator should not make an exact match between the automatically generated set and the answer set that is taken from the base dictionary. Also, considering the NBDV as a semantic word collection model makes it more supportive to the other fields of the information systems such as the query expansion in the information retrieval systems.

The NBDV method includes two phases, the weighing phase that uses the OWS scheme, and the synonyms detection phase that uses the cosine similarity between the vectors that are generated from the first phase to decide if two nouns are synonyms or not.

3.1. The Orbit Weighting (OWS) Phase

The OWS is used in the weighting phase of the NBDV to replace the traditional tf-idf weighting schemes. The OWS is designed for nouns because the nouns are the primary concern of the text mining applications. Mostly, the query terms in the IR field, and the class and category names in text categorization, and the concept/entity in entity recognition, are nouns.

In the OWS, the nouns that should be processed have a semantic relation with the noun that the user wants to find its synonyms. In each run, the similarities are computed between the nouns that share distinctive verbs. Our claim states that the nouns that share a set of specific verbs are more likely to be synonyms. For example, the noun car and automobile have some special verbs that distinguish them from the other nouns such as the verbs “park”, “crash”, and “drive”.

The reason for selecting the verbs as distinguishing factors is that the other parts of speech are normally used with a wide range of nouns. For example, the adjectives are used in the languages to describe objects of wide ranges and different domains.

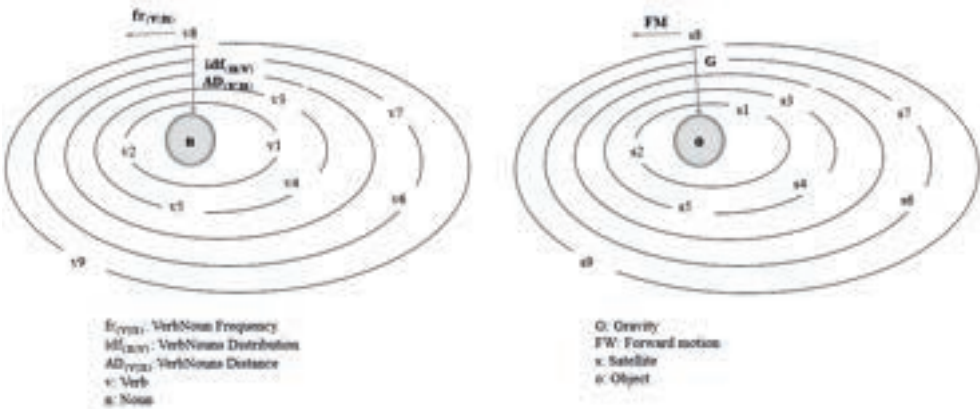


Figure 1. Orbit Representation for the Noun-verbs Relationships (OS(n))

3.1.1. Kinetic Relationship

Figure 1 depicts the idea behind the OWS weighting. The philosophy behind the OWS is to picture the semantic meaning of a noun n [OS(n)]¹ as an orbiting space in which the noun is the main object (placed in the core), and the semantically related verbs are satellites that circulate in fixed orbits around the center. This picture assumes that the semantic meaning of a noun is allows determined by the set of verbs that always spin in the orbits of the OS(n).

In Physics, the orbit of an object results from the balance of the forward motion of an object and the gravity (FM and G in Figure 1). This balance creates a robust structure of the space. The reason why we want to depict the text as a space of objects and orbits comes from the fact that the text is a combination of objects (nouns, verbs, and others) and relationships between these objects. Both the forward motion and the gravity can be represented statistical in the text, the term frequency and the term distribution of a certain term can represent the forward motion, and the singularity of a group of verbs to a noun or a set of nouns, which represent the semantic meaning, can represent the gravity. All we need is to find a mathematical scheme of all the forces that affect the verb.

¹ Though out this paper, we will abbreviate the orbiting representation of the noun n as OS(n)

The OWS sees the nouns and verbs relationship as a kinetic representation in which the verbs are always actions that working interactively and specifically with the nouns. We can represent the verb as an object that holds a specific amount of energy and according to this amount of energy, the verbs round in a specific orbit around the noun. The energy of the verb represents the balance between the semantic relationships and the statistical parameters that can be obtained from a huge corpus.

Based on our assumption, the nouns are grouped in groups (subspaces) according to the meanings of the verbs that are placed in their orbits. In this representation, we depict the semantic context of the noun as a subspace, and this subspace consists of the noun and the verbs that work kinetically with that noun.

The importance of the orbits in this representation is to depict that not all the verbs have the same degree of importance or the same amount of kinetic energy, and the verbs that are close to the center have high energy that increase their effectiveness in determining the subspace of the noun. Note that this representation forces that the effects of the verbs decrease as we move from the inner to the outer orbits. Accordingly, the verbs that appear in the outer orbits are general verbs that are circulating in the outer orbits of the vast majority of the nouns.

In Figure 1, the verbs v_1 and v_2 (could be the verbs “يركض drive” and “يركن park”) spin in the inner orbit, and their contributions are greater than the contributions of the verbs v_8 and v_9 (could be the verbs “يشترى buy” and “يبيع sell”) that are shifted to circulate in the outer orbit.

3.1.2. The Mathematical Representation of the OWS

In the OWS, the noun n is represented as a vector, and the vector of the noun is a set of weights of the verbs that appeared in the $OS(n)$ in the corpus, and it can be represented as follow:

$$\vec{n} = (w_{v1}, w_{v2}, w_{v3}, \dots, w_{vi})$$

Where w_{v1} is the weight of the verb v_1 in the space of n , and i is the number of verbs appeared in the $OS(n)$ in the whole corpus.

The weights that compose the noun vector $\vec{n}$ are computing by the OWS weighting scheme. The OWS computes the weight of a specific verb and decides whether this verb belongs to the n subspace and in which orbit is spinning. Thus, we can see the weight of the verb v with respect to the noun n as the amount of energy hold by v .

The OWS weights the verbs based on their singularity to a group of nouns. The singularity represents the verb energy and the energy is determined using three parameters, (1) the number of times the verb appeared in the $OS(n)$ (forward motion force), (2) the number of orbiting spaces the verb appeared in (gravity force), and (3) the average distance between the verb and the noun in each time the verb appears in the $OS(n)$ (gravity force). These parameters represent the forces that are affected v , and they are necessary to measure the uniqueness of the verb with respect to a specific set of nouns or in another words in which orbit of these nouns' subspaces the verb is located.

The purpose of combining the three parameters is to neglect the verbs that appear in the large number of OSs. For example, if the verb appeared with a large number of nouns, this implies that the verb is a general verb and the value of the second parameter will be very low (the second parameter is inversely proportional to the number of nouns the verb appeared-with as appeared in equation 4), and in this case, the OWS gives the verb tiny weight and shifts it to circulate in the outer orbits.

In Definition 1, two nouns are synonyms if they shared a certain number of verbs. However, our assumption should be updated to process the verbs according to their semantic relation with the nouns, which the orbiting representation reflects. For example, consider the verb “يشتري” (buy) and the verb “يركن” (park) both of them appeared in example 1 as verbs adjacent to the nouns “مركبة”, “سيارة” (appeared in the OS(مركبة) and OS(سيارة)), the verb “يشتري” is a general verb that can appear in the orbiting spaces of a lot of objects or services, but the verb يركن is more specific and related to fewer spaces such as car or bus. The verb “يركن” should make more contribution in determining that the OS(مركبة) and OS(سيارة) are semantically related spaces. It is crucial to determine which verbs should be considered as distinguishing verbs (circulating in the inner orbits) and have a significant effect in determining the synonyms. Therefore, Definition 1 can be updated as follow:

Definition 2: assume that S_n is a set of verbs that appeared in the OS(n) such that: $S_n = \{n_{v1}, n_{v2}, n_{v3}, \dots, n_{vi}\}$, Then, for each Verb v , the weight of v is determined by considering the following parameters:

1. *VerbNoun Frequency* ($\mathbf{fr}_{(v|n)}$): The number of times the verb v appeared in the OS(n) in the whole corpus. This parameter can be seen as the $f(v, n)$ that appears in the PMI definition [12].
2. *VerbNouns Distribution* ($\mathbf{idf}_{(n|v)}$): The number of nouns spaces that contain the verb v in the whole corpus.
3. *VerbNouns Distance* ($\mathbf{AD}_{(v|n)}$): The average distance between the verb v and the noun n in all the (v, n) occurrences in the OS(n).

In the NBDV method, n_j is considered as a synonym to noun n if the similarity between n_j and n exceeded a certain threshold value, and the similarity is computed based on the weights of the shared verbs that are weighted by considering the three parameters, the $fr_{(v|n)}$, the $idf_{(n|v)}$, and the $AD_{(v|n)}$. These three parameters are the identifiers of the OWS.

Based on definition 2, the verb that frequently circulates in the orbits of a certain noun (large value of $fr_{(v|n)}$), and normally located as close as possible to that noun (small value of $AD_{(v|n)}$), and appeared with a small set of nouns (small value of $idf_{(n|v)}$), obtained high weight value and should be spin in the inner orbits of Figure 1.

To define the three parameters mathematically, assume that t refers to any term belongs to the space K , and n refers to any noun belongs to K , and v refers to any verb belongs to K , and N is the number of subspaces in K .

Parameter 1: VerbNoun Frequency ($fr_{(v|n)}$)

VerbNoun Frequency is the number of times the verb v appeared in the OS(n). Parameter 1 or the $fr_{(v|n)}$ identifies the verbs that commonly appear with a specific noun. The $fr_{(v|n)}$ is computed in equation 1:

$$fr_{(v|n)} = \sum_{v,n \in K} f(v,n) \dots (1)$$

But, some verbs are general and appear intensively, and others are specific and appear in certain domains and platforms. The normalization of equation 1 is performed by dividing the $fr_{(v|n)}$ by the total number of time the verb v appeared in K :

$$fr_{(v|n)} = \frac{\sum_{v,n \in K} f(v,n)}{\sum_{v \in K} f(v)} \dots (2)$$

The normalization degrades the importance of the general verbs because the denominator in equation 2 will be high for such verbs, and this will decrease the weight and shift the verb to outer orbits.

Parameter 2: VerbNouns Distribution ($idf_{(n|v)}$)

VerbNouns Distribution is the number of orbiting spaces that contain the verb v in the whole corpus.

$$ndf(v) = \sum_{t \in K} f(n|v) \dots (3)$$

Where $f(n|v)$ is the number of distinctive nouns that appeared with v

To dampen the effect of the $ndf(v)$, equation 3 is normalized as follow:

$$idf_{(n|v)} = \log \frac{N}{\sum_{t \in K} ndf(v)} \dots (4)$$

VerbNouns Distribution parameter indicates the singularity of the verb. The large value of the $idf_{(n|v)}$ parameter means that the verb appeared in a large number of orbiting spaces. If the verb distribution among the nouns is high, the effectiveness of the verb in differentiating the nouns will be reduced. We argued at this point that the verbs that appear intensively in the text should be treated as Stopwords because for mathematical computation, they will not add any value. The smaller the value of $idf_{(n|v)}$ the larger the contribution of v .

In traditional tf.idf, the inverse document frequency (idf) is used to measure the distribution of the term over the whole documents [44]. If the idf value was high, this implies that the term appeared in a large number of documents, and the weight of the term will be low. In our weighting scheme, the idf is represented in a practical way in which the verbs that appear everywhere in the text are discarded. The $idf_{(n|v)}$ is used to measure the distribution of the verbs over all the nouns found in the corpus, which participates in correlating a set of nouns with a specific set of verbs that appeared only with these set of nouns in one semantic space. Similar to idf used in IR

and NLP applications, if the $idf_{(n|v)}$ value was high, this implies that the verb appeared with a large number of nouns and the verb will not be beneficial in distinguishing the nouns (the weight of the verb will be very low, and the OWS makes the verb spins in a far orbit).

Parameter 3: VerbNouns Distance ($AD_{(v|n)}$)

VerbNouns Distance is the average distance between the verb v and the noun n in all occurrences of (v, n) in the OS(n).

$$AD_{(v|n)} = \frac{1}{Avg(v_{pos} - n_{pos})}, \forall f(v, n) \dots (5)$$

Where v_{pos} is the position of the verb v , n_{pos} is the position of the noun n , and $f(v, n)$ represents any occurrence of v and n in OS(n).

In the OWS scheme, the verb and the noun are not necessary to be adjacent because, in some cases, certain words (such as Adjectives, adverbs, ...) may come between them. For example, consider the following statements from our corpus:

هو يقود السيارة
يقود السائق السيارة
يقود السائق المتهور السيارة
يقود السائق المخمور برعونة السيارة

He drives the car
The driver drives the car
The reckless driver drives the car
Recklessly, the drunk driver drives the car

The distance parameter ($AD_{(v|n)}$) imposes that the effect of the verb on the noun becomes stronger if the verb was adjacent to the noun, and this effect is reduced as the noun becomes far away from the verb. In the above example, in sentence number one, the whole concentration will be on the noun car, but in the fourth sentence, it addresses the driver, not the car. So, the $AD_{(v|n)}$ identifier gives the verb drive with respect to the noun car in the first sentence heavier weight than the verb drive in the fourth sentence with respect to the same noun. The importance of $AD_{(v|n)}$ parameter lies in showing how close the verb to the noun and normally the adjacency means a robust relationship between the verb and noun. So, the small value of $AD_{(v|n)}$ implies a large value of the weight of v .

3.1.3. Tf-idf Traditional Weighting

Before proceeding in further details about the employment of the previously mentioned parameters in the weighting equation, the definitions of these parameters in traditional tf.idf are mentioned here as how Imsombut in [17] defined and used them. The purpose is to make the efficiency and accuracy comparisons.

In the traditional tf.idf, the tf and the idf are defined as follow:

$$fr_{(v,n)} = \sum_{t \in K} f(v, n)$$

Where $fr_{(v,n)}$ is the number of times the verb v appeared with the noun n in K ,

The normalization step that appeared in the OWS (equation 2) is not necessary, and we used the traditional normalization as follow:

$$fr(v, n) = \begin{cases} 1 + \log \sum_{t \in k} f(v, n), & \text{if } \sum_{t \in k} count(v, n) > 0 \\ 0 & \text{otherwise} \end{cases}$$

In the traditional tf.idf, we link the noun n with a text segment, not with the verbs that appeared with n . The inverse noun frequency of the noun n (idf_n), is the number of documents d that contains n and can be defined as:

$$idf_{(n,d)} = \log \frac{N}{idf(n)}$$

Where $idf(n)$ is the number of documents that contain n .

The VerbNouns Distance in OWS definition can be employed in the tradition tf.idf using equation 5. This employment unifies the window size and ensures that the same set of verbs are processed in the two weighting schemes (OWS and tf.idf).

3.1.4. The Weighting Equation of OWS

After computing the value of each parameter in the OWS, the weight of the verb v the OS(n) is computed, as shown in equation 6:

$$\text{Weight}(v|n) = fr(v|n) * idf_{(n|v)} * AD_{(v|n)} \dots (6)$$

Equation 6 summarized the OWS weighting scheme, where $fr(v|n)$ is the frequency of v with respect to n , $idf_{(v|n)}$ is the number of n with respect to v , and $AD_{(v|n)}$ is the average distance between v and n .

Whereas, the weighting equation in the tf.idf weighting scheme will be:

$$\text{Weight}(v) = fr(v, n) * idf_{(n,d)} * AD_{(v|n)} \dots (7)$$

Note that in the tf-idf, there is no semantic connection between the noun and the verbs because the idf is computed relative to the document not to the verbs that normally appear with a set of nouns.

3.1.5. The OWS Process Architecture

The OWS weighting process is designed in Figure 2. In Figure 2, the list of verbs that appeared with the noun Nouni are weighted based on equations 2, 4, 5, and 6; then the weights are distributed to the appropriate orbits based on equation 8.

In Figure 2, orbit 1 represents the inner orbit that contains the verbs that gained the highest weights, and orbit j represents the outer orbit that includes the smallest weights. The OWS generates the output as a linked list, and the lists reflect the orbits' representation of the noun-verbs combinations. Nested linked lists are built for the noun being processed, and the list contains the verbs associated with the noun in the corpus.

Each level in the list represents one orbit, and all the verbs found in one orbit have roughly the same weight value (located with the range specified in equation 8). The verbs that are close to the root node (noun node) have the largest weights, and the weights start to decrease toward the leaf.

The pointer data structure with the dynamic memory allocation is used to represent the OWS output, and the purpose of this representation is to optimize the time and storage space.

The weighting process is designed as follows:

1. Compute the weighting parameters ($fr(v|n)$, $idf(n|v)$, and $AD(v|n)$) for each v appeared in $OS(n)$.
2. Compute the weight using equation 6 for each v appeared in $OS(n)$.
3. Construct the vector of n .

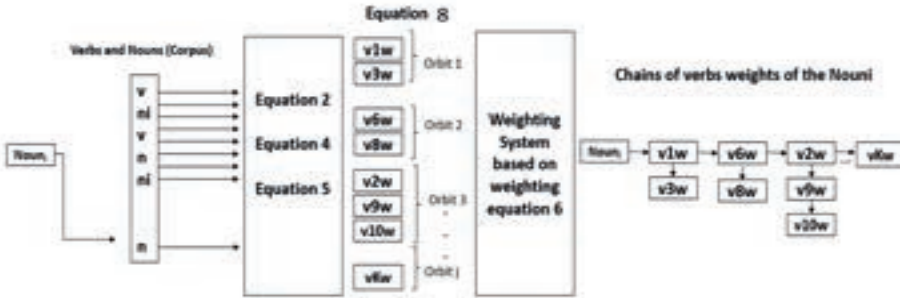


Figure 2. OWS Process Architecture

4. Specify the range of weights that should be included in each orbit. All the weights are located between the interval ($MINw$, $MAXw$). Therefore, the orbit range is assumed to be:

$$Orbit = \frac{MAXw - MINw}{y} \dots (8)$$

Where y is the number of verbs that are weighted in step 2, $MAXw$ is the weight of the verb appears in the inner orbit, and the $MINw$ is the weight of the verb appears in the outer orbit.

5. Extract all the nouns that share the verbs appeared in the first three orbits that are specified in step 4. Here it is important to mention that the NBDV method processes the nouns found in the first, second, and third orbit and three is set as the threshold value of the number of orbits processed by the NBDV method. The identification of this threshold value is made by measuring the number of processed nouns based on the first 13 orbits for 120 value of n (for 120 runs of the NBDV), and the results are presented in Figure 3. For more illustration, the number of nouns appeared in orbit 3 in our sample is 227, and this number increases to 279 in Orbit 4. It was found that the number of nouns becomes very large after the third Orbit.
6. Using OWS equation 6, compute the weights of each verb located in the first three orbits with respect to each noun extracted in step number 5, and generate a vector of weights for each noun.

At the end of the OWS phase, the NBDV model has a number of vectors equal to the number of nouns shared between the verbs that are located in the first three orbits. The outputted vectors are then transferred to the second phase of the NBDV model.

Regarding the tf.idf, in step number two, the weighting will be accomplished using equation 7, and it will be computed for all the verbs appeared in K, and steps 4,5,6 are not necessary because all the nouns will be processed not parts of them, so no need to specify which nouns should be processed and which noun should be neglected.

3.2. Synonyms Detection phase

The purpose of the second phase is to generate the required synonyms set. The input of the synonyms detection phase is a set of vectors generated from the OWS phase. The NBDV investigates the vectors and computes the cosine similarity between the vectors, as shown in Figure 4.

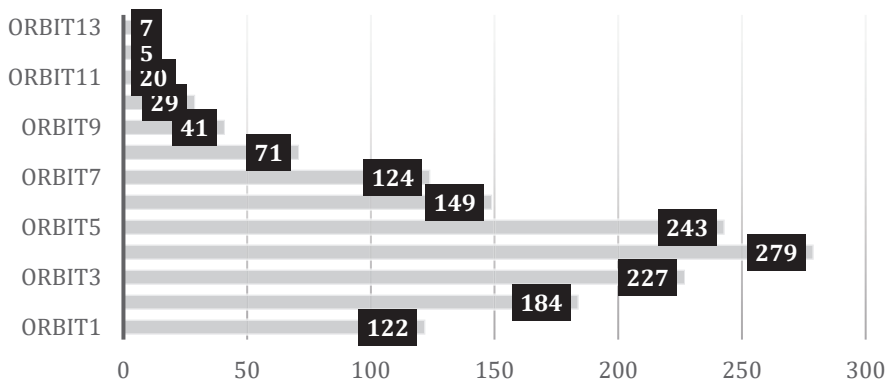


Figure 3. the Number of Processed Nouns at 13 Orbits of the 120 Runs of the NBDV Model

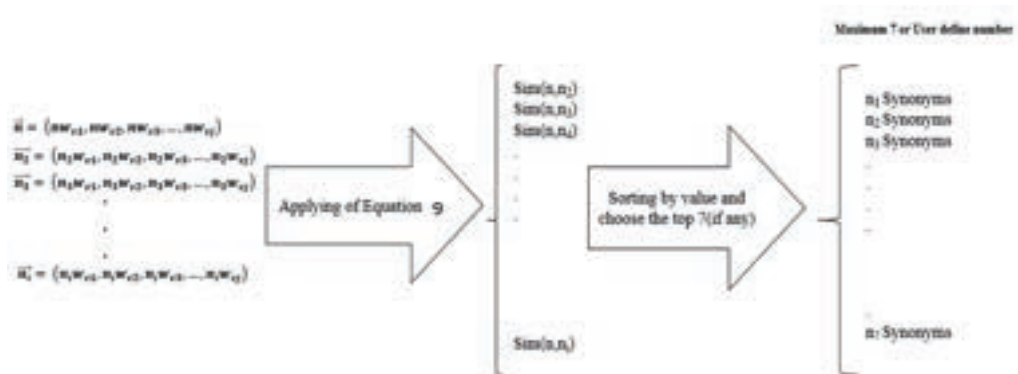


Figure 4. Synonyms Detection Steps Embedded in the NBDV Model

The synonyms detection phase takes the following steps:

1. Find the similarity between $\vec{n}$ and all the vectors $\vec{n}_x$ that is produced from the OWS phase using equation 9.

$$\text{sim}(\vec{n}, \vec{n}_x) = \cos(\vec{n}, \vec{n}_x) = \frac{\vec{n} \cdot \vec{n}_x}{|\vec{n}| \cdot |\vec{n}_x|}$$

$$\text{sim}(\vec{n}, \vec{n}_x) = \frac{\sum_{i=1}^j w(nv_i) \cdot w(n_x v_i)}{\sqrt{\sum_{i=1}^j w(nv_i)^2} \cdot \sqrt{\sum_{i=1}^j w(n_x v_i)^2}} \dots (9)$$

Where j is the number of shared verbs that are identified in the OWS phase, $w(nv_i)$ is the weight of the verb v_i with respect to the noun n , and $w(n_x v_i)$ is the weight of the verb v_i with respect to the noun n_x . The $\text{sim}(n, n_x) = 1$, if all the verbs are shared and have the same weights. ($0 \leq \text{sim}(n, n_x) \leq 1$).

2. Sort the similarity values in descending order. Discard all the similarity values that are less than 0.18. The 0.18 value was determined by scanning the generated similarity values of the first 120 nouns. The threshold value was specified by dividing the similarity value over 8 ranges as appearing in Figure 5, and we counted the number of processed noun located in each range. We note that the range of 0.2-0.3 contained the largest number of nouns (213). Then, and to be more specific, we took this range and the range below it ($0.1 - 0.2$) and divided them into seven subranges, as shown in Figure 5. We noted that below 0.18, the number of processed nouns become small (46). Add to this note, the point appears in Table 2, which shows that the average precision was insignificant at average similarity values below 0.2.

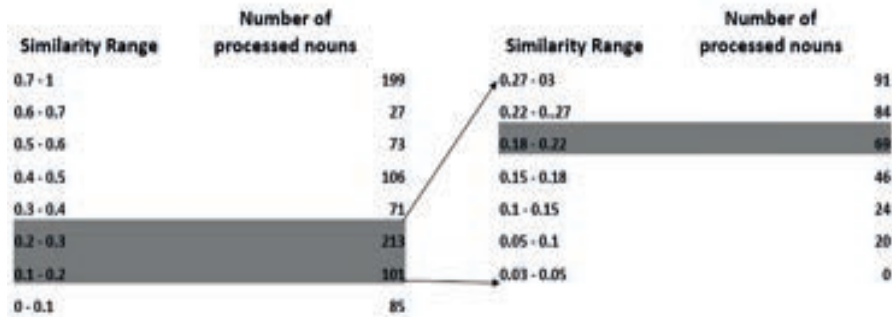


Figure 5. The Number of Processed Nouns Divided into 8 Ranges and 7 Subranges of the Noun Similarity Values.

3. Consider the top similarity values and extract the nouns corresponding to these values as the answer set.

In steps number two and three, the similarity values are sorted, and the top n values are treated. The value of n can be user-defined, but in our experiment section,

we chose seven as the value of n (maximum seven synonyms for each noun). Each similarity value is a value that measures the closeness between two nouns. If the value is large, the NBDV method takes the participating nouns as synonyms.

Back to the orbit representation, the computation function takes the orbit number in consideration because the verbs in the inner orbits should have heavier weights. The equation solves the problem that may arise if a large number of verbs were shared at the outer orbits because their values will be very small to make any difference. This feature distinguishes our equation from the similarity equations used in NLP and IR fields. All the similarity equations such as the Dice's Coefficient, Jaccard's Coefficient, and the Cosine similarity deal with a set of values, not an ordered list, they do not consider the position of the values in the set before computing the similarity.

The selection of seven as the maximum number of synonyms was based on the information that appeared in Table 2, the table traces the precision value of the first 24 top nouns that appeared in the answer set of 120 runs of the NBDV, for example, Top 4 precision is the average precision of all the precision values that were collected from the first four synonyms of the generated answer set in 120 runs. Note that after the top 7, the precision value recorded an abrupt decrease, from 51% to 35%.

The NBDV method is completely statistical and language-independent for the languages that have the following word orders: SVO, VSO, VOS, OVS, but it is not applicable to the languages that have the SOV (like Hindi, Japanese, Korean) and OSV (like Warao) word orders, because the OWS assumes that the verb precedes the noun.

3.3. NBDV Algorithm

The algorithm that appears in Algorithm 1 is designed based on the methodology described in sections 3.1 and 3.2. The algorithm accepts two inputs, the noun being processed (called x), and a preprocessed huge corpus (called K). The preprocessing of the corpus explained in the experiment setting section 4.2. The algorithm creates two dynamic arrays, $verbs(x)$ stores the verbs adjacent to x , and $candidate(x)$ stores the candidate synonyms of the noun x . The output that represents the synonyms for the noun x (maximum seven elements) is retrieved in a static array S . S is an ordered list sorted by the cosine similarity (equation 9) between the noun x and the candidate synonym x_c in S . In the NBDV algorithm, the OWS process is used twice, the first use is to compute the weights of the verbs adjacent to the main noun x (stored in $verbs(x)$), and the second use is for each noun x_c stored in $candidate(x)$. The second use of the OWS will not hurt the time complexity because the algorithm performs it only for the verbs stored in $verbs(x)$ after deleting all the verbs that are not located in orbits 1 -3 (called O_1 , O_2 , O_3).

	Average Precision	Average Similarity
Top 1	0.91	1
Top 2	0.908333333	0.749838303
Top 3	0.75	0.601859652
Top 4	0.791666667	0.515274347
Top 5	0.575	0.423002959
Top 6	0.566666667	0.386232659
Top 7	0.511666667	0.355228858
Top 8	0.358333333	0.326606785
Top 9	0.291666667	0.300332795
Top 10	0.266666667	0.274658761
Top 11	0.175	0.253573794
Top 12	0.166666667	0.246014353
Top 13	0.15	0.236191662
Top 14	0.15	0.220238948
Top 15	0.116666667	0.209058545
Top 16	0.116666667	0.195219259
Top 17	0.083333333	0.180584797
Top 18	0.083333333	0.173604638
Top 19	0.066666667	0.168626283
Top 20	0.058333333	0.165138188
Top 21	0.025	0.161756153
Top 22	0.016666667	0.152375659
Top 23	0.016666667	0.142409236
Top 24	0.016666667	0.139284236

Table 2. the Average Precision and Average Similarity at 24 Levels of the Answer Set of the 120 Runs of the NBDV Synonyms extraction

4. Experiment Preparation

The experiments are designed to measure the performance in terms of efficiency and relevancy of the NBDV method. This implies comparing the results that are generated from the NBDV method in two cases, in the first case, the NBDV will use the OWS to generate the vectors for the verbs, and in the second case, the tf.idf weighting scheme will be used to generate the verbs weights. In both cases, the accuracy measurements (Precision and Recall) and the efficiency measurements (the number of verbs and the number of nouns) should be collected in every single run of the NBDV model.

ALGORITHM 1: NBDV Extraction

Input: the noun x , preprocessed Text Corpus K // *Kalimat corpus with term-tag-stem format*

Output: the set S of synonyms of the noun x of the form: $S = \{syn_1, syn_2, \dots, syn_i\}$, where $sim(x, syn_1) \leq sim(x, syn_j) \leq sim(x, syn_i)$, with $max(i) = 7, j = 1, 2, \dots, max(i)$

Method:

Begin

Construct $vec(x) = \{\}$; // *vector of x contains the OWS weights of the verbs adjacent to x*

Construct $verbs(x) = \{\}$; // *creating dynamic array to store the verbs adjacent to x*

Search through K ;

$c = 0$;

For each v_i appeared within i^{th} locations of x // *we set 5 as the value of i "window size"*

{

Add v_i to $verbs(x)$

Find $fr(v_i|x)$ // *using equation 2*

Find $idf(x|v_i)$ // *using equation 4*

Find $AD(v_i|x)$ // *using equation 5*

Find $W(v_i|x)$ // *using equation 6*

Add $W(v_i|x)$ to $vec(x)$; $vc = vc + 1$; // vc : verbs counter

}

$Orbit = (max(w) - min(w)) / vc$; // *computing the orbit range*

For each $w \in vec(x)$ do

{

if $max(w) \geq w \geq (max(w) - orbit)$ add w to O_1 ; // *inner orbit*

Else if $(max(w) - orbit) > w \geq (max(w) - 2*orbit)$ add w to O_2 ;

Else if $(max(w) - 2*orbit) > w \geq (max(w) - 3*orbit)$ add w to O_3 ; // *the outer orbit*

Else delete w from $vec(x)$; delete v from $verbs(x)$; // *excluded all the verbs that located after orbit 3*

}

Construct $candidate(x)$ // *creating dynamic array to store the candidate synonyms of x*

For each $v_i \in verbs(x)$ do

If noun x_c adjacent to v_i add x_c to $candidate(x)$ // *add noun x_c the candidate array*

For each $x_c \in candidate(x)$ do

{

compute the weights of each v_i verbs (x) with respect to x_c

construct $vec(n_c)$;

if $sim(vec(x), vec(x_c)) < 0.18$ delete x_c from the $candidate(x)$ // *similarity equation 9*

}

Sort $candidate(x)$;

$S =$ the first seven element of $candidate(x)$; // *the final synonyms set*

End

4.1. Arabic and English Datasets

Huge datasets from the Arabic and English languages are used to test the effectiveness of the new weighting scheme. Almost, the English language has been used to test the performance of all the state-of-the-art models such as the SG, CBoW, and GloVe. Therefore, we chose the Common Crawl corpus with 42 billion terms. This corpus is used to compare the performance of the NBDV model with the performance of the GloVe model as showing in section 5.3.

The Arabic language has a well-defined structure with no irregular forms of the structures or the verbs. The feature that pushes toward the use of the Arabic language as the testing language is the flexibility in constructing the sentences. In Arabic, the sentence can be constructed in more than one-word orders, and the writers of the Arabic language have the fixability to structure the sentences using the form Subject-Verb-Object (SVO) or Verb-Subject-Object (VSO). So, in the experiment, instead of using two different languages with two-word orders (SVO, VSO), we used one language that accepts both word orders.

A huge dataset of Arabic text has been used in the experiment of our model. This corpus collected four datasets of the Arabic language. The corpus contains millions of words. The corpora that included in this corpus include:

Essex Arabic Corpus: This corpus published free on <http://www.lancaster.ac.uk/staff/elhaj/corpora.htm>. The corpus used recently by Al-Radaideh and Bataineh [45].

Kalimat data corpus2 : Kalimat contains 20,291 Arabic articles. The corpus comprises greater than 6,000,000 terms. The data was taken from Omani newspapers

242 data corpus, the corpus includes 242 Arabic text documents. The corpus was used by many researchers who investigated the Arabic IR field [46].

AH-Dataset corpus: It's a new dataset that comprises a huge number of Arabic words. The data is collected from three Arabic newspaper websites (Aljazeera.net, Alarabiya.net, and Addustour.com) and the Arabic website of Wikipedia. All the necessary preprocess operations (Tokenization, POS tagging, and Lemmatization) were performed using the ALP tool³. This tool is developed by Freihat et al. and available free for processing Arabic text. We tested the output of this tool manually for groups of documents, and the accuracy was significant.

We tried to vary the topics and the domain of knowledge, so the selected data talking about health, science, history, art, religion, technology, environment, economic, and financial aspects.

4.2. Experiment Setting

This section describes the experiment environment used to test the behavior of the NBDV for synonyms extraction. The experiment was performed on Intel® Core™ i5-7200U CPU @ 2.5GHz processor with 8 GB RAM and Windows 10 OS.

The NBDV method of synonyms extraction is implemented in the VSyn software package (see Figure 6). The purpose of developing the VSyn software is to test the performance of the NBDV. The VSyn was designed and implemented according to the detailed specifications of the NBDV algorithm described in section 3.3. The VSyn allows the user to enter the noun and search for the synonyms.

The VSyn software interface includes three output panels:

- The first one displays the sentences that contain the noun.

² The corpus is available free on <http://www.lancaster.ac.uk/staff/elhaj/corpora.htm>

³The tool is available online on <http://arabicnlp.pro/alp/>

- The second panel displays the verbs that appeared with this noun sorted by their distance from the noun.
- The third panel displays the generated synonyms.

Also, the software generates an excel sheet that contains all the processed verbs and their obtained weights.

For automatic evaluation with automatic evaluation tools such as the ROUGE tool, the system generates a text file for each processed noun that contains its synonyms list (see Figure 6).

As discussed in the previous section, the Kalimat dataset is used in the experiment. In Kalimat, the terms are already tagged, but preprocessing operations were performed to eliminate the Stopwords, punctuation markers, and special and strange symbols. Also, a simple modification is made to unify all the subtypes under one tag. For example, Kalimat classifies the types of the nouns, for example, اسم الآلة (the nouns that refer to equipments or tools such as key, saw, lathe, fan, radiator, and scalpel), اسم الزمان و المكان (nouns indicate the place and time of the action such as park, airport, appointment), and all the nouns types were unified under the “noun” tag. The same thing was done for the verbs; all verb types were unified under the tag “verb”. After the preprocessing, the text is stored in (term-tag-stem) format.



Figure 6. VSyn Interface

The selection of the nouns to be tested in the experiment includes 564 nouns from the Kalimat dataset. The nouns are chosen randomly. The random selection allows the testing of nouns that vary in the number of synonyms they have. For example, some nouns are common and have a large number of synonyms, and some nouns are special and have a small number of synonyms. The NBDV method is significant if it

returns a large number of synonyms for the common nouns and a few numbers of synonyms for the special nouns.

The selected nouns are processed one by one, and the generated synonyms were collected for evaluation. Also, the verbs and nouns processed in each run were collected to measure the processed portion of the corpus and to estimate the time complexity needed to finish every single synonyms extraction operation. The types of the collected results in the experiment with the purpose of each type appear in the next section.

4.3. Experiment Results

In the experiment, the following results are collected for evaluation purposes:

1. **The verbs that appeared in each run with their weights.** These results are used in the evaluation to assess the ratio of processed verbs in each run to the total number of verbs in the whole corpus. The number of processed verbs is essential to determine the time complexity of the NBDV, as shown in section 5.3. For example, consider the noun “هجوم”, the list of verbs and their computed weights (using the OWS) came as follow:

نجا	زحف	تورط	رتل	جرح	عنف	صد	شنا	بشن	شن
Past of survive	Past of crawl	mire	intone	hurt	expostulate	repulsed	Past of launch for plural	Present of launch	Past of launch
0.0914	0.0952	0.101	0.126	0.17	0.193	0.265	0.543	0.794	0.829

2. **The maximum and minimum weights of each run:** these are necessary to compute the value of the orbit range in each run (the output of the applying equation 8). For example, for the noun “هجوم”, the maximum weight was 0.829 for the verb (launched), and the minimum weight was 0.0914 for the verb (survived).

$$Orbit = \frac{0.829 - 0.091}{16} = 0.046$$

3. **The distribution of the verbs in the orbits:** as in the following example for the noun “هجوم”:

نجا	زحف	تورط	رتل	يلطف	جرح	اعنف	صد	شنا	بشن	شن
0.091	0.095	0.10	0.12	0.15	0.179	0.19	0.265	0.543	0.79	0.829
Outer orbit			Fourth orbit			Third orbit	Second orbit	Inner orbit		

4. **The set of candidate synonyms.** Similar to the number of verbs, the number of processed nouns in each run is collected to estimate the complexity of the NBDV method. For example, the candidate synonyms of the noun “هجوم”:

عدوان	اعتداء	قوات	عمليات	حملة	هجوم	اعتداءات	ناس	رئيس	هجمات
aggression	assault	troop	operations	campaign	attacks	People	President	attacks	attacks

5. **The final set of synonyms** after deleting the candidate synonyms that have low similarity with the main noun: as in the following example for the noun “هجوم”.

هجوم	هجمات	ناس	حملة	عمليات	اعتداء	عملية
attack	attacks	people	campaign	operations	assault	operation

6. **The nouns with their synonyms in one table for all runs.** The outputs of 564 runs of the VSyn were collected in the following format:

Term	Syn1	2Syn	3Syn	4Syn	5Syn	6Syn	7Syn
------	------	------	------	------	------	------	------

These results are important to evaluate the accuracy (Precision and Recall) of our method. The final sets of synonyms were evaluated by the ROUGE evaluation tool and assessed by the manual evaluators. Table 3 shows a sample of our results.

5. Evaluation

After collecting the complete results, the results were evaluated in two separate ways. Firstly, by comparing our results with two online sources of Arabic Language synonyms; Almaany⁴ and Google Translate. A sample of nouns found in our corpus was randomly chosen, and a comparison between the automatically generated synonyms by VSyn system and the synonyms sets available on those two online sources has been established. Secondly, six Arabic language experts were hired to measure their degree of satisfaction with the accuracy of the VSyn system.

For accuracy comparisons with the other publications in the field of statistical synonyms extraction, we used the recall and precision relevancy measurements that are used to test the accuracy of the well-known models; the CBoW and the SG model. The Recall is the number of correct synonyms of a noun returned by our method relative to the number of actual synonyms number found in the Arabic language for that noun (taken from a base dictionary or an expert knowledge).

$$Recall = \frac{\text{the number of correct synonyms of the noun generated automatically}}{\text{the actual number of synonyms of that noun found in the Arabic Language}}$$

The Precision is the number of correct retrieved synonyms of a noun relative to the total number of generated synonyms by the automatic synonym extraction system.

$$Precision = \frac{\text{the number of correct synonyms of the noun generated automatically}}{\text{the number of synonyms of the noun generated automatically}}$$

Also, to measure the behavior during the synonyms extraction process, and to assess the relevancy at each point a new noun is processed by the NBDV method, two new evaluation schemes are proposed:

⁴ <https://www.almaany.com/ar/thes/ar-ar/>

Term	Syn 1	Syn 2	Syn 3	Syn 4	Syn 5	Syn 6	Syn 7
ناس people	ناس people	قوم folk	السكان residents	رسول messenger			
منطقه area	منطقه area	مدینه city	شباب youth	ولايه state	ولايات States	مناطق areas	عديد numerous
مجموعه collection	مجموعه collection	جماعه group	شكل form	وفد delegation	اكثر More	عديد numerous	عام general
ولايه state	ولايه state	منطقه area	عام general	محافظة governorate	مناطق Areas	بحريه marine	مدینه city
شارع street	شارع street	طريق road	منطقه area	وادي valley	مختلف different	ولايه states	
مليار	no synonyms generated						
شرکه company	شرکه company	شرکات companies	وزاره ministry	منظمه organization	مؤسسه institution	عام general	مشاركه participation
عدوان aggression	عدوان aggression	رئيس president	عديد numerous	اعتداء assault	هجوم Attack	هجمات attacks	
کاتب writer	کاتب writer	مؤلف author	کتاب book	کاتبه writer (female)	عمل Work	تاريخ history	عالم world
زعيم leader	زعيم leader	زعيمه leader (female)	يوم day	غزو invasion	رئيس president	عام general	وقت time
بحث research	بحث research	دراسه study	تقديم introducing	تحقيق investigation	شباب Youth	تجدید renewal	عمل work
صور pictures	صوره picture	صور pictures	تاريخ history	تصورات perceptions			
وقت time	وقت time	شكل form	قدر destiny				
معرفة knowledge	معرفة knowledge	تحقيق investigation	وقت time	مجال domain	نور light	نפט petrol	معلومات information
مسلم Muslim	مسلم Muslim	مسلمون Muslims	مسلمين Muslims	عالم world			
طعام food	طعام food	حقوق Fields	حديث speech	غذاء nutriment	بروتينات proteins	ماکولات foods	

Table 3. Samples of Generated Synonyms by our Synonyms Extraction System

- Average Recall at point: the average recall after the processing of the noun number i :

$$A(R|i) = \frac{\sum_{n=1}^i R_n}{i}$$

- Average Precision at point: the average precision after the processing of the noun number i :

$$A(P|i) = \frac{\sum_{n=1}^i P_n}{i}$$

The $A(R|i)$ and $A(P|i)$ trace the average recall and the average precision trends during the processing of the nouns by NBDV method. The importance of the $A(R|i)$ and $A(P|i)$ is to measure the fluctuation on the recall and precision values of the individual runs of the VSyn software. The fluctuation should be in minimum, and this can be obtained when the values of the $A(R|i)$ and $A(P|i)$ reach to the final average of the recall and precision after processing a small number of nouns.

The recall and precision are manually and automatically collected, and the automatic evaluation is performed using ROUGE 2.0 tool. ROUGE 2.0 is widely used in literature to test the accuracy of the summarization or extraction systems [47], [48]. It evaluates the system generated extract against a reference or gold extracts (typically the reference extracts are performed manually or taken from a well-known source). To measure the precision and recall using the ROUGE tool, the generated text file from the VSyn software is matched against the reference extract taken from the base dictionary.

The evaluation includes the assessment of the precision and recall values obtained in the experiment and the time complexity necessary to run the NBDV method. But, before evaluating them, the size of the produced answer set from the VSyn system should be investigated.

5.1. The Size of the Answer Set Evaluation

The size of the answer set is important because if the number of generated synonyms is always high this means that the parameters specified in the description of the NBDV method are not robust and cannot control the synonyms retrieval process, and if the number of synonyms retrieval is always low this means that the parameters cannot establish a real semantic relationship between the noun and the candidate synonyms.

The number of generated synonyms for each noun was statistically determined and divided into two categories, less than or equal 3 and greater than 3. On average, 20% of the nouns gained between one to three synonyms, and 70% of the nouns gained more than 3 synonyms (the remaining 10% of nouns gained 0 synonyms). Figure 7 shows the ratio of the nouns that gained greater than a certain number of synonyms. For example, from Figure 7, 20% (110 nouns out of 564 nouns experimented) of the nouns gained at least one synonym and at most three synonyms, and 70% of the corpus nouns gained at least four synonyms and at most 7. Figure 8 revealed that from 564 of the tested nouns, 90% gained at least one synonym, and 70% gained at least three synonyms. Almost, the output answer is not empty, and the VSyn system that was

built based on the NBDV method succeeded to return the reasonable number of synonyms.

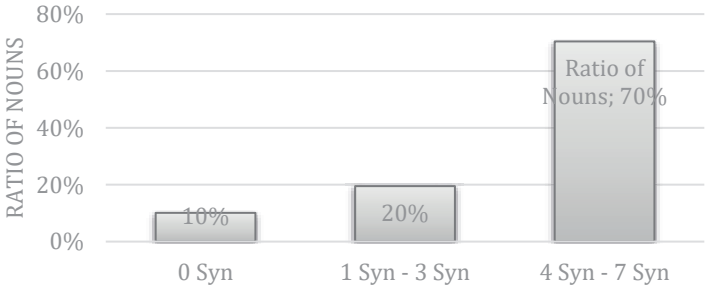


Figure 7. The Ratio of Nouns that gained 0, 1-3, and 4-7 Synonyms.

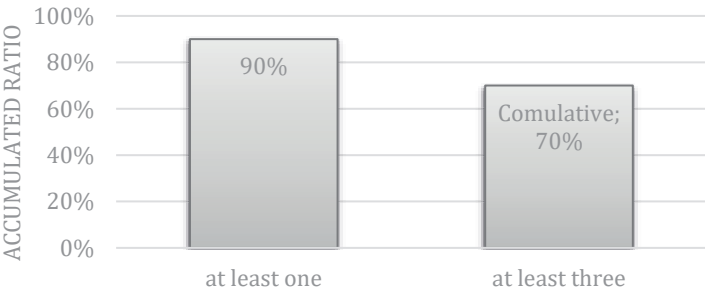


Figure 8. The Accumulative Ratio of Nouns that Gained more than 1 and more than 3 Synonyms

5.2. Accuracy Assessment Evaluation

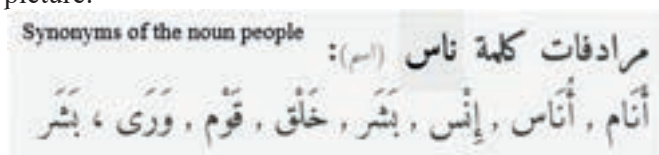
Both recall and precision are used intensely to assess the accuracy of the Natural Language Processing and Information Retrieval applications. The precision indicates the ratio of correctness relative to the answer set, while, the recall gives a broader view and estimates the accuracy relative to the typical answer. However, in such kind of text mining applications, the determination of the typical answer is practically hard, but we can assume that the synonyms set found in the base dictionaries are the ideal answer and prepare our calculation accordingly. Also, Arabic language experts and speakers were hired to take their opinions in the accuracy of the generated answer set. In the manual evaluation, it is hard to ask the experts and the speakers to find the recall because this needs large effort from them to find the optimal synonyms set, so from the manual evaluation, the precision is the only collected relevancy measure. Brief descriptions of the figures and tables appear in this section are as following:

- Figure 9 shows the recall and precision (Almaany dictionary as an optimal answer).

- Figure 10 shows the recall and precision (Google Translate synonyms set as an optimal answer).
- Figure 11 Compares the average recall in the case of using Almaany as a base of evaluation and in the case of using Google Translate as a base of evaluation.
- Figure 12 Compares the average precision in the case of using Almaany as a base of evaluation and in the case of using Google Translate as a base of evaluation.
- Figure 13 Compares the trend of the average recall in case of using the OWS weighting and in case of using tf.idf weighting (Google Translate as a base of evaluation).
- Figure 14 Compares the trend of the average precision in the case of using the OWS weighting and in the case of using tf.idf weighting (Google Translate as a base of evaluation).
- Figure 15: The spearman rank correlation results of the word similarity models over the generated similarities from the NBDV and GloVe.
- Table 4 shows the final average precision and average recall using manual and automatic evaluation strategies.
- Table 5 shows the precision and recall values for the automatically generated synonyms for the first 10 nouns based on OWS and tf.idf weighting schemes.
- Table 6 shows the average precision for the experts' and speakers' manual evaluation.

5.2.1. Almaany-Based Evaluation of the NBDV based on OWS Scheme

Almaany online Dictionary contains the meanings, synonyms, and antonyms of the Arabic language words. Almaany is a pioneering online tool that composes a database that was taken from a set of famous Arabic dictionaries including “Lesan Alarab لسان العرب”, “Alraa’d الرائد”, “Alwaseet الوسيط”, “Alghany الغني”, “Modern Arabic Language اللغة العربية المعاصر”, and “Aljaam’a الجامع”. The output of Almaany dictionary looks like the following picture:



The answer set of Almaany usually contains repeated words, so, a simple preprocessing stage to remove the duplicates was performed before the evaluation process. For example, the answer set for the noun “فوز winning” includes the following synonyms:

انتصار، انتصار، انتصار، ظفر، ظفر، ظهور، غلبه، غلبه، غلبه، غلب، غلب، فتح، فلاح، مفازة، منجاة، نجاح، نصر

Note that the Arabic noun “انتصار triumph” repeated three times, the noun “غلبة predominance” repeated five times.

For the manual and automatic evaluation, a group of nouns was inserted into Almaany dictionary, and the generated synonyms were collected in the following format.

Synonyms Generated from Almaany	Synonym Generated from our automatic synonyms finder	Recall	Precision
---------------------------------	--	--------	-----------

For example, for the noun “الناس people”, the results were:

Synonyms Generated from Almaany	Synonym Generated from our automatic synonyms finder	Manual Recall	Manual Precision
انام , اناس , انس , بشر , خلق , قوم , وري , بشر , ساكن	ناس السكان قوم رسول	3/9 = 33%	3/4 = 75%

As mentioned previously, the ROUGE tool is used for automatic evaluation. The ROUGE precision and recall results of Almaany based evaluation were summarized in Figure 9. Figure 9 reveals that the precision was higher than the recall, this means that among the returned set of synonyms for a specific noun, the accuracy was significant (the number of correct synonyms to the number of automatically generated synonyms was high), but the system did not return the sufficient number of synonyms found in the Arabic language (the number of correct synonyms to the number of synonyms found in Almaany was low). Also, the majority of the precision values are confined between 0.4 and 0.5 (the average is 0.46 see Table 4), whereas the recall values fluctuated from 0.05 to 1.0, and the reason for that is the contents of Almaany reference set. Almaany reference sets contain one or two synonyms for certain nouns and contain more than 30 synonyms for other nouns.

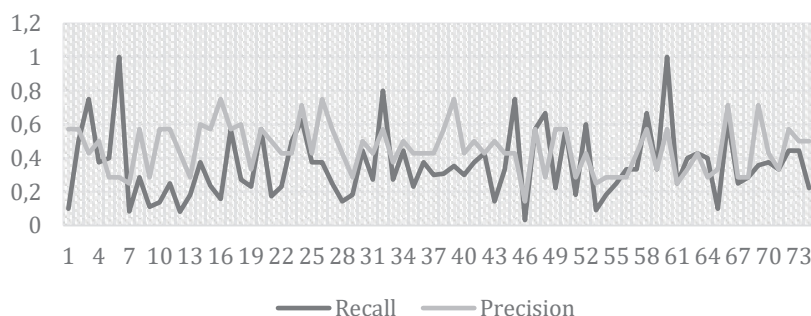


Figure 9. Recall and Precision – Almaany-based Evaluation

5.2.2. Google Translate-based Evaluation of the NBDV based on OWS Scheme

The problem we faced in Almaany-Based Evaluation was the contents of the synonyms sets. As described previously, Almaany combines six well-known and ancient dictionaries, and most of its vocabularies are not in use in today's newspapers and journals (the source of Kalimat Dataset). For example, in the synonyms list of the term "people" ("ناس"), the synonym "وَرَى" is not in use in today's language, and the synonym "خَلَقَ" is not used in these days to refer to "people" (it refers to anything created by God). Therefore, the search for a new source of synonyms that reflects the modern Arabic language is necessary.

Google Translate was the result of this search because it gives a list of modern synonyms for any Arabic term being translated. For example, the term used in our example above ("ناس" people) has the following synonyms in Google Translate: (folk قوم, people ناس, population سكان, society مجتمع, family أسرة). Google Translate uses a statistical machine translation approach to translate the Arabic language, and it collects the meaning and synonyms from a massive number of Arabic articles found on the internet at the time of translation. (Most of these articles are written in modern Arabic vocabularies).

Figure 10 shows the precision and recall curve based on GoogleTranslate synonyms set. In Figure 10, the values of the precision and the recall are convergent, and the recall is more stable comparing with Almaany based recall because the sets of synonyms that were appeared in Google Translate (the base of the comparison) are smaller than the synonyms set of Almaany dictionary and roughly contain the modern Arabic terms. Also, the size and contents of Google Translate synonyms set positively affected the final average precision and average recall.

Table 4 shows the final recall and precision values that were obtained in this experiment. Table 4 shows that the obtained average precision and average recall based on GoogleTranslate are higher than their corresponding values based on Almaany dictionary and the reason for that is the type of language used in GoogleTranslate that uses the same language used in our corpus. Thus, the obtained average precision(51%) and average recall (47%) in GoogleTranslate based evaluation are more significant than the obtained results in the Almaany based evaluation (5% improvement on average precision, 11% improvement on the average recall).

Figure 11 represents the average recall trend $A(R|i)$. The vertical axis represents the $A(R|i)$ values and the horizontal axis represents the id of the processed noun. Figure 12 represents the average precision trend $A(P|i)$ at each run of the VSyn program. The vertical axis represents the $A(P|i)$, and the horizontal axis represents the id of the processed noun. Both figures show the stability of the recall and precision values. In Almaany based evaluation or GoogleTranslate based evaluation, the recall and precision curves converge to their final average values after processing few numbers of nouns (roughly after the noun number 40). The fast convergence gives a good indication of the accuracy of the generated answer set by the VSyn program. If the recall and precision were very low in some cases and very high in other cases (large fluctuations) this requires the process of a large number of nouns to see the

stability. The indication that can be obtained from the curves that in most cases, the precision and recall were close to their average. Also, it is important to note that the recall and precision were higher in the GoogleTranslate based evaluation than in Almaany based evaluation.

Evaluation Type	Weighting Scheme	Average Recall	Average Precision
Almaany Based Evaluation	OWS	36%	46%
Google Translate Based Evaluation	OWS	47%	51%
Google Translate Based Evaluation	Tf.idf	36%	41%
Expert and Speakers Evaluation	OWS	N/A	57.5%

Table 4. Average Precision and Average Recall Using Three Evaluation Strategies

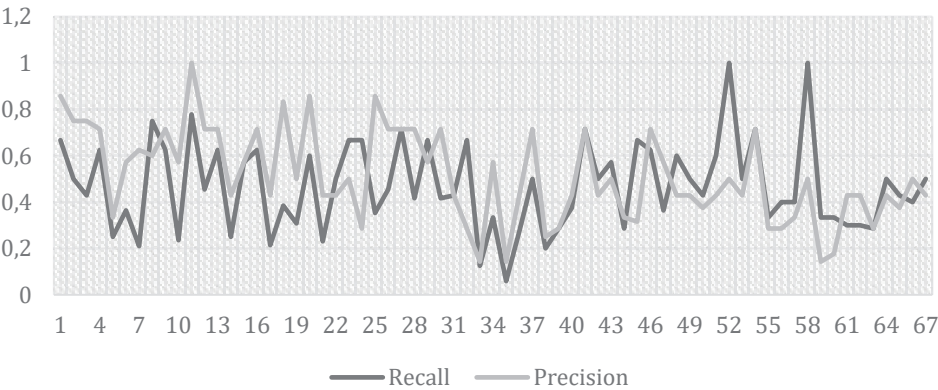


Figure 10. ROUGE Recall and Precision - GoogleTranslate-based Evaluation

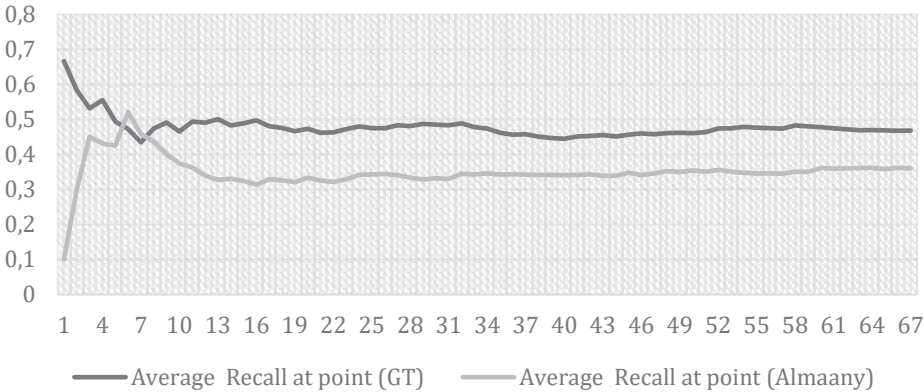


Figure 11. Average Recall Trends at every Noun Processed

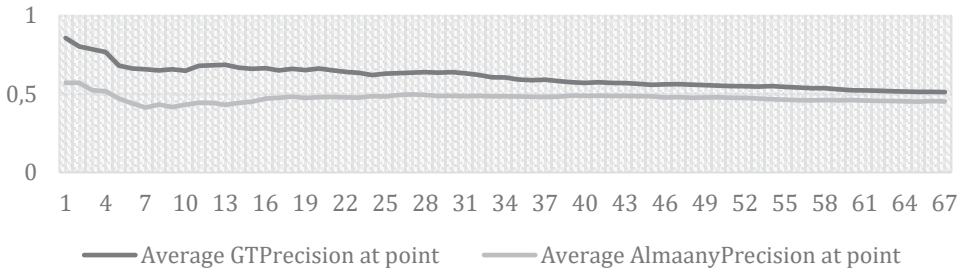


Figure 12. Average Precision Trends at every Noun Processed

5.2.3. Relevancy Comparison between OWS and Tf.idf

This subsection presents the recall and precision evaluation for the NBDV based on the tf.idf weighting scheme, and it offers a comparison between these results and the results that were obtained in the previous section. The precision and recall results based on the GoogleTranslate synonyms set are more significant than the precision and recall results based on the Almaany. Thus, our comparison in this subsection is based on the synonyms set of Google translate as the optimal answer.

Back to Table 4, The NBDV evaluation based on tf-idf achieved 36% average recall and 41% average precision. Table 5 shows a sample of the obtained recall and precision results by the two scheme experienced in this paper. For the most nouns that are mentioned in Table 5, the recall and precision values of the OWS scheme is greater than their equivalent values in the tf.idf scheme, and the difference is significant.

Noun	Recall		Precision	
	OWS	tf.idf	OWS	tf.idf
اجتماع Meeting	0.4167	0.25	0.7143	0.42857
احتفال elebration	0.36364	0.36364	0.57143	0.57143
اعتداء Assault	0.41667	0.16666	0.71429	0.28571
افتتاح Opening	0.21429	0.21429	0.42857	0.42857
انتصار Victory	0.5	0.5	0.42857	0.42857
اولاد Children	0.42857	0.71429	0.375	0.25
بحث Research	0.57143	0.57143	0.57143	0.57143
بطولة Championship	0.23529	0.23529	0.57143	0.57143
بيانات Data	0.66667	0.33333	0.5	0.28571
تاريخ History	0.7500	0.5	0.6000	0.4
جائزة Award	0.3	0.2	0.42857	0.28571

Table 5. Precision and Recall Values for the Automatically Generated Synonyms for the First 10 Nouns (Based on OWS and tf.idf Weighting Schemes)

To trace the complete behavior of the tf.idf recall and precision results, we redraw Figures 11, 12 to reflect a comparison in the trend of the tf.idf recall and precision with the OWS recall and precision. Figure 13 shows the recall trend, and Figure 14 shows the precision trend. From left to right, the trend becomes more stable, and the curves converge to their final mean. The two figures show that the OWS relevancy measurements overtake the tf.idf relevancy measurements.

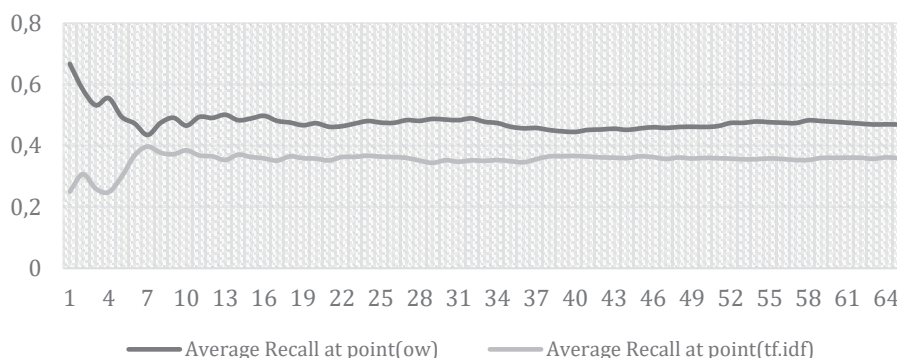


Figure 13. the Trend of the Average Recall Based on OWS and Based on tf.idf

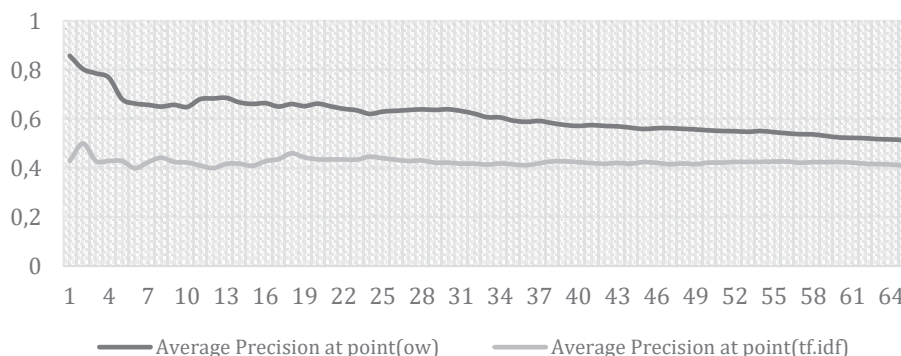


Figure 14. the Trend of the Average Precision Based on OWS and Based on tf.id

5.2.4. Evaluating using Arabic language experts

The results of the OWS recall and precision revealed a significant performance of our system, but it showed that 64% of the synonyms are not returned in Almaany based evaluation. The explanation was that the nature of the base data that were used in the evaluation. However, it is necessary to measure the satisfaction of the native speakers of the modern Arabic language about the accuracy of the synonyms sets returned by the NBDV method. The use of human evaluators has been reported in many research publications [7], [8], and [43].

Two Arabic language experts and four Arabic language speakers from Prince Sattam bin Abdel Aziz University in Saudi Arabia voluntarily evaluated our system. The evaluation was conducted in two groups; each group evaluated 82 nouns' synonyms. From their experience, the experts wrote the number of correct synonyms

that were generated from our system for every noun. The precision was redefined as follow:

Precision

$$= \frac{\text{the number of automatically generated synonyms that the expert agreed their correctness}}{\text{total number of automatically generated synonyms of the noun}}$$

Group one of nouns containing 81 noun		Group two of nouns containing 83 noun	
Expert name	Precision	Expert name	Precision
Adeel(expert)	55%	Sadam(expert)	50%
Firas(speaker)	62%	Bassam(speaker)	57%
Sana(speaker)	60%	Nour(speaker)	61%
Average	59%	Average	56%
Average	57.5%		

Table 6. the Average Precision for the Manual Evaluation

Table 6 shows the manual evaluation results. The experts' evaluation showed that the precision was significant; ranging from 50% to 62%. The experts' precision proves the precision values that were gained from GoogleTranslate -based evaluation. Two experts, Sadam and Adeel are Arabic Language specialists who gave 55% and 50% of satisfaction. The other evaluators are native Arabic speakers, and their rate of satisfaction ranges from 57% to 62%.

In [8], [43] the manual evaluation yields 76%, 80% average precision, respectively. The manual evaluation depends on the assessors' point of view and the assessors' knowledge. In the manual evaluation accomplished in this research, the difference between the experts and the native speakers' decisions in whether the words are related words (hyponym, hypernym, plural) or synonyms affected the final precision. For example, for the noun "نوع type" the system returned "نوع, نمط, طراز, رمز symbol" as synonyms, Sana wrote five as correct synonyms, excluded "رمز symbol" whereas Adeel wrote four, and she excluded "رمز symbol" and "فِرَق sects". Adeel considered "فِرَق sects" as a hyponym of the word "نوع type". Another difference between the speakers' judgment and the experts' judgment was the plural, the speakers considered the plural as synonyms, for example, that VSyn generated the following synonyms for the word "area":

منطقه	منطقه	مدينة	شباب	ولاية	ولايات	مناطق	عديد
Area	Area	City	youth	State	States	Areas	numerous

Nour considered "areas" as synonymous to "area", whereas, Sadam excluded it. Sadam also excluded the word "states".

5.2.5. Recall and Precision Final Results

Table 4 depicted that in Almaany based evaluation, the recall was somehow low (36%), but the precision was significant (comparing with the precision values obtained from the publications in the field as shown in Figure 18). The recall reflects the fact that among all the synonyms found for a noun, 36% of them were returned, whereas the precision demonstrates the fact that among the returned synonyms by our system 46% of them were relevant. Both the Google Translate based evaluation and the manual evaluation showed that more than half of the generated elements in the answer set are correct synonyms, and the Google Translate based evaluation showed that around half of the synonyms found in Google Translate were retrieved by our method.

Regarding the tf.idf recall and precision values, which should be compared with the Google translate OWS recall and precision values, Table 4 shows 11% difference in the recall and 10% in the precision. This difference is significant, and it proves our claim that the accuracy of the synonyms extraction improves by linking the nouns to their semantic context.

5.3. Comparison with State-of-the-art Models

The performance of the NBDV model should be compared against the performance of the state-of-the-art models in the same field, such as the CBOW, SG, and GloVe. The evaluation results of these models were mentioned in [10], and to unify the experiment conditions, we used the same dataset that was used [10], and we used the same word similarity tasks and the same statistical models. The following points summaries the aspects we consider to unify the experiment conditions:

- In [10], the authors performed a series of experiments that include: the word analogy task, the words similarity, and the use of GloVe in NER. And, because the OWS is a weighting scheme whose effect directly affected the word similarity between two nouns in the NBDV model, then we choose the comparison of the word similarity to be the base of the comparison between our model and the state-of-the-art models.
- In [10], the results showed that the GloVe model overtook the state-of-the-art models, such as the SVD, SVD-S, SVD-L, CBOW, and SG. Therefore, we need only to compare the word similarity between our model and the GloVe model.
- In [10] the authors used five datasets of the English language and obtained the most significant results on the largest corpora (Common Crawl corpus), which contains 42 billion terms, as appeared in table 3 in [10]. Thus, we chose this corpus in our comparison experiment. Also, the authors employed five word-similarity models, WordSim-353 [49], MC [50], RG [51], SCWS [52], and RW [53]. From these models, we chose the recent two tasks, the SCWS, and RW.

The Spearman rank correlation results of the word similarity models over the generated similarities from the NBDV and GloVe appears in Figure 15. The results

showed that our model's Spearman rank correlation was less than the GloVe Model's Spearman rank correlations in SCWS by 0.2 and greater than the GloVe Model's Spearman rank correlations by 0.5 in RW similarity. These results are roughly convergent, but the time efficiency improvement of the NBDV is more significant as it appears in the next section.

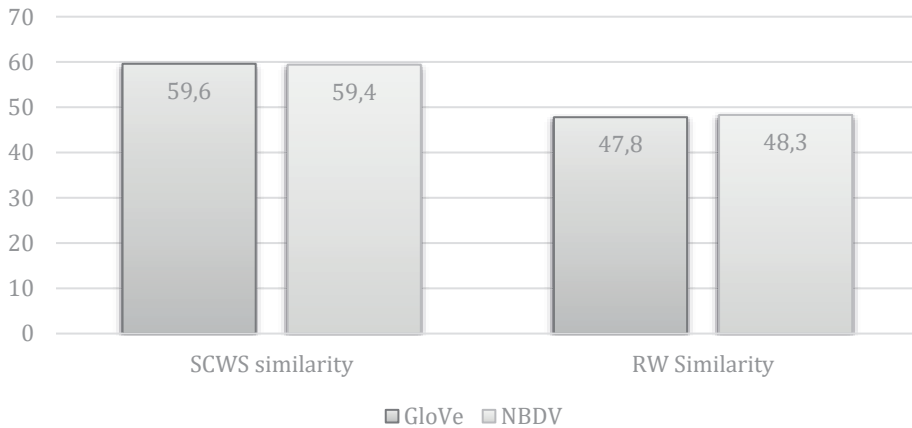


Figure15. The Spearman Rank Correlation Results of the Word Similarity Models over the Generated Similarities from the NBDV and GloVe.

5.4. Time Complexity Analysis

Assuming that the number of nouns in the whole corpus is N , the number of verbs in the entire corpus is v , and the number of all terms in the corpus is n . According to the NBDV method, to find the synonyms of the noun x , the necessary computational steps are listed in Table 7:

The worst-case time complexity in step 8 is $O(N.v.n)$, this occurs if $y = v$ and $j = N$, the meaning of $y = v$ is that all the verbs in the dataset appeared with the noun x , and the meaning of the $j = N$ is that all the nouns in the dataset are sharing the set of verbs stored in S_{nv} . Actually, these conditions are impossible to happen because in real languages we cannot find one verb that comes with all the nouns or all the nouns share a specific set of verbs, so we can consider y, j as constant, which means that the total complexity of the NBDV method will be $O(j.y.n) + O(j.n) \Rightarrow O(n)$. Figure 16 supports our claim regarding the y possible value, the number of shared verbs processed by the OWS in every run of the NBDV system was counted, and the maximum obtained value of y is 829, the average value of y is 186 verb, and in 63% of the runs, the value of y was less than 200. Regarding j , the maximum value of j recorded in our experiment was 521. Figure 17 shows that in 72% of the NBDV runs, the number of processed nouns is less than 100, and a very small ratio of runs processed a high number of nouns (10% of runs processed more than 200 nouns).

In the NBDV method that hires the traditional tf-idf weighting scheme, the worst case is allows occurred, which means that step number eight will always need $O(N.v.n)$. Also, the worst case in the Synonyms Detection phase will always be $O(j.n)$. In addition, in the tf.idf version of the NBDV model, the values of n and v are significant, and we can not ignore them (the ratio of v in Kalimat is 30%, and the ratio on n is 56%).

The NBDV operation		Expected time	Description
OWS phase	1) Extracting the set of verbs S_{nv} adjacent to the noun n , assume that the number of extracted verbs is y	$O(n)$	Scanning all the corpus elements with n number of terms.
	2) Computing each parameter mentioned in equations 2,4, and 5	$O(n)$	
	3) Computing the OWS weight	$O(1)$	
	4) Constrcting of the $\vec{x}$, Repeat step 2 and 4 for each verb $\in S_{nv}$	$O(y.n)$	In the worst-case $O(v.n)$ If $v = y$.
	5) Computing the orbit range (orbit in equation 8)	$O(1)$	
	6) Dividing the $\vec{x}$ vector components in sets according to the value of orbit and create the $s1, s2, s3, s4$	$O(y)$	
	7) Take $s1, s2, s3$ and extract all the distinctive nouns x_i adjacent to verbs appeared in $s1, s2, s3$. Assume the number of extracted nouns is j	$O(y.n)$	In the worst-case $O(v.n)$ If $v = y$.
	8) Repeating steps 2,3, and 4 for each noun extracted in 7, computing $\vec{x}_i$	$O(j.y.n)$	In the worst case $O(N.v.n)$ If $y = v$ and $j = N$
	Total OWS Complexity	$O(j.y.n)$	The max values of the complexity from step 1 - 8
Synonyms Detection	9) Computing $\text{sim}(\vec{x}, \vec{x}_i)$, equation 8	$O(j)$	
	10) Extracting the synonyms, if $\text{sim}(\vec{x}, \vec{x}_i) > 0.18$	$O(j.n)$	In the worst case $O(N.n)$ If $j = N$.

Table 7. Time Complexity Analysis of the NBDV model

Table 7 and Figure 16, 17 depicted the time analysis of the NBDV method and showed the achieved efficiency improvement. To be more accurate, the average number of verbs processed was 186 verbs for each noun, and the maximum number of verbs processed was 839 for the noun “عمل work”. Thus, in our method, the

determination of the semantic relations between a specific noun and the other nouns found in the corpus is performed by processing (weighting) 186 verbs appeared with that noun. Comparing with the tf.idf [17], the improvement in the time consuming came in the terms weighting step and in the similarity computations between the nouns.

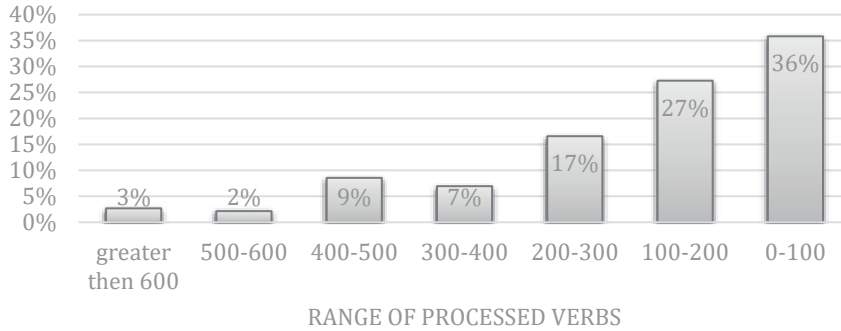


Figure16. The Ratio of Processed verbs in every Run of 564 Runs

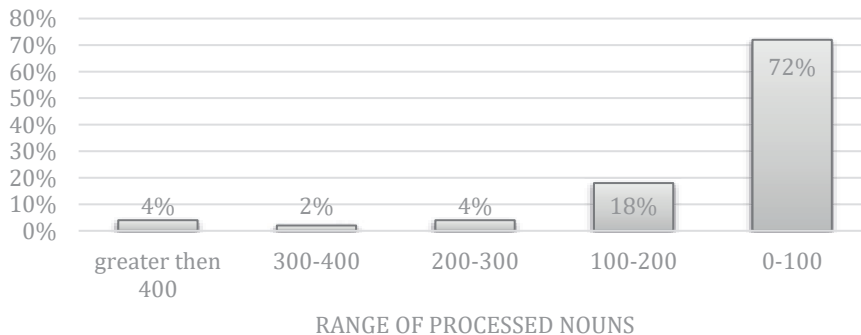


Figure 17. The Ratio of Processed Nouns in every Run of 564 Runs

5.5. Relevancy Comparison with Other Publications in the Field

In the previous section, the time complexity analysis of the NBDV methods showed that the method needs $O(n)$ to extract the synonyms of a specific noun. However, an accuracy comparison of our method with other publications in the field is necessary to show that we have not enhanced the efficiency at the expense of precision. Figure 18 presents a comparison between the results mentioned in Figures 9, 10, 11, 12, and Table 4, with other research in this field. In [9], [7], [38], and [6] the precision calculations are presented in a clear manner. The authors of these references

experienced different approaches of synonyms extraction (Henriksson used enhanced distributional hypothesis model, Leeuwenberga used Statistical approaches with relative cosine similarity, Lonneke used machine translation approach, Lobanova used learning approach, and Minkov used graph-based approach)

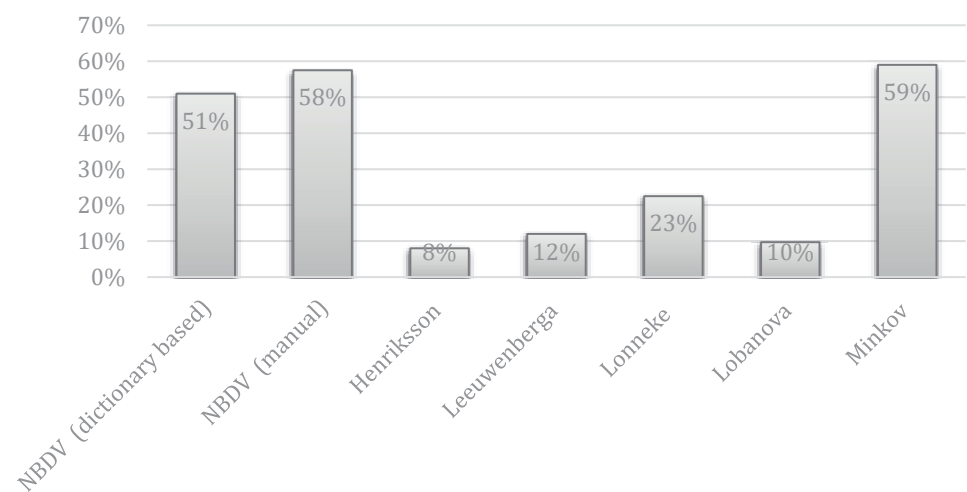


Figure 18. Precision Comparison with Existing Synonyms Extraction Systems

Figure 18 reveals that the precision of the NBDV was significant compared with other statistical methods used for synonyms extraction. The VSyn system obtained 51% average precision in the dictionary-based evaluation in which the automatic synonyms were matched against the synonyms taken from online dictionaries. This precision value was less than the precision obtained by Minkov and Cohen [6] by 8% and greater than the precision of the other systems. Minkov and Cohen [6] used a path constrained graph, and the problem with this graph is the time required to construct the graph and the space needed to store the graph. The graph stores each term in the corpus with all existing edges that link this term to the other terms found in the corpus, add to this the time needed to follow all the paths that lead to the terms. So, the improvement in the time obtained in the NBDV method is much more important than the 8% loss of accuracy, especially that the precision of the NBDV method was more than 50%.

6. Discussion

6.1. Factors Affected the Precision

The evaluation of the NBDV model based on the OWS weighting scheme shows significant efficiency and accuracy improvement. And, we have strong thought that the relevancy results should be more significant, but some factors affected the

extraction process and caused a kind of degradation in the relevancy values. These factors are summarised in three factors:

The first factor was the existence of a set of nouns that are not synonyms (sometimes antonyms) and shared a set of distinctive verbs. For example, the direction names (north, south, east, and west), the month names, and the currency names. To see the effect of such kind of nouns, consider the generated synonyms set for the noun “جنوب South”, the VSyn system produced the following candidate synonyms:

جنوب	شمال	شماليه	شرق
south	north	north	east

The nouns in the sample above represent the four directions names, and they are not synonymous to each other, but the question is why the system returned them. To answer this question, we returned to our results and scanned the verbs appeared with the noun south, see the following samples from our corpus:

تهب الرياح شمالا	The wind <u>blows</u> to the north
شق طريقة الى الشمال	<u>Cleave</u> its road to the north
يمتد من شمال الكوكب	<u>Extend</u> from the north of the planet
تقع شمال الصين	<u>located</u> in the north of China
يبعد نحو 77 كيلو متر الى الشمال	about 77 km to the north
يبدو في شمال الكرة الارضية	<u>Appear</u> in the North of the global
تتجه نحو الشمال	heading to the north
تظهر شمال	<u>appeared</u> in the north
التي كانت تتمركز شمالا	Which was <u>stationed</u> north
تبدأ قافلة الشمال الاول بدخول	the first north convoy <u>starts</u> to enter

The replacement of the word north with south, east, or west in these sentences is acceptable, and lexically the sentences remain correct. This means that the verbs (underlined above) are common for these nouns (north, south, east, west) and they have a convergent effect on the weighting computation. Therefore, the NBDV method considered north, south, east, and west as synonyms. The verb “تتجه head” appeared with these four nouns and got significant weights. The weight of this verb with respect to the north was 0.32, and with respect to the south was 0.283, and with respect to the east was 0.2942, and with respect to the west was 0.2678. These weights and the weights of other common verbs produced high similarity between the nouns north, south, east, and west.

The second factor that degraded the precision in the case of the dictionary-based evaluation was the synonyms set of the base dictionary; in some cases, it was empty. See Table 8:

Id	Noun	Almaany Set of synonyms	The Automatically generated synonyms
N6	دينار	Not Mentioned	يورو, سنه, طريق, وان, ريال, طاقه, دينار
N17	شركه	Not Mentioned	شركه, شركات, وزاره, منظمه, مؤسسه, عام, مشاركه

N204	بيانات	Not Mentioned	بيانات, معلومات, نتائج, طلاب, كافه, نسبه, مصادر
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Table 8. Sample of the Nouns that have Empty Synonyms Set in Almaany-based Evaluation

The nouns “دينار Dinar”, “بيانات data”, “شركة corporation” did not have synonyms in Almaany dictionary. In such a case, the precision computation is not possible because no base set of synonyms is found, so we neglected them during the precision computation. The negligence in such cases distorts the results (appeared in Figure 9 and 10) because the precision for the same nouns in the manual evaluation that was accomplished by the Arabic language experts showed reasonable values. See Table 9:

ID	The Automatically generated synonyms	Adeel Evaluation precision	Firas Evaluation precision	Saddam Evaluation precision
N6	يورو, سنه, طريق, وا, دينار, ن, ريال, طاقه	43%	43%	43%
N17	شركة, شركات, وزاره, منظمه, مؤسسه, عام, مشاركه	57%	86%	71%
N204	بيانات, معلومات, نتائج, طلاب, كافه, نسبه, مصادر	57%	71%	57%

Table 9. Precision Evaluation of the Nouns Appeared in Table 8

The third factor that also affected our precision value was the mistakes found in the part of speech tagging produced in the Kalimat dataset, for example, the candidate synonyms set produced by our systems for the noun "constitution الدستور" contains the following: { قرار, قانون, دستور, ايضا, كلمه, ثلاثه, مشروع }, the word "ايضا" is a Stopword means “also” or “as well”. The mistake in this case directly affected the precision because it happened in the synonyms set. Also, some tagging mistakes affected the weighting phase of our system, for example, the verbs list of the noun "حروب" contains the noun “دخان smoke”.

6.2. NBDV Advantages and Disadvantages

The NBDV method of synonyms extraction has the following merits:

- **The semantic investigation of the text contents:** the NBDV synonyms extraction method used the distinctive verbs to find the semantic relations that link the nouns with their semantic context. The OWS draws an orbiting space in which the verbs are spin in orbits around the noun located in the center of this orbiting space. The verbs that have strong semantic relation to the center will be placed in the inner orbits, and the first three orbits will be the most important orbits to determine the nouns' semantic context.
- **The efficiency constraints are considered in the NBDV method.** Note that the design of the NBDV involved the use of a new weighting scheme (OWS)

that substituted the traditional tf-idf weighting scheme used in the CBoW and SG models [7], [17], [18]. The tf-idf weighting scheme in ASE is time-consuming and takes $O(N.v.n)$ as we see in the evaluation section, and the OWS scheme processes the weighing phase in linear time (see Figures 16, 17, and Table 7).

However, the NBDV have the following limitations:

- **NBDV does not solve the synonyms of verbs and adjectives.** In the design of the NBDV for synonyms extraction, we used the verbs to find the synonyms of the nouns, but at this stage, we can not pretend that if a reverse process can help to identify the verbs' synonyms, and we will transfer this question to future research.
- **The NBDV model under the Algorithm 1 design cannot process the word orders that end with the verbs (OSV, SOV).** The OWS scheme, upon which the NBDV method is built, assumes that the verbs precede the nouns (Subject, Object). This drawback prohibited the use of the NBDV in certain languages such as Hindi, Japanese, and Korean. However, simple modifications in the design of Algorithm 1 will cover this problem. For example, building a co-occurrence matrix of the corpus and processing the verbs that precede or follow the noun.
- **The low obtained recall for the ancient nouns of the Arabic language.** The ancient nouns are important because they are found in AL Quran Al Kareem, which is the source of the Islamic religion. The system developed based on the NBDV method succeeded to return only 36% of the synonyms found in the Almaany dictionaries, and this reflects the gap between the shallow vocabulary set used in the Arabic language media and the rich vocabulary set found in the Arabic language literature.

7. Conclusion and Future Perspective

7.1. Achievements

In this research, an automatic synonyms extraction method is proposed, designed, and implemented. The method uses an unsupervised learning strategy to extract nouns synonyms. The method substituted the traditional tf-idf weighting scheme with an efficient weighting scheme that weights the terms based on their semantic relation with the noun being processed. The targeted contribution of this research is to improve the efficiency of the extraction process and at the same time, obtaining significant precision. This contribution is achieved improving by the following achievements,

Robust weighing scheme: the evaluation of the OWS precision and recall showed that the OWS overtakes the traditional tf.idf weighing scheme. The OWS recall was greater than the tf.idf recall by 11%, and the OWS precision was greater than the tf.idf precision by 10%.

Efficiency improvements: the average number of terms needed to be processed for each run was 186 (instead of the processing of the whole terms found in the

corpus). This average number is supported by a time complexity analysis that showed that the processing of each run of the NBDV method is accomplished in linear time. This point shows that the semantic context linking was significant and increased the extraction accuracy.

Significant precision: the average precision, which was evaluated based on well-known online dictionaries for the Arabic language, was significant (51%), and human experts who showed that 57.5 of the answer set contents are correct proved this precision.

The drawback that emerged during the evaluation was the low recall obtained when we used the Almaany dictionary as the base of evaluation. The NBDV method succeeded to return only 36% of the synonyms found in the Almaany dictionaries, and this reflects the gap between the shallow vocabulary set used in the Arabic language media and the rich vocabulary set found in the Arabic language literature.

7.2. Future perspective

The modification and enhancement of the OWS to find the verbs synonyms are necessary, our plans involve the exploiting of the OWS semantic context to investigate the verb synonyms. Also, measuring the effect of the OWS schemes in other text mining applications such as the named entity recognition, pattern recognition, and information retrieval is important to generalize this scheme. And, If the obtained results resemble the results achieved in the synonyms extraction field, then the OWS can replace the traditional tf-idf weighting scheme in the text mining applications which will improve the efficiency of such applications.

8. Compliance with ethical standards

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual participants included in the study.

References

- [1] S. Webb, "The effects of synonymy on second-language vocabulary learning," *Reading in a Foreign Language*, vol. 19, no. 2, pp. 120-136, 2007.
- [2] H. Schütze, C. D. Manning and P. Raghavan, *Introduction to information retrieval*, vol. 39, Cambridge University Press, 2008.
- [3] L. Barak, I. Dagan and E. Shnarch, "Text Categorization from Category Name via Lexical Reference," in *NAACL-Short '09 Proceedings of Human*

- Language Technologies: The 2009 Annual Conference of the North American Chapter of the Association for Computational Linguistics, Companion Volume, Boulder, 2009.
- [4] D. Dinh and L. Tamine, "Identification of concept domains and its application in biomedical information retrieval," *Information Systems and e-Business Management*, vol. 13, no. 4, p. 647–672, 2015.
 - [5] M. AlMaayah, M. Sawalha and M. Abushariah, "Towards an automatic extraction of synonyms for Quranic Arabic," *International Journal of Speech Technology*, vol. 19, no. 2, 2016.
 - [6] E. Minkov and W. W. Cohen, "Graph based similarity measures for synonym extraction from parsed text," in *Workshop Proceedings of TextGraphs-7 on Graph-based Methods for Natural Language Processing Association for Computational Linguistics*, Jeju, Republic of Korea, 2012.
 - [7] A. Leeuwenberga, M. Vela, J. Dehdar and J. v. Genabith, "A Minimally Supervised Approach for Synonym Extraction with Word Embeddings," *The Prague Bulletin of Mathematical Linguistics*, vol. 105, no. 1, p. 111–142, 2016.
 - [8] A. Benabdallah, M. Abderrahim and M. Abderrahim, "Extraction of terms and semantic relationships from Arabic texts for automatic construction of an ontology," *International Journal of Speech Technology*, vol. 20, no. 2, pp. 289-296, 2017.
 - [9] A. Henriksson, H. Moen, M. Skeppstedt, V. Daudaravicius and M. Duneld, "Synonym extraction and abbreviation expansion with ensembles of semantic spaces," *JOURNAL OF BIOMEDICAL SEMANTICS*, vol. 5, no. 6, 2014.
 - [10] J. Pennington, R. Socher and C. Manning, "Glove: Global vectors for word representation," in *Proceedings of the 2014 conference on empirical methods in natural language processing (EMNLP)*, 2014.
 - [11] Z. He, S. Deng and X. Xu, "A Fast Greedy Algorithm for Outlier Mining," Ng WK., Kitsuregawa M., Li J., Chang K. (eds) *Advances in Knowledge Discovery and Data Mining. PAKDD 2006. Lecture Notes in Computer Science*, Volume 3918. Sprin, vol. 3918, 2006.
 - [12] K. Church and P. Hanks, "Word association norms, mutual information, and lexicography," *Computational linguistics*, vol. 16, no. 1, pp. 22-29, 1990.
 - [13] C. D. Manning and H. Schütze, *Foundations of statistical natural language processing*, MIT press, 1999.
 - [14] L.-C. Yu, L. Lung-Hao, Y. Jui-Feng, S. Hsiu-Min and L. Yu-Ling, "Near-synonym substitution using a discriminative vector space model," *Knowledge-Based Systems*, vol. 106, pp. 74-84, 2016.

- [15] D. Inkpen, "A statistical model for near-synonym choice," *ACM Transactions on Speech and Language Processing (TSLP)*, vol. 4, no. 1, p. 2, 2007.
- [16] L. C. Yu, C. H. Wu, R. Y. Chang, C. H. Liu and E. Hovy, "Annotation and verification of sense pools in OntoNotes," *Information Processing & Management*, vol. 46, no. 4, pp. 436-447, 2010.
- [17] A. Imsombut, "A statistical approach for semantic relation extraction," in *In 2009 Eighth International Symposium on Natural Language Processing*, 2009.
- [18] T. Mikolov, K. C. Chen, G. Corrado and J. Dean, "Efficient Estimation of Word Representations in Vector Space," *arXiv preprint arXiv*, vol. 1301, no. 3781, 2013.
- [19] A. Alsaeed, "A survey of term weighting schemes for text classification," *International Journal of Data Mining, Modelling and Management*, vol. 12, no. 2, pp. 237 - 254, 2020.
- [20] J. Pennington, S. Richard and M. Christopher, "Glove: Global vectors for word representation," in *Pennington, Jeffrey, Richard Socher, and Christopher Manning. "Glove: GlobalProceedings of the 2014 conference on empirical methods in natural language processing (EMNLP)*, 2014.
- [21] G. Miller, R. Beckwith, C. Fel, . D. Gross and K. Miller, "Introduction to WordNet: An On-line Lexical Database," *International Journal of Lexicography*, vol. 3, no. 4, p. 235–244, 1990.
- [22] C. Fellbaum, "WordNet and wordnets," *Encyclopedia of Language and Linguistics*. Elsevier, pp. 665-670, 2005.
- [23] C. Fellbaum and P. Vossen, "Connecting the Universal to the Specific: Towards the Global Grid," *Lecture Notes in Computer Science*, vol. 4568, 2007.
- [24] C. Fellbaum and P. Vossen, "Challenges for a multilingual wordnet," *Lang Resources & Evaluation*, vol. 46, no. 2, pp. 313-326, 2012.
- [25] S. Elkateb, W. Black, H. Rodríguez, M. Alkhalifa, P. Vossen, A. Pease and C. Fellbaum, "Building a WordNet for Arabic," in *In Proceedings of the fifth international conference on language resources and evaluation (LREC 2006)*, 2006.
- [26] S. S. Scott and S. Matwin, "Text classification using Word Net hypernyms," 1998.
- [27] S. Bloehdorn and A. Hotho, "Boosting for text classification with semantic features," in *In Proceedings of the MSW 2004 workshop at the 10th ACM SIGKDD conference* , 2004.

- [28] L. Jianqiang, Z. Yu and L. Bo, "Fully Automatic Text Categorization by Exploiting WordNet," in *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 2009.
- [29] Q. Luo, E. Chen and H. Xiong, "A semantic term weighting scheme for text categorization," *Expert Systems with Applications*, vol. 38, no. 10, pp. 12708-12716, 2011.
- [30] S. Bloehdorn, R. Basili, M. Cammisa and A. Moschitti, "Semantic Kernels for Text Classification Based on Topological Measures of Feature Similarity," *Hong Kong*, 2006.
- [31] P. Wang and C. Domeniconi, "Building semantic kernels for text classification using wikipedia," *Las Vegas*, 2008.
- [32] G. Evgeniy and M. Shaul, "Harnessing the Expertise of 70,000 Human Editors: Knowledge-Based Feature Generation for Text Categorization," *Journal of Machine Learning Research*, pp. 2297-2345, 2007.
- [33] C. J. Crouch, "An approach to the automatic construction of global thesauri," *Information Processing and Management*, vol. 26, no. 5, p. 629–640, 1990.
- [34] H. Chen and K. Lynch, "Automatic construction of networks of concepts characterizing document databases," *IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS*, vol. 22, no. 5, pp. 885 - 902, 1992.
- [35] R. Lakshmi and S. Baskar, "Novel term weighting schemes for document representation based on ranking of terms and Fuzzy logic with semantic relationship of terms," *Expert Systems with Applications*, vol. 137, pp. 493-503, 2019.
- [36] I. Alsmadi and G. K. Hoon, "Term weighting scheme for short-text classification: Twitter corpora," *Neural Computing and Applications*, vol. 31, p. 3819–3831, 2019.
- [37] D. Lin, S. Zhao, L. Qin and M. Zhou, "Identifying synonyms among distributionally similar words," In *IJCAI*, p. 1492–1493, 2003.
- [38] v. d. P. Lonneke and T. Jorg, "Finding Synonyms Using Automatic Word Alignment and Measures of Distributional Similarity," in *Proceedings of the COLING/ACL 2006 Main Conference Poster Sessions*, Sydney, 2006.
- [39] R. Ageishi and T. Miura, "Automatic Extraction of Synonyms Based on Statistical Machine Translation," in *2010 22nd IEEE International Conference on Tools with Artificial Intelligence*, Arras, France, 2010.
- [40] G. Grefenstette, *Explorations in Automatic Thesaurus Discovery*, Springer US, 1994.

- [41] P. P. Senellart and V. D. Blondel, "Automatic Discovery of Similar Words," in *Survey of Text Mining , Clustering, Classification, and Retrieval*, Springer, 2004.
- [42] G. Salton and M. J. McGill, *Introduction to modern information retrieval*, McGraw-Hill, 1986.
- [43] L. Zhang, J. Li and C. Wang, "Automatic synonym extraction using Word2Vec and spectral clustering," in *Control Conference (CCC)*, 2017 36th Chinese, Dalian, 2017.
- [44] Y.-L. Chen and Y.-T. Chiu, "An IPC-based vector space model for patent retrieval," *Information Processing & Management*, vol. 47, no. 3, pp. 309-322, May 2011.
- [45] Q. A. Al-Radaideh and D. Q. Bataineh, "A Hybrid Approach for Arabic Text Summarization Using Domain Knowledge and Genetic Algorithms," *Cognitive Computation*, vol. 10, no. 4, p. 651–669, 2018.
- [46] E. Hanandeh, "Building an Automatic Thesaurus to Enhance Information Retrieval," *IJCSI International Journal of Computer Science Issues*, vol. 10, no. 1, 2013.
- [47] Y. Sankarasubramaniam, K. Ramanathan and S. Ghosh, "Text Summarization Using Wikipedia," *Information Processing & Management*, vol. 50, no. 3, p. 443–461, 2014.
- [48] F. M. Ba-Alwi, G. H. Gaphari and F. N. Al-Duqaimi, "Arabic Text Summarization Using Latent Semantic Analysis," *British Journal of Applied Science & Technology*, vol. 10, no. 2, pp. 1-14, 2015.
- [49] L. Finkelstein, E. Gabrilovich, Y. Matias, E. Rivlin, Z. Solan, G. Wolfman and E. Ruppín, "Placing search in context: The concept revisited," *The concept revisited. ACM Transactions on information systems*, vol. 20, no. 1, pp. 116-131, 2002.
- [50] G. A. Miller and W. G. Charles, "Contextual correlates of semantic similarity," *Language and cognitive processes*, vol. 6, no. 1, pp. 1-28, 1991.
- [51] H. Rubenstein and J. B. Goodenough, "Contextual correlates of synonymy," *Communications of the ACM*, vol. 8, no. 10, pp. 627-633, 1965.
- [52] E. H. Huang, R. Socher, C. D. Manning and A. Y. Ng, "Improving word representations via global context and multiple word prototypes," in *In Proceedings of the 50th Annual Meeting of the Association for Computational Linguistics*, 2012.
- [53] T. Luong, R. Socher and C. Manning, "Better word representations with recursive neural networks for morphology," in *In Proceedings of the*

Seventeenth Conference on Computational Natural Language Learning, 2013.

- [54] A. Lobanova, J. Spenader, T. v. d. Cruys, T. v. d. Kleij and E. T. K. Sang, "Automatic Relation Extraction Can Synonym Extraction Benefit from Antonym Knowledge?," in 2009 Proceedings of WordNets and other Lexical Semantic Resources - between Lexical Semantics, Lexicography, Terminology and Formal Ontologies. , 2009.
- [55] R. Brandow, M. Karl and F. R. Lisa, "Automatic condensation of electronic publications by sentence selection," *Information Processing & Management*, vol. 31, no. 5, pp. 675-685, 1995.
- [56] T. Sakai and K. Sparck-Jones, "Generic Summaries for Indexing in Information Retrieval," in *Proceedings of the 24th annual international ACM SIGIR conference on Research and development in information retrieval*, 2001.
- [57] J. M. Perea-Ortega, E. Lloret, L. A. Ureña-López and M. Palomar, "Application of Text Summarization Techniques to the Geographical Information Retrieval Task," *Expert systems with applications*, vol. 40, no. 8, pp. 2966-2974, 2013.



EAFP: Enterprise Architecture Fusion Process

Nedim Dedić

nd@nedimdedic.com

*Salzburg AG für Energie, Verkehr & Telekommunikation
Salzburg, Austria*

Abstract

Enterprise Architecture (EA) is well-researched and well-developed concept, and even a two decades ago there were a plenty of frameworks in this field. However, the functional integration of EA at operational and tactical levels in organisations is identified as one of the biggest challenges faced by many Enterprise Architects today. To overcome this challenge, a comprehensive literature review on EA is conducted, which resulted with the identification of the knowledge gap. To overcome this gap, Enterprise Architecture Fusion Process (EAFP), a novel practical approach that demonstrates the capability of integrating EA activities into operational and tactical activities in respective organisation is developed, validated, and presented in this paper.

Keywords: enterprise architecture, architecture fusion, demand management process

1. Introduction

Enterprise Architecture (EA) is the well-established concept, which is covered by a plenty of publications and frameworks trying to define, organize, and standardize this field. However, as identified in Chapter 2., one of the biggest challenges faced by many Enterprise Architects today is the functional integration of EA at operational and tactical levels in organisations. Despite the fact that the most of the frameworks analysed in this paper, which are as well identified as the most used and most accepted by industry professionals and academia, do the job they are intended to, none of them covers the aspects on how to functionally integrate and fuse EA activities with existing processes of the respective organisation. This, and the fact that he faced the same challenges during his work as Domain and Enterprise Architect, motivated the author of this paper to develop appropriate approach that fills the identified knowledge gap and extends existing practical knowledge in the field of EA.

This paper introduces Enterprise Architecture Fusion Process (EAFP), a novel practical approach that demonstrates the capability of integrating EA aspects into existing operational and tactical activities in respective organisations. The aim of EAFP itself, however, is not to be yet another EA framework, but rather practical extension to the existing EA frameworks. It is intended to serve as a guide and as an

example for organisations that want to incorporate appropriate EA activities into their existing processes, meaning, EAFP is rather descriptive than prescriptive.

The overall structure of the paper is as follows. This chapter introduces the paper and aims of the paper. The second chapter describes Enterprise Architecture and the most common concepts and frameworks in this field, identifies the knowledge gap, and provides motivation for the development of Enterprise Architecture Fusion Process, covering the challenges that need to be addressed. Third chapter describes the process of EAFP development, explaining the activities and methods used in the scope of research approach that was used to develop EAFP. The same chapter provides information about evaluation method and primary mean used to assess the success of EAFP. The proposed final version of EAFP is described in chapter number four, where every process and subprocess is explained in detail, covering various aspects for each of them, such as inputs, outputs, people, and tools or equipment. Chapter number five provides conclusion and information about potential future work.

2. Related work

The first thoughts about the concept we today refer as Enterprise Architecture date back to the 60s [1], [2]. In the same time, there is a multitude of publications that define and describe this concept from various perspectives [3], [4], [5], [6], [7], [8], [9]. However, there is still no single definition of the Enterprise Architecture concept that could be considered as the overall consensus [10]. The aim of this paper is not to provide a comprehensive explanation or a new, updated definition of EA; however, for the better understanding of this paper, Enterprise Architecture is defined as a discipline that: i) defines, organises, standardizes, and documents the whole infrastructure and all important elements of the respective organisation, covering relevant domains such as business, digital, physical, or organisational; and ii) the relations and interactions between elements that belong to those domains, such as processes, functions, applications, events, data, or technologies.

Enterprise Architecture is well researched and well-developed concept, and even a two decades ago there were a plenty of frameworks in this field [11]. Today, there are even more frameworks, however, only few of them, such as The Open Group Architectural Framework (TOGAF) [3] and The Zachman Framework [7], got massive and markable attention from the industry and academia. Other frameworks such as Department of Defense Architecture Framework (DoDAF) [12] and Federal Enterprise Architecture Framework (FEAF) [13] found their home within the organisations and the industries they are intended for, however, without any evidence of being applied massively by other industries or fields. According to the several sources TOGAF is the most common EA Framework used by the organisations today [4], [14], [15].

Despite the fact that the most of analysed frameworks do the job they are intended to, and even some of them, such as TOGAF and its Architecture Development Method (ADM) go deep enough in providing coherent instructions how to develop and how to live Enterprise Architecture, none of mentioned frameworks provides solution or specific instructions on how to functionally integrate and fuse EA activities with

existing processes of the respective organisation, such as with existing demand processes for example. For example, TOGAF ADM describes a method and relevant activities for developing and managing the lifecycle of an enterprise architecture [3], however, it does not provide any reference what practical steps need to be taken to incorporate and fuse such activities into existing operational and tactical activities. The phrase “existing operational and tactical activities” refers to the activities that are performed in the scope of existing and already established processes in the respective organisation.

Establishing the Enterprise Architecture at operational and tactical levels in respective organisations is identified as one of the biggest challenges by many Enterprise Architects today [16]. One of the main reasons is the complexity of such activity, as it requires consideration of and fusion with all relevant domains and elements of the enterprise. For example, identifying and defining relevant elements, such as processes or events in the scope of business domain of specific organisation, for the sake of including appropriate enterprise architecture activities there, could be very challenging, complex and time-consuming activity [9]. Especially in the larger organisations that have complex organisational and functional structure, and in the same time legacy-based digital infrastructure. During his work as Domain and Enterprise Architect in two large companies in Austria, the author of this paper faced the same challenges as well. After analysing relevant set of literature concerned with the concept of EA and its establishment [3], [7], [9], [12], [13], [17], [18], [19], [20] and despite the fact that some provide a great overview of EA use scenarios [9], it was identified that none of them delivers applicable approach or suitable methodology to support integration of tactical and operational EA activities in respective organisation. This motivated the author of the paper to develop EAFP, a new, fully applicable, and comprehensive approach for integrating EA aspects into operational and tactical activities of the respective organisation.

3. Research Approach

A pragmatic approach to research, based on well-established design science research (DSR) approach [21], was used to develop Enterprise Architecture Fusion Process (EAFP), meaning, a combination of different procedures, techniques, and methods was used to define, develop, and evaluate the concept.

3.1. Problem Identification and Motivation for further Work

The first phase of DSR included **identification of the problem and motivation for the further work**. As soon as the challenged was faced in real-world environment, a literature review, as essential method to identify what has been already written on a subject and to determine the extent to which a specific subject has been researched [22] was used as a starting research methodology to address the initially identified challenge. In this case subject was Enterprise Architecture and practical fusion of its activities and methods with existing organisational processes. In that context, a background research was conducted on existing related work concerned with the

concept of EA and its establishment. It was identified that analysed literature describes and explains EA, its scope, development methods, lifecycle activities and stakeholders, and most of the other relevant aspects quite well. However, the functional references on how to integrate and fuse EA activities and processes with existing operational and tactical activities and processes were not identified. Thus, the literature review confirmed the previously identified knowledge gap that needed to be bridged.

3.2. Defining Objectives of the Artefact

Consequently, the problem could be clearly defined and next phase of DSR could be started – namely, **definition of the objectives of the artefact**. As the problem originated from the real-world challenge where a specific solution was needed, it was easy to define the objective to be achieved, which actually reflected requirements of the solution that was needed. Thus, the next phase of the DSR, **design and development of the artefact** could be conducted.

3.3. Design and Development of the EAFP

To bridge the identified gap and to develop needed artefact, the empirical process design and process development methods were used, settled into environment identified as appropriate.

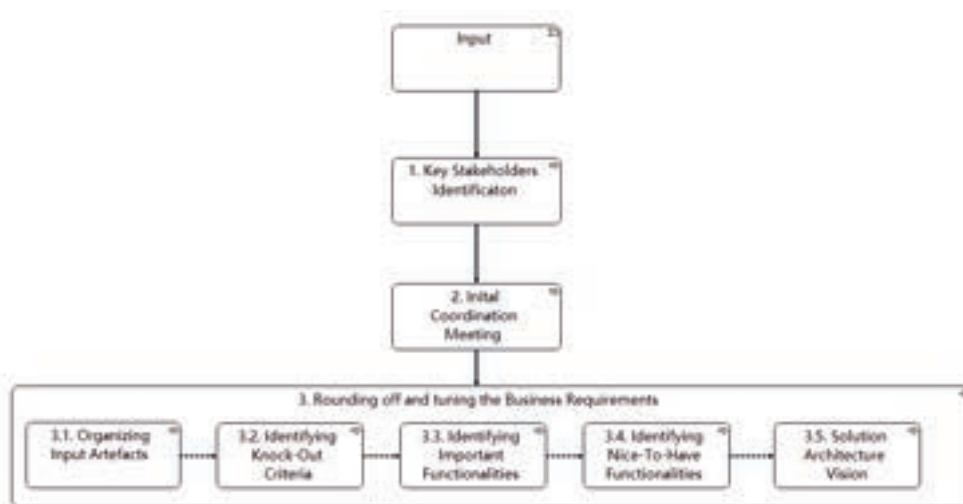


Figure 1. Initial draft of the first part of EAFP process

The first step was to identify appropriate organisational context or a discipline in which a respective fusion process would be developed and tested. Hanschke [9] identifies Demand Management (DM) as one of the appropriate fields to integrate Enterprise Architecture into. DM is a discipline that manages strategical themes and translates them into concretized tactical and operational artefacts. It is identified as

one of the most important techniques to maximize benefits for the utilities and clients, both internal and external [23]. It is a planning methodology that is used to manage, plan and forecast various types of enterprise elements, such as products and services from different types of domains, such as business or information technology [24]. In that context, Demand Management was identified as well-suitable candidate for EAFP to be demonstrated on.

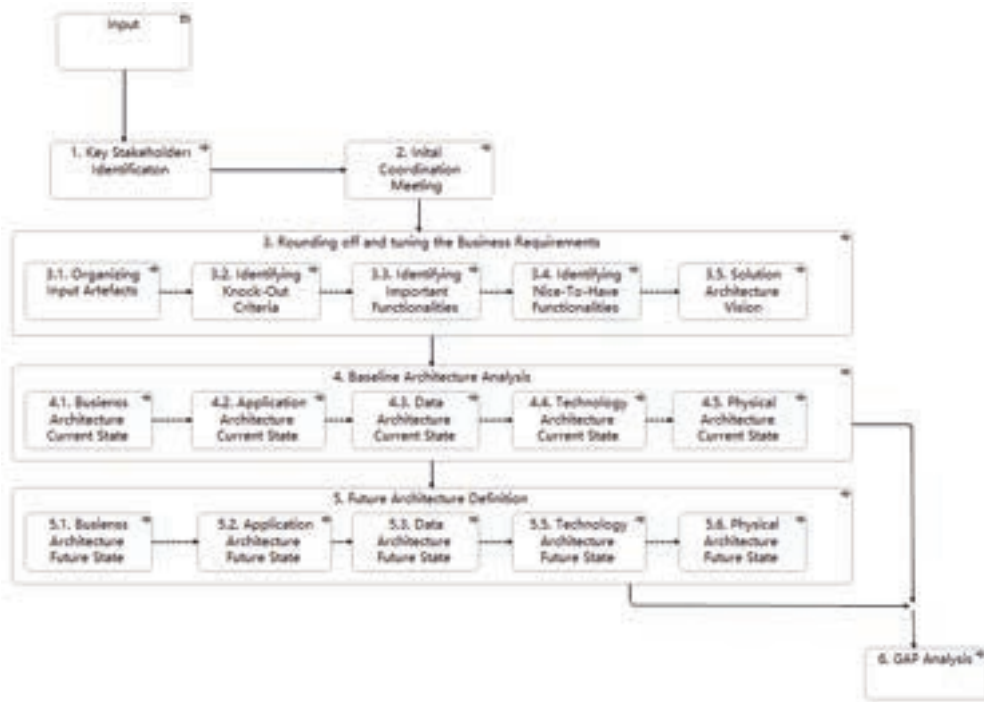


Figure 2. Extended version of the initial EAFP draft

The second step in design and development phase included identification of activities and aspects relevant in the scope of Demand Management Process (DMP) and their relation to the potential activities performed in the scope of EA. As ITIL is the most widely accepted approach to IT management and the most popular framework that exists today to deliver services [25], [26], its concept of DM, where DMP should be triggered through relevant *Input* was used as a starting point for the EAFP as well. This base is further extended with the practical aspects of IT Demand Management identified in three Austrian companies – two regional and one international. In this case, in addition to the *Input*, other activities relevant for *stakeholder collaboration to identify the requirements of wanted solution* are added to the initial draft of the first part of EAFP process (Figure 1).

Additional parallel activity to the second step in design and development phase included identification of appropriate architectural domains that might be considered in the scope of initial EAFP. This is done by analysing four EA frameworks, which

are the most accepted today: TOGAF [3], The Zachman Framework [7], [18], DoDAF [12], and FEAF [13]. Five EA domains are identified as potentially appropriate for the purpose of initial EAFP: Business Architecture, Application Architecture, Data Architecture, Technology Architecture, and Physical Architecture. These domains are then placed into conventional gap analysis scenario. This scenario includes activities to capture existing and planned architectures with the purpose to identify artefacts needed to move from baseline to wanted architecture. Initial draft of the first part of EAFP is then extended with those activities resulting with the extended version of the initial draft (Figure 2).

Appropriate EAFP activities, which follow after the process of Gap Analysis from Figure 2, were identified on the basis on authors' industrial experience (Figure 3). Those activities included two events (*E1. New Solution* and *E2. Extending Existing Solution*), two main processes (*7. Finalizing Solution Concept* and *8. Solution Selection*), and four subprocesses (*8.1. Market Research*, *8.2. Rough Selection*, *8.3. Fine Selection*, and *8.4. Final Selection*). Despite the fact, it was defined as the last step in Figure 3, *Implementation* was not considered as a part of EAFP, but rather as external activity that followed after the EAFP process is executed.

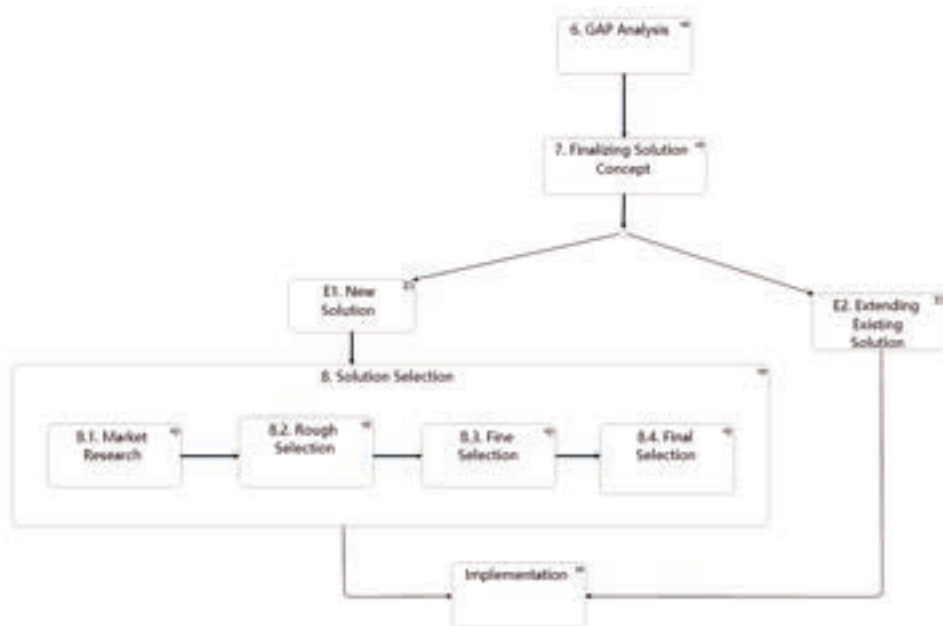


Figure 3. Activities that follow after Gap Analysis

For the purpose of evaluation, the first version of the complete EAFP, which was combination of Figure 2 and Figure 3, was then presented to the 23 IT experts (seven Domain Architects, 10 Solution Architects, and six Heads of IT Teams). A form of individual semi-structured interview was used, meaning the draft was presented and explained to the IT experts, followed by open-ended questions by interviewer that allowed unformalized discussions. EAFP is then modified according to the

suggestions and inputs from IT experts interviewed. The process that triggers EAFP is renamed from *Input* to *Solution Requirement Created* to better reflect DMP. All four solution selection subprocesses (Figure 3, processes 8.1. *Market Research*, 8.2. *Rough Selection*, 8.3. *Fine Selection*, and 8.4. *Final Selection*) are extended with additional subprocesses to reflect different activities that might be the part of those subprocesses (Figure 4). As seen from Figure 4 as well, a few additional events, identified as appropriate in regard to the new, extended version of the *Final Selection* subprocess, are also added to the first version of EAFP. This also led to the identification of one additional process – 9. *Fulfilling Conditions*, which might be relevant in the case of the event *E4. Approved under Conditions*. The external process, names as *Implementation* in Figure 3, was renamed to more specific *Implementation Planning and Governance* process.

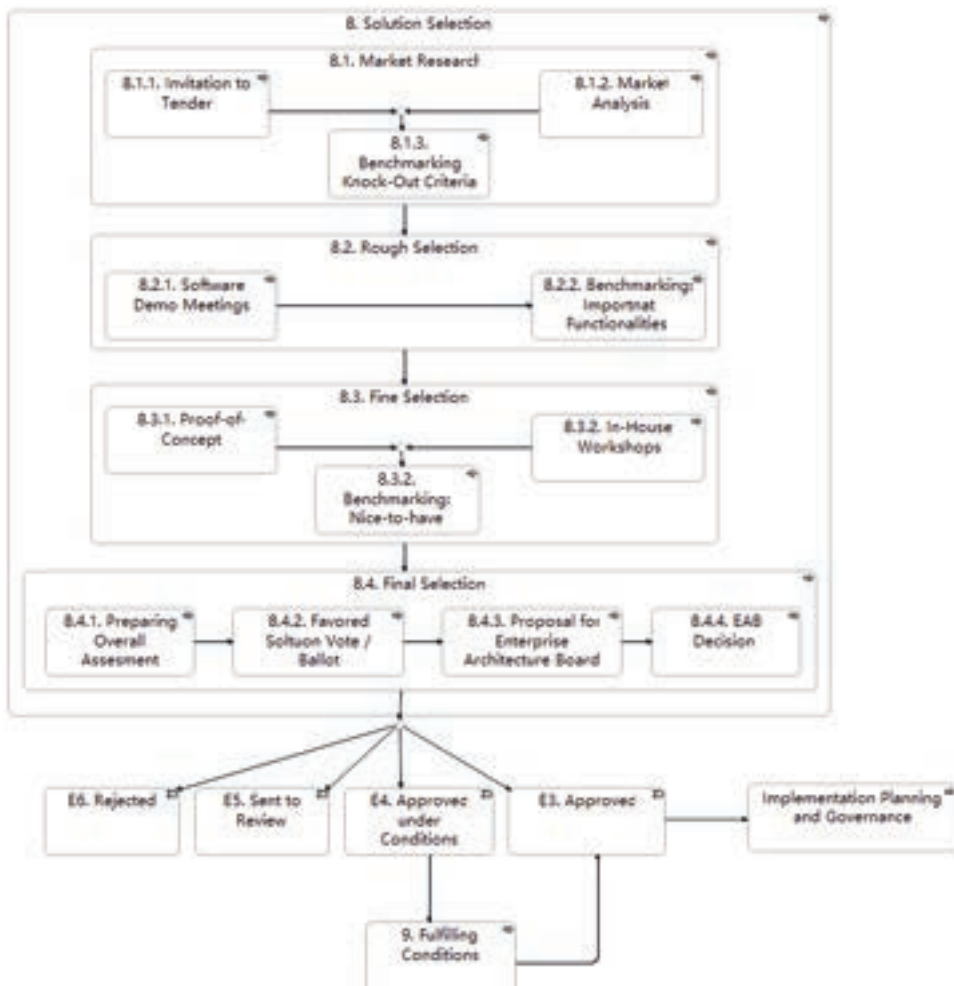


Figure 4. Extended version of the Solution Selection Process including new events

The last step covering design of complete and final version of EAFP included separation of the internal and external EAFP processes, which resulted with the final version of EAFP described in the next chapter and presented in the Figure 5.

The fourth phase of DSR included demonstration of the artefact. A hypothesis of functional concept was tested by applying previously created situation in the real-world environment, to check its efficiency. Meaning, the final version of the approach was demonstrated and validated through the real-world implementation in one Austrian regional company, where the full version of the EAFP was integrated into existing IT demand process of the respective organisation.

Fifth phase of DSR covered the **evaluation of the artefact**, where end user satisfaction, conventionally recognized as critical measure of success of Information Systems (IS) concepts [27], was used as a primary mean for assessment. A simple concept to measure the affective attitude of the end users, which were different stakeholders relevant for EA activities in the scope DM (12 Business Key Users and six Solution Designers/Architects) is used. The stakeholders that experienced EAFP during the demonstration period and which also had experience with previous IT DM environment that did not include EAFP, had a possibility to decide which of those two environment is more preferable for them. 15 stakeholders (10 Business Key User and 5 Solution Designers/Architects) stated that the IT DM process that includes EAFP is more preferable for them, as it's more transparent. Two stakeholders (both Business Key Users) had no preferences, while one stakeholder belonging to the category of Solution Designers/Architects stated that the environment without EAFP is preferred, as the EAFP itself requires additional human resources to be executed.

The presentation of the evaluation results to the six decision-making stakeholders during the fifth DSR phase, actually reflected the requirements of the last DSR phase - namely **communication of the results**.

As the all (six) decision-making stakeholders, to which the results of the evaluation were communicated in the scope of the last DSR phase, proposed to continue using EAFP in the scope of IT Demand Management in real-world environment, it can be concluded that EAFP demonstrated added value and usefulness for the respective organisation.

The next chapter presents EAFP and describes its components.

4. Enterprise Architecture Fusion Process

Enterprise Architecture Fusion Process (Figure 5) is a novel practical approach to integrate Enterprise Architecture aspects into operational and tactical activities in respective organisation; however, this paper focuses on EAFP in the scope of Demand Management Process.

Despite the fact that this paper focuses on EAFP which is demonstrated in the scope of DMP, it can be used as a basis framework for any other similar processes triggered through some kind of a input requirement, such as Innovation Management, Business Capability Management, Change Management, Project Development, Release Management, or Business Transformation. It could be also scaled and used

only in the scope of specific architecture domain, such as Data Architecture, Technology Architecture, or Business Architecture.

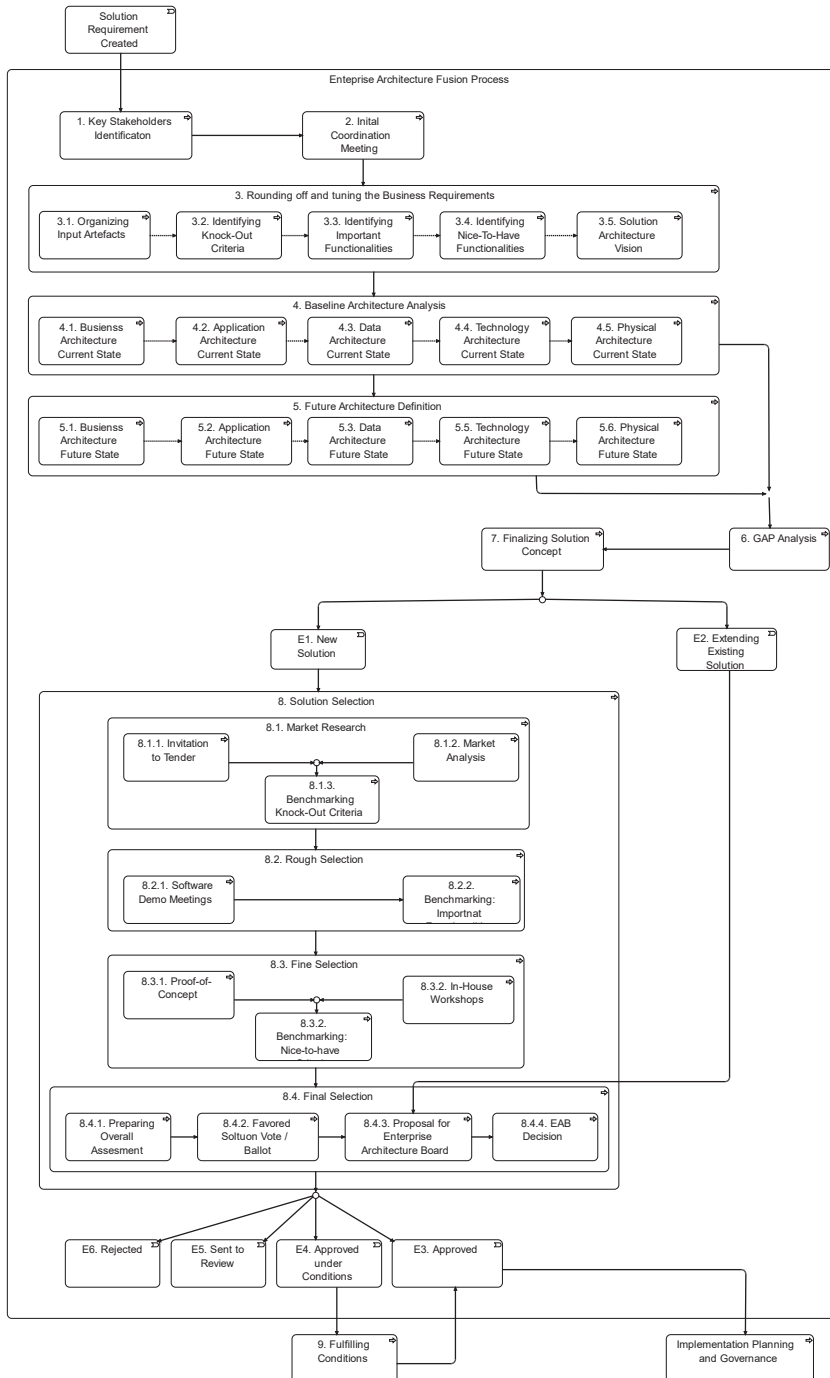


Figure 5. EAFP: Enterprise Architecture Fusion Process

As seen in the final version of EAFP, the process is triggered by creating a new solution requirement - in demonstrated case in the scope of Demand Management Process. It has total of ten lead processes, such as *1. Key Stakeholder Identification* or *8. Solution Selection Process* - meaning they have subprocesses by themselves, or they have significant differences in regard to other lead processes, or both. Some of the lead processes are composed of several subprocesses, referred as second-level processes in this paper, such as *4.1. Business Architecture Current State* or *8.1. Market Research*. Additionally, some of the second-level processes are as well composed of several other subprocesses, referred as third-level processes in this paper, such as *8.1.2. Market Analysis* or *8.3.1. Proof-of-Concept*. In addition to the processes, EAFP is composed of six potential events as well, such as *E1. New Solution* or *E3. Approved*.

EAFP is the off-the-shelf framework for architecture fusion processes. For example, Enterprise Architects could identify existing organisational processes where EAFP should be included and select the processes of EAFP they find useful and practical to be integrated there – building their own version of the EAFP. This especially relates to the second-level processes that composite the lead processes numbered three, four, five and eight. For comprehensive architecture fusion process, EAFP recommends to use as much processes as possible from those presented here; however, it does not impose the required minimum of the processes that must be used. Depending on the path of the EAFP cycle determined in the lead process number seven, the maximum of processes which could be executed in the scope of one EAFP cycle is 30 - with addition of three events.

4.1. Identification of Key Stakeholders

As seen in the Figure 5, the lead process *1. Key Stakeholders Identification* is the very first step done in the scope of EAFP. This step should be conducted as soon as there is a formal requirement for a new solution. Freeman [28] defines the stakeholders as any group or individual who can affect or is affected by the respective concept. However, in the context of EAFP we are concerned with identification of Key Stakeholders only, which are individuals often acting as Business Relationship Managers (BRMs) or department Key Users (KUs). Similar to the definition of Primary Stakeholders from Sandhu & Weistroffer [29], KUs can be defined as individuals, which in the scope of concerned requirement, have authority & power to speak in the name of organisational unit they represent, and responsibility to clarify and interpret business vision of required solution.

There are many ways, methodologies and techniques to identify appropriate stakeholders. Trentim [30] defines this process as part science and part art - meaning we are allowed to be very creative for the sake of identifying most appropriate and most relevant persons. However, the care must be taken, as the outcome of such process has serious relevance for the overall acceptance of the new solution - and consequently for the successful execution of the whole EAFP as well.

It is a common for larger organisations to have a lists of identified KUs or BRMs for every department, which could or should be contacted in the case of implementing

or enabling something that has relevance for their organisational units. If however, a specific organisation has no such list, the initiative should be started to create one. Such list could be used to identify appropriate and relevant stakeholders when starting a new EAFP cycle. A simple email to all persons from the list would be sufficient, explaining the new requirement and asking to whom, i.e. to which department it might be relevant. Persons that answer as interested or relevant should be included into the next step of EAFP – namely “2. *Initial Coordination Meeting*”.

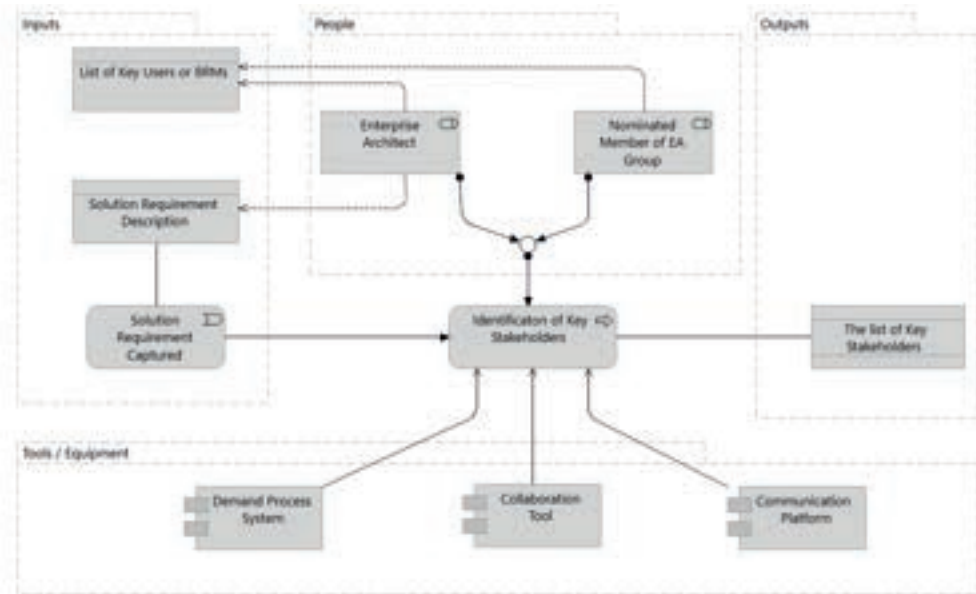


Figure 6. Inputs, Outputs, People, and Tools relevant for the Identification of Key Stakeholders

A leaner and slight-modified set of aspects from Process Audit Turtle Diagram, which is often used in ISO 9001 audits [31], such as Inputs, Outputs, People and Tools, could be used to provide a good overview of this lead process and to help to better understand it. Such set of aspects is visualised in Figure 6 using ArchiMate EA modelling language. In EAFP context, Inputs represents the artefacts that trigger or that are needed to start the process, and those are: an event when Solution Requirement is captured, a Solution Requirement Description itself, and a List of KUs or BRMs. However, depending on perspective, the artefacts Solution Requirement Description and a List of KUs or BRMs could be considered as the tools as well. Output would be the final list of relevant Key Stakeholders that would be actively involved in the whole architecture fusion process. Tools that could be used in this step of EAFP include, but are not limited to: A system that enables Demand Process, Documentation Management System providing a required lists, and a platform that enables communication, such as email. The person responsible for execution of this part of the EAFP should have the Enterprise Architect role, or be a nominated member that belongs to the EA group. As soon as Solution Requirement is formally captured, Enterprise Architect should use the other inputs as well to start and to conduct the

process of stakeholders identification. This should be done by using the appropriate tools, which serve the process. The output is the Agreed List of relevant key stakeholders.

4.2. Initial Coordination Meeting

The lead process 2. *Initial Coordination Meeting* is the second step of EAFP. Enterprise Architect, or a nominated person should organise the meeting, define the agenda and act as moderator of the meeting. This meeting has the aim to connect the group together and to clearly specify the focus. The members of the group are Enterprise Architect and the relevant key stakeholders identified as such in the previous step of EAFP.

As we can see from Figure 7, there are two input artefacts that are relevant for this step. First of them is the list of relevant stakeholders that should take a part in Initial Coordination Meeting anyway. However, in this case we use the list as a basis to identify other potentially important key stakeholders, which might be omitted when considering only KUs or BRMs lists. Such stakeholders could be Business Architects, Domain Architects, Portfolio Managers, external experts, etc. The final list of relevant Stakeholders should be the outcome of a such activity. Solution Requirement Description is the other artefact that we use as an input. Its consideration, together with other additionally possible ad-hoc inputs, should be the basis for the output artefact – namely, a List of required information. Such information could be anything that might be relevant or helpful for further clarification and fine tuning of solution requirements.

The potential tools and equipment that could be needed in the scope of initial coordination meeting are physical or virtual meeting room, optical display technology, such as projector, and communication or collaboration platform, such as video conferencing system.

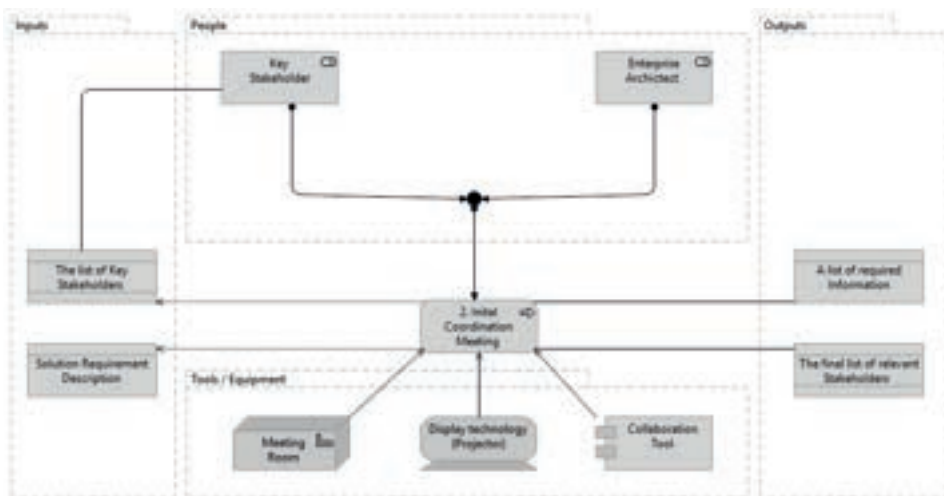


Figure 7. Initial Coordination Meeting lead process

It is important to stress that this meeting is not a collaboration or a kick-off meeting, and is not intended to arbitrate decisions, determine trade-offs, or solve any technical problems. The aim is to coordinate not to collaborate.

4.3. Rounding off and tuning the Business Requirements

Rounding off and fine tuning the Business Requirements through collaboration between key stakeholders, which should be moderated by Enterprise Architect or other nominated person from EA group, makes the third step of EAFP. As a third lead process, this process is a composition of several second-level processes (Figure 8), which outcomes have crucial implications on decision to be made in the further steps of the EAFP.



Figure 8. Rounding Off and tuning Business Requirements lead process

In contrast to the previous step, this step requires in-depth discussions to find common and clear definitions of business requirements to the solution, which fit well with existing enterprise architecture, and are in the same time acceptable by all involved stakeholders. According to Mascitelli [32], in collaborative meetings, trade-offs are made, decisions are arbitrated, problems are solved; and this is exactly case with this step of EAFP - however only in the scope of business requirements.

The first step in this lead process is to *organise input artefacts* to be able to support identification of Knock-Out (KO) criteria for desired solution. Inputs to this step can be various – basically any information that is relevant for tuning business requirements, including but not limited to, Solution Requirement Description, list of EA Principles, list of Constraints, relevant Blueprints, and Mindmaps. The second step is to *identify the KO Criteria* of desired solution, meaning, defining capabilities or attributes that desired solution must have, fulfil, or comply with under any circumstances, such as business requirements, architecture principles, or legal constraints. Third step is the *identification of Important Functionalities* that desired solution should have, but are not eliminatory in their nature. The fourth step is the *identification of Nice-To-Have Functionalities* that are not eliminatory or important, but would be nice to have them within desired solution. All these requirements, identified in the previous three steps, should lead to creation of the Solution

Architecture Vision, represented through the first draft of desired business architecture.

4.4. Analysis of the Baseline Architecture and Definition of the Desired Architecture

Previous three sections (4.1, 4.2, and 4.3) cover each one lead process of EAFP, namely *1. Key Stakeholders Identification*, *2. Initial Coordination Meeting*, and *3. Rounding off and tuning the Business Requirements*; however, from practical reasons, this section (4.4) covers three lead processes together: *4. Baseline Architecture Analysis*, *5. Desired Architecture Definition*, and *6. Gap Analysis*.

To conduct the lead processes *4. Baseline Architecture Analysis* and *5. Desired Architecture Definition*, EAFP recommends the use of following phases from TOGAF Architecture Development Cycle (ADM): B. Business Architecture, C. Information Systems Architecture, and D. Technology Architecture. Phases B, C, and D could be used to record corresponding domains of Baseline Architectures, and to define corresponding domains of Desired Architectures. The same phases, B, C, or D, could be used to get an idea what could be needed to record Baseline or Desired Architectures of any additionally needed domain, such as in the EAFP example Physical Architecture.

The first draft of Desired Business Architecture is used as an input for both lead processes. Solution Architecture Vision serves as an orientation to identify and capture relevant existing artefacts of Baseline Architecture, and as a guide to define artefacts required by Future Architectures. Outputs of the both lead processes should be relevant architectures, which are to be used as the Inputs for the next subprocess, namely *6. Gap Analysis* (Figure 9).

The aim of the lead process number 6, namely *Gap Analysis*, is to identify differences between Baseline and Future Architectures and is very similar to the Phase E of TOGAF Architecture Development Cycle. Baseline and Future Architectures are consolidated, refined and compared to identify what artefacts already exists and what artefacts need to be implemented to deliver the Future Architecture. If required, the implementation chronology should be delivered as an output as well - in addition to the list of the artefacts that need to be implemented.

The identification of the artefacts, needed to deliver desired solution, supports a holistic view on the existing situation and provides the basis for decision-making; thus, enabling the execution of the next lead process - *7. Finalizing Solution Concept*". In this step, taking into account current situation and all artefacts that need to be implemented, a decision is to be made, if there is a need for a new solution or extending existing solution would be sufficient.

If decision is made to extend the existing solution (event E2 in Figure 5), a proposal should be prepared to be presented in the front of Enterprise Architecture Board (EAB). According to TOGAF, EAB should be representative of all the key stakeholders in the enterprise architecture, and will typically comprise a group of executives responsible for the review and maintenance of the overall architecture, having decision-making capabilities and global, regional, or business line scope.

If, however, decision is made that there is a need for a new solution, than the lead process number eight, namely “*Solution Selection*”, should be started.

4.5. Solution Selection

Solution Selection is the lead process number 8, which is concerned with the selection of appropriate solution, that should fulfil the requirements of artefacts identified as needed to deliver Desired Business Solution. In my most cases, this process is executed to select a new software or a new digital technology that should fulfil the business requirements.

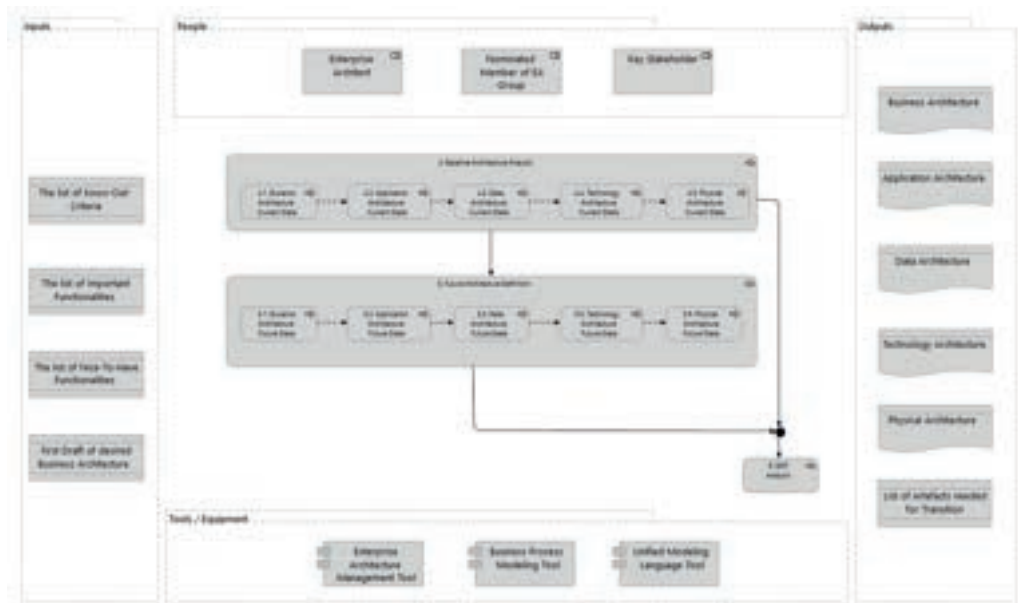


Figure 9. Baseline/Desired Architecture Analysis and Gap Analysis

Solution Selection process has three selection processes and one processes where final decision should be made. The first second-level process (stage 8.1. in Figure 5.), is concerned with the *Market Research*. At this stage, all relevant existing solutions identified through public invitation tender or market analysis, are considered and benchmarked against KO Criteria defined as relevant in the second-level process 3.2. Only those solutions that fulfil KO Criteria are considered in the following stage – namely, *Rough Selection* (stage 8.2. in Figure 5).

In *Rough Selection* phase, the companies that produce the solutions that fulfilled KO Criteria are invited to demonstrate their solutions, and to provide answers to the questions about Important Functionalities, identified as relevant in the second-level process 3.3. Two or three fittest solutions that fulfil the most of the Important Functionalities, should be selected for the *Fine Selection* phase – a stage number 8.3.

During the *Fine Selection* process, selected solutions should be verified through appropriate Proof-Of-Concept or in-house workshops, and benchmarked against

Nice-To-Have Functionalities, identified as relevant in the second-level process 3.4. As soon as this step is done, the next second-level process, namely “Final Selection” can be executed.

As seen in Figure 5, the first step of *Final Selection* is to prepare the Overall Assessment Report (third-level process 8.4.1.). This report is to be presented to the Key Stakeholders as the part of the third-level process 8.4.2., and is to be used as a basis for voting for preferred solution. After the vote, a proposal for EAB should be prepared in the scope of the third-level process 8.4.3., and presented to EAB in the scope of the third-level process 8.4.4.. EAB makes final decision to approve or to reject the acquisition of the proposed solution, and can seek for a specific review or fulfilment of additional conditions found as appropriate and relevant in respective situation. The EAB decisions *E3. Approved* or *E6. Rejected* represent in the same time the end of EAFP cycle, while decisions *E5. Sent to Review* or *E4. Approve under Conditions* could involve additional activities relevant for the architecture fusion, but not foreseen in the scope of EAFP.

Further activities, such as *Implementation Planning and Governance*, as seen in the Figure 5 are not considered as a part of EAFP cycle, as they don't define architecture, but only realize it.

5. Conclusion and Future Work

The first chapter described the paper and its intention. The second chapter described Enterprise Architecture, the most common concepts and frameworks in this field, identified knowledge gap, and provided motivation for the development of Enterprise Architecture Fusion Process, covering the challenges that need to be addressed. The chapter number three explained research approach, activities and methods used to develop EAFP. The chapter number four presented the final version of the EAFP, including its processes and subprocesses. As the last chapter in this paper, this section provides conclusion and the view on potential future work.

This paper presented EAFP, a new, practical approach to integrate Enterprise Architecture activities into existing operational and tactical processes in respective organisation with the focus of IT Demand Management; thus, filling in the existing knowledge gap identified through literature review. The final version of the approach was demonstrated and validated through real-world implementation in one Austrian company, where the full version was integrated into existing IT demand process of the respective organisation. EAFP demonstrated added value and usefulness for the respective organisation, as the relevant decision-making stakeholders, to which the results of the evaluation were communicated, proposed to continue using EAFP in real-world environment.

Despite the fact that the focus of the paper was Enterprise Architecture Fusion in the scope of IT DMP, it can be used in any other field or at any other level of the organisation, where Enterprise Architecture is needed. EAFP is presented as the off-the-shelf approach enabling the companies to pick what they need and to build their own version of the architecture fusion process. EAFP is not prescriptive, but rather descriptive.

The limitation of the EAFP is that it covers cases of acquiring new of-the-shelf solutions and extending existing inhouse solutions; thus, the potential future work includes extending EAFP with additional cases, such as building a new inhouse solution from the scratch. Also, application of EAFP through other organisational aspects, such as Business Transformation, Innovation Management, or Change Management offers a basis for further research as well. Additional fields for potential future work include validation and evaluation of EAFP in organisations applying agile concepts of work, such as Scaled Agile Framework (SAFe) for example [33].

References

- [1] R. McCarthy and L. Halawi, "Foundations Of EA," Eabok.org. [Online]. Available: http://www.eabok.org/foundation_of_ea/historical_perspectives.html. [Accessed: 12-Apr-2019].
- [2] M. K. Evans and L. R. Hague, "Master Plan for Information Systems", in Harvard Business Review, vol. 40, no. 1, pp. 92-103, 1962.
- [3] The Open Group, The TOGAF standard, version 9.2. Zaltbommel: Van Haren Publishing, 2018.
- [4] S. Aier, C. Riege and R. Winter, "Unternehmensarchitektur – Literaturüberblick und Stand der Praxis", Wirtschaftsinformatik, vol. 50, no. 4, pp. 292-304, 2008. Available: 10.1365/s11576-008-0062-9.
- [5] A. Wegmann, "On the Systemic Enterprise Architecture Methodology (SEAM)", in Proceedings of the 5th International Conference on Enterprise Information Systems, Angers, France, 2003, pp. 483-490.
- [6] M. A. Rood, "Enterprise architecture: definition, content, and utility," Proceedings of 3rd IEEE Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises, Morgantown, WV, USA, 1994, pp. 106-111.
- [7] J. A. Zachman, "A framework for information systems architecture," in IBM Systems Journal, vol. 38, no. 2.3, pp. 454-470, 1999.
- [8] The International Organization for Standardization, "ISO/IEC/IEEE 42010:2011 Systems and software engineering — Architecture description," ISO, 16-Aug-2017. [Online]. Available: <https://www.iso.org/standard/50508.html>. [Accessed: 15-Nov-2019]
- [9] I. Hanschke, Enterprise Architecture Management - einfach und effektiv: Ein praktischer Leitfaden für die Einführung von EAM, 2nd ed. München: Hanser, Carl, 2016.
- [10] G. Bondel, "EAM-Initiative : EA and EAM Definition", Eam-initiative.org. [Online]. Available: [https://eam-](https://eam-initiative.org)

- initiative.org/pages/rs8r4ch3fs1f/EA-EAM-Definition. [Accessed: 15- Apr-2020].
- [11] J. Schekkerman, How to survive in the jungle of enterprise architecture framework: creating or choosing an enterprise architecture framework. Victoria: Trafford, pp. 89 – 198, 2006.
- [12] United States Department of Defense, "The DoDAF Architecture Framework Version 2.02.," Chief Information Officer - U.S. Department of Defence. [Online]. Available: <https://dodcio.defense.gov/Library/DoD-Architecture-Framework>. [Accessed: 15-Mar-2020].
- [13] Federal Government of the United States, "Federal Enterprise Architecture (FEA)," National Archives and Records Administration. [Online]. Available: <https://obamawhitehouse.archives.gov/omb/e-gov/FEA>. [Accessed: 02-Jan-2020].
- [14] S. Kotusev, "TOGAF-based Enterprise Architecture Practice: An Exploratory Case Study," Communications of the Association for Information Systems, vol. 43, no. 1, pp. 321–359, 2018.
- [15] R. Ali Rakhman, "A Design Of Government Enterprise Architecture Framework Based On G-Cloud Services", International Journal of Scientific & Technology Research, vol. 8, no. 9, pp. 1692-1700, 2019. [Accessed 15 April 2020].
- [16] N. Dedić, "Der Weg zur erfolgreichen Etablierung der Enterprise Architektur als unvermeidbare und anerkannte Disziplin in jeder Organisation", in Konferenz 2020: IT-Enterprise Architecture Management Digitalisierung, Innovation & Agilität, Vienna, 2020.
- [17] The Open Group, ArchiMate® 3..0.1 Specification, 5th ed. Zaltboomel: Van Haren Publishing, 2017.
- [18] J. Zachman, "The Concise Definition of The Zachman Framework by: John A. Zachman", Zachman.com, 2020. [Online]. Available: <https://www.zachman.com/16-zachman/the-zachman-framework/35-the-concise-definition>. [Accessed: 15- Apr- 2020].
- [19] J. F. Sowa and J. A. Zachman, "Extending and formalizing the framework for information systems architecture," in IBM Systems Journal, vol. 31, no. 3, pp. 590-616, 1992.
- [20] M. Lankhorst, Enterprise Architecture at Work, 4th ed. Berlin Heidelberg: Springer-Verlag, 2017.
- [21] K. Peffers, T. Tuunanen, M. Rothenberger and S. Chatterjee, "A Design Science Research Methodology for Information Systems Research", Journal of Management Information Systems, vol. 24, no. 3, pp. 45-77, 2007. Available: 10.2753/mis0742-122240302.

- [22] Paré G., Trudel M.-C., Jaana M., Kitsiou S. Synthesizing information systems knowledge: A typology of literature reviews. *Information & Management*. 2015;52(2):183–199.
- [23] S. M. Ali, C. A. Mehmood, M. Jawad and R. Nasim, "Intelligent energy management scheme for home area networks using fair emergency demand response programs in smart grids," *IEEE International Conference on Electro/Information Technology*, Milwaukee, WI, 2014, pp. 190-196.
- [24] J. Hernández, A. Hasayen and J. Aguado, *Cloud Migration Handbook Vol. 1: A Practical Guide to Successful Cloud Adoption and Migration*. Lulu Publishing Services, 2019.
- [25] A. Krishna Kaiser, *Reinventing ITIL® in the Age of DevOps: Innovative Techniques to Make Processes Agile and Relevant*. Bengaluru, India: Apress, 2018.
- [26] R. Smallwood, *Information Governance: Concepts, Strategies, and Best Practices*. Hoboken, NJ: John Wiley & Sons, 2014.
- [27] N. Dedić and C. Stanier, "Measuring the success of changes to Business Intelligence solutions to improve Business Intelligence reporting", *Journal of Management Analytics*, vol. 4, no. 2, pp. 130-144, 2017. Available: 10.1080/23270012.2017.1299048.
- [28] R. E. Freeman, *Strategic management: A stakeholder approach*. Boston: Pitman, 1984.
- [29] R. K. Sandhu and H. R. Weistroffer, "A Review of Fundamental Tasks in Requirements Elicitation," *Information Systems: Research, Development, Applications, Education Lecture Notes in Business Information Processing*, vol. 333, pp. 31–44, 2018.
- [30] M. H. Trentim, *Managing stakeholders as clients sponsorship, partnership, leadership, and citizenship*. Newtown Square, PA: Project Management Institute, Inc, 2015.
- [31] C. Kymal, *How to audit ISO 9001:2015: a handbook for auditors*. Milwaukee, WI: ASQ Quality Press, 2016.
- [32] R. Mascitelli, *Building a project-driven enterprise: how to slash waste and boost profits through lean project management*. Technology Perspectives, 2002.
- [33] "SAFe 5.0 Framework", Scaled Agile Framework, 2020. [Online]. Available: <https://www.scaledagileframework.com/>. [Accessed: 30- April-2019].



UDC 005.7:005.94:677(549.1)

Original Scientific Paper

Influence of Organizational Culture & Intellectual Capital on Business Performance in Textile Industry of Pakistan

Syed Muhammad Fahim*muhammad.fahim@iobm.edu.pk**Assistant Professor- Marketing Department
Institute of Business Management, Pakistan***Syeda Misbah Inayat***std_26870@iobm.edu.pk**College of business management
Institute of Business Management, Pakistan***Syed Muhammad Rafay Zaidi***std_26814@iobm.edu.pk**College of business management
Institute of Business Management, Pakistan***Daniyal Ahmed***std_26924@iobm.edu.pk**College of business management
Institute of Business Management, Pakistan***Ramish Hassan***std_26983@iobm.edu.pk**College of business management
Institute of Business Management, Pakistan***Syed Zulfiqar Ali***zulfiqar.dadc@gmail.com**Assistant Professor- DHACSS
Degree College Phase VI DHA, Karachi*

Abstract

This paper aims to find out the extent to which organizational culture and intellectual capital influence the textile industry's business performance in Pakistan. The study uses causal and explanatory research design. Several 200 textile industry employees participated in this survey, selected as the study sample using the purposive sampling technique. The study detects that both organizational and intellectual capital directly impact the textile firms' business performance. However, the impact of intellectual capital on business performance is more substantial than that of organizational culture. The mediating effect of technological innovation in the relationship between organizational culture and business performance is also supported. The study can be used by the textile industry managers to set up policies on how to improve business

performance in the textile firms. The study also fills the literature gap as prior studies do not have worked on the mediating aspect of technological innovation.

Keywords: Organizational culture, intellectual capital, business performance, technological innovation.

1. Introduction

The textile and apparel industry is a bulwark of Pakistan's economy. The largest manufacturing industry in Pakistan is the textile industry, which contributes 8.5% of its GDP. The textile industry accounts for about 60 percent of the nation's overall export earnings, contributes 46 percent of entire manufacturing, and uses more than 40 percent of bank loans for manufacturing. It provides 38 percent of the total country labor force with employment [36]. This sector is flourishing and needs to be researched to better the organizations involved in textile manufacturing in Pakistan [35]. Sector significance requires an in-depth study that is required both at the industrial and firm levels.

The textile sector is traditional in the global industrial segment. Its growth depends on its ability to develop its products through advanced and innovative methods, emphasizing competitiveness organizational structure and business practices [38].

Organizational culture is one of the variables that can inspire creativity. Even though it affects the workers' actions, organizational culture may affect their acceptance of innovation as a critical factor for its growth, enhancing its dedication to innovation. Organizational culture is also seen as one indicator of innovation because it can encourage or impede innovation. Moreover, organizational innovation needs to be followed by an appropriate organizational structure [37].

Specifically, Malinowska-Olszowy claimed that I.C. plays a vital part in the textile industry's sustainable growth. To accomplish this, textile companies need to emphasize I.C. strategies' execution and develop new skills and competencies in today's competitive market climate [39].

The purpose of this research is to determine the void in previous studies. This research aims to concentrate on O.C. and I.C.'s influence on firms' performance and stabilize the relationship by cooperating governance. More precisely, the mediator that is technical innovation and mediates the relationship between variables is the problem that was a new subject of measurement in Karachi, Pakistan's textile industry. There have been no studies carried out with these mediators and in this context, specifically in Pakistan's textile sector moderate. The study was helpful to the management of Textile companies, and, through this analysis, people employed at the top management were able to evaluate the significance of these performance functions. The theoretical justification lies in the possibility of understanding how culture influences innovation and business performance results. Given the increase in studies, few works refer to industrial-organizational studies, so this study contributes to filling that void [40]. The following are the objectives made in research.

1. To determine the impact of O.C. and I.C. on business performance.

2. To evaluate the moderating Relationship of corporate Governance between I.C. and business performance.
3. To analyze the mediating Relationship of technological Innovation between O.C. and business performance.

The following are the research questions.

1. What is the impact of O.C. and I.C. on organizational performance?
2. How corporate governance moderates the Relationship of I.C. with business performance?
3. How innovation mediates the Relationship between O.C. and business performance?

The proposed research could be useful as a strategic method for companies to become aware of the activities that affect their technologies' success. This research also influences all textile sector departments' top management to enhance their organizational performance by understanding the Importance of the organizational culture in maintaining better organizational operations and results. It is the first comparative analysis of I.C.'s impact in emerging markets on firm Performance in the textile industry. Secondly, the current textile I.C. literature is mainly descriptive summaries and lacks systematic work. This study also benefits scholars, statespersons, and corporate executives who have a general interest in textile production. This research is limited only to professionals working in the textile industry of Pakistan.

2. Literature Review

Firm performance is a crucial regression coefficient of interest among researchers in every management field; it can reference how significant performance has been in its operations. Moreover, it also refers to an enterprise's ability to attain high profit, quality service, large profit margins, strong financial performance, and predetermined survival [1]. Technological innovation is positively associated with the firm's performance; several studies have shown that both innovation and creativity mediate the Relationship between O.C. and Performance [28], suggesting that technological innovation mediates the relationship between organizational culture business performance.

[3] have concluded that a company's intellectual capital has a positive effect on a firm's performance and can predict potential financial success. [4] suggested that I.C. is related to firm operating performance substantially and constructively; also, I.C. brings value and improved financial performance to a company [2].

Previous studies on this topic have certain limitations, which leads us to research this field [7] and [5] have mentioned that their research limits significant innovation types. Therefore, financial performance must be considered. Other dimensions like customer performance, non-financial & economic performance should also be considered while evaluating a firm's performance.

Richard (1992) evaluated that business performance (profits, assets, return on investment, etc.), product performance (sales, market share, etc.), and shareholder return are incorporating overall organizational performance. The organizational

performance satisfaction level included four items: achieved growth, employee satisfaction, customer satisfaction or quality service, and product quality. Performance measurement included three items: sale, export, and profitability [5]. Various researchers think of performance differently because performance is a complex process among organizational researchers. The word performance was used mainly by researchers to describe the scope of performance efficiency, input & output quality measurements [6]. All these researchers talk about performance efficiency through innovation in an organizational, internal, or external environment in only one specific industry area.

Organizational culture is an essential resource for organizations to stay in their thoughts, principles, standards, practices, and beliefs to ensure their sustainability. Organizational culture plays a significant role in shaping signs of progress within organizations [8]. According to Sackmann, in 1991, Organizational culture can serve as a control mechanism for building organizational engagement, achieving cohesion within organizations, and helping organizations respond to external changes [10].

The literature on innovation claimed that organizational culture plays a vital role in shaping creativity in organizations [11]; Also embracing the idea that companies have a clear need to respond to external threats and change their internal capital, culture, activities, technology, and structure. Strategic Innovation focuses on preparing the organization through proactive innovation to address potential challenges [12]. Corporate organizations would benefit from forming a creative and high-performance organizational culture and improved competitiveness to maintain better market shares and productivity in increasing competition, higher customer demands, and rapid technological growth and change [13].

Kotter and Heskett, in 1992, found that corporate culture has a massive impact on the long-term financial performance of the company. They noticed that businesses with a culture that stressed all the major managerial constituents (customers, shareholders, and employees) and managerial leadership at all levels outperformed businesses that did not have extensive margins [14]. Therefore, organizational culture is the driving factor of organizations. Thus, developing an organizational culture that stimulates innovation and creativity is a vital and strategic choice to improve the organization and make it more competitive [15].

Organizational culture affects the organizational structure and operating structures of a company (Armstrong, 1995). The structure seems to highlight specific values that influence in organizations promoting or restricting innovation. Researchers have noted that organizational culture on an innovation-fostering system, such as versatility, independence, and collective teamwork, can encourage innovation [16]. Various other conditions could influence the study results in internal validity, but researchers have not discussed it. However, these studies examine the relationship between organizational culture and innovation but are more focused on an entirely different sector, including SMEs, educational institutes, health care, and banking sectors. Therefore, these limitations help us to initiate additional research on textile firms.

According to Denison (1984), there is a significant correlation between how an organization works and decision-making methods. Denison's theory of organizational culture supports the link between organizational culture and business performance. The impact of organizational culture on a firm's performance in different sectors is well-researched. However, some research findings outline a cross-sectional relationship between organizations' culture and outcomes [17]. These recent studies have begun to provide insights into how organizational culture may positively or negatively affect the firm's performance.

Hypothesis: H_1 (a) = Organizational culture has a positive impact on firm performance.

The *Intellectual Capital* model was initially discovered in 1969 through a letter from John Kenneth Galbraith to Michael Kalecki. And in 1991, it came to light through a Journal by Tom Stewart. The resource-based theory states that intellectual capital (I.C.) is a principal source to improve business performance [29]. As a result, many past researchers have studied in intellectual capital. [33], [30] and [32], who inquired how business performance is influenced by intellectual capital. Nevertheless, almost all previous researchers concentrated on how the individual intellectual capital affects performance while ignoring the impact of particular components of intellectual capital.

Suppose you want to know Intellectual capital in a firm better. In that case, you will need to address its employees to evaluate their core capabilities, especially in those regions where they can attain or have already attained "Best-in-the-world" status. In business, the intellectual capital signifies the fortune of concepts and skills to innovate, determining the business's future. You have to think about why the financial analysts and accountants avoided this area? The only reason is that it is not that easy to quantify. Previously accountants find it very difficult and sometimes impossible to calculate [30]. So we should recognize the significance of intellectual capital as it already exists and has real value [31].

Hypothesis: H_1 (b) = Intellectual Capital has a positive impact on firm performance.

Technology innovation has become a necessary element for organizations in recent times after experiencing various approaches in the concept of innovation, as Schumpeter first identified back in 1934. Innovational development in organizations is published in research articles [18], where this invention's implementation is discussed. After gaining various statistical data regarding technological innovation, it defines this factor as executing an updated process to develop an altered product with better specifications. Moreover, an organization also uses this tool to upgrade their marketing approaches and maintain better relations with external bodies. Concerning the requirement, the Green Paper also considered technological innovation as the source of production. They also comprehend and utilize profitable new solutions for economic and social issues considering the needs of the whole community and individual, thus successfully improving the economy sectors globally on the macro scale [19].

Technology innovation often works as a mediator between organizational culture and firm performance as an organization's culture has a positive impact on the firm's innovation. Mediation is only possible by enhancing creativity among the employees [20]. The culture within the organization that reinforces innovation considers various factors involving the firm's educational level, socio-economic information, two-way communication between the lower and higher management, possible exchange of ideas, and the positive attitude towards the better change [22]. One research article concluded that technology innovation has a weaker link with firm growth if it is large and old [23]. But if the above-discussed factors are considered useful, the productivity in both small and large firms could increase up to a greater extent. Starbucks, Google, and MasterCard are examples of such large firms adopting innovation successfully. Therefore, a firm must develop such an innovative climate within the firm that enables it to think through out-of-the-box and search for the new product or process.

Hypothesis: $H_1(c)$ = Technological Innovation mediates the Relationship between Organizational culture and firm performance.

Corporate governance plays a central role in attracting investors for the firm's capital growth. The transparency in the company's financial structure leads the decision-makers to invest and believe in its goodwill. Corporate governance regulates accountability. Nonetheless, big business enhances a company's capacity to recruit talented workers, take creativity, and maintain a strong relationship with stakeholders and vendors. [24]. A study is undergoing in the banking sector of Pakistan that explains corporate governance's role in a firm's performance. Still, this study is limited to the banking sector and does not showcase its technological giants. [25] Many studies are proven successful in explaining C.G.'s role, but those are not about the Pakistani listed companies.

Corporate governance defines the level of disclosure of Intellectual capital that can create value for the firm as gaining or maintaining a competitive edge [31]. This competitive advantage results in the excellent business performance of the company. But this statement again acts as the limitation because the study is done on Italian listed companies and not on Pakistan's listed companies.

Our Research model entails two independent variables, organizational culture, intellectual capital, and one dependent variable is business performance. The mediator and moderator are, respectively, technological innovation and corporate governance. These variables supported by different theories are discussed below. These theories explain and predict the relationship between variables and organize our ideas.

Hypothesis: $H_1(d)$ = Corporate Governance moderates the Relationship between Intellectual capital and firm performance.

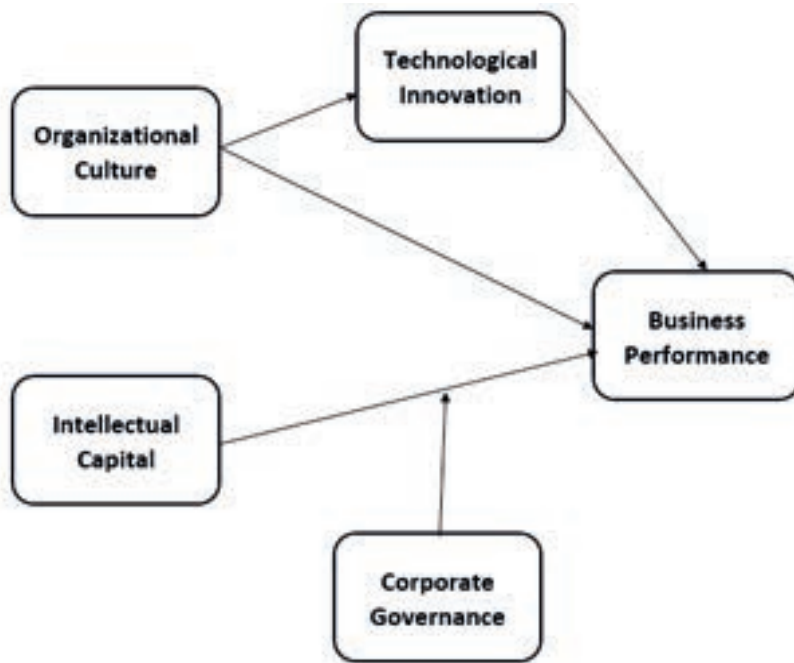


Figure 1. Conceptual Model Regarding Variables Affecting Business Performance

3. Methodology

The philosophy is considered a belief about how the Researchers gathered the research [41]. An investigator aims to utilize positivism philosophy as it directs the minimum bias from the researcher. Researchers play a vital role in the data collection process, and Researchers chose to execute unbiased data gathering. The research perceives truth, reality, and knowledge regarding the research subject to carry out significant results [42]. The researcher's own opinion was regarded in this research, and only the valid results were acquired through unknown target respondents.

We have selected a Quantitative research paradigm for our research to gather responses and enhance the research process. The positivist philosophy underpins the quantitative paradigm to execute study; hence Pure quantitative research paradigm focuses on measuring data quantitatively [43].

Quantitative design research is dealt with to quantify and analyze variables to get results. It is selected to develop numerical data using statistical techniques to answer the questions set up for this research [44]. All the data exerted is in the form of a numerical basis and numbers through statistical measures.

Researchers used a deductive approach for the quantitative study. The process starts from a theoretical point of view requiring theories; it deals with formulating hypothesis, observation, and confirmation of a new conceptual understanding [45]. It follows the steps to conclude an understanding of the phenomenon.

Non-probability sampling opts for the sampling design. Moreover, the non-probabilistic method is used to take respondents representing the population [46]. A frame is not available for everyone, as specifically, employees from the various managerial levels are chosen from the textile organizations operating in Pakistan.

Purposive sampling technique is used, by researchers, to gather data from the representative of the population. The main aim to choose this technique where randomization is not possible, such as in this case, not every respondent can be reached due to certain limitations [47].

In this research, a sample of 200 was taken that are the whole population's representatives. 90 and 120 men filled the questionnaire. Respondents ranged from the age bracket of 23 to 45. Most of the respondents were between 23-30. (67% of all the participants are between the age of 23-30). 28.5% are between the ages of 31-37. Lastly, 3.3% lie between the age bracket of 38-45). The reported textile industry experience level of respondents included 1-4 years (64%), 5-8 years of experience (21%), 9-15 years of experience (15%). Of all the responses, 13% belonged to Alkaram (28 Participants), 13% belong to Artistic, 11% to Feroze, 32% to Gul-Ahmed, 7% to Soorty, 6% to Younus, the remaining 7% belonged to 'Other' category in textile firms. All the respondents belonged to the different departments in the textile organizations of Pakistan. Such a spread of respondents in various departments helped the researcher to maintain variance in the data set.

The research purely forms quantitative design; therefore, utilizing Partial least squares structural equation modeling as a statistical technique is vital to analyze the chosen responses. This technique is suitable to analyze each variable dependent, mediator, moderator, and independent variable to produce significant results. The estimation model was used to decide the data's quality and legitimacy and the relationship between constructs [48].

3.1. Measurement

The source questionnaire serves as measures for this study.

Item Code	Items	Citation
WE1	My Firm's mission is to serve society.	[54]
WE2	My organization constantly scans the external environment for inputs such as technology, ideas, information, knowledge, etc.	
WE3	My organization valued employees' opinions.	
MS1	The management style emphasizes on team building.	
MS2	Our management promotes consideration among employees.	

OL1	Top management is actively involved in communication and planning of organizational goals.	
OL2	Top leadership provides powerful means to improve & maintain quality.	
OL3	Top leadership anticipate changes and make plans to accommodate them.	
L1	My organization strongly emphasizes on the profit of the customer.	
L2	My organization shows social responsibility.	
L3	My organization provides sincere services.	
LE1	My organization promotes teamwork within the firm.	
LE2	The company's employees undergo continuous training programs every year.	
LE3	My Firm Promotes a sense of learning within Employees.	
LE4	Employees are experts in their respective areas.	
CPP1	Employees' experience and expertise affect the company's productivity.	[55]
CPP2	Employees' experience and expertise affect the company's profitability.	
FPI1	The market share of my firm is higher among the competitors.	
FPI2	Our firm has a higher debt to equity ratio.	[56]
FPI3	My firm takes care of short-term liabilities.	
FPI4	Our firm has high Cash flows.	
OPI1	The inspection of incoming material is essential.	
OPI2	We are delivering inputs on time.	
OPI3	In my firm, there is a low level of absenteeism.	[57]
OPI4	Are your firm has a higher rate of new product development?	
BI1	The priority of our firm is to gain customer satisfaction.	
BI2	My firm has a reputed image in the market.	[58]
BI3	We have higher public demand.	
BI4	Our firm has gained higher customer loyalty.	

A1	Our firm has sufficient resources to develop new products/processes.	
A2	Our product has sufficient technological capabilities to develop new products/processes.	
A3	For my organization, vision assessment is necessary for innovation.	
A4	Our firm continuously tests new ideas.	
RE1	In my organization, multi-disciplinary collaboration and training are essential.	[59]
RE2	Responsibilities are redefined among employees in my organization.	
RE3	Reflexive capacity within scientists should be carried out.	
I1	Establishing a Sense of Belonging is Necessary.	
I2	A top-down approach is not enough.	
I3	Inclusion is a continuous on-going process.	
I4	My organization always encourages its employees.	
RL1	Our firm's governance follows legal frameworks.	
RL2	My organization protects human rights.	
RL3	We are providing freedom-to-speech to employees.	
RL4	Our firm always avoids illegal activities.	
T1	Our firm always reports financial position to investors.	(Abrha, J Civil Legal Sci 2016, 5:3) [60]
T2	My firm provides a strategy outline for investors.	
T3	We always disclosed a conflict of interest.	
R1	We are serving stakeholders within a reasonable period.	
R2	How approachable is your company?	
R3	We Delivered the services timely.	
AC1	My firm upholds proper accountability for operations.	
AC2	We are answerable to our stakeholders.	
AC3	Our firm is always responsible for avoiding social injuries.	

Table 1. Questionnaire.

4. Results & Discussion

4.1. Descriptive statistics

Descriptive statistics are used to define the fundamental characteristics of the data in a sample. They provide simple summaries of the model and the steps. As stated earlier, this research data is analyzed using the PLS-SEM technique, which is best suited for data of this nature. The results and conclusions shall proceed in the following stepwise explanation of the whole process of study.

Any data whose skewness and kurtosis remain within ± 3 are considered to be normally distributed [50]. All sample data gathered in this research is usually distributed based on the parameters shown in Table 2.

	Age	Gender	Education	Organization	Experience	Department	Managerial Level
Skewness	1.231	-0.291	0.804	0.204	1.075	0.536	1.344
Std. Error of Skewness	0.168	0.168	0.168	0.168	0.168	0.168	0.168
Kurtosis	0.547	-1.934	-0.957	-1.566	-0.342	-0.384	0.499
Std. Error of Kurtosis	0.335	0.334	0.334	0.334	0.334	0.334	0.334

Table 2. The above table shows the normality of demographic indicators, which is within the limits of ± 3 .

The below cross-tabulation results indicate that 56.9 percent of employees are males, and the remaining 43.1 percent are females. The findings show that 67.9 percent of employees belong to the 23–30 age group, 28.7 percent of employees belong to the 31–37 age group, and just 3.33 percent of employees are in the 38–45 year age group.

The results also indicate that 69.9 percent of employees have graduation education qualifications in various fields such as engineering, science, and arts, and 29.7 percent of employees have postgraduate educational qualifications.

		Gender					
		Female			Male		
		Age			Age		
		23-30	31-37	38-45	23-30	31-37	38-45
Education	B.E.	4.8%	1.9%	0.0%	6.7%	1.9%	0.0%

BS	21.1%	2.4%	0.0%	23.0%	3.3%	0.0%
BBA	3.3%	0.5%	0.0%	0.0%	1.0%	0.0%
ME	0.0%	1.4%	0.0%	1.0%	0.0%	0.0%
MS	1.9%	1.4%	0.0%	1.9%	3.3%	0.0%
MBA	1.9%	2.4%	0.0%	1.9%	9.1%	3.3%
BA	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%
Total	33.0%	10.0%	0.0%	34.9%	18.7%	3.3%

Table 3. The above table shows the cross-tabulation of the socio-economic profile of textile industry employees.

As a purposive sampling technique was used to gather data from the population-representative, below table 4 shows that many respondents sent are from Gul Ahmed textile. The main objective is to use this technique where randomization is not feasible, as in this case, not every respondent can be reached due to some constraints. Therefore, less data was collected from the most experienced employees.

Organization Name		Managerial Level			
		Middle Manager	Senior Manager	Executive	Total
Gul Ahmed		50	9	7	66
Alkaram		14	9	5	28
Soorty		11	3	0	14
Yunus		6	5	2	13
Artistic		21	4	3	28
Feroze		18	4	1	23
Other		24	11	3	38
Total		144	45	21	210

Table 4. The above table shows the cross-tabulation of the organization and the Managerial level of the respondent. This table indicates that from which textile organization data is collected and how much the respondent is experienced.

4.2. Measurement Model

The measurement model is the ultimate destination of any quantitative analysis method evaluating data using PLS-SEM techniques [52]. The outer loadings evaluate all study constructs' indicator reliability with the desired range of 0.7, and above that, all external loadings indicators below 0.7 should be discarded [50].

	B.P.	CG	I.C.	OC	TI
A					0.839
AC		0.808			
BI	0.868				
CPP			0.798		
FPI	0.761				
I					0.879
L				0.832	
LE			0.896		
MS				0.828	
OL				0.877	
OPI	0.896				
R		0.878			
RE					0.899
RL		0.816			
T		0.737			
WE				0.85	

Table 5. Note: The above table indicates item loadings/external loadings, and all of the outer loadings are above the threshold of 0.7 [51]. Therefore, none of the above indicators was discarded, as all are having extreme loading values greater than 0.7.

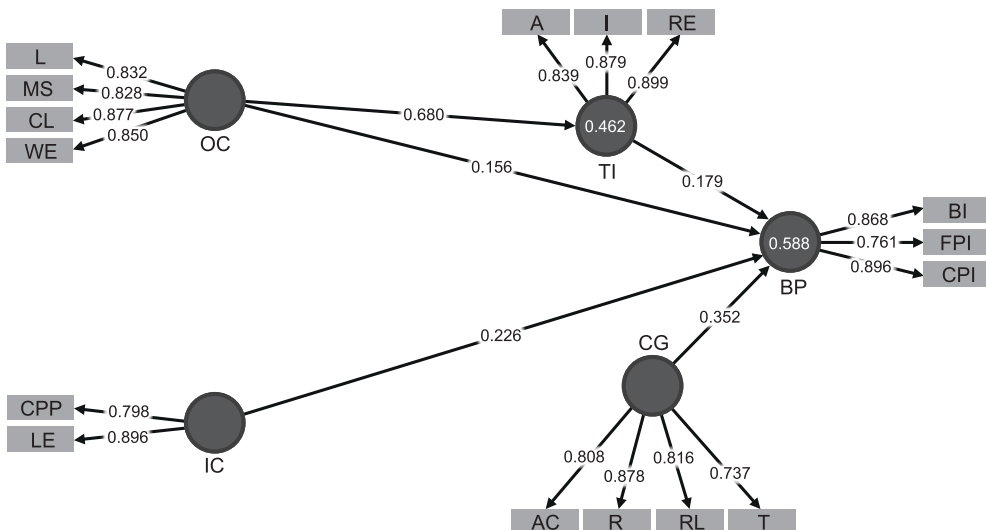


Figure 2. Conceptual Model after PLS Algorithm

Multiple regression analysis is performed to explore the reliability and validity factors that affect the textile industry's business performance, and the findings are presented in Table 5. Reliability and validity are principles, which are used to determine research quality. They state how well something is calculated by a process, technique, or examination. Reliability is about a measure being consistent, and validity is about an action being reliable. According to the thumb rule, composite reliability is tested for data to be deemed reliable when its composite reliability is > 0.7 [51]. The composite's reliability establishes the internal stability and reliability of constructs. Table 6 shows that all the constructs have composite reliability greater than 0.7.

Composite Reliability	
BP	0.88
CG	0.885
IC	0.837
OC	0.91
TI	0.905

Table 6. The above table indicates that all the constructs have composite reliability greater than 0.7 [51].

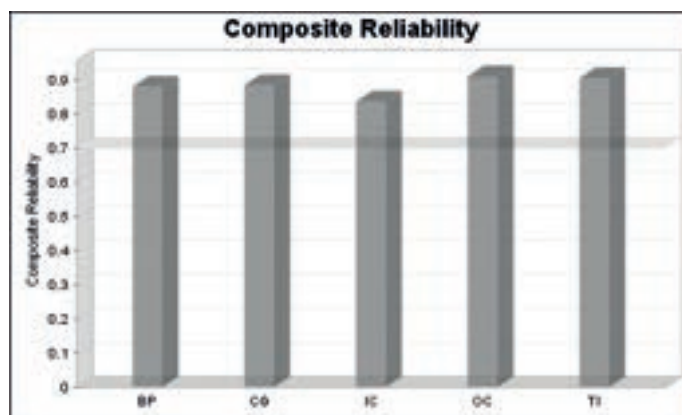


Figure 3. Composite Reliability

Validity refers to the accuracy with which a system calculates what it is supposed to measure. If research is highly credible, it produces real properties, characteristics, and physical or social environment variations. (Taherdoost, Hamed, 2016). All indicators must have AVE (Average Variance Extracted) greater than or equal to 0.5 [51] for testing convergent validity.

Average Variance Extracted (AVE)	
BP	0.711
CG	0.658
IC	0.72
OC	0.717
TI	0.762

Table 7. The above table indicates that all the constructs have an average variance extracted greater than 0.5 [51].

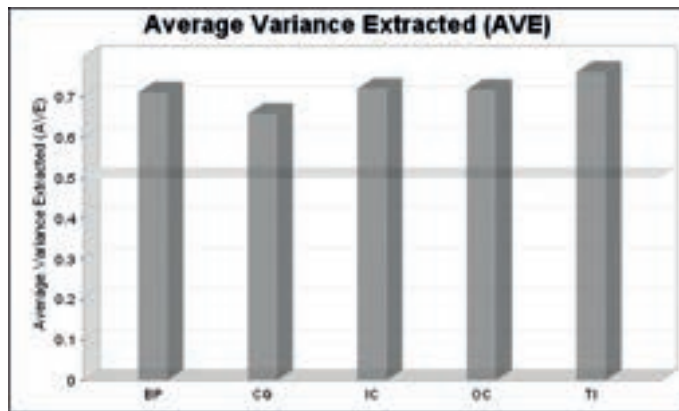


Figure 4. Convergent Validity

Discriminant validity specifies the differentiation or uniqueness between all the constructs in the model, and only those constructs with a discriminating validity value of 0.85 or less are considered valid [51].

	B.P.	CG	I.C.	OC	TI
BP					
CG	0.861				
IC	0.993	0.823			
OC	0.823	0.656	1.133		
TI	0.853	0.805	0.988	0.79	

Table 8. Discriminant validity

The above table indicates that all constructs in this research are very well valid except Business Performance-Corporate governance, organizational culture-intellectual capital & intellectual capital-technological innovation having borderline exceeding values greater than 0.5 [51].

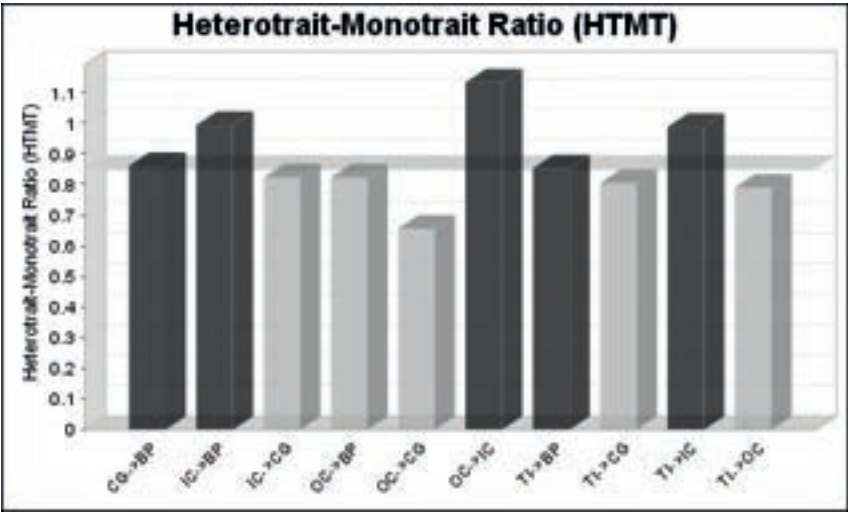


Figure 5. Discriminant validity

4.3. Structural Model Evaluation

After the measurement model, the data set’s structural model is measured on PLS, establishing the internal model’s predictive validity and the relationship between the proposed constructs. All proposed hypotheses that are evaluated and verified based on the results of that method. All hypotheses with a P value of less than 0.05 is accepted in quantitative analysis; the remaining are rejected [53].

	Original Sample (O)	Standard Error	T Statistics (O/STDEV)	P Values	Decision
IC -> BP	0.224	0.098	2.286	0.011	Supported
OC -> BP	0.17	0.089	1.901	0.029	Supported

Table 9. Direct Relationship Testing

The above table highlights the direct relationship between an independent and dependent variable based on results from these model hypotheses H1 and H2 are accepted.

The mediation relationship is evaluated through path coefficient and specific indirect bootstrapping effects. The results indicate that the H3 hypothesis is accepted.

	Original Sample (O)	Standard Error	T Statistics (O/STDEV)	P Values	Decision
OC -> TI -> BP	0.121	0.052	2.339	0.019	Supported

Table 10. Mediating Relationship Testing

This table indicates the relationship between mediator, independent and dependent variables; from the above results of bootstrapping and two-tailed testing, the hypotheses H3 supports the model.

To find the moderating effect of corporate governance between intellectual capital and business performance, bootstrapping is the sun on one-tailed testing after creating a moderating impact on smart PLS.

	Original Sample (O)	Standard Error	T Statistics (O/STDEV)	P Values	Decision
IC*CG -> BP	0.042	0.057	0.742	0.229	Not Supported

Table 11. Moderating Relationship Testing

Table 11 indicates the relationship between the moderator (corporate governance), the independent variable (intellectual capital), and the dependent variable (business performance). From the above results of bootstrapping and one-tailed testing the hypotheses, H4 not supports the model.

This study aimed to evaluate and compare the influence of organizational culture & intellectual capital on business performance, which is Karachi's textile industry (Pakistan). The results show that corporate culture, intellectual capital, and technology innovation significantly influence the textile industry's production. Therefore, the null hypothesis that there is no critical impact on the textile industry's output by organizational factors is dismissed.

The textile industries should implement advanced technology and creative methods, increasing their competitiveness level. The industrial textile units must have effective leadership, an effective communication system, and a good governance structure to enhance industrial textile units' efficiency.

5. Conclusion

Through this research, it is concluded that the organizational culture within the firm and Intellectual capital both directly impact the business performance of the textile firms. With the help of Smart PLS Software, the hypothesis that the firm culture and intellectual capital has a positive impact on business performance is found to be supported. Moreover, it is also proved that technological innovation works as a mediator between the organizational culture and business performance. However, corporate governance does not affect moderation between the textile industry's intellectual capital and business performance. The findings discussed here will benefit researchers and textile industries. This study will contribute to the valuation of companies and serve as a comparison between textile industries. Managers may use the model to define and compare the most relevant metrics to industry-wide benchmarks.

This research has a few limitations as well. It is tough to study every textile industry of Pakistan. Surveying the country is not possible within a limited period; therefore, this research is only based on Karachi's textile industries having a better reputation and market demand. Analysis of the textile industries in other cities of Pakistan could be carried out in the future. The moderator could be rapid changes in technology, business strategy, or environmental dynamism.

References

- [1] S. Paudel, "Entrepreneurial leadership and business performance: Effect of organizational innovation and environmental dynamism," *South Asian Journal of Business Studies*, Vol. 8 No. 3, pp. 348-369, 2019.
- [2] Q. L. Kweh & I. W. K. Ting & L. T. M. Hanh & C. Zhang, "Intellectual capital, governmental presence, and firm performance of publicly listed companies in Malaysia," *International Journal of Learning and Intellectual Capital, Inderscience Enterprises Ltd*, Vol. 16(2), pp 193-211, 2019.
- [3] D. Zeghal and A. Maaloul. "Analyzing value-added as an indicator of intellectual capital and its consequences on company performance," *Journal of Intellectual Capital*, Vol. 11 No. 1, pp. 39-60, 2010.
- [4] L. June. "Are personal innovativeness and social influence critical to continue with mobile commerce?", *Internet Research*, Vol. 24 No. 2, pp. 134-159, 2014.
- [5] V. Singh, A. Kumar, T. Singh, "Impact of TQM on organizational performance: The case of Indian manufacturing and service industry," *Operations Research Perspectives*, Vol. 5, pp 199-217, 2018.
- [6] P. Stannack "Perspectives on Employee Performance," *Management Research News*, Vol. 19 No. 4/5, pp. 38-40, 1996
- [7] Y. Zhang & U. Khan & Seoyeon Lee & M. Salik, "The Influence of Management Innovation and Technological Innovation on Organization Performance. A Mediating Role of Sustainability," *Sustainability, MDPI, Open Access Journal*, Vol. 11(2), pages 1-21, 2019.
- [8] Y. Muchtar, & I. Q. Lubis, "The Influence of Transformational Leadership Style on Innovation Mediated by Organizational Culture." *Journal of Management Research*, Vol. 6(4), 176, 2014.
- [9] Y. Muchtar, & I. Q. Lubis, "The Influence of Transformational Leadership Style on Innovation Mediated by Organizational Culture." *Journal of Management Research*, Vol. 6(4), 176, 2014.

- [10] N. H Abdullah, A. Shamsuddin, E. Wahab, & A. H. N. Aziati, "The Relationship between Organizational Culture and Product Innovativeness." *Procedia - Social and Behavioral Sciences*, 129, 140–147. 2014
- [11] E.C. Martins and F. Terblanche, "Building organizational culture that stimulates creativity and innovation," *European Journal of Innovation Management*, Vol. 6 No. 1, pp. 64-74, 2003.
- [12] Y. Godiwalla "Making MNC Competitive Through Effective Cross-Cultural Negotiations," *International Journal of Social Science Studies*. Vol. 7(1)21, 2018.
- [13] M. Greco, M. Grimaldi, & L. Cricelli, "An analysis of the open innovation effect on firm performance." *European Management Journal*, Vol. 34(5), pp. 501–516, 2016.
- [14] A.M. Marampa, R. W. V. Khananda, A. I. Anggraeni "The Effect of Organizational Culture on Organizational Performance," *International Conference on Rural Development and Entrepreneurship*. Vol. 6, Issue 1, pp. 65-72, 2019.
- [15] S. M. Hazem & S. Zehou, "Organizational culture and innovation: A literature review," *Advances in Social Science, Education and Humanities Research*. Vol. 344, 2019.
- [16] L. T. Tuan, "Organizational culture, leadership and performance measurement interestedness," *International Journal of Management & enterprise development*. Vol. 9, Issue 3, pp. 251-275, 2010.
- [17] S. H. Wahyuningsih, A. Sudiro & E. A. Troena , D. W. Irawanto "Analysis of organizational culture with Denison's model approach for international business competitiveness," *Problems and Perspectives in Management*. Vol. 17(1) pp. 142-15, 2018.
- [18] L. Miller, R. Miller, J. Dismukes, "The Critical Role of Information and Information Technology in Future Accelerated Radical Innovation," *Information, Knowledge System, Management, IOS Press*, Vol. 5, Nr. 2, pp. 63-69, 2006.
- [19] A.Jolly, Team to Teach: "A Facilitator's guide to professional learning teams," Oxford OH: *National Staff Development Council*, 2008
- [20] T. Buschgens, A. Bausch, D. B. Balkin, "Organizational culture and innovation: A meta – analytic review." *Journal of Product Innovation Management*, 30 (94), 1-19, 2013.
- [21] G. J. Tellis, J. C. Prabhu, and K. C. Rajesh, "Radical innovation across nations: the preeminence of corporate culture," *Journal of Marketing*, Vol. 73 No. 1, pp. 3-23, 2009.

- [22] J. Perenc, J. H. Iwan, "Innovation in developing companies' competitiveness, importance, support and examples of applications," 2011.
- [23] B. Hall, F. Lotti, J. Mairesse, Innovation and Productivity in SMEs—Empirical Evidence for Italy. *Small Business Economics*, Vol. 33, issue 1, pp. 13–33, 2009.
- [24] A.MA. M. Ahlia University. "Corporate Governance and Intellectual Capital: Evidence from Gulf Cooperation Council Countries," *Academy of Accounting and Financial Studies Journal*, Vol. 22, Number 1, 2018.
- [25] I.Sohail, Z. Murtaza, M. B. Saeed, Corporate Governance and Firm Performance: A study on moderating effects of firm size and leverage on the relationship between corporate governance and firm performance in banking sector of Pakistan. *Jinnah Business Review*, Vol. 1, no. 2, pp. 40-46, 2013
- [26] M. A. Baldini, G. Liberatore, "Corporate governance and intellectual capital disclosure: An empirical analysis of the Italian listed companies." *Corporate Ownership & Control*, vol. 13, issue 2, 2016.
- [27] Dr. S. B. Ahmad, A. B. Mushraf, "The Relationship between Intellectual capital and Business Performance: An empirical study in Iraqi industry" *International Conference on Management and Artificial Intelligence*. vol.6, 2011
- [28] J. J. P. Jansen, F. A. J. V. D. Bosch, H. W. Volberda, "Exploratory innovation, exploitative innovation, and performance: Effects of Organizational Antecedents and Environmental Moderators," *Management Science*, Vol. 52 No. 11, pp. 1661-1674, 2006.
- [29] J. Roos, G. Roos, L. Edvinsson, "Intellectual Capital: Navigating in the New Business Landscape," *Macmillan Publications*, 1997.
- [30] N. Bontis "Intellectual capital disclosure in Canadian corporations," *Journal of Human Resource Costing and Accounting*, Vol. 7 No. 1, pp. 9-20, 2003.
- [31] M. D. R. Cabrita, J. L. D. Vaz, N. Bontis, "Modelling the creation of value from intellectual capital: A Portuguese banking perspective," *International Journal of Knowledge and Learning*, Vol. 3, Nos 2/3, pp. 266-80, 2007.
- [32] Y. An, H. Davey, I. R. C. Eggleton, Z. Wang, "Intellectual capital disclosure and the information gap: Evidence from China" *Advances in Accounting*. Vol. 31(2), pp. 179-187, 2015.
- [33] C. D. Ittner and D. F. Larcker, "Enhancing the Financial Reporting Model." *Journal of Accounting Research Studies*. Vol. 36, pp. 1-35, 1998.

- [34] E. Amir, B. Lev, "Value-Relevance of Nonfinancial Information: The Wireless Communications Industry." *Journal of Accounting and Economics*. Vol. 22(1-3), pp. 3-30, 1996.
- [35] S. Jabbar and T. Afza, "Relationship between intellectual capital and financial performance of Pakistani non-financial firms" *Vidyabharati International Interdisciplinary Research*, Vol. 3(1), pp.67-80, 2014.
- [36] M. A. Tanveer, S. Zafar, "The stagnant performance of the textile industry in Pakistan." *European Journal of Scientific Research*, Vol. 77, Nos.3, pp.362-372, 2012.
- [37] G. Gomes, D. D. P. N. Machado, J. Alegre, "Determinants of Innovation Culture: A Study of Textile Industry in Santa Catarina," *Brazilian Business Review*. Vol. 12, Nos.4, pp. 99-122, 2015.
- [38] C. K. Padilha & G. Gomes, "Innovation culture and performance in innovation of products and processes: a study in companies of textile industry," *RAI Revista de Administração e Inovação*, Vol. 13, Issue 4, pp.285-294, 2016.
- [39] M. Malinowska, Olszowy, "The choice of appropriate tools for measuring intellectual capital as a determinant of success with special emphasis on the textile and clothing market," *Autex Research Journal*, Vol. 13, No. 4, 2013.
- [40] J. Xu, B. Wang, "Intellectual Capital Performance of the Textile Industry in Emerging Markets: A Comparison with China and South Korea." *Sustainability*. Vol. 11(8):2354, 2019.
- [41] M. N.K. Saunders, P. Lewis, A. Thornhill, "Understanding research philosophies and approaches. Research methods for business students," Vol. 4 pp.106-135, 2019.
- [42] G. Ryan, "Introduction to positivism, interpretivism and critical theory," *Nurse researcher*, Vol. 25(4), pp. 41-49, 2018.
- [43] S. K. Antwi, H. Kasim, "Qualitative and quantitative research paradigms in business research: A philosophical reflection," *European journal of business and management*, Vol. 7(3), pp. 217-225, 2015.
- [44] O. D. Apuke, "Quantitative research methods: A synopsis approach," *Kuwait Chapter of Arabian Journal of Business and Management Review*, Vol. 6(10), pp. 40-47, 2017.
- [45] S.M. A. Burney, H. Saleem, "Inductive and deductive research approach." *Soft Computing Applications for Decision Making in Supply Chain Management*, 2008.

- [46] N. Showkat, H. Parveen, "Non-probability and probability sampling," *Media and Communications Study*, pp. 1-9, 2017.
- [47] Etikan, S. A. Musa, R. S. Alkassim, "Comparison of convenience sampling and purposive sampling," *American Journal of theoretical and applied statistics*, Vol. 5(1), pp. 1-4, 2016.
- [48] J. F. Hair Jr, M. Sarstedt, L. Hopkins, V. G. Kuppelwieser, "Partial least squares structural equation modeling (PLS-SEM)," *European business review*, Vol. 26, Issue. 2, pp. 106-121, 2014.
- [49] H. Taherdoost, "Validity and Reliability of the Research Instrument; How to Test the Validation of a Questionnaire/Survey in a Research," *International Journal of Academic Research in Management*. Vol. 5. pp. 28-36, 2016.
- [50] J. F. Hair, M. Sarstedt, C. M. Ringle, J. A. Mena, "An Assessment of the Use of Partial Least Squares Structural Equation Modeling in Marketing Research," *Journal Academy of Marketing Science*, Vol. 40, pp.414–433, 2012.
- [51] C. Fornell, D. F. Larcker, "Evaluating Structural Equation Models with Unobservable Variables and Measurement Error." *Journal of Marketing Research*, Vol. 18, Issue. 1, pp. 39–50, 1981.
- [52] G. Dastgeer, A. U. Rehman, W. Rahman, "Examining Data and Measurement Model Specification in SEM: An Illustration from Management Development," *Journal of Business Economics and Management*. Vol. 4, pp. 62-88, 2013.
- [53] S. Hussain, A. Siddiqi, Z. Ali, Z. Fangwei, "Structural Equation Model for Evaluating Factors Affecting Quality of Social Infrastructure Projects," *Sustainability*, Vol. 10(5):1415, 2018.
- [54] M. Naqshbandi, S. Kaur and P. Ma, "What organizational culture types enable and retard open innovation?", *Quality & Quantity*, vol. 49, no. 5, pp. 2123-2144, 2014. Available: 10.1007/s11135-014-0097-5.
- [55] A. Sharabati, S. Naji Jawad and N. Bontis, "Intellectual capital and business performance in the pharmaceutical sector of Jordan", *Management Decision*, vol. 48, no. 1, pp. 105-131, 2010. Available: 10.1108/00251741011014481.
- [56] E. Anderson and V. Mittal, "Strengthening the Satisfaction-Profit Chain", *Journal of Service Research*, vol. 3, no. 2, pp. 107-120, 2000. Available: 10.1177/109467050032001.
- [57] A. Fernandes, P. Sampaio, M. Sameiro and H. Truong, "Supply chain management and quality management integration", *International Journal of*

- Quality & Reliability Management, vol. 34, no. 1, pp. 53-67, 2017.
Available: 10.1108/ijqrm-03-2015-0041.
- [58] F. Bergeron, The concept of fit in information systems research. Québec: Faculté des sciences de l'administration, Université Laval, 1999.
- [59] F.W. Geels and J. Schot, "The dynamics of transitions: a socio-technical perspective—a multi-level perspective on transitions," in *Transitions to Sustainable Development: New Directions in the Study of Long Term Transformative Change*, J. Grin, J. Rotmans, J. Schot, Eds. New York: Routledge, 2010, pp. 18-28.
- [60] F. Weldu Abrha, "Assessment of Responsiveness and Transparency: The case of Mekelle Municipality", *Journal of Civil & Legal Sciences*, vol. 05, no. 03, 2016. Available: 10.4172/2169-0170.1000191.



Dissimilarity Clustering Algorithm for Designing the PID-like Fuzzy Controllers

Essam Natsheh

dr_natsheh@hotmail.com

*Dep. of Informatics Engineering, College of Engineering
AMA International University, Bahrain*

Abstract

Fuzzy logic controller is one of the most prominent research fields to improve efficiency for process industries, which usually stick to the conventional proportional-integral-derivative (PID) control. The paper proposes an improved version of the three-term PID-like fuzzy logic controller by removing the necessity of having user-defined parameters in place for the algorithm to work. The resulting non-parametric three-term dissimilarity-based clustering fuzzy logic controller algorithm was shown to be very efficient and fast. The performance study was conducted by simulation on armature-controlled and field-controller DC motors, for linguistic type and Takagi-Sugeno-Kang (TSK) models. Comparison of the created algorithm with fuzzy c-means algorithm resulted in improved accuracy, increased speed and enhanced robustness, with an especially high increase for the TSK type model.

Keywords: Three-term controller, PID controller, fuzzy systems, fuzzy logic controller, clustering algorithms

1. Introduction

Fuzzy logic, as opposed to classical true-false digital logic, is based on the idea that variables may take values continuously from 0 to 1. Values in regular Boolean logic can be only true or false (1 or 0). Fuzzy logic allowed creating machine control systems that calculated solutions on a scale rather than discretely on or off. This way, a machine could express behaviors that are different from “do” and “not do”, such as “do a little”, “do moderately”, etc. In many cases this approach allowed to build effective systems that operated smoothly.

Being applied in many industries, research on fuzzy logic controllers (FLCs) resulted in algorithms improving more and more over the years. The research is still ongoing, and mathematic tools have improved drastically since the advent of the fuzzy logic controller. We, specifically, are interested in the three-term version of it, which combines the benefits of the almost century-old PID (or proportional–integral–derivative controller) with fuzzy logic. The regular PID controller algorithms are to this day the most widely used in process industries, such as chemicals, pharmaceuticals, petroleum, coal, plastics, etc. PID-like FLC, on the other hand, is on the rise, and every year research produces increasingly complex and useful

algorithms. One of the main benefits of the three-term controller is that it better emulates how humans think, therefore allowing staff with much less training in control to design a particular control system.

Clustering algorithms are used to group objects into clusters with high similarity between objects in the same cluster, and low similarity between objects in different clusters. For the purpose of this study, the dissimilarity measure was chosen. Therefore, the former statement could be reformulated as follows: these algorithms will group objects into clusters with low dissimilarity between objects in the same cluster, and high between objects in different clusters. The problem is that predefined user parameters affect the clustering and could be detrimental to the performance of the FLC.

The main objective of this paper is to derive a clustering algorithm that, without parameters defined by the user, would generate a rule-base for a proportional-integral-derivative-like FLC. The numerical data will be clustered based on the dissimilarity of the object's "position".

2. Literature Review

A lot of work has been put into the research of the FLC since Mamdani and Assilian introduced the concept in [1]. They applied their novelty controller to a simulated model of an industrial plant – a steam engine. Resulting from their study was a groundbreaking conclusion that fuzzy set theory is applicable and useful in the design of controllers. They proved that an unstructured set an efficient algorithm could be derived from an unstructured set of heuristics.

Esposito et al. in [2] reviewed different dissimilarity measures for symbolic descriptions, including Boolean and probabilistic descriptions. They provide an overview and mathematical basis for different approaches in calculating the dissimilarity measure in multivariate data using ASSO (analysis system of symbolic official data) software. The DISS module of the ASSO software was used to obtain dissimilarity measure with different methods. The VDISS module was used "for the visualization of dissimilarities by means of two-dimensional scatterplots and line graphs".

Gowda and Diday in [3], [4] propose symbolic clustering using their new dissimilarity measure. It is "non-parametric, hierarchical and agglomerative in nature", and therefore is invaluable for our current research. They selected the least dissimilar mutual pair of objects by finding the ones with the smallest possible increase in the sum of squared error.

The paper [5] of Appice et al. proposed a symbolic objects' classification (clustering) method SO-NN as an extension of the k-nearest neighbor method, as a lazy learning approach. Their research resulted in a conclusion that the SO-NN method was able to show adaptive behavior by approximating the symbolic object's unknown class value locally, while the prediction accuracy remained high. They also were able to compare different measures for dissimilarity, for both Boolean and probabilistic symbolic objects. Finally, they suggest that by weighting each variable separately to compute the dissimilarity between objects, it is possible to significantly

improve the predictive capability of the proposed symbolic objects nearest neighbor algorithm as compared to the conventional k-nearest neighbor classification.

Malerba et al. in [6] were able to compare different dissimilarity measures and obtained controversial results. First, they established that a comparative investigation has never been done on dissimilarity measures to check their performance on real data. Then, they conducted the study with a data set for which there was a defined expected property. Among seven dissimilarity measures only two were found to exhibit stable behavior when applied to a real data set with understandable properties. They concluded that more extensive experimentation is required in this case.

Djamal Ziani proposed an improved algorithm Minset-Plus in [7]. This algorithm was used to select discrimination variables from a set of symbolic objects. They conducted experiments on both real and generated databases, and compared the discrimination power and discrimination by extent between the two algorithms. The obtained results indicated good cluster selection with strong discrimination for any types of data.

In [8], El-sonbaty and Ismail suggested a modified fuzzy c-means algorithms for clustering of symbolic objects. They tested it on real and simulated data sets and compared the results with those that could be found in the literature. Their new algorithm was said to surmount almost all of the drawbacks that come with clustering symbolic data using hierarchical algorithms. It was achieved through representing the clustering of symbolic objects as an optimization problem, where the function was constrained by specific boundary conditions.

Ng et al. in [9] looked into updating the k-modes categorical data clustering algorithm (which is the k-means algorithm that uses a matching dissimilarity measure, frequency-based method and clusters' modes instead of means) by using a new dissimilarity measure. Their results suggest that their improved version of the k-modes is more efficient in clustering categorical data sets, which is proved using both mathematical means and experimentation. In particular, they found that the convergence and clustering efficiency is better with the new dissimilarity measure.

3. Non-parametric dissimilarity-based clustering for designing a FLC

In our previous study [10], various clustering algorithms that could be used to design a PID-like FLC were discussed. These algorithms require the determination of some parameters that affect the number of clusters to be generated. In next subsections, an algorithm based on Gowda and Diday's dissimilarity measure is proposed.

3.1. Composite objects

Successive merging lies at the heart of agglomerative clustering methods. Merging is the process of gathering together, on the basis of the similarity or dissimilarity measures, two samples and assigning them a same-cluster membership or a label for further clustering [3], [4]. For example, let A and B be two objects; Gowda and Diday proposed to compose these two objects by consideration their minimum interval

which include both A and B . Due to non-interval data, the composite object O resulting from the merging of A and B is proposed as:

$$O = \text{mean} (A, B) \quad (1)$$

3.2. Mutual pair

The concept of mutual pair consists of two elements that are part of two different groups of data. One element or object of one group X_i and a second element or object of a second group X_j , which share the same boundary, may have the highest similarity or the lowest dissimilarity. If one of the two previous conditions occurs effectively, it means that it constitutes a mutual pair.

The two concepts are not technically the same condition, but similar to the mathematical concept of limit, the two conditions must occur for mutual pair condition.

The concept of *mutual nearest neighborhood*, introduced by Gowda and Krishna [11], [12], is not exclusive for computer sciences. Still, it applies in biology with the condition of two or more cells that are physically one side to another, sharing similar chemical and biological characteristics. In computer sciences, there are common characteristics such as learning, editing, condensed nearest-neighbor rule, desegregate clustering, and error correction.

3.3. Dissimilarity and similarity measures

The relative positions of two points, named A and B , can be analyzed from a dissimilarity and similarity, considering the similar characteristics of two points of differences. The dissimilarity, named as D , is represented mathematically as a difference between the points " A " and point " B ." The dissimilarity is as follows:

$$D (A, B) = \| A - B \| \quad (2)$$

The symbol " $\|$ " shows an inner product norm metric, according to the Euclidian norm. It could be rewritten using the square root of a sum, as-is:

$$D (A, B) = \sqrt{\sum_{i=1}^n (A_i - B_i)^2} \quad (3)$$

The dissimilarity (D) is inside the norm, between 0 and 1, using the following:

$$D' = \frac{D - D_{\min}}{D_{\max} - D_{\min}} \quad (4)$$

The calculation considers D 's value for a specific position, and its transformation considers the maximum and minimum value of dissimilarity.

3.4. Dissimilarity measure-based algorithm (DMBA)

The calculation of the dissimilarity measure-based algorithm (DMBA) can be developed in four steps, according to the following procedure [3], [4]:

1. It is necessary to identify the system's different objects, using the letter X with the identification of the initial number of clusters N equal to number of objects. For example, $X_1, X_2, \dots, X_N$. As was told previously, the number of clusters is a discrete value; and each cluster has a specific weight of 1.
2. Calculate between the different points of the data the weighted dissimilarity D_w . The calculation considers the dissimilarity of a specific (X_i, X_j) object and the total amount of objects. The mathematical equation is the following:

$$D_w(X_i, X_j) = D(X_i, X_j) \cdot \sqrt{\frac{n_i \cdot n_j}{n_i + n_j}} \quad (5)$$

n_i and n_j represent the cluster weights for X_i and X_j , and the dissimilarity is given by $D(X_i, X_j)$ that calculated using equation (3). The calculation provides a weighted measurement because the ratio is below a square root calculation.

The number of clusters is reduced to 1. According to previous definitions, the pair of individuals is merged using a composite object using the lowest dissimilarity.

3. Steps 2 must be repeated until the number of clusters is equal to 1.
4. Calculate the cluster indicator (CI). The calculation considers three stages: “ p ”, “ $p+1$ ” and “ $p-1$ ”. The recommendation is to calculate the value of R_p for each stage and later determine the value of CI

It is necessary to use the minimum dissimilarity for the current stage, the previous stage, and the forward stage in each stage. The higher this value, the more improper it is to merge the two objects of the mutual pair at this stage [3]. The use of a calculation loop is useful when there are a large number of clusters to calculate. The CI equation is the following:

$$CI = \frac{R_p}{R_{p+1}} \quad (6)$$

where

$$R_p = \frac{D_{min} \text{ at } (p)}{D_{min} \text{ at } (p+1) + D_{min} \text{ at } (p-1)} \quad (7)$$

4. Developing the rule-base of the PID FLC using clustering algorithms

Fuzzy system models basically fall into two categories [13]. The first category is linguistic models (LMs) that contains list of IF–THEN rules with vague predicates. The second category of fuzzy models called Takagi-Sugeno-Kang (TSK) method [14] where the rules have a fuzzy antecedent part and a functional consequent; essentially,

they are combination of fuzzy and non-fuzzy models. This section is a discussion of how both kinds of models can be applied in the design of a three-term FLC.

4.1. Linguistic models as tools for three-term FLC representation

Starting with the observed data pairs (e_k, de_k, se_k, U_k) the clustering methods provide a collection of clusters and their centers $(e_{Ci}, de_{Ci}, se_{Ci}, U_{Ci})$. Each center can be viewed as a prototypical fuzzy point in the relationship between input and output, as shown in Figure 1.

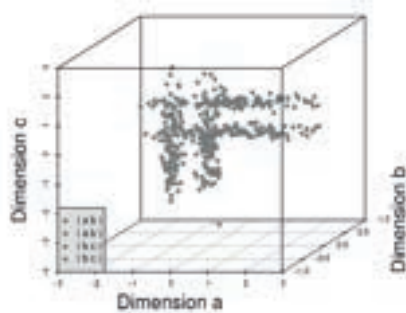


Figure 1: Three-dimensional data clustering for rule determination.

It is proposed that the rules in the PID-like FLC rule-base are formed linguistically as follows:

IF error is close to *cluster i* AND error-change is close to *cluster i* AND error-sum is close to *cluster i*, THEN control action is close to *cluster i*.

$$\text{For } i = 1 \dots C \quad (8)$$

where C is the number of clusters. The cluster centers $(e_{Ci}, de_{Ci}, se_{Ci}, U_{Ci})$ of each fuzzy variable are considered to be the peaks of their membership functions.

To achieve a systematic method of defining the membership functions of the antecedent fuzzy sets, the use of the Gaussian curve membership function is proposed:

$$\mu_i(y) = \exp\left(\frac{-(y - y_i^*)^2}{2\sigma^2}\right) \quad (9)$$

where y is the input vector, y_i^* is the center of the cluster i , and σ is the width of the cluster i . To compute the initial value of σ for the clusters in the fuzzy variable X (e , de , se , and U), the following equation is proposed:

$$\sigma = \frac{\text{Maximum point in } X - \text{Minimum point in } X}{\text{Number of clusters}} \quad (10)$$

To refine the σ value for each variable, the algorithm 1 is proposed. The use of a decrease_ratio of 0.7 and an increase_ratio of 1.05 is suggested.

Algorithm 1: optimizing σ values

Input: initial σ value for each variable
Output: optimized σ value for each variable

- 1 Use eq. (10) to get the initial σ value to each variable;
- 2 Initialize SSE (sum-squared error) to large value;
- 3 For $i=1$ to maximum number of epochs to refine all σ
- 4 If $SSE < sse_goal$, break, end if
- 5 For $j=1$ to minimum no. of epochs to refinement one σ
- 6 Run the experiment and get new_sse;
- 7 If ($new_sse \leq SSE$)
- 8 $SSE = new_sse$;
- 9 Save σ ;
- 10 $\sigma = \sigma \times increase_ratio$;
- 11 else
- 12 $\sigma = \sigma \times decrease_ratio$;
- 13 end if
- 14 end for
- 15 end for

4.2. Takagi-Sugeno-Kang models as tools for three-term FLC representation

A definition of the TSK rules in the PID-like FLC rule-base is proposed as follows:

If error (y_1) is close to *cluster i* AND error-change (y_2) is close to *cluster i* AND error-sum (y_3) is close to *cluster i*, THEN control action is $a_{i1}y_1 + a_{i2}y_2 + a_{i3}y_3 + a_{i4}$

$$\text{For } i = 1 \dots C \quad (11)$$

This subsection contains a description of Chiu's method [15], [16] for fuzzy model identification. His method for fuzzy model identification from data is based on the use of a cluster estimation method to create the rules and their initial parameters and then on the application of optimization algorithms to tune these parameters. Chiu uses a *recursive least squares* estimation algorithm to optimize the fuzzy model. The issue with this algorithm is that it is iterative and slow. To optimize the fuzzy model, the use of a *singular value decomposition* method is proposed. This is a non-iterative algorithm capable of obtaining the parameter estimates very quickly and reliably.

4.2.1. Fuzzy model identification

Consider a set of C cluster centers $\{c_1, c_2, \dots, c_C\}$ in an M dimensional space. Let the first N dimensions correspond to input variables and the last $M-N$ dimensions correspond to output variables. Each vector c_i is decomposed into two components y_i^* and z_i^* , where y_i^* contains the first N elements of c_i (i.e., the coordinates of the cluster center in input space) and z_i^* contains the last $M-N$ elements (i.e., the coordinates of

the cluster center in output space). Given an input vector y , the degree to which rule i is fulfilled is defined as [15], [16]:

$$\tau_i = \exp(-\|y - y_i^*\|^2) \quad (12)$$

The output vector z can be computed via:

$$z = \frac{\sum_{i=1}^C \tau_i z_i^*}{\sum_{i=1}^C \tau_i} \quad (13)$$

To systematically define the membership functions of the antecedent fuzzy sets, the use of the Gaussian curve membership function as defined by (9) is proposed. Equation (10) should be used to compute the σ value for the Gaussian curves.

4.2.2. Optimizing the fuzzy model

The use of different variables increases the complexity of the calculation. It is possible to optimize the fuzzy model with the use of a set of clusters by a direct way of calculation. The calculation requires the optimization of rules using several variables' linear function, better than using only a simple constant. That is,

$$z_i^* = G_i y + h_i \quad (14)$$

where G_i is a matrix of $(M-N) \times N$ constant elements. To be consistent, h_i is a vector with $(M-N)$ constant elements. The z_i^* expression is a linear function that allows it to calculate with low computational complexity.

The optimization process of the equation is possible using the principle of the *least-squares* estimation procedure [14]. The equation for the calculation is:

$$\rho_i = \frac{\tau_i}{\sum_{j=1}^C \tau_j} \quad (15)$$

Equation (13) can then be rewritten as

$$z = \sum_{i=1}^C \rho_i z_i^* = \sum_{i=1}^C \rho_i (G_i y + h_i) \quad (16)$$

or

$$z^T = [\rho_1 y^T \quad \rho_1 \quad \dots \quad \rho_c y^T \quad \rho_c] \begin{bmatrix} G_1^T \\ h_1^T \\ \vdots \\ G_c^T \\ h_c^T \end{bmatrix} \quad (17)$$

where z^T and y^T are row vectors. With “ n ” input data points in the form of $y_1, y_2, \dots, y_n$; the result of the matrix operation is the following:

$$\begin{bmatrix} z_1^T \\ \vdots \\ z_n^T \end{bmatrix} = \begin{bmatrix} \rho_{1,1} y_1^T & \rho_{1,1} & \dots & \rho_{c,1} y_1^T & \rho_{c,1} \\ & & & & \\ & & \vdots & & \\ \rho_{1,n} y_n^T & \rho_{1,n} & \dots & \rho_{c,n} y_n^T & \rho_{c,n} \end{bmatrix} \begin{bmatrix} G_1^T \\ h_1^T \\ \vdots \\ G_c^T \\ h_c^T \end{bmatrix} \quad (18)$$

The value of $\rho_{i,j}$ is evaluated in the value of y_j . In the matrix operation, the product is confirmed by two sides. The left hand of the product is constant, while the second side of the matrix contains all the optimized parameters.

The estimation of least-squares can be calculated with the following procedure:

$$AX = B \quad (19)$$

B 's value is the output calculation; A is a constant matrix, and X is the parameters matrix to be calculated. Let us choose X in such a way that the following objective function J is minimized [17], [18]:

$$J = \|B - AX\|_2^2 \equiv (B - AX)^{-T} (B - AX) \quad (20)$$

To carry out the minimization, J is differentiated with respect to X and the result is equated to zero. Thus,

$$\frac{\partial J}{\partial X} = -2A^T B + 2A^T X = 0 \quad (21)$$

from which X can be solved as

$$X = (A^T A)^{-1} + A^T B \quad (22)$$

In practice, the most reliable method of computing the pseudo-inverse of a matrix is the *singular value decomposition* (SVD). For an overview of the SVD, its theory, and numerical details, the reader is referred to [19].

5. Performance analysis of the proposed design method

In the next sections, the use of two performance measures with two simulated systems is proposed. The objective of the simulation is to demonstrate the feasibility of the proposed three-term design method when applied to second-order systems. A comparison of its performance with the performance of other clustering methods is carried out.

5.1. Performance study

To test the models, two performance measures have been chosen, which will be used to analyze the performance of the proposed methods for designing a FLC. They are:

1. Accuracy: To design a PID-like FLC with clustering algorithms, the rise-time, overshoot, and settling-time performance measures will be omitted, because a teacher signal is used with these algorithms as a reference model. To validate the results, it is proposed that an accuracy criterion be employed. Accuracy means the correctness of the answer. In order to measure it, the use of the sum of squares for error is proposed. Thus, the smaller the error, the better the accuracy, and the larger the error, the worse the accuracy will be. The error here is the error between the output of the system under analysis and its reference model.
2. Robustness: To measure robustness, it is proposed that the defuzzification method parameter be varied. During the design of the FLC, center of area (COA) was chosen as a defuzzification method. To measure the robustness of this controller, the use of bisector of area (BOA) as a defuzzification method [20] is suggested. The procedure used to implement this method shown in [24].

Two types of direct current (DC) motors are analyzed to examine the performance of proposed design methods: *armature-controlled* with fixed field and *field-controlled* with fixed armature current [21]. The same details and parameters as described in our previous studies [22], [23], [24], [25] were used for these two systems.

For the clustering technique, the reference model with inputs $[e, de, se]^T$ and output U is used to designate the desired performance. To design a PID-like FLC using the *fuzzy c-means* (FCM) algorithm, the weighting exponent parameter q for the membership functions matrix M was chosen as 2.0 [26], [15]. To design a PID-like FLC with a subtractive algorithm, the cluster radius r_a as 0.5 for all data dimensions, squash factor r_b as 1.5, accept ratio ε_+ as 0.5, and reject ratio ε_- as 0.15 [15] were chosen.

5.2. Simulation results

The performance of the PID-like FLC design methods is examined by analyzing the transient response and accuracy in subsection 5.2.1 and robustness in subsection 5.2.2.

5.2.1. Transient response and accuracy

The following subsection focuses on the performance of the armature-controlled DC motor, while subsection 5.2.1.2 focuses on the performance of the field-controlled DC motor.

5.2.1.1 Armature-controlled DC motor system

The *CI* for the armature-controlled DC motor system is shown in Figure 2. This figure shows that the DMBA generates only 5 clusters from 40 sampling points.

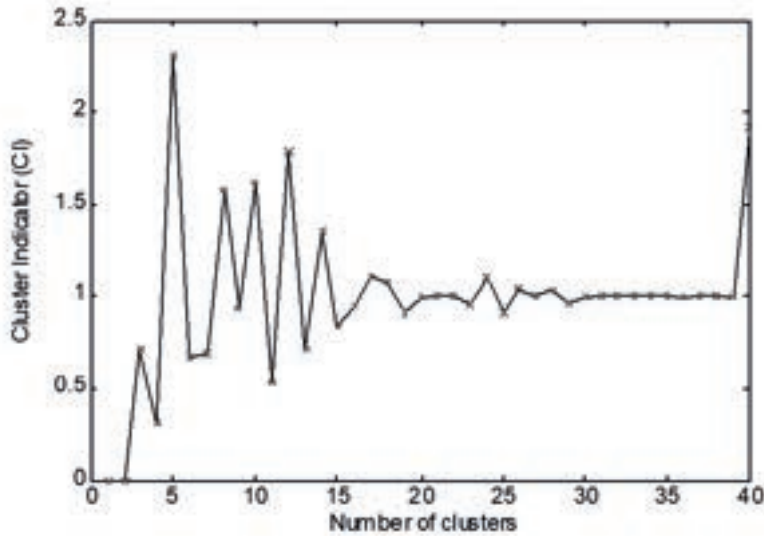
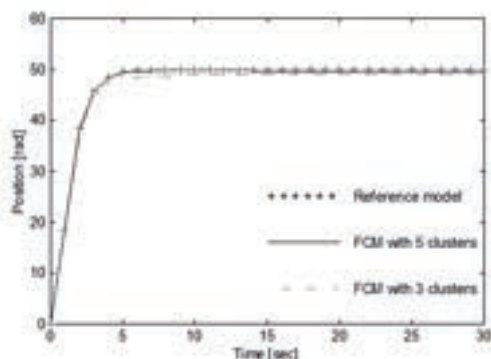


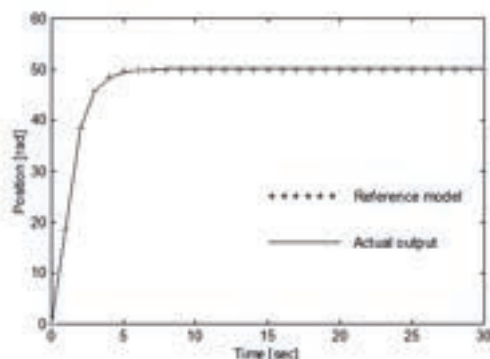
Figure 2: Cluster indicator for armature-controlled DC motor system

Figure 3 shows the step responses and accuracy of the armature-controlled DC motor system. The FCM algorithm used to generate 3 clusters and 5 clusters for comparison. It can be seen how the controller output gets close to the reference model as more clusters are considered. The subtractive algorithm generates only one cluster for this system, so it cannot be used with this model. A comparison between the SSE for the linguistic-type DMBA and other controller shows that they are comparable. Note that SSE for the DMBA is significantly smaller than the SSE for the other controller. Thus, we can conclude that no over-transient response occurs with DMBA method.

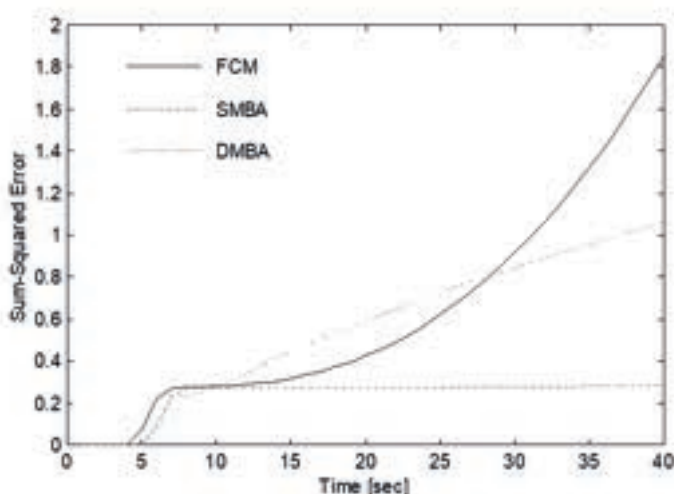
Figure 4 shows the step responses and accuracy of the armature-controlled DC motor system using the FCM algorithm (used to generate 5 clusters), the subtractive algorithm, and the DMBA for the TSK-type model of the PID-like FLC. In figure 4-B, the values of SSE for FCM and DMBA are multiplied by ten to the power of negative seven which mean they are clearly more accurate than the subtractive clustering algorithm.



(A-1) FCM with 3 clusters and 5 clusters



(A-2) Proposed non-parametric DMBA.



(B) Accuracy of clustering algorithms.

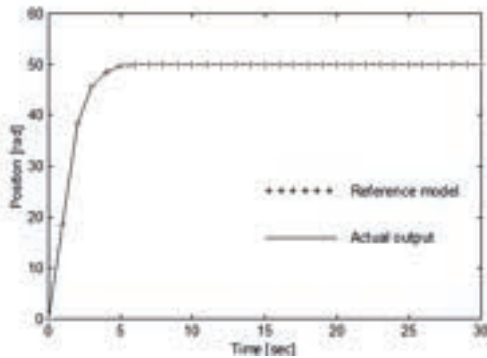
Figure 3: Step responses (A) and accuracy (B) of armature-controlled DC motor system using clustering algorithms used to develop linguistic type model PID-like FLC.

Actually, in that very small range of values for SSE we can say the accuracy of the two algorithms is almost the same and that is clear from the figure 4-A.

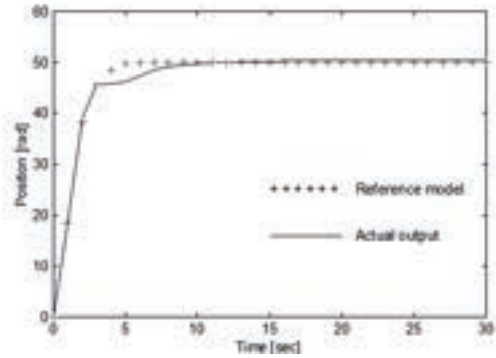
5.2.1.2 Field-controlled DC motor system

The cluster indicator (CI) for the field-controlled DC motor system using DMBA is shown in Figure 5. This figure shows that the DMBA generates 5 clusters from 40 sampling points.

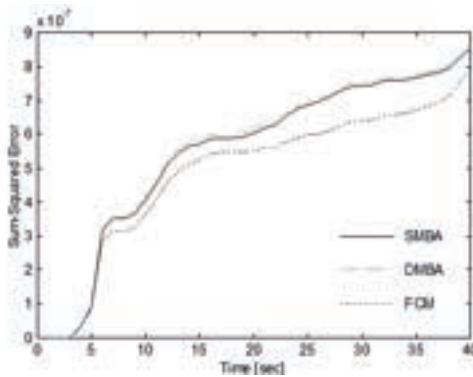
Figure 6 shows the step responses and accuracy of the field-controlled DC motor system using the FCM algorithm (used to generate 5 clusters) and the DMBA to develop a linguistic-type model of the PID-like FLC.



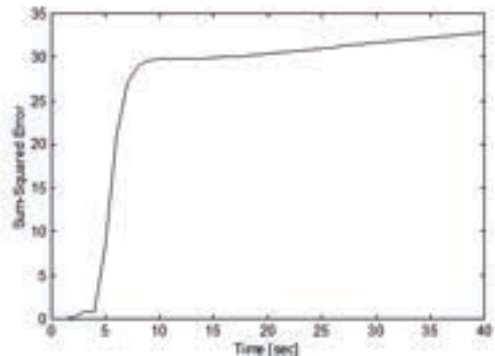
(A-1) FCM and DMBA.



(A-2) Subtractive clustering algorithm.



(B-1) FCM and DMBA.



(B-2) Subtractive clustering algorithm.

Figure 4: Step responses (A) and accuracy (B) of armature-controlled DC motor system using clustering algorithms used to develop TSK type model PID-like FLC.

The subtractive algorithm generates only one cluster for this system, so it cannot be used to develop a linguistic-type model of the PID-like FLC.

The system obtained with the controller responds to load disturbances and measurement noise. This is observed from Figure 6-A. The overshoot for setpoint changes is smallest for DMBA, which is the case to avoid large transients in the control signal due to sudden changes in the setpoint. Even though it generates higher SSE values for DMBA compared with FCM, as shown in Figure 6-B, the transient response for both algorithms is almost the same which is clearly shown in Figure 6-A.

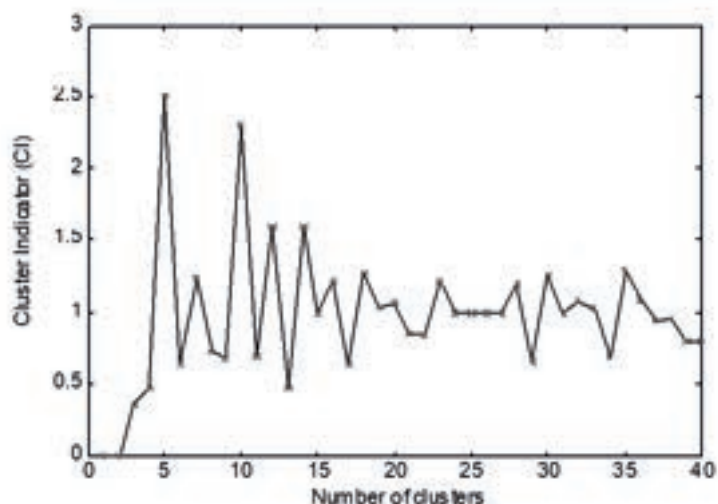


Figure 5: Cluster indicator for field-controlled DC motor system using DMBA

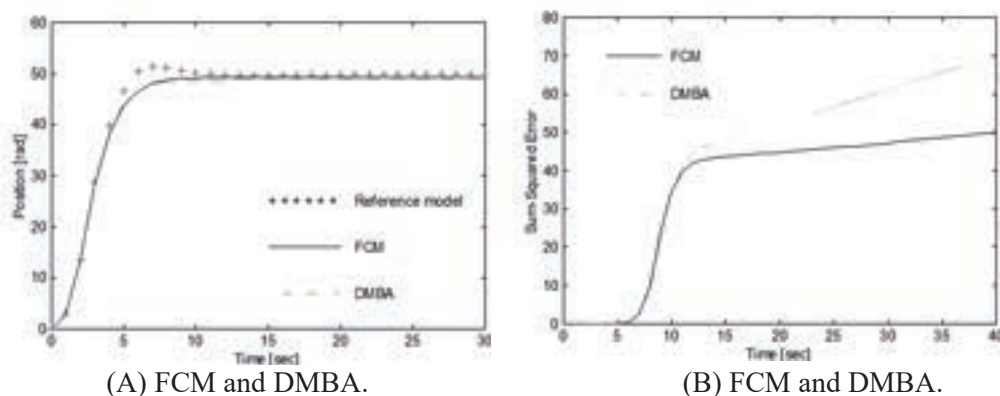
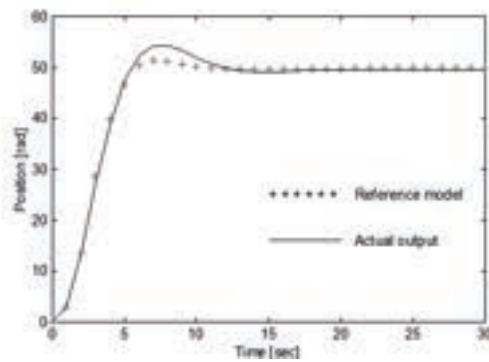
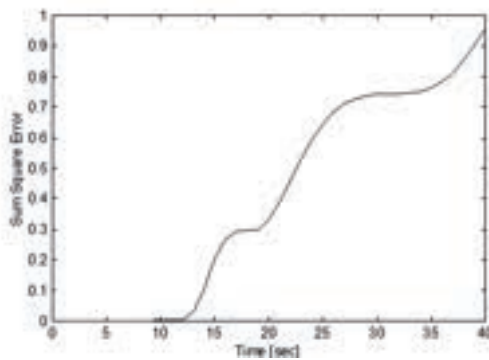


Figure 6: Step responses (A) and accuracy (B) of field-controlled DC motor system using clustering algorithms used to develop linguistic type model PID-like FLC.

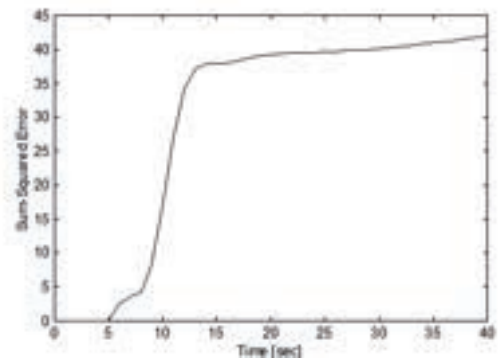
Step responses of field-controlled DC motor system using FCM and DMBA used to develop TSK type model PID-like FLC is similar to figure 4-A. It can be seen that the step response results by these methods is better than the subtractive clustering algorithm shown in figure 7-A. Where, zero overshoot achieved in FCM and DMBA methods. The figure 7-B shows that the proposed DMBA tuning method works more precisely than other tested controllers.



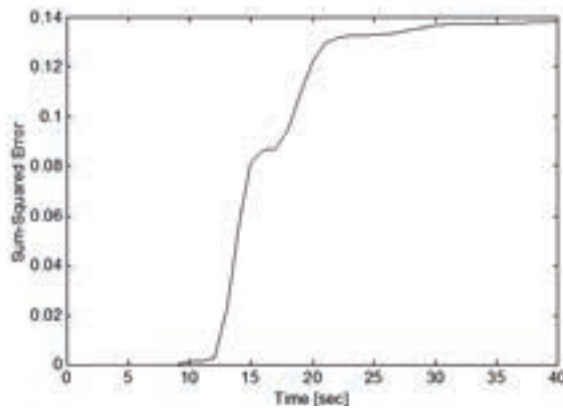
(A) Subtractive clustering algorithm.



(B.1) FCM clustering algorithm.



(B.2) Subtractive clustering algorithm.



(B.3) Proposed non-parametric DMBA.

Figure 7: Step responses (A) and accuracy (B) of field-controlled DC motor system using clustering algorithms used to develop TSK type model PID-like FLC.

5.2.2. Robustness test

The following subsection analyzes the robustness of the PID-like FLC design methods when varying the defuzzification method from center of area (COA) to bisector of area (BOA). This test cannot be used with the TSK-type model. The only defuzzification method that can be used with this model is the *weighted average* method, because the fuzzy output does not have a geometric shape.

Figures 8 and 9 show the step responses and accuracy of the armature-controlled DC motor and the field-controlled DC motor respectively, using the FCM algorithm (used to generate 5 clusters) and the DMBA to develop a linguistic-type model of the PID-like FLC. It is shown that there is a substantial improvement in the time domain specification in terms of lesser rise time, settling time and overshoot using DMBA algorithm. Hence this method is a robust design method for determining the PID controller parameters.

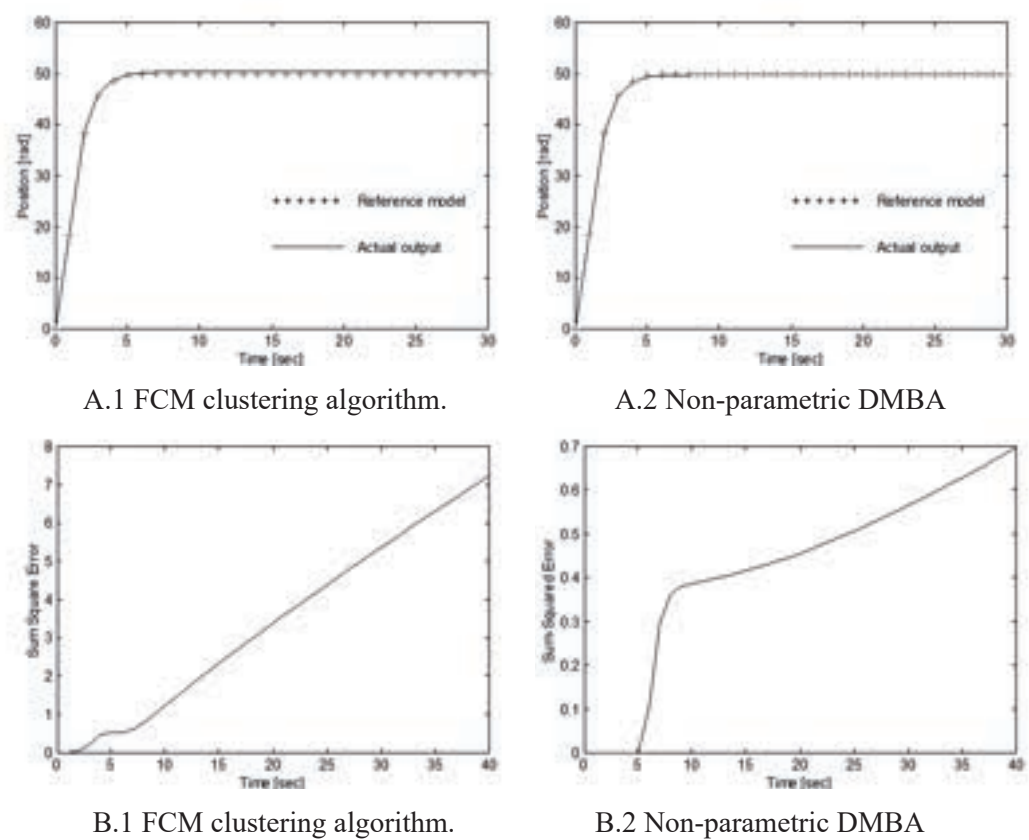
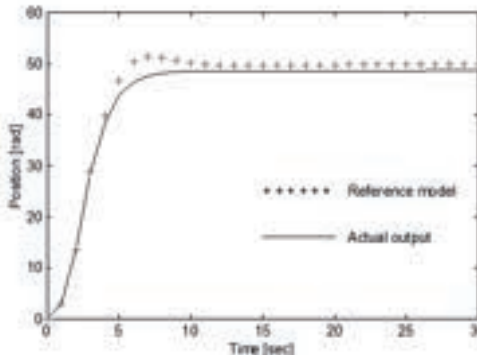
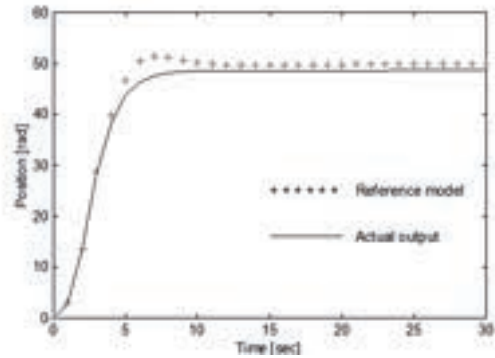


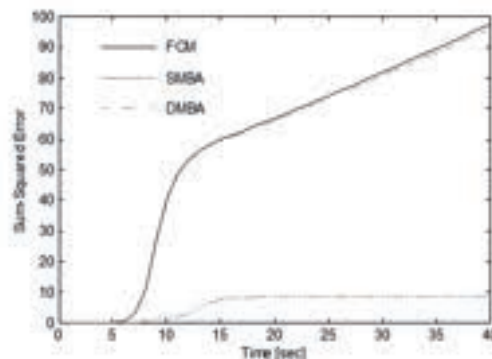
Figure 8: Robustness test to varying of defuzzification method for armature-controlled DC motor system: (A) Step responses and (B) Accuracy test.



A.1 FCM.



A.2 Proposed non-parametric DMBA.



B. Accuracy of clustering algorithms.

Figure 9: Robustness test to varying of defuzzification method for field-controlled DC motor system using clustering algorithms used to develop linguistic type model PID-like FLC.

5.2.3. Discussion

The graphs in the Section 5 provide an outlook at the effectiveness of the proposed non-parametric DMBA applied to create linguistic type and Takagi-Sugeno-Kang (TSK) type models of three-term fuzzy logic controllers. In graphs for the armature-controlled DC motor system with linguistic type model, the following results were obtained. The sum of squared error is increasing exponentially with time for the FCM and subtractive algorithms, while for the DMBA it is linear. Therefore, DMBA in this case is superior in terms of accuracy. As for the TSK type model used for the armature-controlled DC motor system, the sum of squared error is also lower for the DMBA, proving its increased correctness.

The simulation graphs for the robustness test show that non-parametric DMBA is more accurate and robust when different defuzzification methods are applied. Also, from the graphs we can conclude that TSK type model shows better accuracy than the linguistic type model.

The transient response for FCM and DMBA is almost the same for many cases studied in this paper. The main problem of supervised FCM clustering algorithms is

determination of the number of clusters that satisfactorily represent the system. Besides that, FCM have another problem. It requires determination of some parameters that will affect (increase/decrease) the number of generated clusters. Unsupervised DMBA clustering algorithms solve these problems.

6. Conclusions

Three-term PID-like fuzzy logic controllers better simulate the decision-making process of humans. Therefore, engineers are not required to understand everything in the complicated mathematical apparatus to set up a control system. On the other hand, a problem arises that there are parameters that a user has to define manually for the clustering algorithm to start working. This step affects the amount of generated clusters and could be deemed unnecessary and excessive. As an attempt to find a solution, we proposed a non-parametric dissimilarity clustering algorithm.

Resulting from the performance study, we identified that the dissimilarity measure based clustering algorithm is more accurate than regular FCM and subtractive clustering algorithms. Together with singular value decomposition the proposed dissimilarity measure based algorithm has been shown to be fast and reliable in terms of construction of a fuzzy model from numerical data input. The algorithm shows improved accuracy, increased speed and enhanced robustness as compared to the FCM and subtractive clustering algorithms for both linguistic type and Takagi-Sugeno-Kang type models. We also conclude that the latter perform better than the former.

Acknowledgements

The author would like to express his appreciation to College of Engineering at AMA International University Bahrain for supporting this research.

References

- [1] E. H. Mamdani and S. Assilian, "An experiment in linguistic synthesis with a fuzzy logic controller", *International journal of man-machine studies*, Vo.7, No.1, pp. 1-13, 1975
- [2] F. Esposito, D. Malerba, & A. Appice, "Dissimilarity and matching", *Symbolic Data Analysis and the SODAS Software*, pp. 61-66, 2008
- [3] K. C. Gowda and E. Diday, "Symbolic Clustering using a New Dissimilarity Measure", *Pattern Recognition*, Vol.24, No. 6, pp. 567-578, 1992
- [4] K. C. Gowda and E. Diday, "Symbolic Clustering Using a New Similarity Measure", *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. SMC-22, No. 2, pp. 368-378, 1992

- [5] A. Appice, C. d'Amato, F. Esposito, & D. Malerba, "Classification of symbolic objects: A lazy learning approach", *Intelligent Data Analysis*, Vol.10, No.4, pp. 301-324, 2006.
- [6] D. Malerba, F. Esposito, V. Gioviale, & V. Tamma, "Comparing dissimilarity measures for symbolic data analysis", *Proceedings of Exchange of Technology and Know-how and New Techniques and Technologies for Statistics*, Vol.1, pp. 473-481, 2001.
- [7] D. Ziani, "Feature selection on Boolean symbolic objects", *arXiv preprint arXiv:1405.0647*, 2014.
- [8] Y. El-Sonbaty and M. A. Ismail, "Fuzzy clustering for symbolic data", *IEEE Transactions on fuzzy systems*, Vol.6, No.2, pp. 195-204, 1998
- [9] M. K. Ng, M. J. Li, J. Z. Huang, & Z. He, "On the impact of dissimilarity measure in k-modes clustering algorithm", *IEEE Transactions on Pattern Analysis & Machine Intelligence*, No.3, pp. 503-507, 2007
- [10] E. Natsheh, "Taxonomy of Clustering Methods Used in Fuzzy Logic Systems", *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, vol.4, no.1, pp. 65-72, 2012
- [11] K. C. Gowda and G. Krishna, "Disaggregative Clustering Using the Concept of Mutual Nearest Neighborhood", *IEEE Trans. on Systems, Man, and Cybernetics*, Vol. SMC-8, No. 12, pp. 888-895, 1978
- [12] K. C. Gowda and G. Krishna, "The Condensed Nearest Neighbor Rule Using the Concept of Mutual Nearest Neighborhood", *IEEE Transaction on Information Theory*, Vol. 25, No. 4, pp. 488-490, 1979.
- [13] R. R. Yager and D. P. Filev, "*Essentials of Fuzzy Modeling and Control*", Wiley India, 2002.
- [14] T. Takagi and M. Sugeno, "Fuzzy Identification of Systems and Its Applications to Modeling and Control", *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. SMC-15, No. 1, pp.116-132, 1985
- [15] S. Chiu, "Fuzzy Model Identification Based on Cluster Estimation", *J. of Intelligent & Fuzzy Systems*, Vol. 2, No. 3, pp. 267-278, 1994.
- [16] S. Chiu, "Selecting Input Variables for Fuzzy Models", *J. of Intelligent & Fuzzy Systems*, Vol. 4, No. 4, pp. 243-256, 1996
- [17] J. Yen and R. Langari, "Fuzzy Logic: Intelligence, Control and Information", Prentice-Hall, 1999.
- [18] J. R. Jang, C. Sun, and E. Mizutani, "Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligent", Prentice-Hall, 1997.

- [19] W. H. Press, S. A. Teukolsky, W. T. Vetterling, and B. P. Flannery, "*Numerical Recipes in C: The Art of Scientific Computing*", 3rd Edition, Cambridge University Press, 2007.
- [20] J. Jantzen, "Foundations of Fuzzy Control: A Practical Approach", 2nd Edition, Wiley, 2013.
- [21] M. Golob, "Decomposition of a Fuzzy Controller Based on the Inference Break-up Method", *Intelligent Data Analysis*, Vol. 3, Issue 2, pp. 127-137. 1999.
- [22] E. Natsheh and K. Buragga, "Comparison between Conventional and Fuzzy Logic PID Controllers for Controlling DC Motors", *International Journal of Computer Science Issues (IJCSI)*, vol. 7, no. 5, pp. 128-134, 2010.
- [23] E. Natsheh and K. Buragga, "A Performance Comparison for Various Methods to Design the Three-Term Fuzzy Logic Controller", *International Journal of Computer Science and Network Security (IJCSNS)*, vol. 10, no. 5, pp. 142-151, 2010.
- [24] E. Natsheh, "Designing and Tuning PID Fuzzy Controllers for Armature-Controlled DC Motor", *International Journal of Human and Technology Interaction (IJHaTI)*, vol.2, no.2, pp. 17-24, 2018
- [25] E. Natsheh, "Designing a Fuzzy Logic Controller with a Non-Parametric Similarity-Based Clustering Algorithm", *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, vol.12, no.4, pp. 21-29, 2020.
- [26] I. Gath and A. B. Geva, "Unsupervised Optimal Fuzzy Clustering", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 11, No. 7, pp. 773-781, 1989



Real-time Web Search Framework for Performing Efficient Retrieval of Data

Falah Al-akashi

*Faculty of Engineering
University of Kufa, Najaf, Iraq*

falahh.alakaishi@uokufa.edu.iq

Diana Inkpen

*Faculty of Engineering
University of Ottawa, Ottawa, Canada*

Diana.Inkpen@uottawa.ca

Abstract

With the rapidly growing amount of information on the internet, real-time system is one of the key strategies to cope with the information overload and to help users in finding highly relevant information. Real-time events and domain-specific information are important knowledge base references on the Web that frequently accessed by millions of users. Since real-time data have only a short time to live, real-time models have to be continuously adapted, ensuring that real-time data are always up-to-date. The focal point of this manuscript is for designing a real-time web search approach that aggregates several web search algorithms at query time to tune search results for relevancy. The evaluation showed that the proposed approach outperforms the traditional models and allows us to adapt the specific properties of the considered real-time resources. Compared with offline approach, Wikipedia implication was highly improved the relevancy of our real-time approach, 0.405 for precision and 0.430 for nDCG, the average search duration was $4.9 \pm 3.2s$ ($N = 1000$ searches or queries). The mean search duration to each individual resource was between 0.05s and 4.55s. The average system runtime or system overhead was 0.12s, whereas, the deadline for receiving responses from all resources over the network was 10s. Overall, the proposed outcomes were significantly better than those available in similar methods presented previously, it is highly relevant for today searched queries, consistent in its performance, and resilient to the drawbacks faced by other algorithms.

Keywords: Wikipedia, Resources Correlation, Federated Search, Web Mining, Vector Space Model

1. Introduction

Crawling and indexing immense volume of web content has been a new challenge. Web has drastically moved the way of presenting and anticipating information. Its international ecosystem of applications and services platform allows us to search, aggregate, combine, transform, replicate, cache, and archive the information that

underpins today's digital society. Despite its chaotic growth and having barely entered its serious years, it's the biggest and least formal integral project ever attempted. Today, users are the direct consumers of the services offered by the majority of today's web applications. Given its success in managing user information needs at such phenomenal scale, this raises the question: how the Web's underlying architectural would be used to building a federated system that able to deal with such kind of massive data, particularly the kinds of distributed systems typically implemented by enterprise applications and developers? One solution to deal with such phenomena is to use a federated index platform which is a special kind of array that ensembles similar topics of documents in each vertical, such index is generic in nature that efficiently lookup any of the index-key topics [1]. To involve this technique, web search algorithms use a web crawler which is an internet bot that systematically browses content and collects data. Due the volume of internet is growing up, the largest crawler might unable to create a complete index and search algorithms have extreme difficulties in finding relevant search results. Although this is slightly improved by modern search models and relevant results are now available instantly, they are still not refreshed adequately. To address this, some search models have used different crawlers for different topics; for example, an academic-focused crawler is used to access only academic-related documents. Although the process of indexing prioritizes of one task over another, indexing the whole collection created in different periods is highly challenged. This means that the collection is still not refreshed unless the indexing process is created at query time. As a consequence, searching the internet with broad queries tends to produce results or conclusions that differ systematically from the truth [2]. Such search technique is knotted as the quality of data in each web resource that cannot be assessed through analyzing its content alone [3].

In this paper, we tend to use a canonical real-time model for collaborating information on the basis of different information computations between web resources. Studying the impact of information quality value and communication cost aims to show different resources are optimal for different informational need. Within the context of real-time system design, we tend to be able to address many analysis problems like handling words with multiple meanings (polysemy), user modeling, cooperation among agents, and communication between user and resources. It's necessary to grasp the state-of-the-art applied to information quality and information optimization in Web resources to conduct a study regarding the benefits and shortcomings that the system presents. Different resources used in every topic means different algorithms are involved since each resource associates with different features for its algorithm. Despite researchers have recommended using authoritative indexes for specific queries, but indices still require more information for each resource to produce reliable content. Learning to rank tends to be a solution to narrow diverse queries but it could not distinguish between authoritative and non-authoritative content [4]. As a result, the probabilistic models for task specific category based grasping had been alternative solutions. Web connectivity is relevant topically and search services have turned to information of resources rather than web content itself, Ding et al. [5] and Lawrence and Giles [6] and Kaptein et al. [7]

showed how the external resources were important to improve the quality of data. However, the federated search is the last attempt to handle such problem, but generalizing Web search task involves more challenges than federated search for specializing Web search task [8]. Various resources in common topics mean encompassed several different algorithms because each resource is usually treated with combination of different features. Grouping high-level resources in different topical federated verticals is very important at this time. This helps efficient adhoc queries without need to create different indices for different sets of topics. Indexing real-time data for real-time query searches is challenge since new data, e.g. micro-blogs, news, tweets... etc. created in a short term meanwhile user query functions remain permanently changeable over time [9]. However, we aim to address all discussed challenges by exploiting the adaptation technology for developing our previous offline web search algorithm, which was the best ranking model according to the TREC evaluation campaign, to real-time search model.

The rest of paper is organised as follows: Section 2 outlines some related works to our model. Section 3 describes how we formulated our approach by discussing features and other signals exploited in the algorithm. Section 4 details the experimental results. Section 5 lists some challenges that faced our experiments, and finally, Section 6 will provide conclusion remarks

2. Related Work

Federated search, social search, real-time search and aggregated search are kinds of adaptive searches. Building an efficient adapted learning model remains challenge and several concerns faced this obstacle such as communication, scalability, heterogeneousness of data, and privacy. Researchers addressed some of the communication and scalability challenges in federated learning using some efficient communication in federated learning methods with provable performance guarantees. Meta adaptive index introduces valid alternatives for a large number of non-adaptive indexes or specialized indexes and improves runtime, robustness, and convergence speed over the standard methods [10]. Adaptive indexing in real time search e.g. twitter was proposed by [11] to provide trends including recommendations, recognition, and manual and automated searches. Arya et al. [8] proposed a personalized federated search at LinkedIn; they proved that federated searches for generalized Web search engines present more problems than federated searches for specialized tasks. Some heterogeneous methods simulate large set of particularized indexes. Experimental tests showed how the traditional real-time indexes were comparable with the traditional offline index, and there was a superior performance with different workloads and an average speed limit 2x. However, several researchers were argued for demonstrating the importance of adaptive search, e.g. [1, 12, 13, 14, 15, 16]. Nevertheless, unlike traditional Web search engines that typically blend either a block of results or individual results from different verticals [17]. Some models used particular offline data and resources for their indexes, researchers [22] explored additional idea for building an efficient index over offline Web page collection while their algorithm ranked as the best run

in the Web diversity task. They managed the collection and exploitation of knowledge in Wikipedia for enhancing the relevancy of topics' predictions and findings. Our proposed approach exploited this technique for aggregating individual results from verticals and/or blocks of verticals, normalized some difficult features, and finally, produced relevancy rank which is comparable across verticals' results and its features (i.e., individual vs. block). When we started to scrape results from independent Web search resources in all predictive kinds, we hoped to inspire a research that is able to come up with elegant and efficient solutions to the distributed search. To the best of our knowledge is all existing real-time indexing techniques focus on creating only single dimensional indices that is not suited to an efficient and effective task. Traditional models fail to index large size of data in real-time, or sometimes, fall short of providing flexible data retrieval capabilities and scalable indexing services [1]. The University of Glasgow [27] used reformulations algorithm for the user's initial query with a Terrier data-driven learning algorithm which was a learning-to-rank logistic regression platform for the fast computation of document features. The model was based on gradient-boosted regression trees. In logistic regression, interaction could be included through various degrees of terms' interactions, and consequently, the uogTr algorithm technically faced computational challenges with model estimation and poor fit. The exponentially increasing Internet contents along with the rapid expansion of Web applications caused the problem of information overload. One solution to resolve the above problem is to personalize the network applications for individual users [18]. However, recommending web pages for users is another solution; Kim [19] proposed a system that learns user interests by reading the user's bookmark items and monitoring user's behaviour. Based on the automatically constructed user profile, it collects and filters web pages to recommend related web pages as bookmark items.

3. The Proposed Approach

The goal of our approach, as shown in Figure 1, is to achieve and benefit from the popular global indices available in the public resources over the Internet while the cost of index creation is the main assumption. While hiding or minimizing index is important, it seems to turn side effects to read only queries into update transactions which sometimes form locking argument. Despite all the difficulties and the challenges that faced, concurrency controlling in the context of federated indices is very important. Implementing and controlling federated network rigorously separates index structures from index contents which minimizes the requirements and other constraints during index creation. It confirms the fact that federated indices iterated continuously and take advantages of concurrency assumptions. However, federated index must: (a) preserve its advantages even when evolving to run synchronizing queries, (b) utilize the parallelism opportunity for concurrent queries, and (c) follow the overheads of federated behavior, e.g. the number of concurrent conflicts and other concurrency assumption. The federated search requires centralized coordination of the searchable resources, and this assumption does not exist in distributed search. This involves both coordination of the queries

transmitted to the individual search algorithms and fusion of the search results returned by each algorithm. Our proposed algorithm is composited from several resources bunched topically in labeled verticals. The technique for selecting the relevant resources and grouping them in verticals will be discussed below.

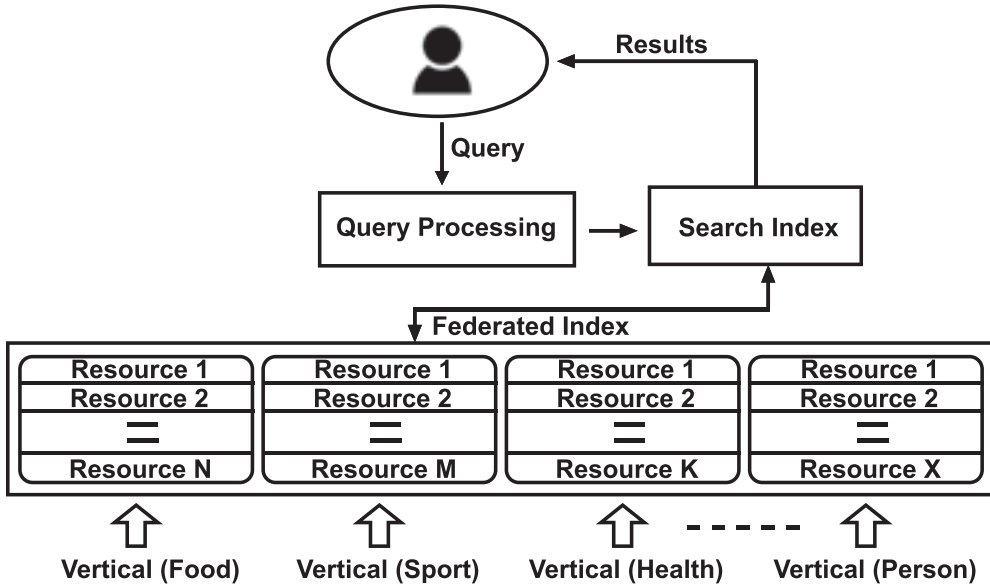


Figure 1. Our overall approach

3.1. Verticals Modeling

Classifying and grouping articles topically into verticals is important to reduce the margining of user's needs. Labelling vertical topics is an essential step in the federated indices [20]. Determining topics in the distributed resources requires a pool of intelligent data be able to classify the web resources into topical verticals. In Internet, knowledge is controlled by some important resources e.g. Word Press, Wikipedia, etc. Wikipedia is a knowledge-based system that continually being revised and updated, and articles on historic events can be accessed within minutes rather than months or years. Since professionals can update and improve it, Wikipedia has become the most comprehensive knowledge and information resource to date. In addition to quantity, contributors also address content quality, which makes Wikipedia a continuous work-in-progress with millions of articles in various stages of completion. As articles developed, they tend to become more diverse and balanced, and the quality improves over time as misinformation and other errors are removed or repaired. Due to these characteristics, our approach to vertical classifications is based on the relationship between the Wikipedia content and topic specification. Wikipedia has a list of major topic classifications that used to organize

the presentation of links to articles in various categories¹. First of all, all articles in Wikipedia corpus have been read to tokenize the first blocks and extracting the required keywords. For example, the first block in the ‘lymphoma’ article is “*Lymphoma is a group of **blood cancers** that develop from lymphocytes (a type of white **blood cell**). The name often refers to just the cancerous versions rather than all such **tumors***”. Hence, the target keywords are ‘cancer’, ‘blood’, ‘cell’, and ‘tumor’, and all keywords are related to a topic “disease” which later be label of vertical. Another example, a query “University of California” returns “*The **University** of California (UC) is a public **university** system in the U.S. state of California. Under the California Master Plan for Higher **Education**...*”; the target keywords are ‘Education’ and ‘University’. Table 1 shows sample of vertical names and the relative keywords.

Keywords	Verticals
Actress, maker, player, born, former, president, minister, ...	People
Benign, tissue, tumor, disease, diagnosis, cancer, blood, stomach, ...	Disease
University, School, Faculty, Institution, Academy, Education, ...	Academic
Diet, Overweight, Sport, Olympic, game, activity, skills, racing, ...	Sport
Tax, Property, Money, Finance, Fund, taxpayer, income, payment, ...	Finance
Brand, Goods, Hardware, Software, Game, Machine, Money, ...	Shopping
Sport, Diet, Overweight, Food, Recipe, Health, Well-being,....	Health
Why, What, How, Where, Cause, Reason, Fact, Question, Answers, ...	Q /A
Country, City, Capital, State, Location, Place, Geography, Street,, ...	Place

Table 1. Vertical names and its keywords

However, computing the impact of keywords in the first block of each article refers specifically to term impact in the entire document content [2]. Such an algorithm is relevant because Wikipedia also computes the relevancy of terms in the documents to classify their contents into different topics. The algorithm below shows pseudo codes for assigning vertical names.

ALGORITHM 1: Vertical Modeling

Inputs: Individual keywords from Wikipedia (*W*) and Query (*Q*)
Output: Aggregated Resources in Vertical
Q ← query string, W ← Wikipedia vector, V ← Vertical, S← Resource
t[]← tokenize Q, f[] ← tokenize W

¹ https://en.wikipedia.org/wiki/Category:Main_topic_articles

```

forEach (m) in (T), forEach (n) read (f)
if (m==n) then for i=1 to length(V)
V → List.Add(Si)

```

Return: Resources List

3.2. Resources Modeling

Federated search often integrates disparate information resources within a single large organization ("enterprise") or for the entire web. Researchers typically classify web resources and type of user queries into three categories: navigational, information, and transactional [21]. Similarly, information belong to one category is specified to a particular area of interest, and resources belong to the same category were not ranked equally. Global rankings based on 'Alexa.net'² ranks resources differently and the weight of resource is equal to the number of visits. Our approach for resource selection is adequate to use this assumption, that is, each vertical selects the top resources that utilize better services than others as reported by a global rank. The key abstraction of data in REST may be a resource. Any data provider is a resource, e.g. document or image, temporal service (e.g. "today's weather in Los Angeles"), group of alternative resources, non-virtual object (e.g. in alternative words, associative conception which may be the target of an author's machine-readable text reference that matches among the definition of a resource. A resource may be an abstract mapping to a group of entities, not the entity that corresponds to the mapping at any specific purpose in time. It is vital to select the proper resources and model them at the proper graininess. GitHub API is an example of a fairly elegant API model that used within the right resources. A resource must capture dataflow and dependencies among the functional elements in federated systems, at that point, each vertical might hold few or several resources belong to similar topics. Given a query, a list of resources and related knowledge about resource feedback and network conditions are important to exploit. The resource selection approach produces a ranking list of resources ordered by the query and the impact on the network conditions. Resource selection includes balancing network resource consumption against response quality [9]. We can look at the properties of specific search terms or introduce ancillary query components such as the information sought. The resource specification algorithm creates search plan in two steps, in the first step, resources are ranked with respect to the query and current network conditions, and in the second step, concurrency must be computed as the number of resources simultaneously searched. Resources are ranked by predicting which has the highest probability to return relevant results, which includes hosting a query score in the server with the expected waiting time and the number of results returned in specific interval. The query score is computed by determining the relevancy weight for each resource that corresponds to the query terms, which means, the weights are divided by the total feedback of resources that returned from a vertical.

² <http://www.alexa.com>

For a user's query, the method includes identifying highly-relevant resources that match the query, wherein each online resource is associated with returned results in particular time interval. Obtaining a respective query-specific score for each resource matches the query, identifying one or more relevant resources according to the query specific scores. Thus, the query score $Q_{r,q}$ of resource 'r' and query string 'q' was computed as:

$$Q_{r,q} = \sum_{t \in q} \frac{w_{t,r}}{W_r} \quad (1)$$

where $w_{t,r}$ is the weight of query term t in resource r , and W_r is the sum of all weights for resource r matches query q .

The scores were normalized by adding the performance information of resource, by which, the five most recent queries for resource r used to compute the average number of hits H_r and average response time T_r . The performance information of resources was combined in the fraction:

$$P_r = \frac{H_r}{100 \cdot T_r} \quad (2)$$

The denominator is multiplied by an arbitrary constant of 100, making the performance data and magnitude smaller than the score data. The goal was to rank the better resources utilizing index data alone, and then normalized with respect to the global world rank using resource popularity rank Pop_r which was utilized at Alexa.net³. The two computations were combined to determine the overall rank $R_{r,q}$:

$$R_{r,q} = (Q_{r,q} + P_r) / Pop_r \quad (3)$$

Appendix (A) shows the topical classification of our selected resources in each vertical whereas Appendix (B) shows the topical classification of resources in each vertical involved by related approaches.

On another side, simultaneous between resources is the first and foremost challenge that every federated network has to face. The purpose of simultaneous calculation is to reduce the resources costs generated by queries in a period of high network disturbance and machine traffic. Concurrency is inversely proportional to query cost; the higher cost of submitting resource search queries, the fewer search services will be queried. Concurrency is computed from three cost variables: global network load, local CPU load, and query discrimination value. Ideally, long queries mean high discrimination and low CPU cost, and vice versa. In addition, the expected network load should be estimated by timely inter-networks traffic, and since this is difficult to assess, the typical load must be computed at a particular time of day, as shown in Figure 2.

A high value of concurrency contribution occurs during periods of low network load, (e.g. 3:00 am), and vice versa. The discrimination value addresses how many resources are likely needed for each vertical to find a satisfactory response, by

³ <http://www.alexa.net>

measuring how specified or generalized the query is against the resources. If a term has a relatively high number of results and contributions of resources (e.g. London), it presumably represents an area with many resources covering the topic; thus, we expect fewer resources will need to be queried. If a query has little or no results, (e.g. Cheilitis), we need to search more resources to find relevant results.

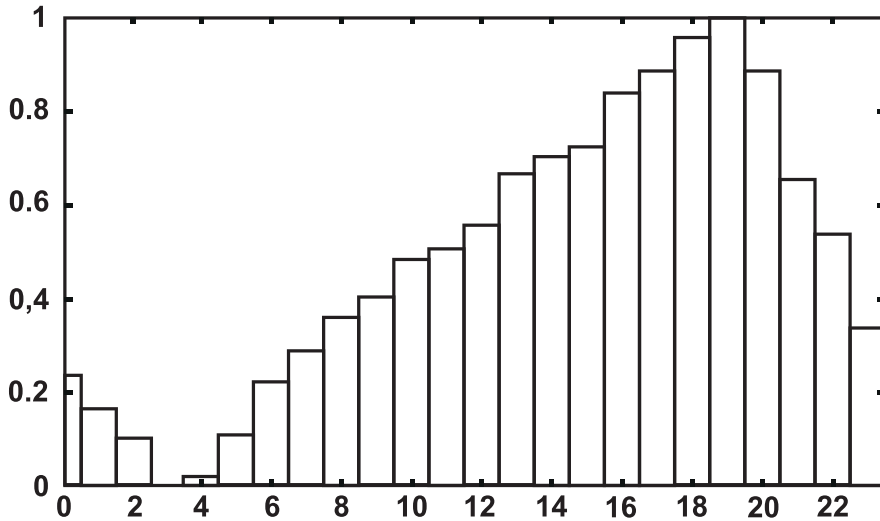


Figure 2. Overall traffic throughout the day

3.3. Query Processing

Query processing is an essential part in the federated search, as it includes: determining the type, searching, and normalizing of a query. To ascertain the type, it was submitted subsequently to three web resources: Wikipedia, Twitter, and Word Press, the responses were analyzed to find the requested verticals. More contrast, submitting a query “lipoma” to the Wikipedia web service using a request REST API; it will return “*A **lipoma** is a benign tumor made of fat tissue. They are generally soft to the touch, movable, and painless. They usually occur just under the skin, but occasionally may be deeper.*” The target keywords are ‘benign’, ‘tumor’, ‘tissue’, and ‘skin’ that point to the vertical “Disease”. We used a syntactic similarity keywords matching as shown in Table 1 for corresponding vertical name and its topic. If a vector is specified, the system will forward the query to all resources belong to that vertical, wherein the returned results will be stored for strictly ranking. Although term frequency is important for measuring the occurrences of terms and then specifying the topics of documents in resources, it is important to look for different types of document configurations. Two document vectors with the same term occurrences might have different relevancy, because the user preferences are not the same as our current preferences. Al-akashi and Inkpen [22] addressed this by applying ‘term impact’ rather than term frequency. Term impact computes the weight of each term in a vector based on certain features. Each

vector was mapped to the resource impact factor computed by cosine similarity between two vectors. The first vector represents the occurrences of terms in a document, and the second represents the query terms. The length of a document vector is inversely proportional to the terms in the query vector. The normalized cosine similarity formula is shown below:

$$\text{Similarity}(D, Q) = \sum_{j=1}^m \frac{(Q_j)^2}{\sqrt{(Q_j)^2} * \sqrt{\sum_{i=1}^n \text{tf}(Q_i)^2}} \quad (4)$$

where m denotes the length of the query terms, Q represents the occurrence of terms in document vector D , Q_j denotes the occurrence of the query term j in D , n represents the number of terms in D and $\text{tf}(Q_i)$ denotes the impact of the query term i in D .

In order to filter out non-relevant vectors and establish the best similarity impact, our model assigned a strict threshold value that used several sampling vectors to determine only the vectors that had a high impact for all query terms. Below shows a complete algorithm used to resort the aggregated document vectors and generate the final ranking list:

ALGORITHM 2: Result Ranking

$Q \leftarrow$ query string, $V \leftarrow$ document vector, $K \leftarrow$ Scoring, $T \leftarrow$ Scoring threshold

- If $\text{length}(Q) = \text{length}(\text{URL}) \rightarrow V = 1.0$.
- If $\text{length}(Q) = \text{length}(\text{title}) \rightarrow V = 0.9$.
- If $\text{length}(Q) \cap \text{length}(\text{description})$ and Q in consecutive location $\rightarrow V = 0.8$.
- If $\text{length}(Q) = \text{length}(\text{title})$ and Q distributed over title $\rightarrow V = 0.7$.
- If $\text{length}(Q) \cap \text{title}$; $K > T$ and $T > 0.5 \rightarrow V = 0.6$.
- If $\text{length}(Q) \cap \text{snippet}$; $K > T$ and $T > 0.5 \rightarrow V = 0.5$

However, the average query search duration was $4.9 \pm 3.2s$ ($N = 1000$ searches or queries). The mean search duration to each individual resource was between 0.05s and 4.55s. The average system runtime or system overhead was 0.12s, whereas, the deadline for receiving responses from all resources over the network was 10s.

3.4. Query Expansion

Search engines use query expansion and optimization techniques to enhance the quality of search results and improve efficiency [31]. It is assumed that users do not always formulate search queries to expand the initial results and narrow the final results to satisfy user needs [23]. As a consequence, rather than using fuzzy-wuzzy techniques, external resources play a significant roles in this paradigm, e.g. Word Net, used word sense disambiguation for automatic query expansion for long queries in addition to short queries [11]. Since Wikipedia feedback is suitable for query expansion, researchers [2, 24] exploited the behavior of some Wikipedia writers who

adopted the preferences in the dynamic properties of the Wikipedia collection. However, we proposed two techniques, firstly, we used the inter-links between articles, by which, we generally assume that an article 'A' and 'B' are related to each other and shared similar topics if they are inter-linked together. Thus, if a user's query is 'A', the alternative query is 'B' and vice versa. Secondly, we exploited the synonyms and morphologic variation for titling the articles if involved similar contents but titled differently. If the first title matches the user's query and returns few results, the second title will be used alternatively.

However, query expansion and reformulation was not used for all queries, it was used only when the initial ranking list was short and the resulting list contained at least one Wikipedia label that matched the user's query. For example, while the initial results for a query 'angular chelitis' were considered few; the alternative query 'angular stomatitis' would improve the final results. Another obstacle faced our query processing algorithm was fuzzy queries, e.g. 'fibromyalgia', which are one of the most powerful features. To address and resolve this complexity, we applied a computational linguistic algorithm using n-gram string similarity. The n-grams dictionary terms were typically collected from the Wikipedia corpus. For single-word queries we used a unigram model, for multi-words queries we used bigram and trigram models. This helps to search for similar words across hundreds of documents on the index. Wikipedia implication was highly improved the relevancy of our real-time approach even with or without query expansion, the precision was improved from 0.405 to 0.584 whereas the nDCG was improved from 0.214 to 0.430, because Wikipedia was returned 977 out of 1000 results over all queries.

4. Experimental Evaluation

The TREC evaluation campaign provides training and testing sets of queries, whereas the relevance judgments team provides the proposed solutions for each query. Experimentally, web information retrieval approaches evaluated in two tasks: diversity and adhoc. The diversity task is similar to the adhoc task but it differs in the evaluation metrics and judging process. The final goal is to provide a complete coverage and ranked list of pages for a query that aim together to avoid excessive redundancy. The primary effectiveness measure for both tasks is specified by measuring the graded precision of top ten results or graded precision at k, in which documents can be judged as Nav, Key, Hrel, Rel or Non-relevant. The relevancy of selected resource is determined by calculating precision in the subset of results [25, 26]. While the Normalized Discounted Cumulative Gain (nDCG) is the metric of measuring ranking quality for maximizing the relevancy as a whole, it takes into account the graded relevance levels of documents within top ten. Similarly, selecting a best vertical for a given query is determined by running best search query in all resources in that vertical. That means the relevancy of vertical is computed by maximizing the precision of its resources. In the final analysis, the precision of vertical is specified by a threshold since some queries have a small set of relevant verticals, we assumed 0.5 is a threshold of relevant precision). However, if no

vertical was selected for a given query, the top vertical with maximum relevancy had been selected as relevant. In terms of testing queries, we used the same set of queries proposed by TREC web track, whereas for training, we used the set of queries in the Million Query track⁴. The testing and training queries involve both tasks adhoc and diversity to represent different complexities of relevancy. Follows is the comparison between our real time algorithm with offline and real time related approaches.

4.1. Comparison with Real-time Approaches

In the information retrieval, comparisons between models must be within similar cluster of training and test dataset. Despite the proposed systems used in our comparisons are little bit old, but it is important to show how real-time search is more efficient than offline search when used with similar dataset and resources. While the similar models used 200 resources distributed among 24 agents, our approach used 59 resources distributed in 20 agents. Recent studies have used single resources for particular topics which are not bearing on the matter being considered except some specifications, and recently, various models have been used large realistic data collections sampled from multitude of online search engines. Table 2 shows the comparison between our mode, Sama, which used custom resources and agents with other top models that used a large collection of agents and resources. The best proposed effective models used similar techniques that aggregate indices from tremendous retrieval algorithms. The best effective models [29] proposed indexes with only documents (rather than snippets) and mix results were improved from the traditional retrieval algorithms like variations; but however, they failed to use external resources efficiently, e.g. Wordnet and Wikipedia. Wikipedia results were showed the content is necessary for features extraction. We have a tendency to assume that for a given query all search results were readily available but more realistic strategies would be initially make selection of a small number of relevant engines to increase recalls and re-rank results again. A notable exception was the RS_clue baseline that used the assortments' of snippets together with the ClueWeb'09 collection to form size estimations. The most efficient model was proposed by the Chinese Academy of Sciences (ICTNET) [30] ranked 0.402 on nDCG@20 scores in all queries. The organizers' baseline runs used the static rankings from the equivalents size-based resource baselines. In our perspective, querying the TREC FedWeb 2013 indices is totally different from the realistic collections. Despite the results of the best run were not qualified well compared to our results, querying several resources at the same time and selecting only five resources deemed the internet to shut down from overload which was not applicable when real-time tasks were involved. Also, one more thing that makes real-time algorithms better than offline algorithms is that in real-time algorithm all spam

⁴ The goal of this track is to run a retrieval task similar to standard ad-hoc retrieval, but to evaluate large numbers of queries incompletely, rather than a small number more completely. Participants run 10,000 queries and random of 1,000 or so were evaluated.

documents did not have implication and did not affect the overall retrieval performance because most of documents in the web search resources were filtered out by their administrators. Table 2 shows the comparison between the result of proposed approach “SAMA “ and the results of the best approaches that used real-time contents of 157 online resources, including traditional search engines, in order for representing the whole picture of the retrieval methodologies as well as involving heterogeneous content sorts for each approach. The online test set queries is shown on Appendix (C); whereas Million Queries Track⁵ was used for training our approach.

Group ID	Run ID	nDCG@20
CMU_LTI	googTermWise7	0.286
	googUniform7	0.285
	plain	0.277
	sdm5	0.276
ECNUCS	basedef	0.289
ICTNET	ICTNETRM01	0.247
	ICTNETRM02	0.309
	ICTNETRM03	0.348
	ICTNETRM04	0.381
	ICTNETRM05	0.354
	ICTNETRM06	0.402
	ICTNETRM07	0.386
SCUTKapok	SCUTKapok1	0.313
	SCUTKapok2	0.319
	SCUTKapok3	0.314
	SCUTKapok4	0.318
	SCUTKapok5	0.320
	SCUTKapok6	0.323
	SCUTKapok7	0.322
ULugano	ULugFWBsNoOp	0.251
	ULugFWBsOp	0.224
dragon	FW14basemR	0.322
	FW14basemW	0.260
SAMA	Real Time	0.417

Table 2. Overall comparisons between top real time approaches using real time queries

⁵ <https://trec.nist.gov/data/million.query.html>

4.2. Comparison with Offline Approaches

To better focusing on the value and novelty of the proposed approach and its application, we compared our experiment with the best published approaches. For the adhoc task documents were assessed with respect to the topic as a whole. Relevance categories were similar in structure to the categories used in traditional Web search, including spam and junk removal. Also, the top two assessments' structures were closely associated to the home page finding and topic distillation tasks. For the diversity task, documents were assessed based on the subtopics, as well as with respect to the topics as a whole. As a comparison, using assessment metrics shown in Table 3 could achieve the tradeoff between effectiveness (overall gains across queries) and robustness (minimizing the possibility of significant failure, relative to a given baseline). SAMA as our continual improvement of performance that compared with the best models in TREC Web track / the ClueWeb09 collection by using the same set of test queries (Appendix D). The best approach was proposed by [27] at the University of Glasgow (uogTr) used reformulations of the user's initial query with a Terrier data-driven learning model which is a framework for the fast computation of document features. It used with a state-of-the-art learning-to-rank logistic regression algorithm based on gradient-boosted regression trees. Realistically, the predictive model did not capture the complex interactions among the variables in data. In logistic regression, interaction can be included through various degrees of interaction terms, but uogTr approach normally led to computational challenges with model estimation and poor fit. Contrary to our proposed method, logistic regression does not provide a way to focus the computations on the smallest subset of variables linking decision variables to the target variable. The second ranked approach "DFalah" used terms impact in document content with query structures [22]. Chinese Academy of Sciences (ICTNET) [28] contacted Learning-To-Rank layer to aggregate several features simultaneously, but the effectiveness was very poor because of the low quality of training data. Quantum Interaction (QI) group proposed information about word associations used first and second order relationships in natural language known as syntagmatic and paradigmatic associations.

Model	P@20	NDCG@20
University of Glasgow (uogTr)	0.453	0.238
IBM Lab (Srchvrs)	0.315	0.176
QUT's Quantum Interaction (QI) group (QUT_Para)	0.305	0.167
University of Twente (Utwente)	0.221	0.113
Chinese Academy of Sciences (ICTNET)	0.257	0.110
Muñgla University IRRA (IR-Ra) group	0.367	0.143
University of Ottawa (DFalah)	0.405	0.214
University of Ottawa (SAMA)	0.584	0.430

Table 3. Overall comparisons between the offline runs and our real-time run

5. The Faced Challenges

We hereby introduce four of the problems faced our work with a solution while most of them are related to the communication between resources in the adapted network. These problems make an adaptive- learning realized from other traditional-learning, e.g. adaptive learning available in remotely data in each resource.

- **System Communication:** Communication between a client and remotely resources is a critical bottleneck in adaptive networks since that incorporate with privacy issues over sending raw data. It requires data presented in each resource to be transferred to the user or client and combined concurrently with other results from other resources. Indeed, adaptive data are potentially consisted of a large number of resources, and if tons of resources shared similar topics, it makes communication in the network very slow. In order to make our approach to fit data produced by the resources in the adapted network, it is, therefore, urgently to develop efficient communication algorithm that recursively receive results from resources concurrently as fraction of the training process, as opposed to producing the results in the local resources. To assist minimize communication in such network, three issues are assumed: (1) minimizing the total number of communication cycles, (2) minimizing the size of transferred data at each cycle, and (3) synchronizing the data between resources.
- **Hardware Heterogeneity:** The computation, storage, and link abilities between resources in adaptive networks for providing results might differ because of variability in hardware capability; e.g. CPU, memory, etc., or sometimes a resource communicates with other resources locally. Thus, the adaptive system must afford strong hardware.
- **Resource Trustworthiness:** Most resources share similar topic in a vertical. Some resources might also be unreliable for some query results. It is critical for any selected resource to stop at a given time or cycle due to time-out connectivity and time-out for aggregating relevant data. Additionally, the network size represented by the number of resources at each request might high if the query is diverse. Also, system limitations between resources typically result when a small number of the active resources being selected instantly. As a result, at the moment of determining the type of query and specifying the relevant resources extremely increase the system challenges. Thus, adapted learning algorithms that are improved must therefore: (i) exploit a small amount of resources in irrelevant queries, (ii) stop slower resources in the network when time exceeded properly.

6. Conclusion

This paper proposes a novel algorithm for developing the ground-breaking research initiated at the University of Ottawa in 2012. A great deal of effort has been done for building a real-time web search algorithm for various types of queries to remedy

some drawbacks in context of related approaches. Building real-time approach with real-time events is not easy task. We showed how to implement an algorithm that uses the Web's predominant application protocol to leverage REST's tenets. We explained how Wikipedia is relevant in real-time task and how is relevant for specifying types of queries and topics of resources with low disk overhead. Exploiting multiple data sources simultaneously could thereby provide end-users with real-time query results directly from the desired information resources. Query results could be integrated to look as they are from one source, or can be displayed in separated sections of the same search resulting list. However, it can be difficult to rank results from disparate resources in real-time, as this requires application of multiple predictive algorithms and understanding deep learning concepts. Our framework⁶ faced many issues, including: coordination, synchronization, topic correlation, and controlling multiple autonomous web resources.

Conflict of Interest

The author declares that there is no a competing financial interest or personal relationships that could have appeared to influence the work reported in this manuscript.

Appendix A: Real time resources used by our proposed approach

Resources	Agent / Topics	Resources	Agent / Topics
Indeed.co.uk	Jobs	Wikihow.com	Q/A
Totaljobs.com	Jobs	Mapquest.com	Local
Optnation.com	Jobs	Embassypasges.com	Local
Monster.co.uk	Jobs	Zoominfo.com	Local
Wikicfp.com	Academic	Foursquare.com	Local
Dblp.org	Academic	Openweathermap.org	Weather
Citeseerx.edu	Academic	Wikipedia.org	Encyclopedia
Univerzities.com	Academic	Nationsonline.com	Encyclopedia
Conferencealert.com	Academic	Gov.uk	Encyclopedia
Researchgate.com	Academic	Geonames.org	Encyclopedia
Taste.com	Recipes	Nationsonline.org	Encyclopedia
Simplerecipes.com	Recipes	Reference.com	Encyclopedia
Saveland.ca	Shopping	Thoughtco.com	Encyclopedia
Amazon.com	Shopping	NPR.org	Encyclopedia
Ebay.com	Shopping	News-medical.net	News
Alibaba.com	Shopping	Uptodate.com	Health
Answers.com	Q/A	Verywell.com	Health
Answers.yahoo.com	Q/A	Mayoclinic.org	Health
Drugs.com	Health	Thebalance.com	Finance
Everydayhealth.com	Health		Finance

⁶ <http://site.uottawa.ca/~falak081>

Nhs.uk	Health	Historynet.com	History
Patient.info	Health	Twitter.com	Social
derm101.com	Health	Facebook.com	Social
Cntravel.com	Health	Wordpress.com	Blog
Hotelscombined.com	Travel	Thefreedictionary.com	Dictionary
Tripsavvy.com	Travel	Merriam-webster.com	Dictionary
Tvguide.com	Travel	Cambridge.org	Dictionary
Hollywoodlife.com	Shows	Google.com	Scholar
Imdb.com	Shows	Worldcat.org	Scholar
Thespruce.com	Shows	360daily.com	Video
Investopedia.com	Home	Vimeo.com	Video

Appendix B: Real time resources used by related works

ID	Name	Vertical	ID	Name	Vertical
e001	arXiv.org	Academic	e100	Chronicleing America	News
e002	CCSB	Academic	e101	CNN	News
e003	CERN Documents	Academic	e102	Forbes	News
e004	CiteSeerX	Academic	e104	JSOnline	News
e005	CiteULike	Academic	e106	Slate	News
e007	eScholarship	Academic	e108	The Street	News
e008	KFUPM ePrints	Academic	e109	Washington post	News
e009	MPRA	Academic	e110	HNSearch	Shopping
e010	MS Academic	Academic	e111	Slashdot	News
e011	Nature	Academic	e112	The Register	News
e012	Organic Eprints	Academic	e113	DeviantArt	Photo/Pictures
e013	SpringerLink	Academic	e114	Flickr	Photo/Pictures
e014	U. Twente	Academic	e115	Fotolia	Photo/Pictures
e015	UAB Digital	Academic	e117	Getty Images	Photo/Pictures
e016	UQ eSpace	Academic	e118	IconFinder	Photo/Pictures
e017	PubMed	Academic	e119	NYPL Gallery	Photo/Pictures
e018	LastFM	Audio	e120	OpenClipArt	Photo/Pictures
e019	LYRICSnMUSIC	Audio	e121	Photobucket	Photo/Pictures
e020	Comedy Central	Video	e122	Picasa	Photo/Pictures
e021	Dailymotion	Video	e123	Picsearch	Photo/Pictures
e022	YouTube	Video	e124	Wikimedia	Photo/Pictures
e023	Google Blogs	Blogs	e126	Funny or Die	Video
e024	LinkedIn Blog	Blogs	e127	4Shared	General
e025	Tumblr	Blogs	e128	AllExperts	Q&A
e026	WordPress	Blogs	e129	Answers.com	Q&A
e028	Goodreads	Books	e130	Chacha	Q&A
e029	Google Books	Books	e131	StackOverflow	Q&A
e030	NCSU Library	Academic	e132	Yahoo Answers	Q&A
e032	IMDb	Encyclopedia	e133	MetaOptimize	Q&A
e033	Wikibooks	Encyclopedia	e134	HowStuffWorks	Encyclopedia
e034	Wikipedia	Encyclopedia	e135	AllRecipes	Recipes
e036	Wikispecies	Encyclopedia	e136	Cooking.com	Recipes
e037	Wiktionary	Encyclopedia	e137	Food Network	Recipes
e038	E! Online	Entertainment	e138	Food.com	Recipes
e039	Entertainment Weekly	Entertainment	e139	Meals.com	Recipes

e076	WebMD	Health	e167	Ars Technica	Tech
e077	Glassdoor	Jobs	e168	CNET	Tech
e078	Jobsite	Jobs	e169	Technet	Tech
e079	LinkedIn Jobs	Jobs	e170	Technorati	Tech
e080	Simply Hired	Jobs	e171	TechRepublic	Tech
e081	USAJobs	Jobs	e172	TripAdvisor	Travel
e082	Comedy Central Jokes.com	Jokes	e173	Wiki Travel	Travel
e083	Kickass jokes	Jokes	e174	5min.com	Video
e085	Cartoon Network	Kids	e175	AOL Video	General
e086	Disney Family	Kids	e176	Google Videos	Video
e087	Factmonster	Kids	e178	MeFeedia	Video
e088	Kidrex	Kids	e179	Metacafe	Video
e089	KidsClicks!	Kids	e181	National geographic	General
e090	Nick jr	Kids	e182	Veoh	Video
e092	OER Commons	Encyclopedia	e184	Vimeo	Video
e093	Quintura Kids	Kids	e185	Yahoo Screen	Video
e095	Foursquare	Local	e200	BigWeb	General
e041	TMZ	Entertainment	e140	Amazon	Shopping
e043	Addicting games	Games	e141	ASOS	Shopping
e044	Amorgames	Games	e142	Craigslist	Shopping
e045	Crazy monkey games	Games	e143	eBay	Shopping
e047	GameNode	Games	e144	Overstock	Shopping
e048	Games.com	Games	e145	Powell's	Shopping
e049	Miniclip	Games	e146	Pronto	Shopping
e050	About.com	Encyclopedia	e147	Target	Shopping
e052	Ask	General	e148	Yahoo! Shopping	Shopping
e055	CMU ClueWeb	General	e152	Myspace	Social
e057	Gigablast	General	e153	Reddit	Social
e062	Baidu	General	e154	Tweepz	Social
e063	Centers for Disease Control and Prevention	Health	e156	Cnet	Software
e064	Family Practice notebook	Health	e157	GitHub	Software
e065	Health Finder	Health	e158	SourceForge	Software
e066	HealthCentral	Health	e159	bleacher report	Sports
e067	HealthLine	Health	e160	ESPN	Sports
e068	Healthlinks.net	Health	e161	Fox Sports	Sports
e070	Mayo Clinic	Health	e163	NHL	Sports
e071	MedicineNet	Health	e164	SB nation	Sports
e072	MedlinePlus	Health	e165	Sporting news	Sports
e075	University of Iowa hospitals and clinics	Health	e166	WWE	Sports
e076	WebMD	Health	e167	Ars Technica	Tech
e077	Glassdoor	Jobs	e168	CNET	Tech
e078	Jobsite	Jobs	e169	Technet	Tech
e079	LinkedIn Jobs	Jobs	e170	Technorati	Tech
e080	Simply Hired	Jobs	e171	TechRepublic	Tech
e081	USAJobs	Jobs	e172	TripAdvisor	Travel
e082	Comedy Central Jokes.com	Jokes	e173	Wiki Travel	Travel
e083	Kickass jokes	Jokes	e174	5min.com	Video
e085	Cartoon Network	Kids	e175	AOL Video	General
e086	Disney Family	Kids	e176	Google Videos	Video
e087	Factmonster	Kids	e178	MeFeedia	Video
e088	Kidrex	Kids	e179	Metacafe	Video
e089	KidsClicks!	Kids	e181	National geographic	General
e090	Nick jr	Kids	e182	Veoh	Video
e092	OER Commons	Encyclopedia	e184	Vimeo	Video
e093	Quintura Kids	Kids	e185	Yahoo Screen	Video
e095	Foursquare	Local	e200	BigWeb	General
e098	BBC	News			

Appendix C: Online Test Queries

ID	Query	ID	Query
7015	the raven	7230	council bluffs
7044	song of ice and fire	7235	silicone roof coatings
7045	Natural Parks America	7236	lomustine
7072	price gibson howard roberts custom	7239	roundabout safety
7092	How much was a gallon of gas during depression	7242	hague convention
7111	what is the starting salary for a recruiter	7249	largest alligator on record
7123	raleigh bike	7250	collagen vascular disease
7137	Cat movies	7252	welch corgi
7146	why do leaves fall	7261	elvish language
7161	dodge caliber	7263	hospital acquired pneumonia
7167	aluminium extrusion	7265	grassland plants
7173	severed spinal cord	7274	detroit riot
7174	seal team 6	7293	basil recipe
7176	weather in nyc	7299	row row row your boat lyrics
7185	constitution of italy	7303	what causes itchy feet
7194	hobcaw barony	7307	causes of the cold war
7197	contraceptive diaphragm	7320	cayenne pepper plants
7200	uss stennis	7326	volcanoe eruption
7205	turkey leftover recipes	7328	reduce acne redness
7207	earthquake	7431	navalni trial
7211	punctuation guide	7441	barcelona real madrid goal messi
7212	mud pumps	7448	running shoes boston
7215	squamous cell carcinoma	7486	board games teenagers
7216	salmonella	7491	convert wav mp3 program
7222	route 666	7501	criquet miler

Appendix D: Offline Test Queries

151:403b	176:weather strip
152:angular cheilitis	177:best long term care insurance
153:pocono	178:pork tenderloin
154:figs	179:black history
155:last supper painting	180:newyork hotels
156:university of phoenix	181:old coins
157:the beatles rock band	182:quit smoking
158:septic system design	183:kansas city mo
159:porterville	184:civil right movement
160:grilling	185:credit report
161:furniture for small spaces	186:unc
162:dnr	187:vanuatu
163:arkansas	188:internet phone service
164:hobby stores	189:gs pay rate
165:blue throated hummingbird	190:brooks brothers clearance
166:computer programming	191:churchill downs
167:Barbados	192:condos in florida
168:lipoma	193:dog clean up bags
169:battles in the civil war	194:designer dog breeds
170:scooters	195:pressure washers

171:ron howard	196:sore throat
172:becoming a paralegal	197:idaho state flower
173:hip fractures	198:indiana state fairgrounds
174:rock art	199:fybromyalgia
175:signs of a heartattack	200:ontario california airport

References

- [1] Jin, S. and Lan, M. (2014). "Simple May Be Best - A Simple and Effective Method for Federated Web Search via Search Engine Impact Factor Estimation," in *Proceedings of the 23rd Text Retrieval Conference (NIST)*, Special Publication 500-308.
- [2] Al-Akashi, F. and Inkpen, D. (2011). "Term Impact-Based Web Page Ranking," in *Proceedings of the 4th Web Intelligence, Mining, and Semantics (WIMS) International Conference*, Greece.
- [3] Dalton, J. and Dietz, L. (2012). "Bi-directional Linkability from Wikipedia to Documents and Back Again," in *Proceedings of the 21st Text Retrieval Conference (TREC), Knowledge Base Acceleration Track*, USA.
- [4] Kamps, J., Kaptein, R., and Koolen, M. (2010). "Using Anchor Text, Spam Filtering and Wikipedia for Web Search and Entity Ranking," in *Proceedings of the 19th Text Retrieval Conference (TREC)*, USA.
- [5] Ding, L., Finin, T., Joshi, A., Pan, R., Cost, R., Peng, Y., Reddivari, P., Doshi, V., and Sachs, J. (2004). "Swoogle: A Search and Metadata Engine for the Semantic Web," in *Proceedings of the 13th ACM Transactions on Information and Knowledge management*, 1581138741/04/0011.
- [6] Lawrence, S., and Giles, C. (1999). "Accessibility of information on the web," *Journal of Intelligence, Volume 11, Issue 1*, pp. 32-39, USA.
- [7] Kaptein, R., Koolen, M., and Kamps, J. (2010). "Result Diversity and Entity Ranking Experiments: Anchors, Links, Text and Wikipedia," in *Proceedings of the 19th Text Retrieval Conference (TREC)*, USA.
- [8] Arya, D., Ha-Thuc, V., and Sinha, S. (2015). "Personalized Federated Search at LinkedIn," in *Proceedings of the 15th International Conference on Information and Knowledge Management*, pp. 1699-1702.
- [9] Shu, W., Wang, W. and Wang, Y. (2014). "A novel energy-efficient resource allocation algorithm based on immune clonal optimization for green cloud computing," *EURASIP Journal on Wireless Communications and Networking*. 64 (2014). <https://doi.org/10.1186/1687-1499-2014-64>

- [10] Schuhknecht, F., Dittrich, J., and Linden, L. (2018). "Adaptive Indexing," in *Proceedings of 34th IEEE International Conference on Data Engineering (ICDE)*, Paris, France, April 16-19.
- [11] Chen, C., Li, F., Ooi, B. C. and Wu, S. (2011), "TI: An efficient indexing mechanism for real-time search on tweets," in *Proceedings of the ACM SIGMOD, International Conference on Management of Data*, pp. 649—660.
- [12] Lu J. (2007). "*Full-Text Federated Search in Peer-to-Peer Networks*," A Ph.D. Thesis, Language Technologies Institute School of Computer Science, Carnegie Mellon University.
- [13] Vasco P. (2009). "*Federated Ontology Search*," A Ph.D. Thesis, Language Technologies Institute School of Computer Science, Carnegie Mellon University.
- [14] Nguyen, D., Demeester, T., Trieschnigg, D., and Hiemstra, D. (2007). Resource Selection for Federated Search on the Web. ArXiv:1609.04556, CTIT Technical Report TR-CTIT-16-12.
- [15] Wang, S., Tuor, T., Salonidis, T., Leung, K., Makaya, C., He, T., and Chan, K. (2019). "Adaptive Federated Learning in Resource Constrained Edge Computing Systems," *Journal on Selected Areas in Communications*, 37:1205–1221.
- [16] Li, T., Sahu, A., Talwalkar, A., and Smith, V. (2019). Federated Learning: Challenges, Methods, and Future Directions. arXiv preprint arXiv:1908.07873.
- [17] Rijke, M., Kenter, T., Vries, A., Zhai, C., Jong, F., Radinsky, K., and Hofmann K. (2014). "Advances in Information Retrieval," *36th European Conference on IR Research, ECIR*, pp. 184-196.
- [18] Lee W. (2007). "Personalizing Internet Information Services: Passive Filtering and Active Retrieval," *International Journal of Computers and Applications*, 29:2, pp. 124-131, DOI: 10.1080/1206212X.2007.11441840.
- [19] Kim J. (2001). "Hybrid Filtering of web Pages for a Recommendation Agent," *International Journal of Computers and Applications*, 23:2, pp. 99-105, DOI: 10.1080/1206212X.2001.11441638.
- [20] Ponnuswami, A., Pattabiraman, K., Wu, Q., Bachrach, R., and Kanungo, T. (2011). "On composition of a federated web search result page: using online users to provide pairwise preference for heterogeneous verticals," *Proceedings of the fourth ACM International Conference on Web Search and Data Mining (WSDM)*, pp.715-724, DOI: 10.1145/1935826.1935922.
- [21] Jansen, J., Booth, D., and Spink, A. (2008). "Determining the Informational, Navigational, and Transactional Intent of Web Queries,"

- Information Processing & Management*, 44(3):1251-1266, doi:10.1016/j.ipm.2007.07.015.
- [22] Al-akashi, F. and Inkpen, D. (2012). "Intelligent Web Page Retrieval Using Wikipedia Knowledge," in *Proceedings of the 2nd Web Intelligence, Mining and Semantics (WIMS) International Conference*, Romania.
- [23] MacKinnon, I., and Vechtomova, O. (2008). "Improving Complex Interactive Question Answering Enhanced with Wikipedia Anchor Text," in *Proceedings of the 30th European Conference on Advances in Information Retrieval (ECIR)*, Glasgow, UK, pp. 438-445.
- [24] Xing, Y., and James, A. (2010). "A Content based Approach for Discovering Missing Anchor Text for Web Search," in *Proceedings of the 10th SIGIR*, pp. 19-23.
- [25] Kekäläinen, J. and Järvelin, K. (2013). "Using graded relevance assessments in IR evaluation," in *Proceedings of the ACM SIGIR, JASIST 53*, USA.
- [26] Baykan, E., Henzinger, M., and Marian, L., (2009). "Weber-1. Purely URL-based Topic Classification," in *Proceedings of the 18th International conference on World wide web (WWW)*, pp. 1109-1110, Spain.
- [27] Limsopatham, N., McCreadie, R., Albakour, M., Macdonald, C., Santos, R., and Ounis, I. (2012). "University of Glasgow at TREC 2012: Experiments with Terrier in Medical Records, Microblog, and Web Tracks," in *Proceedings of the 21st TREC Web Track Conference*, USA.
- [28] Xue, Y., Guo, S., Guan, F., Yu, X., Liu, Y., Cheng, X. and Li, H. (2012). "ICTNET at Web Track 2012 Ad-hoc Task". Text Retrieval Conference.
- [29] Demeester, T., Trieschnig, D., Nguyen, D., Zhou, K., and Hiemstra, D. "Overview of the TREC 2014 Federated Web Search Track," The Twenty-Third Text Retrieval Conference (TREC), Proceedings, NIST Special-Publication: SP 500-308, 2014.
- [30] Guan, F., Zhang, S., Liu, C., Yu, X., Liu, Y., and Cheng, X. (2014). "ICTNET at Federated Web Search Track2014", Text Retrieval Conference.
- [31] San Julián, C. (2008). "Automatic query expansion and word sense disambiguation with long and short queries using WordNet under vector model," *Actas de los Talleres de las Jornadas de Ingeniería del Software Bases de Datos*, Vol. 2.



UDC 303.025:331.5(4-6EU)

Original Scientific Paper

The Flexibility of Temporary Employment in Europe

Margarida Rodrigues*mmmrodrigues@sapo.pt**University of Beira Interior, Covilhã, Portugal***Cidália Oliveira***cidalia.oliveira@eeg.uminho.pt**NIPE (Center of Research in Economics and Management)**University of Minho, Braga, Portugal***Rui Silva***ruisilva@utad.pt**CETRAD (Center of Transdisciplinary Development Studies)**University of Trás-os-Montes e Alto Douro, Portugal*

Abstract

Temporary employment is not influenced by the unemployment rate, but shows a positive relation with the social protection expenses of the companies. Poland is the country with the highest percentage of temporary workers (2013). The objective of this research is to study this flexibility, by obtaining empirical evidence in the European Union, using a quantitative research method. Research is still missing towards a better understanding of the relation between temporary employment and unemployment. The relevance of understanding of the effects of temporary employment in the European Labor Market. As future research, it is suggested that this study be replicated for the time span of 2006 to 2020. This research focuses on the geographical area studied, providing a better understanding of the relation between temporary employment and unemployment. This research is based on quantitative research using a European Union secondary database (Eurostat).

Keywords: European Union, Employment, Social Protection Expenses, Temporary employment and Unemployment

1. Introduction

Global economic transformation and financial crises increase job insecurity, employee's vulnerability and even the social risk of exclusion [1], [2]. Thus, temporary work agencies have addressed this vulnerability, because the vast majority of people have failed to ensure a permanent and secure job, and are continuously unemployed [3]. As it can be seen, the use of the temporary work force was promoted by the globalization phenomena, and its implications in institutional and organizational environments have been widely studied [4].

Work flexibility can provide, through the temporality of their workers, more flexible human resources structures [5], allowing for the reduction of their labour costs

[6]. Thus, this flexibility is understood as the capacity of the companies to use temporary employees as a valid work force [7].

Regarding the theoretical framework, the choice was based on the resource-based view, in which the company is seen as a set of tangible and intangible resources [8]–[11]. Teece, Pisano, & Shuen [12] state that there are three aspects essential to the dynamic configuration of resources and competences. The first aspect is related to sensing features of individual capacities of organizational process, to collect information through a scan of the market in order to discover new opportunities. The following is concerning seizing, it refers to adapting products to needs, according to a product and architecture selection, within the scope of a business model. Finally, reconfiguring is also of great interest, since it characterizes the possibility of transforming resources and skills, according to the needs of customers, based on specialization and knowledge management. Dynamic capabilities support new challenges and protect knowledge, achieving a competitive advantage [12], [13]. Due to the need for constant adaptation, dynamic capabilities are organizational indicators based on resources, with the goal of competitiveness, since without the support of dynamic capabilities, organizations regress in their competitive advantage [14]. These capacities reflect the potential of the organization in integrating, creating, reconfiguring internal and external competences, in order to correspond to market fluctuations [12]. Eisenhardt & Martin [15] report, that the primary value of dynamic capabilities is not linked to capabilities per se, but to resource configuration. It is the configuration of resources and skills that will allow them to have a dynamic characterization. These stand out in highly dynamic markets, as they aspire to advantage in an unpredictable scenario, which requires that they exceed the characteristics of the resource-based theory, named RBV [16], [17].

Despite a significant number of research topics in this area, the literature on the link between the evolution of temporary work and total unemployment is limited, thus this research gap was identified for the present study. Total employment and social expenditure in the 28 member-European Union [18], lead countries to make deep reforms in their labour markets due to the financial crisis (2008), which, among others, created high rates of unemployment. In view of the above, the aim of this article is to analyse the relationship between job flexibility and unemployment, employment and associated social expenditure, in the European context in the year 2013. In this context, the following research question is raised: What influence do unemployment rates, employment rates and social protection expenses have on temporary work (European context)?

2. Literature Review

Given the complexity of the labour market, there has been a decrease in stable/permanent jobs in favour of other forms of employment, with greater contractual flexibility, working hours and more quantitative benefits to the employer, as is the case of temporary work [19]. To this author, in the world context, where the financial logic and short-term income continue to be predominant, there is an incessant pressure for a greater flexibility of the labour market, as companies want a

workforce that responds quickly, easily and at a low cost to market fluctuations. Due to these constant changes, the adaption to the market's requirements are crucial [12], [20], [21].

Thus, in the recent decades, and in numerous countries, there has been a significant increase in the number of temporary workers, reflecting an increased competition between companies and markets (globalization), which implied that they had to adapt swiftly to the changes in the conditions of supply and demand [22]. On the other hand, the global economic recession caused by the 2008 crisis also reduced the bargaining power of workers and their opportunities to continue to have permanent jobs, and in the countries where there was some recovery in employment, this focused on the temporary employment, the same authors concluded.

In view of the above, in the last decades, the increase of temporary work has been a response to high unemployment in many countries, however the legal framework differs from country to country [23]–[25]. Kovacs [19] argued that there was empirical evidence that flexible work has been increasing all over Europe, despite the subsistence of differences among countries. This type of job has been considered to be the main way for unemployed people (e.g. women, young people and people with low qualifications) to enter working life, that is, the labour market [19], [26]. These temporary jobs, with short-term contracts, can act as a springboard to better paid employment or be a vehicle of transition between school and employment [27]. Also Kyyrä [28] said that the option of the individuals for this form of employment is, to an extent, involuntary because of the difficulty in getting a better job in some countries

In short, temporary work can be the vehicle for regular employment [29], [30][31], [32], as well as a way to reduce the unemployment rate, if competent entities set social security programs with benefits for the employer and the employee [33].

Costa [34] argued that it is only possible to create more jobs for people through flexible labour legislation and working conditions (e.g., Socials). De Graaf-Zijl et al. [30] so as recently Caroleo, Rocca, Mazzocchi, Quintano [35] concluded that there is a growing trend of temporary work in many countries and there is a broad debate about the benefits of this type of job in relation to the unemployment numbers. It means that if a temporary worker gets a permanent job, they will have the possibility of obtaining a higher remuneration than when they were effectively unemployed, explained these authors. Pulignano & Doerflinger [36] considered that this type of work can be seen as a protection for the maintenance of permanent jobs, especially in situations of economic crisis. On the other hand, the dispersed legislation about labour relations in the labour market has contributed to contractual flexibility, where companies have the option of having seasonal workers [7]. These authors argued that this seasonality brings benefits for the companies both in terms of fixed costs and future burdens of eventual redundancies. According to Chen and Funke [37] a rigid labour legislation may increase the demand for temporary workers, but although there are different legislative frameworks, they follow the recommendations of the European Union [38]. Also, many of the people who use temporary work have low or medium skills and as such are seeking short-term jobs, allowing subcontractors to have minor expenses [39]. This means that temporary work companies reduce the labour costs of contracting companies, since they are the first to support wages and taxes,

and there are even some companies that provide adequate training for contracted employees [40]. The growing demand for this form of employment by companies is largely related to the need to reduce their labour costs, since these labour contracts are flexible [19].

As it turns out, the use of temporary workforce has become a global phenomenon, so researchers have a growing interest in the implications of its use around the world [38]. An organization can better manage its human resources this way because of its flexible human resource structure [5]. In addition, organizations seek a temporary workforce to reduce their labour costs [6], [41], so resorting to temporary agencies is a way to achieve this reduction. In this context, temporary work can contribute to improving the enterprises' economic performance by allowing them to reduce fixed labour costs (such as social protection) associated with permanent workers [42]–[45] and also to solve the work cycles recessions depending on the market [44], [46]. From another point of view, Osuna and García-Pérez [47] argued that temporary work does not necessarily reduce the unemployment rate, since this reduction is related to the level of social expenses that companies have to bear towards the type of contractual relationship with the worker. Also to Kopycińska and Kryńska [44], measures must be taken to strengthen the temporary workers' social protection and the wage balance must prevail regardless of the type of contractual relationship, among others.

The exposure to global competition, the volatility of the demand and supply law, the development of new production processes and the current degree of uncertainty are relevant factors [49]–[51]. Consequently, there is the need of flexible employment contracts from the point of view of the employer companies, once they always seek a strategy of efficiency [52]. Of course this situation has resulted in the segmentation of the labour market, originated by a wide institutional negotiation process around the world [52]. In the last decades, many economists have argued repeatedly that Europe's high unemployment rate should be reduced by making labour markets more flexible [53], in particular by introducing efficient education mechanisms to enable continuous and dynamic learning, which may lead to better wage conditions and a strong protection against lay-off. Thus, all over Europe, there is a duality of the labour market, which contrasts being employed to being unemployed, but in between the two there is temporary work in the middle of which comes the temporary work with lower rights, less protection, but leads to the reduction of social expenses of the companies [54]. These authors pointed out that the regulations of this type of work in Europe aim to fight the high unemployment and to maintain the competitiveness of companies. In particular, with regard to western Europe, the researchers identified an increase in temporary work from the 80s and in the middle of the 90s they noticed a significant positive evolution [38], e.g., in the 90s, Spain suffered a high demand for temporary workers by companies, reaching one third of the workers in its business fabric. Specifically, Koene and Ansari [55] argued that the appearance of a new labour market in Spain was sustained by institutional changes. According to these authors, temporary work was legalized in Spain in 1994, in the context of wide institutional reforms implemented in this market that aimed to construct a long term sustainable labour market. These authors argued that temporary work has grown quickly in Spain since the middle of the 80s because in the previous period its legislation was strict in

the protection of employment. However, the growing internationalization of the economy and the economic crisis helped to trigger market reforms in 1984, which were directed towards flexibility and temporary contracts [56]. Thereby, Spain developed a dual labour market in the early 90s, where protectionism for permanent jobs coexisted with low-quality temporary labour with little protection. In Spain, there is a high percentage of temporary workers because the relevant legislation is more flexible and less bureaucratic, as a way to avoid an increase in the rate of job destruction [47].

Thus, based on the literature review conducted, the following research hypothesis arise.

Hypothesis 1: Unemployment leads to Temporary work.

Hypothesis 2: Employment may be increased by Temporary work.

Hypothesis 3: Temporary work has a positive relation with companies' social expenses.

Hypothesis 4: Spain is the European country with the largest number of temporary workers.

3. Research methodology

The research method used was quantitative research using a European Union secondary database (Eurostat) which provides a variety of statistical information on the member countries of the European Union- In this study, only data related to population and social conditions will be taken into account.

Table 1 presents a summary of the methodology and Table 2 the essential aspects considered.

Research planning (introduction and review of the literature)	Definition of the subject to be investigated and its framework in terms of literature review.
Data collection and preparation	Identification of the database to be used, compilation and harmonization of the data, to be comparable and subject to statistical analysis.
Data analysis	Identification of the statistical techniques to be used and the interpretation and discussion of results, according to Marôco (2014); Pestana & Gageiro (2014)

Table 1. Structure of the methodology

Unit of analysis	Countries
Research countries	28 European Union countries
Geographical area	Europe
Data collection	Eurostat secondary data – <i>Population and Social Conditions</i>
Analysis period	2013
Quantitative software	IBM SPSS Statistic (version 24)
Data analysis	This analysis is divided into two distinct parts:

	• Descriptive statistics (tables and graphs) • Construction of 4 regression models, until a model with statistically significant independent variables was obtained, to conclude on the previously defined research hypothesis (1, 2, 3). Research hypothesis 4 is analysed with descriptive statistics only.
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Table 2. Essential aspects followed

4. Presentation and Discussion of Results

In order to make a statistical treatment of the obtained raw data, a harmonization of the data was made. In other words, in order to be able to use the regression model, the data from different dimension countries, the absolute data relative to the number of employees, unemployed and temporary employees had to be put in perspective, so the active population was used, calculating the % values of employees, unemployed and temporary employees by the active population. Note that the global data from Europe are only presented for comparative purposes with other countries' data, once only data from 28 countries will be used in the regression. Data on the unemployed are for a wider age range, between 15 and 74 years old, in contrast to the remaining, that are for an age range between 15 and 64 years old. However, this approach had to be used, since there was no other information regarding the unemployed in the data base.

Country	% Temporary Employees	% Unemployed	% Employees	Social Protection Expenses
European Union (28 countries)	10,20%	11,03%	89,01%	7.416,10
European Union (27 countries)	10,20%	10,98%	89,06%	7.460,33
European Union (15 countries)	10,26%	11,22%	88,82%	8.853,25
Euro area (19 countries)	11,08%	12,13%	87,91%	8.348,87
Euro area (18 countries)	11,16%	12,13%	87,91%	8.407,71
Euro area (17 countries)	11,21%	12,13%	87,91%	8.448,97
Belgium	6,35%	8,50%	91,51%	10.116,40
Bulgaria	4,30%	13,13%	86,94%	979,19
Czech Republic	7,00%	7,08%	92,96%	2.936,85
Denmark	7,50%	7,16%	92,85%	14.425,99
Germany	11,33%	5,35%	94,67%	9.715,54
Estonia	2,90%	8,96%	91,15%	2.106,85
Ireland	7,19%	13,38%	86,68%	8.084,11
Greece	4,67%	27,81%	72,30%	4.291,27
Spain	14,09%	26,26%	73,78%	5.567,60

France	12,28%	10,00%	90,03%	10.262,71
Croatia	9,94%	17,54%	82,50%	2.199,65
Italy	8,82%	12,37%	87,67%	7.633,22
Cyprus	12,31%	16,21%	84,00%	4.650,19
Latvia	3,36%	12,21%	87,93%	1.631,94
Lithuania	2,08%	12,01%	88,02%	1.708,34
Luxembourg	6,02%	5,90%	94,02%	19.442,71
Hungary	8,74%	10,26%	89,77%	2.113,56
Malta	6,05%	6,49%	93,51%	3.372,81
Netherlands	15,73%	7,40%	92,70%	11.333,50
Austria	7,66%	5,43%	94,58%	11.011,37
Poland	18,87%	10,48%	89,54%	1.966,04
Portugal	14,60%	17,07%	82,99%	4.243,66
Romania	0,93%	7,39%	92,61%	1.050,67
Slovenia	12,33%	10,28%	89,70%	4.275,88
Slovakia	4,94%	14,28%	85,76%	2.435,89
Finland	12,28%	8,36%	91,65%	11.338,88
Sweden	13,52%	8,30%	91,76%	13.376,66
United Kingdom	4,78%	7,78%	92,29%	8.859,72

Table 3. Relative data under analysis for the year 2013

In terms of descriptive statistics, , for the quantitative variables in the study we present some relevant data – table 4 – and illustrative graphs of the values distribution in each variable, figures 1 to 4.

	N	Average	Standard deviation	Coefficient of variation	Minimum	Maximum
% Temporary employees	28	8,59%	4,55%	53%	0,93%	18,87%
% Unemployed	28	11,34%	5,60%	49%	5,35%	27,81%
% Employed	28	88,71%	5,58%	6%	72,30%	94,67%
Social protection expenses (euros per capita)	28	6468,97	4846,87	75%	979,19	19442,71

Table 4. Variables descriptive statistics

In the sample, the % of temporary employees presents an average value of 8.59%, with a dispersion of values of 53%. The minimum and maximum values are, respectively, 0.93% and 18.87%. It can be observed that the distribution of values of

the % of temporary employees mainly occurs between 2.5% and 15%. In the sample, the % of unemployed presents an average value of 11.34%, with a dispersion of values of 49%. The minimum and maximum values are respectively 5.35% and 27.81%. It can be observed that the distribution of values of the % of unemployed mainly occurs between 5% and 15%, and while all values over 20% (for Greece and Spain) are outliers, extreme cases that go out of the distribution normal values. In the sample, the % of employees present an average value of 88.71%, with a dispersion of values of 6%. The minimum and maximum values are, respectively, 72.30% and 94.67%. It can be observed that the distribution of values of % of employees is mainly between 82.5% and 95%, and while all values below 80% (for Greece and Spain) are outliers, extreme cases that go out of the normal distribution of values. In the sample, social protection expenses have an average value of 6 468.97 €, with a dispersion of values of 75%. The minimum and maximum values are, respectively, € 979.19 and € 19.442,71. Turning now to the multiple linear regression model, the following formula is given:

$$Y_n = \beta_0 + \beta_{1X_1} + \beta_{2X_2} + \beta_{3X_3} + \varepsilon$$

Thus, the dependent variable is the % temporary employees (Y_n) and the % employees (X_1), the % employees (X_2) and the social protection expenses (X_3) are the independent variables. n corresponds to the 28 countries of the European Union. Thus, the determination coefficients are shown in table 5.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,339 ^a	,115	,004	4,53646
a. Predictors: (Constant), social protection expenses, % employees, % employees				

Table 5. Model Summary Source: own elaboration

The coefficient of determination $r^2=0,115$ indicating that 11,5% of the variation occurs in the % temporary employees is explained by the variables included in this model. The coefficient of determination adjusted $r_a^2=0,004$ is 0,4%.

To determine if this model is globally significant, table 6 and 7 are presented.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	63,931	3	21,310	1,036	0,395
	Residual	493,908	24	20,579		
	Total	557,839	27			
a. Dependent Variable: % temporary employees						
b. Predictors: (Constant), Social protection expenses, % employees, % unemployed						

Table 6. ANOVA

The F test, to the global significance of the model, is not validated because it presents a probative value higher than 5% ($p=0,395$) which does not allow to reject the hypothesis.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1042,333	1537,065		-,678	,504
	% Unemployed	10,603	15,306	13,069	,693	,495
	% Employee	10,468	15,368	12,840	,681	,502
	Social protection expenses	,000	,000	,346	1,641	,114

Table 7. Variables' coefficients in the model and level of significance

The variables included in the model indicate that there are no significant variables for the model, that is, for the explanation of the dependent variable % temporary employees.

On the other hand, Pearson's correlation coefficient was applied to study the nature of the relationship between the dependent variable and the independent variables, and it was concluded that there are no statistically significant relationships between the dependent variable and the independent ones.

However, since this model includes 3 independent variables, tests were performed on the assumptions associated with it, that is, multicollinearity (Pearson's correlation matrix), in which it was concluded that there is multicollinearity between % unemployed and % employees. In this context, since the violation of this assumption is so evident, it makes no sense to proceed with the analysis of this regression model.

Thus, a new regression model is presented without one of the variables that present a strong multicollinearity between them, being the variable % employees the excluded variable. Thus, the model only has as independent variables the % unemployed and the social protection expenses (Table 8).

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,312 ^a	,097	,025	4,48757
a. Predictors: (Constant), social protection expenses, % unemployed b. Dependent Variable: % temporary employees				

Table 8. Model Summary

The determination coefficient $r^2=0,097$ indicating that 9,7% of the variation occurs in % temporary employees is explained by the independent variables included in the model, having decreased relatively to the first model, since it presents an independent variable less. The adjusted determination coefficient $r_a^2=0,025$ is 2,5%, and has increased considerably, with respect to the first model, which indicates that

this model is better, in explanatory terms, of the % temporary employees. For the overall evaluation of the model, the following tests were performed (Tables 9 and 10).

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	54,383	2	27,191	1,350	,277 ^b
	Residual	503,456	25	20,138		
	Total	557,839	27			

Table 9. ANOVA

The F Test, to the model's global significance, is again not validated because it presents a test value higher than 5% ($p=0,277$).

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4,629	2,762		1,676	,106
	% Unemployed	,178	,167	,219	1,069	,295
	Social Protection expenses	,000	,000	,320	1,560	,131

Table 10. Coefficients of the variables and level of significance

The variables included in the model indicate that there are no significant variables for the model, that is, for the explanation of the percentage of temporary employees none of the two variables chosen for this new model are statistically significant for the explanation of the variation observed in the % temporary employees.

In view of this result, standardized residues were analyzed, where Poland was identified as an *outlier*. From the analysis of the standardized residues, shown in the graph above, the detection of outliers allows us to identify as outlier the case corresponding to Poland.

The new model of regression integrates now the % unemployed and the social protection expenses (Tables 11,12 and 13).

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,462 ^a	,214	,148	3,83012

a. Predictors: (Constant), social protection expenses, % unemployed b. Dependent Variable: % temporary employees

Table 11. Model Summary

The coefficient of determination $r^2=0.214$ indicates that 21.4% of the variation occurring in the % temporary employees is explained by the two independent

variables included in the model, having increased considerably compared to the previous model. The adjusted coefficient of determination $r_a^2 = 0.148$ is 14.8% also significantly increased in relation to the previous model, which indicates that this model is better in terms of the % temporary employees.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	95,592	2	47,796	3,258	,056 ^b
	Residual	352,075	24	14,670		
	Total	447,667	26			
a. Dependent Variable: % temporary employees b. Predictors: (Constant), social protection expenses, % unemployed						

Table 12. ANOVA

The F test, to the global significance of the model, remains uncorrected because it presented a test value higher than 5% ($p = 0.056$).

Model		Unstandardized Coefficients		Std. Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2,878	2,419		1,189	,246
	% Unemployed	,228	,143	,313	1,593	,124
	Social Protection expenses	,000	,000	,484	2,459	,022

Table 13. Coefficients of the variables and level of significance

It is concluded that the percentage of temporary employees increases significantly with the increase of social protection expenses. Also in this model, multicollinearity, the normal distribution of residues and the assumption of homoscedasticity were absent. In order to better understand the effects of multicollinearity, we present a regression model with % employees and social protection expenses, without Poland (Tables 14,15 and 16).

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,460 ^a	,212	,146	3,83420
a. Predictors: (Constant), social protection expenses, % employees b. Dependent Variable: % temporary employees				

Table 14. Model Summary

The determination coefficient $r^2=0,212$ indicates that 21,2% of the variation occurring in the % temporary employees is explained by the two independent

variables included in the model, similar to the previous model. The adjusted determination coefficient $r_a^2=0,146$ is 14,6% and is also similar to that of the previous model, which indicates that the latter two models are similar in explanatory terms of the % temporary employees.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	94,840	2	47,420	3,226	,057 ^b
	Residual	352,827	24	14,701		
	Total	447,667	26			

a. Dependent Variable: % temporary employees b. Predictors: (Constant), social protection expenses, % employees

Table 15. ANOVA

The F Test, to t the global significance of the model, remains not validated, as it presents a test value higher than 5% ($p=0,057$).

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	25,554	12,376		2,065	,050
	% employees	-,226	,144	-,310	1,575	,128
	Social protection expenses	,000	,000	,482	2,449	,022

Table 16. Coefficients of the variables and level of significance

It can be concluded that the % temporary employees increases significantly with the rise in social protection expenses. For the % employees, the results are inverse to those of the previous model to the % unemployed, since the relation between these is inversely proportional. In this model, all standardized residues are now within desirable limits, so there is no outlier in this new model. We also verify the absence of the multicollinearity assumption, the normal distribution of residues and the homoscedasticity assumption.

Finally, by the application of the Backward method and the Pearson correlation, it can be concluded that between the % temporary employees and the % unemployed and the % employed and the social protection expenses there are no statistically significant relationships in an isolated way.

Regarding the comparison of the results with the literature review for each of the defined research hypothesis, we conclude that:

Hypothesis 1: Unemployment leads to Temporary work

This hypothesis is not confirmed, as there is no significant correlation between the % of unemployed and the percentage of temporary employees in any of the presented models, more specifically in the final model, that is, the 1% increase in the

% unemployed causes an average increase of the % temporary employees of $B = 0.228$, however, this relation is not statistically significant ($p = 0.124$) (table 13). The non-verification of this hypothesis contradicts the arguments that temporary employment would be a half or one influential factor in reducing unemployment.

Hypothesis 2: Employment may be increased by Temporary work

This hypothesis is not confirmed, as there is no significant correlation between the % unemployed and the percentage of temporary employees in any model, in particular in the final model, that is, the 1% increase in the % unemployed causes an average decrease of the % temporary employees of $B = -0.226$, however, the relationship is not statistically significant ($p = 0.128$) (table 16). In addition, there is no significant relationship between the % employees and the percentage of temporary employees because the relationship that occurs even has a negative signal, which contradicts the hypothesis presented. Although some authors consider temporary employment as a means to increase employment [19], [26]–[28], this was not the case. For Osuna & García-Pérez [47] the reduction of the unemployment rate is more related to the cost of social expenses to be borne by companies. This type of employment will only have positive effects on unemployment if there is less rigid legislation and labour markets [34], [59].

Hypothesis 3: Temporary work has a positive relationship with social expenses of companies.

This hypothesis is verified for the final model developed, since there is a significant correlation between social protection expenses and the % temporary employees, where the increase of one euro in social protection expenses per inhabitant causes an average increase of the % temporary employees of $B = 0.000413$, the ratio being statistically significant ($p = 0.0022$) (table 16). Therefore, we can affirm that for each increase of 1,000 euros in social protection expenses per capita, the percentage of temporary employees increases by 0.413 percentage points, on average, as we can see in hypothesis 3. This positive relation is corroborated by several authors [39], who showed that this type of employment allows for the reduction of human resources and the lower rigidity of the structure [5]. On the other hand, this positivity can improve the financial performance of companies, especially in times of recession/economic crisis [42], [48], [60].

Hypothesis 4: Spain is the European country with the largest number of temporary workers

Country	% Temporary employees
Poland	18,87%
Netherlands	15,73%
Portugal	14,60%
Spain	14,09%
Sweden	13,52%

Slovenia	12,33%
Cyprus	12,31%
France	12,28%
Finland	12,28%
Germany	11,33%
Croatia	9,94%
Italy	8,82%
Hungary	8,74%
Austria	7,66%
Denmark	7,50%
Ireland	7,19%
Czech Republic	7,00%
Belgium	6,35%
Malta	6,05%
Luxembourg	6,02%
Slovakia	4,94%
United Kingdom	4,78%
Greece	4,67%
Bulgaria	4,30%
Latvia	3,36%
Estonia	2,90%
Lithuania	2,08%
Romania	0,93%

Table 17. Relative data in analysis, for the year 2013

This hypothesis is not verified either, since the country with the highest percentage of temporary employees in 2013 is Poland with 18,87%, contrary to what Osuna & García-Pérez [47] argue. Below, we have a summary table of the Hypotheses of this Research, with their Status (table 18):

Hypothesis	Results
1	Not confirmed
2	Not confirmed
3	confirmed
4	Not confirmed

Table 18. Final Results

5. Conclusions

In line with the research question, we can conclude that the increase of temporary employment in the European Union has not achieved the desired performance in terms of reducing unemployment and, inherently, increasing employment. However, it has been found that this increase is related to companies' aim to reduce their fixed costs with human resources and to make their structure less rigid being an effective way to improve financial performance. On the other hand, in the analysed period, Poland has more temporary employees than Spain.

Considering the limitations of this study, it might be considered that the analysed timespan should be improved, in further studies, as the used database only allows for the timespan from 2014 to 2015 of the 28 members of the European Union.

The contributions of this article are related to the scope of the geographical area studied, as most of the research focuses on a specific geographic context, furthermore it provides a better understanding of the relation between temporary employment and unemployment.

For future research, we suggest the replication of this study for the time period 2006-2015, which would provide comprehensive and relevant empirical evidence for a longer time span. Furthermore, it would be relevant to understand the reasons why Poland is the country with the highest % of temporary employees.

Funding: This paper is financed by National Funds of the FCT – Portuguese Foundation for Science and Technology within the project «UIDB/03182/2020 and UIDB/04011/2020.

Acknowledgments: The authors gratefully acknowledge the technical support received from NIPE (Centre for Research in Economics and Management), University of Minho and CETRAD (Centre for Transdisciplinary Development Studies), University of Trás-os-Montes e Alto Douro.

Conflicts of Interest: The authors declare no conflict of interests.

References

- [1] J. Burgess and J. Connell, "Temporary work and human resources management: issues, challenges and responses," *Pers. Rev.*, vol. 35, no. 2, pp. 129–140, Mar. 2006.
- [2] A. Pollert and A. Charlwood, "The vulnerable worker in Britain and problems at work," *Work. Employ. Soc.*, vol. 23, no. 2, pp. 343–362, 2009.
- [3] E. Preenen, P. Verbiest, S. Vianen, A. e Wijk, "Informal learning of temporary agency workers in low-skill jobs : The role of self-profiling , career control , and job challenge," *Career Dev. Int.*, vol. 20, no. 4, pp. 339–362, 2015.
- [4] T. T. Selvarajan, J. Slattery, and D. Y. Stringer, "Relationship between gender and work related attitudes : a study of temporary agency employees," *J. Bus. Res.*, vol. 68, no. 9, pp. 1919–1927, 2015.

- [5] S. A. Way, D. P. Lepak, C. H. Fay, and J. W. Thacker, "Contingent workers' impact on standard employee withdrawal behaviors: Does what you use them for matter?," *Hum. Resour. Manage.*, vol. 49, no. 1, pp. 109–138, Jan. 2010.
- [6] A. S. Boyce, A. M. Ryan, A. L. Imus, and F. P. Morgeson, "'Temporary Worker, Permanent Loser?' A Model of the Stigmatization of Temporary Workers," *J. Manage.*, vol. 33, no. 1, pp. 5–29, 2007.
- [7] J. Michie and M. Sheehan-Quinn, "Labour market flexibility, human resource management and corporate performance," *Br. J. Manag.*, vol. 12, no. 4, pp. 287–306, 2001.
- [8] J. Barney, "Firm Resources and Sustained Competitive Advantage," *J. Manage.*, vol. 17, no. 1, pp. 99–120, 1991.
- [9] J. B. Barney and D. N. Clark, "Resource-based theory: Creating and sustaining competitive advantage," *Long Range Plann.*, vol. 3, no. 24, pp. 32–39, 1991.
- [10] K. M. Eisenhardt, "Building Theories from Case Study Research," vol. 14, no. 4, pp. 532–550, 1989.
- [11] J. T. Mahoney, "The management of resources and the resource of management," *J. Bus. Res.*, vol. 33, no. 94, pp. 91–101, 1995.
- [12] D. J. Teece, G. Pisano, and A. Shuen, "MANAGEMENT," *Strateg. Manag. J.*, vol. 18, no. 7, pp. 509–533, 1997.
- [13] M. Augier and D. J. Teece, "Dynamic Capabilities and the Role of Managers in Business Strategy and Economic Performance," *Organ. Sci.*, vol. 20, no. 2, pp. 410–421, 2009.
- [14] L.-Y. Wu, "Entrepreneurial resources, dynamic capabilities and start-up performance of Taiwan's high-tech firms," *J. Bus. Res.*, vol. 60, no. 5, pp. 549–555, 2007.
- [15] K. M. Eisenhardt and A. J. Martin, "Dynamic capabilities: what are they?," *Strateg. Manag. J.*, vol. 21, pp. 1105–1121, 2000.
- [16] V. S. Katkalo, C. N. Pitelis, and D. J. Teece, "Introduction : On the nature and scope of dynamic capabilities," vol. 19, no. 4, pp. 1175–1186, 2010.
- [17] A. J. Kraaijenbrink, J., Spender, J. C., & Groen, "The resource-based view : A review and assessment of its critiques.," *J. Manage.*, vol. 36, no. 1, pp. 349–372, 2010.
- [18] A. . Martín-Artiles, O. . Molina, and P. . Carrasquer, "Uncertainty and attitudes pro-redistributive: Labour market and welfare models in Europe [Incertidumbre y actitudes pro-redistributivas: mercados de trabajo y modelos de bienestar en Europa]," *Polit. y Soc.*, vol. 53, no. 1, pp. 187–215, 2016.

-
- [19] I. Kovács, “Emprego flexível em Portugal 1,” *Sociologias*, vol. 6, no. 12, pp. 32–67, 2004.
 - [20] S. G. Helfat, C.E.; Finkelstein, S., Mitchell, W., Peteraf, M.A., Singh, H., Teece, D.J., Winter, *Dynamic capabilities: Understanding strategic change in organizations*. 2007.
 - [21] S. G. Winter, “Understanding dynamics capabilities,” *Strateg. Manag. J.*, vol. 24, pp. 991–995, 2003.
 - [22] F. Moscone, E. Tosetti, and G. Vittadini, “The impact of precarious employment on mental health: The case of Italy,” *Soc. Sci. Med.*, vol. 158, 2016.
 - [23] G. S. F. Bruno, F. E. Caroleo, and O. Dessy, “Temporary contracts and young workers ’ job satisfaction in Italy,” 2013.
 - [24] R. Bardazzi and S. Duranti, “Atypical work: a threat to labour productivity growth? Some evidence from Italy,” *Int. Rev. Appl. Econ.*, vol. 30, no. 5, pp. 620–643, 2016.
 - [25] A. Bagnai and C. A. Mongeau Ospina, “Monetary integration vs. real disintegration: single currency and productivity divergence in the euro area#,” *J. Econ. Policy Reform*, vol. 21, no. 4, pp. 353–367, 2018.
 - [26] T. Boeri, “Institutional Reforms and Dualism in European Labor Markets,” Elsevier, 2011.
 - [27] A. Bugarin, “Linking Welfare Recipients to Jobs: The Role of Temporary Help Agencies,” 1998.
 - [28] T. Kyrrä, “Partial unemployment insurance benefits and the transition rate to regular work,” *Eur. Econ. Rev.*, vol. 54, no. 7, pp. 911–930, 2010.
 - [29] A. L. Booth, M. Francesconi, and J. Frank, “Temporary jobs: Stepping stones or dead ends?,” *Econ. J.*, vol. 112, no. 480, pp. F189–F213, 2002.
 - [30] M. . de Graaf-Zijl, G. J. . c d e f van den Berg, and A. . Heyma, “Stepping stones for the unemployed: The effect of temporary jobs on the duration until (regular) work,” *J. Popul. Econ.*, vol. 24, no. 1, pp. 107–139, 2011.
 - [31] D. Lane, J., Mikelson, K. S., Sharkey, P., & Wissoker, “Pathways to Work for Low- Income Workers : The Effect of Work in the Temporary Help Industry,” *J. Policy Anal. Manag.*, vol. 22, no. 4, pp. 581–598, 2003.
 - [32] M. de Graaf-Zijl, G. J. van den Berg, and A. Heyma, “Stepping stones for the unemployed: The effect of temporary jobs on the duration until (regular) work,” *J. Popul. Econ.*, vol. 24, no. 1, pp. 107–139, 2011.
 - [33] M. Gerfin and M. Lechner, “a Microeconomic Evaluation of the Active Labour Market Policy in Switzerland *,” vol. 112, pp. 854–893, 2002.
-

- [34] H. A. Costa, “Desafios e dilemas da sua aplicação,” *Rev. Crit. Cienc. Sociais*, vol. 86, pp. 123–144, 2009.
- [35] F. Ernesto, C. Antonella, R. Paolo, and C. Quintano, *Being NEET in Europe Before and After the Economic Crisis : An Analysis of the Micro and Macro Determinants*, vol. 149, no. 3. Springer Netherlands, 2020.
- [36] V. Pulignano and N. Doerflinger, “A head with two tales: trade unions’ influence on temporary agency work in Belgian and German workplaces,” *Int. J. Hum. Resour. Manag.*, vol. 24, no. 22, pp. 4149–4165, 2013.
- [37] Y.-F. . Chen and M. . Funke, “Threshold effects of dismissal protection regulation and the emergence of temporary work agencies,” *Stud. Nonlinear Dyn. Econom.*, vol. 13, no. 4, 2009.
- [38] N. De Cuyper, J. De Jong, H. De Witte, K. Isaksson, T. Rigotti, and R. Schalk, “Literature review of theory and research on the psychological impact of temporary employment: Towards a conceptual model,” *Int. J. Manag. Rev.*, vol. 10, no. 1, pp. 25–51, 2008.
- [39] H. Beynon, *Managing employment change: The new realities of work*. 2002.
- [40] C. E. Connelly and D. G. Gallagher, “Emerging Trends in Contingent Work Research,” *J. Manage.*, vol. 30, no. 6, pp. 959–983, 2004.
- [41] G. R. Oldham and Y. Fried, “Job design research and theory: Past, present and future,” *Organ. Behav. Hum. Decis. Process.*, vol. 136, pp. 20–35, 2016.
- [42] F. J. Carre, *Nonstandard Work: The Nature and Challenges of Changing Employment Arrangements*, vol. 1st. 2000.
- [43] C. E. Helfat, “Know-how and Asset Complementarity and Dynamic Capability Accumulation: The Case of R&D,” *Strateg. Manag. J.*, vol. 18, no. 5, pp. 339–360, 1997.
- [44] D. Kopycińska and E. Kryńska, “The precariat in the labour market in Poland – social and economic aspects,” *J. Int. Stud.*, vol. 9, no. 2, pp. 79–89, 2016.
- [45] A. Skibiński, “Assessment of the Degree Ageing Labour Force for Example of Poland and Slovakia,” *Eur. J. Sustain. Dev.*, vol. 7, no. 3, pp. 473–482, 2018.
- [46] M. Estevao and S. Lach, “Measuring Temporary Labor Outsourcing in U.S. Manufacturing,” *Natl. Bur. Econ. Res. Work. Pap. Ser.*, vol. No. 7421, no. October, 1999.
- [47] V. . Osuna and J. I. . García-Pérez, “On the Effectiveness of Short-time Work Schemes in Dual Labor Markets,” *Econ.*, vol. 163, no. 3, pp. 323–351, 2015.

- [48] E. Kopycińska, D., & Kryńska, "Employment of the disabled in the EU in the framework of Europe 2020 Strategy," *J. Int. Stud.*, vol. 8, no. 3, pp. 9–19, 2015.
- [49] J. B. Barney, "Strategic Factor Markets: Expectations, Luck, and Business Strategy," *Manage. Sci.*, vol. 32, no. 10, pp. 1231–1241, Oct. 1986.
- [50] J. Barney, M. Wright, and D. J. Ketchen, "The resource-based view of the firm: ten years after 1991," *Journal of Management*, vol. 27, no. 6, pp. 625–641, 2001.
- [51] Y. Lin and L. Y. Wu, "Exploring the role of dynamic capabilities in firm performance under the resource-based view framework," *J. Bus. Res.*, vol. 67, no. 3, pp. 407–413, 2014.
- [52] V. Pulignano, G. Meardi, and N. Doerflinger, "Trade unions and labour market dualisation: A comparison of policies and attitudes towards agency and migrant workers in Germany and Belgium," *Work. Employ. Soc.*, vol. 29, no. 5, 2015.
- [53] H. Zhou, R. Dekker, and A. Kleinknecht, "Flexible labor and innovation performance: evidence from longitudinal firm-level data," *Ind. Corp. Chang.*, vol. 20, no. 3, pp. 941–968, 2011.
- [54] T. Vlandas, "The Politics of Temporary Work Deregulation in Europe: Solving the French Puzzle," *Polit. Soc.*, vol. 41, no. 3, pp. 425–460, 2013.
- [55] B. Koene and S. (Shaz) Ansari, "Institutional change and the multinational change agent: A study of the temporary staffing industry in Spain," *J. Organ. Chang. Manag.*, vol. 24, no. 4, pp. 511–531, 2011.
- [56] K. Golsch, "Employment flexibility in Spain and its impact on transitions to adulthood," *Work. Employ. Soc.*, vol. 17, no. 4, pp. 691–718, 2003.
- [57] J. Marôco, *Análise estatística com o SPSS Statistics*. 2014.
- [58] M. H. Pestana and J. N. Gageiro, "ANÁLISE DE DADOS PARA CIÊNCIAS SOCIAIS A Complementaridade do SPSS 6 a EDIÇÃO Revista, Atualizada e Aumentada MARIA HELENA PESTANA JOÃO NUNES GAGEIRO," no. September, pp. 1–2, 2014.
- [59] E. Kopycińska, D., & Kryńska, "Employment of the disabled in the EU in the framework of Europe 2020 Strategy," *J. Int. Stud.*, vol. 8, no. 3, pp. 9–19, 2015.
- [60] V. Pulignano and N. Doerflinger, "A head with two tales: Trade unions' influence on temporary agency work in Belgian and German workplaces," *Int. J. Hum. Resour. Manag.*, vol. 24, no. 22, 2013.



Δ ARLE: Lossless data compression algorithm using delta transformation and optimized bit-level run-length encoding

Branislav Madoš

branislav.mados@tuke.sk

*Faculty of Electrical Engineering and Informatics,
Technical University of Košice, Košice, Slovak Republic*

Zuzana Bilanová

zuzana.bilanova@tuke.sk

*Faculty of Electrical Engineering and Informatics,
Technical University of Košice, Košice, Slovak Republic*

Ján Hurtuk

jan.hurtuk@tuke.sk

*Faculty of Electrical Engineering and Informatics,
Technical University of Košice, Košice, Slovak Republic*

Abstract

Lossless data compression algorithms can use statistical redundancy to represent data using a fewer number of bits in comparison to the original uncompressed data. Run-Length Encoding is one of the simplest lossless compression algorithms in terms of understanding its principles and software implementation, as well as in terms of temporal and spatial complexity. If this principle is applied to individual bits of original uncompressed data without respecting the byte boundaries, this approach is referred to as bit-level Run-Length Encoding. Algorithm for lossless data compression, proposed in this paper, optimizes bit-level Run-Length Encoding data compression, uses special encoding of repeating data blocks, and, if necessary, combines it with delta data transformation or representation of data in its original form intending to increase compression efficiency compared to a conventional bit-level Run-Length Encoding approach. The advantage of the algorithm proposed in this paper is in the increase of the compression ratio in comparison to the bit-level Run-Length Encoding, with the higher time and space consumption as the trade-off. Test results, that were obtained by compression of the segmentation metadata of different volume datasets take place in the last part of the paper.

Keywords: data compression, lossless data compression, run-length encoding, RLE, bit-level run-length encoding, three dimensional data, volume data, sparse voxel octrees, sparse voxel directed acyclic graph, symmetry aware sparse voxel directed acyclic graph

1. Introduction

Information and Communication Technologies (ICT) produce enormous amounts of data daily. Some are discarded after they are created, transferred, and used, but a large portion is subsequently archived, extending the total amount of data currently included in ICT. The data transfer itself represents a significant burden for ICT, so we are looking for ways how to model, optimize and minimize it [1][2]. A large amount of data exists in multiple copies - in uncompressed or compressed forms. In practice, some types of data are even preferentially and almost exclusively stored and transmitted in a compressed version and often happens that they exist in their original form only for a short period of time - during their acquisition and initial processing. Examples are multimedia data such as images, audio sequences, and especially video sequences. A feature film in compressed form requires a storing capacity in GBs of the secondary storage device depending on the required quality and the encoder used. Its uncompressed version of 1920×1080 pixels (FullHD) at 24b/pixel and 25 frames per second with a recording time of 120 minutes requires up to 1TB of storage space on the secondary storage device. Storage of the uncompressed version and its distribution whether through storage media for the secondary storage devices or over computer networks would be impractical and costly for mass use.

Lossy data compression with a higher compression ratio is mostly used in multimedia. Lossless compression usually does not reach such high compression ratios but may be similarly successful in certain cases with domain-specific algorithms. An example could be the compression of a geometry of voxelized three-dimensional images. While in the uncompressed form its binary representation at the resolution of $64K^3$ voxels ($65536 \times 65536 \times 65536$) at 1b/voxel may have a volume up to 32TB. The compression using octant trees and the data structures derived from them allows lossless compression to compress the data down to hundreds of MB depending on the image content. Data structures useful for storing a compressed form of this geometry of voxelized image data include Sparse Voxel Octrees (SVO), Efficient Sparse Voxel Octrees (ESVO) [3], Sparse Voxel Directed Acyclic Graphs (SVDAG) [4] or Symmetry-aware Sparse Voxel Directed Acyclic Graphs (SSVDAG) [5]. Out-of-Core compression algorithm for creating the SVO data structure is described in detail in [6].

In both lossless and lossy algorithms, there are universal as well as domain-specific compression algorithms with different data compression success rates. Their existence is given not only by historical development but also by different temporal and spatial complexity which justifies the use of less efficient compression algorithms that provide lower memory requirements and processing power of the processor while keeping a lower but sufficient compression ratio. Often, such lightweight compression algorithms are implemented on devices that have a significantly limited amount of memory, lower processing power or there is a requirement of a high data throughput such as in data streaming.

Run-Length Encoding (RLE) is one of the simplest methods of lossless data compression that replaces sequences (runs) of the same elements by single element

code and the number of elements in the run (length of the symbol sequence). Element code and related encoded length of the run is called the RLE packet (RLEP).

The history of RLE employment dates back to 1967, when it has been used in television signal transmission [7]. Data that are about to be encoded can be a one-dimensional (1D) stream of data, or may be multidimensional as in the case of images that are a two-dimensional (2D) grids of pixels or a volumetric data that are a three-dimensional grids of voxels (3D).

RLE schemes used for image compression are divided into bit-level, byte-level, and pixel-level compression schemes depending on the type of an encoding atomic element.

Bit-level compression schemes encode runs of bits while ignoring byte or even word boundaries. Typically, one byte is needed for the RLE packet encoding where one of the bits is used to represent the respective bit of the symbol and the 7 other bits represent an unsigned integer representation of the number of these bits in the run. Their number can be in the range $< 0; 127 >$. The byte-level encoding schemes encode runs of identical bytes and most often they create double-byte RLE packets where one byte is the run length in the range $< 0; 255 >$ and is referred to as a *count value* and the second byte represents the value of the symbol itself and is referred to as a *run value*. Three-byte schemes use an extra byte referred to as a *flag value* which is a sign that two more bytes of the RLE packet would follow that encode the symbol and the run length. Thus, sequences of uncompressed data and RLE compressed data can be combined. Pixel level encoding schemes consider multi-byte information that is forming the code of the pixel as the one symbol, and run length is the number of those multi-byte symbols in the run. There is typically one byte used to represent this length value.

RLE variants are known, while encoding images, in which there are scanlines parallel to the x-axis or the y-axis. Zig-zag patterns or 2D tiles are also used. Linearization of data using Morton order [8] is often used in volumetric datasets. Repeat scanline packet or vertical replication packet is an encoding scheme in which the RLE packet contains information on how many times the scanline is consecutively repeated. This uses an image property when several scanlines placed in the image in the sequence do not differ from each other.

Also, there are lossy versions of RLE compression, when different approaches to information discarding, which makes it lossy, are used. For example, changing the overall value of a particular symbol in the stream to make the run homogenous and run-length bigger or changing the Least Significant Bits (LSB) of encoded symbols are used. This approach results in a compression ratio increase when applying RLE.

This paper aims to propose an Out-of-Core algorithm for lossless data compression, which, thanks to the proposed optimization of the bit-level RLE data encoding, along with an alternative application of the delta data transformation, would increase the compression ratio compared to the classical lossless RLE compression, while it still maintains low spatial and temporal complexity. Another goal is to reduce the potential negative effect when unwanted and sometimes significant inflation of data could occur in case of RLE compression of data that is not suitable for compression using this kind of compression algorithm.

Contribution of the paper is in:

- Design of the Out-of-Core lossless compression algorithm using optimized bit-level Run-Length Encoding along with an alternative application of the delta data transformation as well as the design of a binary data structure intended to store such compressed data.
- Optimization of the bit-level run-length encoding by modifying the structure and length of the bit-level RLE packet in which only the length of the run is encoded in its binary representation and the symbol itself is encoded by the RLE packet position in the stream of these RLE packets.
- Optimization of the RLE packet binary representation when it is composed of the variable number of encoding words whose binary representation has a variable length in number of bits.
- Encoding words length optimization separately for each original data block with simultaneous dissociation for encoding word lengths for 0 and 1 symbols.

The structure of the paper is as follows.

Section 2 deals with the related works in the field of lossless data compression using Run-Length Encoding (RLE) paying particular attention to lossless RLE compression schemes and especially the bit-level RLE compression. There are also areas, where the RLE compression has been applied to, mentioned. Because of the broad range of publications in the field, especially when the application of RLE in different fields is taken into account, the section is focused on the papers that are closely related to the work presented in this paper.

Section 3 of the paper presents a detailed description of the data structure proposed as part of this research for the storage of data after Δ RLE data compression. Four different types of data blocks are mentioned and described in detail.

Section 4 of the paper introduces the Δ RLE algorithm for lossless data compression.

Section 5 of the paper summarizes the results of testing within this paper designed Δ RLE lossless compression algorithm using real-life volumetric binarized medical images. Those were obtained by multiple medical imaging methods including Computed Tomography (CT) and Nuclear Magnetic Resonance (NMR), which have been thresholded in the preprocessing phase. The classical bit-level RLE algorithm is compared with different degrees of optimization of the bit-level RLE compression and finally with the full-featured bit-level Δ RLE compression algorithm proposed in this paper with the application of all four types of data blocks, including delta data transformation and optimized RLE data encoding.

Section 6 of the paper presents conclusions, that summarizes the success of the proposed algorithm in data compression. Conclusions were made by testing the algorithm on various volumetric datasets.

2. Related works

Algorithms for data encoding which are incorporating Run-Length Encoding are often part of the data gathering, processing, transmitting, and storing in different kinds of medical applications. In [9] Run-Length Encoding was used in the compression of

data for electrocardiography (ECG) and [10] incorporates compression of ECG data using not only RLE but also Discrete Wavelet Transform (DWT) compression algorithm. The compression of data obtained by Electroencephalography (EEG) combining Discrete Cosine Transform (DCT) and Run-Length Encoding was proposed in [11]. In [12] was performed analysis of hybrid lossy and lossless compression using RLE.

Run-Length Encoding was used for enhancement of user experience in the field of volume datasets reading from secondary storage when bit-level RLE compressed three-dimensional binary images were used as the metadata describing volume datasets [13]. In [14] evaluation of four different encoding schemas for optimization of bit-level Run-Length Encoding within lossless compression of binary images was performed.

Lossless data compression schemes for volume datasets compression, including RLE were considered in [15] and in [16] volume datasets compression using RLE was mentioned. RLE encoded sparse level sets were introduced in [17]. Volumetric datasets characterization using a set of Run-Length Encoding features has been described in [18].

Interesting sources of information regarding data compression in general, that mention also different versions of Run-Length Encoding lossless and lossy compression of text, images - including binary images - and other kinds of data are [19] [20] [21] [22]. Very interesting overview of the compression techniques including lossless compression and RLE represents [23].

3. Description of the proposed Δ RLE data structure

The next chapter of the paper deals with a detailed description of the binary data structure intended for storing the target data compressed using the Δ RLE compression algorithm.

3.1. Data structure

Data structure has its own Global Head (GH) described in section 3.1.1. The original data ready for compression is forming the stream of bits that is divided into blocks with a length of n bits. Since the number of bits of the original data does not necessarily be divisible by n , the last block may be shorter. A Data is thus divided into m original data blocks (ODB). Data block can be left uncompressed as original data block and in that case a Raw Data Block (RawDB) is created - in more detail described in section 3.1.2. A bit-level RLE compression can be applied to the data block creating an RLE Data Block (RleDB) - in more detail described in section 3.1.3. Alternatively, a delta transformation followed by a bit-level RLE compression can be applied, creating a Delta-transformed Data Block (DelDB) - in more detail described in section 3.1.4. If the current block of data is the same as the previous block of data, the Repeating Data Block (RepDB) is used - see section 3.1.5 for details. Information on which of the alternatives was used along with related parameters setup is stored in the header by which each of the m data blocks is extended as shown in Figure 1.

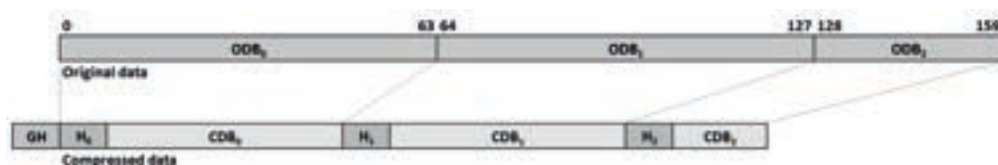


Figure 1. The original data consisting of 160b is divided into blocks with a length of 64b. Two blocks of a standard length 64b were created – named ODB_0 and ODB_1 . the last block named ODB_2 is shorter and has a length of 32b. Compressed data consists of three Compressed Data Blocks (CDB) labeled CDB_0 to CDB_2 each with its own header labeled H_0 to H_2 . There is a Global Head (GH) of the whole data structure in its introductory part.

3.1.1. Global Head

The Global Head (GH) consists of two encoding packets.

The first one is the GLocal Size Packet (GLSP) which carries the number of bits of the source data to be compressed. GLSP consists of one or more consecutive 32b encoding words (EW). The number of bits of source data can be calculated as the sum of the values that are encoded by the individual EWs in the GLSP packet. GLSP makes it possible to stop the decompression algorithm upon obtaining the last bit of the original data.

The second part of the GH is the Data Block Size Packet (DBSP) which consists of one or more consecutively stored 16b EWs. The DBSP carries information about the number of bits comprised in the Original Data Block (ODB). The value can be calculated as the sum of the values that each EW of the DBSP encodes. This information allows the algorithm to stop decompression of Compressed Data Block after the last bit of the corresponding Original Data Block was obtained.

EW meaning can be seen in Table 1. It is possible to find out if another EW will be concatenated using the value of EW as it is shown in Table 1. For GLSP $max = 2^{32} - 1$ and for DBSP $max = 2^{16} - 1$.

EW	Value	Another EW concatenation
$< 1; max - 1 >$	$< 1; max - 1 >$	NO
max	max	YES
0	max	NO

Table 1. Encoding Word values for GLocal Size Packet and Data Block Size Packet.

3.1.2. Raw Data Block

If it is not possible to achieve a sufficient reduction in the length of the binary representation of the original data block (ODB) consisting of n bits (it means the number of bits after compression of ODB is greater or equal to $n + 2$), by using an optimized bit-level RLE compression or by applying a delta transformation and subsequent optimized bit-level RLE compression, then this data block in the target data structure is represented in its original, uncompressed form. Such a block of data

is referred to as Raw Data Block (RawDB) in the target data structure. It consists of a RawDB Head (RawDBH) having a binary representation of '00' and occupying a constant length of 2b and an uncompressed binary representation of ODB consisting of n bits as shown in the Figure 2.



Figure 2. Original Data Block (ODB) with n bit length is transformed into Raw Data Block (RawDB) by creating a RawDBH header consisting of '00' and attaching original data of n bit ODB in unchanged form.

3.1.3. RLE Data Block

The original data can be compressed using in this paper proposed optimized bit-level Run Length Encoding. Rle Data Block (RleDB) has an Rle Data Block Header (RleDBH) followed by an RLE packet stream (RLEPs). Each of these RLE packets has a serial number in the stream (counting starts at 0) so it can be determined for each RLEP whether its serial number is even or odd as can be seen in Figure 3.



Figure 3. The Rle Data Block (RleDB) consists of the RleDBH header and the RLE packet stream (RLEPs). RLEPs are labeled by a serial number starting from 0. In this figure, there are x RLE packets referred to as $RLEP_0$ to $RLEP_{x-1}$.

3.1.3.1 Rle Data Block Header

The RleDBH header contains a two-bit string '01' identifying that a given block of data is compressed using the bit-level RLE. Then, there is a bit labeled as S indicating by its value, which symbol (0 or 1) run-lengths will encode RLEPs with an even sequence numbers. The odd RLEPs then encode the run-length of the inverted bit value (another symbol).

Follows 0 *Word Length* (0WL) represented by 4b. This parameter shows the number of bits used in the EWs in the RLEPs that encode lengths of runs of the symbol 0. The last parameter is 1 *Word Length* (1WL) represented by 4b and this parameter shows the number of bits used in the EWs in the RLEPs that encode lengths of runs of the symbol 1 as shown in Figure 4. Allowed values for 0WL and 1WL are from the range $< 2; 15 >$. The RleDBH header has a constant length of 11b.

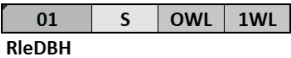


Figure 4. The RleDB Header (RleDBH) consists of an identifier represented by the string '01' followed by a bit indicating which symbols will encode even RLEPs followed by parameters *OWL* and *1WL* which on 4b represent the number of bits in the RLEPs encoding words.

3.1.3.2 RLE Packet

An RLE packet is composed of one EW or a sequence of several EWs. Bit length l of each EW is defined by the parameter *OWL* for the RLEPs for symbol 0 resp. *1WL* for the RLEPs for the symbols 1. The value of each EW can be determined according to Table 1 with the value $max = 2^l - 1$.

The length of the symbol run encoded in RLEP is given as the sum of the values of the individual EWs concatenated in the given RLEP as shown in Figure 5.



Figure 5. RLEP encodes the number of symbols in the run where each EW consists of 3 bits in this example and a) contains one EW set to 0 indicating that the run-length indicated by this EW₀ is 7 (refer Table 1) and that no other EW will be concatenated, b) the RLE Packet consists of two EWs, the first EW₀ is set to 7 and encodes a run-length of 7 while indicating that one more EW will follow. This EW₁ is set to 3 and therefore the run-length encoded by this EW is 3. At the same time, it indicates that no further EW will follow in a given RLEP. Overall, those two EWs indicate that 10 consecutive symbols will follow in a single run (7+3).

If too low *OWL* or *1WL* is selected, then it is necessary to use more concatenated EWs to represent a specific run length which increases the number of bits needed for encoding beyond their optimal number. If too large value of *OWL* or *1WL* is selected, then the EWs contain too many leading 0s which again causes the non-optimal number of bits to be used for encoding as shown in the example in Figure 6. Therefore, it is advisable to determine, based on the analysis of the particular data, the optimal length of EW which allows the use of a minimum number of bits concerning the selected encoding. Since for each RLEP it is possible to determine whether it encodes the run of symbols 0 or 1, it is possible to search for the optimal length separately for EWs encoding run-lengths of symbol 0 and separately for symbol 1. Since the data of the source file is divided into data blocks such an optimum can be found for each data block separately. This procedure of finding and using the optimal EW length for each data block, dissociated for EWs for symbols 0 and 1, is the basis of the bit-level RLE optimization proposed in this work.



Figure 6. Run-length encoding with the number of symbols 14 while selecting different lengths of EWs where a) the EW length set to 3 requires the concatenation of two EWs which means the use of overall 6b b) the use of an EW with a length of 4b allows optimal encoding and c) using an EW with the length of 5b means unnecessarily long bit sequence with one leading 0.

3.1.4. Delta-transformed Data Block

To achieve a higher compression ratio, it is possible to perform a delta transformation of the original data when differential information is generated between the original data of the Previous Data Block (PDB) and the currently compressed original data block, called Actual Data Block (ADB) by applying the XOR function to the respective pairs of bits.

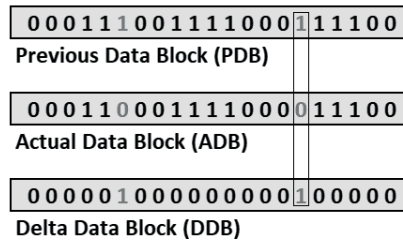


Figure 7. The Delta Data Block (DDB) is derived from the Previous Data Block (PDB) and the Actual Data Block (ADB) using the XOR function on the respective bit pairs. DDB can yield a higher compression ratio over the compression of the original ADB data.

If those two bits match, the result is symbol 0, if they do not match, the result is symbol 1. This creates a Delta Data Block (DDB) and in some cases this information can be better compressed using optimized bit-level RLE than the original ADB data as it shown in Figure 7.



Figure 8. The Delta-transformed Data Block (DelDB) consists of a DelDBH header and a stream of RLE packets that are identified by a serial number starting from 0. There are x RLE packets visible in the figure labeled as $RLEP_0$ to $RLEP_{x-1}$.

DDB is then compressed using an optimized bit-level RLE as described in section 3.1.3 and that is how Delta-transformed Data Block (DelDB) is created with the structure that can be seen in Figure 8.

DelDB header (DelDBH) contains a two-bit string '10', symbol S and 4-bit $0WL$ and $1WL$ with the same meaning as it was described in the subchapter 3.1.3.1. The

DelDBH header has a constant length of 11b as it can be seen in Figure 9 and is followed by a stream of RLEPs with a structure analogous to that described in section 3.1.3.2.

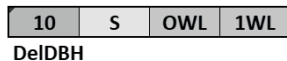


Figure 9. The Delta-transformed Data Block Header (DelDBH) consists of an identifier that is represented by a '10' string followed by a symbol S and 4-bit OWL and 1WL.

3.1.5. Repeating Data Block

If a particular data block (encoded with Raw Data Block, Rle Data Block, or Delta-transformed Data Block) is followed by several other data blocks, containing the same information, then it is possible to represent repeating blocks by Repeating Data Block (RepDB). This block is represented the RepDBH header whose two bits are constantly set to '11'. This identifier is followed by one or more 3-bit EWs that encode the number of consecutive data block repetitions. The value of each EW can be determined using Table I when $max = 7$.

If multiple EWs are concatenated, the number of repeating data blocks is determined as the sum of their repeating data block counts as shown in the example in Figure 10. Thus, for example if 6 same original data blocks are consecutive then the first one is represented as either a Raw Data Block, an RLE Data Block, or a Delta-transformed Data Block followed by a RepDB that indicates its 5 repetitions.

The total length of the $RepDB_{len}$ can be calculated by the formula:

$$RepDB_{len} = 2 + \left\lceil \frac{h}{7} \right\rceil \times 3[b] \quad (1)$$

where h is the number of repetitions:



Figure 10. RepDB Header (RepDBH) contains an identifier set to '11' and there are a) one EW that encodes 7 repetitions of the data block, and the EW indicates that no other EW will be concatenated b) two EWs where the first one encodes 7 repetitions of the data block and at the same time indicates the concatenation of the next EW which encodes 6 further repetitions while indicating that no further encoding word will be concatenated. This means a total of 13 repetitions of the previous data block.

4. ΔRLE compression algorithm

Compression algorithm assumes input that consists of:

- Stream of original data intended for compression,
- parameter m representing overall length of input stream in bits,
- parameter n representing length of Original Data Block (ODB) in bits.

Compression algorithm comprises following steps:

1. **PDB**($n - 1 : 0$) = **0**; **REPS** = **0**; // PDB – Previous Data Block
2. LOAD **ADB**($n - 1 : 0$); // ADB – Actual Data Block
3. IF (**ADB**($n - 1 : 0$) == **PDB**($n - 1 : 0$)) { **REPS**++; GOTO 2; }
4. IF (**REPS** > 0) {CREATE **RepDB**(**REPS**); STORE **RepDB**; **REPS** = 0;}
// RepDB – Repeating Data Block
5. **min** = $n + 2$;
6. [**minRleDB0**, **Rle0WL**] = findMin(**ADB**($n - 1 : 0$), **0**, **2**, **15**);
7. [**minRleDB1**, **Rle1WL**] = findMin(**ADB**($n - 1 : 0$), **1**, **2**, **15**);
8. **minRleDB** = **minRleDB0** + **minRleDB1**;
9. **DDB**($n - 1 : 0$) = **PDB**($n - 1 : 0$) XOR **ADB**($n - 1 : 0$); // DDB – Delta Data Block
10. [**minDelDB0**, **Del0WL**] = findMin(**DDB**($n - 1 : 0$), **0**, **2**, **15**);
11. [**minDelDB1**, **Del1WL**] = findMin(**DDB**($n - 1 : 0$), **1**, **2**, **15**);
12. **minDelDB** = **minDelDB0** + **minDelDB1**;
13. IF (**minRleDB** < **min** AND **minRleDB** ≤ **minDelDB**) {
CREATE **RleDB**(**ADB**($n - 1 : 0$), **Rle0WL**, **Rle1WL**); STORE **RleDB**; GOTO 16; }
// RleDB – RLE Data Block
14. IF (**minDelDB** < **min** AND **minDelDB** < **minRleDB**) {
CREATE **DelDB**(**DDB**($n - 1 : 0$), **Del0WL**, **Del1WL**); STORE **DelDB**; GOTO 16; }
// DelDB – Delta-transformed Data Block
15. CREATE **RawDB**; STORE **RawDB**; // RawDB – Raw Data Block
16. IF (**m** == 0) EXIT;
17. **PDB**($n - 1 : 0$) = **ADB**($n - 1 : 0$);
18. IF (**m** > **n**) { **m** = **m** - **n**; }
ELSE { **n** = **m**; **m** = **0**; }
19. GOTO 2;

Function $[a, b] = \text{findMin}(D(n - 1 : 0), S, L, H)$ is the function which:

- finds the minimal sum of bits of all RLE packets for symbol *S* and data block *D*($n - 1 : 0$) when all encoding word lengths from the range $\langle L; H \rangle$ are tested and returns that minimal length as the output *a*,
- finds the optimal EW length for symbol *S* for data block *D*($n - 1 : 0$) and returns it as the output *b*.

5. Tests and discussion

One of the objectives of the algorithm design was to reduce the risk of significant inflation of data after compression in an unfavorable case. This goal has been met. In situations, when none of the original data blocks can be effectively compressed, each of these blocks is represented by RawDB in the target data structure. Each original data block is in that case accompanied by a two-bit header. Assuming that the original data is divided into *m* blocks and for simplicity, each of these blocks has the same number of *n* bits (including the last data block) then the size of the binary representation after the Δ RLE compression is quantifiable as $SIZE_{max}$:

$$SIZE_{max} = 32 \times \left\lceil \frac{s}{2^{32} - 1} \right\rceil + 16 \times \left\lceil \frac{n}{2^{16} - 1} \right\rceil + m \times (n + 2)[b] \quad (2)$$

Where:

- s is the number of bits of the source data
- n is the number of bits in the original data block
- m is the number of original data blocks

$SIZE_{max}$ is at the same time the largest number of bits that can be generated as the target data structure from the respective source data.

Maximum inflation INF_{max} for individual original data blocks is then quantifiable as the ratio of the Raw Data Block size $(n + 2)$ to the corresponding size of Original Data Block (n) so it can be written as:

$$INF_{max} = \frac{n + 2}{n} \quad (3)$$

With increasing value n the INF_{max} is approaching 1 as it is shown in the following statement:

$$INF_{max} = \lim_{n \rightarrow \infty} \frac{n + 2}{n} = 1 \quad (4)$$

This implies that the larger the selected original data blocks are, the smaller the potential data inflation after compression is. If $n = 256$ then $INF_{max} = 1,00781$ while when $n = 1024$, the $INF_{max} = 1,00195$.

The most favorable (theoretical) case is when the compressed data is made up of the run of only one symbol 0. For compression then it can be advantageous that the Previous Data Block (PDB) buffer is at the start of compression homogeneously filled with the symbol 0. The first Original Data Block of the source data is also homogeneously filled with the symbol 0 and therefore the Repeating Data Block (RepDB) can be used immediately. If it is possible to split data into m data blocks of n bits, then this RepDB will include all original data blocks of the source data.

To minimize the total number of bits used in the target data structure $SIZE_{min}$, it is important that the value of m is as low as possible, which means the number of the original data blocks is as low as possible. This is achieved by maximizing the value of n which is the number of bits in the original data block. Then $SIZE_{min}$ can be calculated as

$$SIZE_{min} = 32 \times \left\lceil \frac{s}{2^{32} - 1} \right\rceil + 16 \times \left\lceil \frac{n}{2^{16} - 1} \right\rceil + 2 + 3 \times \left\lceil \frac{m}{7} \right\rceil [b] \quad (5)$$

where

- s is the number of bits of the source data
- n is the number of bits in the original data block

m is the number of original data blocks

Thus, the lowest number of bits after data compression can be 53, if $m \leq 7$, $n \leq 65\,535$ and $s \leq 458\,745$.

5.1. Datasets

In the tests of the proposed Δ RLE compression algorithm, there were used volumetric datasets consisting of regular three-dimensional grids of scalar values. In the range of $< 0; 255 >$ values were saved to 8b and in the range of $< 0; 4095 >$ to 16b. Datasets had been obtained through medical imaging techniques such as Computed Tomography (CT) or Magnetic Resonance Imaging (MRI). Above these volumetric data a thresholding was performed whose output was the regular three-dimensional grid of scalar values with 1b/vox. The data was then linearized and the stream of bits obtained was subjected to compression via the classical RLE algorithm, RLE algorithm with properties that are part of the proposed Δ RLE algorithm, and finally a full-featured proposed Δ RLE algorithm. Parameters of examples of individual volumetric datasets used in the tests are summarized in Table 2 and visualizations of two-dimensional sections of these volumetric datasets can be seen in Figure 10.

	Volume dataset	Volume dimensions	Voxels [Millions]	b/vox	Size [MB]	Threshold
a	Head	$256 \times 256 \times 113$	7.40	16	14.13	200
b	Brain	$256 \times 256 \times 109$	7.14	16	13.63	1150
c	Visual Cortex	$1024 \times 1024 \times 314$	329.25	8	314.00	25
d	Abdomen	$512 \times 512 \times 174$	45.61	16	87.00	200
e	Human Skull	$256 \times 256 \times 256$	16.78	8	16.00	25
f	Pancreas	$240 \times 512 \times 512$	62.91	16	120.00	225

Table 2. Characteristics of medical imaging volume datasets that were binarized by using thresholding and used for the test purpose.

5.2. Test Results

In the first of the tests, a classical RLE algorithm was applied to the bit stream of the original uncompressed data which uses the 8b RLE packet for encoding in which one bit is used to encode the respective symbol and the other 7 bits are used to encode run-length. In Table 3 this encoding is referred to as RLE-I.

In the second test, the RLE packet described in section 3.1.3.2 was used. The encoding word length of this packet was constantly set to 8b. In Table 3, this encoding is referred to as RLE-II. As shown in the test results the change in the RLE packet encoding resulted in an increase in the compression ratio of 1.058 to 1.819 times in comparison to the RLE-I encoding.

In the third test, the RLE packet described in section 3.1.3.2 was used with the length of the binary representation of the encoding word of this packet being optimized ranging between $< 2; 15 >$ bits. In Table 3 this encoding is

referred to as RLE-III. For each dataset, there is also given the optimal EW length.

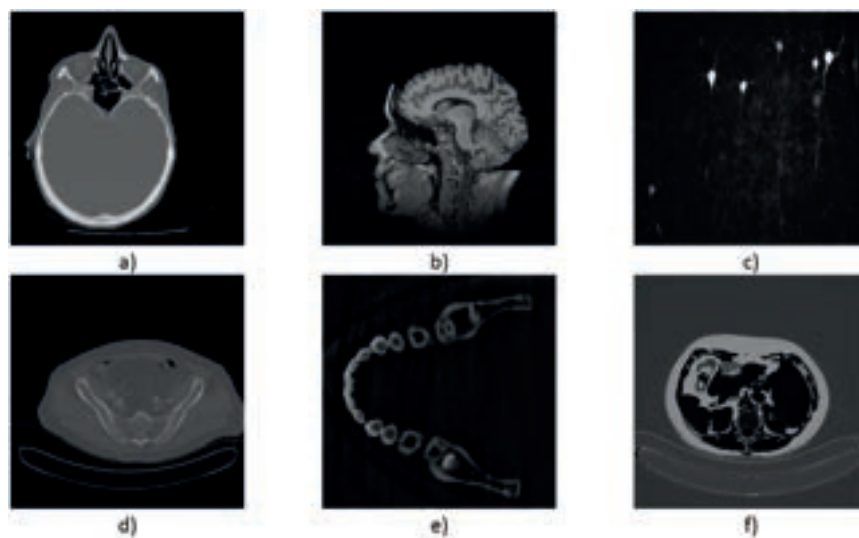


Figure 10. Slices of volume datasets obtained by different medical imaging methods that were used in tests of designed Δ RLE lossless compression algorithm.

As shown in Figure 11 for the dataset a - Head, the optimal length of the encoding packet was set to 7b which allowed a further increase in the compression ratio compared to RLE-I 1.143 times and compared to RLE-II 1.040 times. For all the datasets mentioned in this paper this change in encoding to RLE-III produced from 1.143 to 4.290 times higher compression ratio over RLE-I. Encoding word lengths from 6b to 12b have been shown to be optimal for the individual datasets.

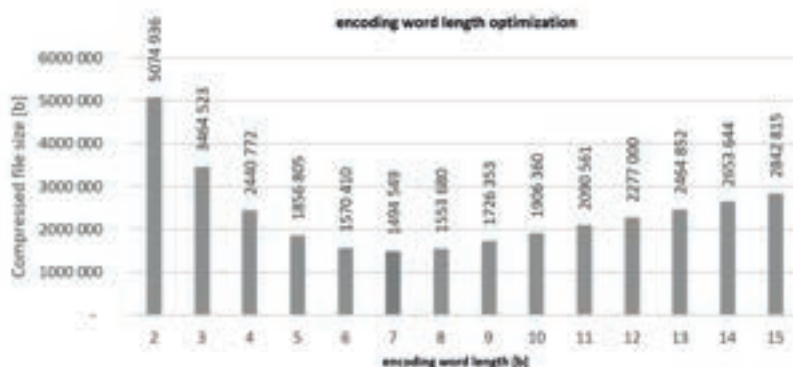


Figure 11. Optimization of encoding word length which is performed by the function findMin in compression algorithm (see chap. 4) allows to choose optimal encoding word length from the range of $\langle 2; 15 \rangle$. For a particular dataset the optimal encoding word length is 7, when data after compression represent the smallest file size (1 494 549 b).

The fourth test criteria were pretty much the same as in the previous test, the only change was made that for the symbol 0 and 1 the EW length of RLE packets were dissociated. In Table 3 this encoding is referred to as RLE-IV. As shown by the results of the tests, this change in encoding made a 1.150 to 7.030 times increase in compression ratio over RLE-I encoding. The EW lengths for the symbol 0 were from the range of $< 2; 8 > b$ for different datasets and for the symbol 1 was in the range of $< 3; 13 > b$. The largest difference in the EW lengths was shown in the dataset f - pancreas where for the symbol 0 the EW length was $2b$ and for the symbol 1 it was $13b$. How the change in the EW length in the range of $< 2; 15 > b$ separately for the symbols 0 and 1 in case of the dataset a – Head influenced the length of compressed data is shown in Figure 12. For this dataset, the optimum EW length for the symbol 0 was set to $7b$ and for the symbol 1 to $6b$.

The last of the tests applied all the properties of the algorithm proposed in this work when the data was divided into blocks with a length equal to the number of voxels on the edge of the respective dataset parallel to the x-axis. At the same time, encoding word length optimization was applied separately for the symbols 0 and 1 and all four types of data blocks were used i.e. RawDB, RleDB, DelDB, and RepDB. This encoding is referred to as Δ RLE in the results table. Compared to the original data (thresholded), a compression ratio of 3.972 to 48.911 was achieved and compared to the classical algorithm (RLE-I), compression rates of 1.24 to 3.44 times higher were achieved. The comparison of the compression ratio of classical RLE algorithm (referred to as RLE-I) and Δ RLE algorithm, proposed in this work, can be seen in Figure 13.

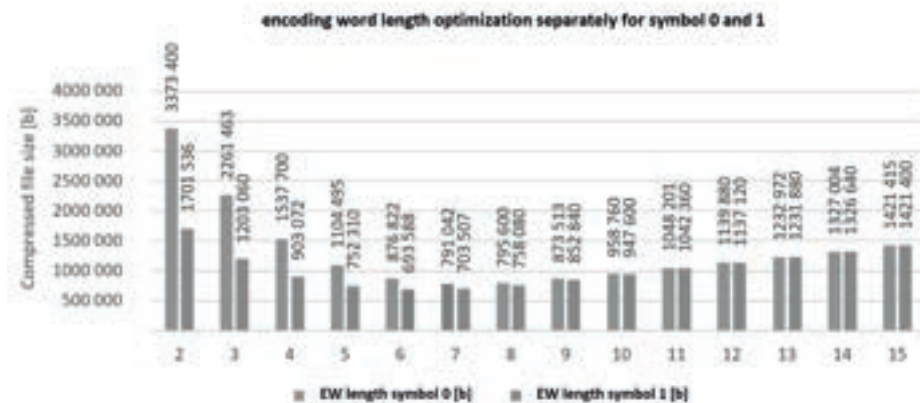


Figure 12. Optimization of EW length dissociated for symbol 0 and 1 allows to choose the optimal length of EW from the range of $< 2; 15 > b$, for symbol 0 and for symbol 1, separately. As it can be seen from the graph, for particular dataset the optimal length of EW for symbol 0 is $7b$ and for symbol 1 is $6b$. In that case the data after compression represent the smallest file size ($693\,588\,b + 791\,042\,b = 1\,484\,630\,b$).

	Dataset					
	a	b	c	d	e	f
Original data	7 405 568	7 143 424	329 252 864	45 613 056	16 777 216	62 914 560
RLE-I	1 708 056	2 074 792	113 812 768	6 200 848	5 393 216	4 418 528
	4.336 ^{*1}	3.443	2.893	7.356	3.111	14.239
	23.06 ^{*2}	29.04	34.57	13.59	32.15	7.02
RLE-II	1 553 680	1 913 272	107 207 224	4 906 792	5 096 336	2 429 064
	4,766	3,734	3,071	9,296	3,292	25,901
	20.98	26.78	32.56	10.76	30.38	3.86
RLE-III	1 494 549	1 815 443	96 845 382	4 906 792	4 628 934	1 030 032
	4.955	3.935	3.400	9.296	3.624	61.080
	20.18	25.41	29.41	10.76	27.59	1.64
WL [b]	7	7	6	8	6	12
RLE-IV	1 484 630	1 749 466	78 515 216	4 902 737	3 892 132	628 533
	4.988	4.083	4.193	9.304	4.311	100.097
	20.05	24.49	23.85	10.75	23.20	1.00
OWL / 1WL [b]	7 / 6	7 / 5	7 / 3	8 / 9	7 / 3	2 / 13
ΔRLE	1 376 192	1 563 792	68 217 184	4 452 256	4 223 248	1 286 312
	5.381	4.568	4.827	10.232	3.972	48.911
	18.58	21.89	20.72	9.76	25.17	2.04

Table 3. Size of original data and size of data after compression for individual compression algorithms and their settings for particular datasets. Compression ratios (^{*}1) and the percentage of data size after compression as compared to the original data (^{*}2) are shown, too.

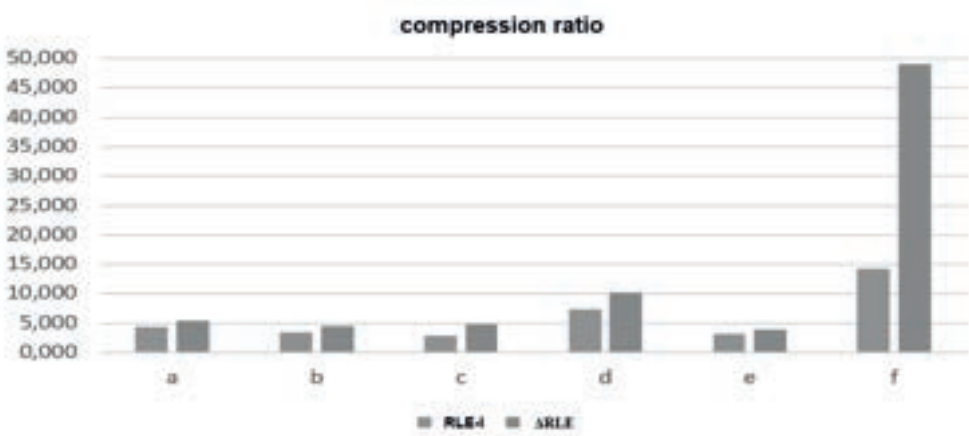


Figure 13. Compression ratio of classical RLE algorithm (referred to as RLE-I) and ΔRLE algorithm for individual datasets.

Table 4 and Figure 14 show the number of individual data block types and their percentage for each dataset. It was not necessary to use RawDB for compression.

	Dataset					
	a	b	c	d	e	f
RawDB	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%
RleDB	11 428 39.50%	13 221 47.38%	187 766 58.40%	48 024 53.91%	38 581 58.61%	41 775 15.93%
DelDB	11 897 41.13%	7 646 27.40%	41 912 13.03%	13 461 15.11%	24 540 37.70%	124 0.05%
RepDB	5603 19.37%	7037 25.22%	91 858 28.57%	27 603 30.98%	2 415 3.69%	220245 84.02%

Table 4. The number of individual types of data blocks in the target data structure along with their percentage representation.

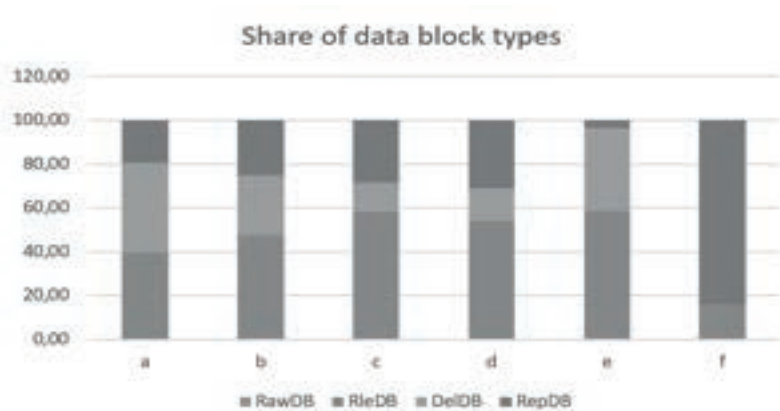


Figure 14. Graphical representation of data block types in Δ RLE compressed data for individual datasets.

Compression		Dataset					
		a	b	c	d	e	f
RLE	Time [s]	0.017	0.016	0.740	0.099	0.038	0.134
	Data throughput [MB]	52.73	52.89	53.02	55.00	52.80	55.81
Δ RLE	Time [s]	0.051	0.051	2.071	0.185	0.133	0.058
	Data throughput [MB]	17.25	16.68	18.95	29.38	15.08	129.46
Ratio		3.06	3.17	2.80	1.87	3.50	0.43

Table 5. Compression time and data throughput for RLE and Δ RLE algorithms for various volume datasets. Data throughput is calculated in relation to uncompressed data amount.

(*1) Ratio represents time of DRLE compression / time of RLE compression.

Execution time measurement was performed using program implementation in C language, applying the same programming approaches where it was applicable, in

compression and decompression programs for RLE and ΔRLE. Tests were performed on the computer with Intel(R) Core(TM) i5-3470 CPU @ 3.20GHz, 8GB RAM, Debian Linux version 4.19.0-6, gcc version 8.3.0. To eliminate influence of the data transfer from secondary storage, that can be of different technology and data transfer speed, the time measurement started when all input data were stored in operating memory and stopped when output data were also stored in the operating memory. Due the binary representation of the ΔRLE compressed data, that is not byte aligned, and time consuming analysis of optimal encoding word lengths, compression time of ΔRLE was 3.50 times longer in comparison to RLE in the worst case. However, effective work with repeating data blocks, especially when there is higher number of those blocks consecutively in ΔRLE, allowed ΔRLE compression to use 0.43 of the time in comparison to RLE in most optimistic case, as it is shown in the Table 5. Same reasons allowed slower decompression time of ΔRLE ranging from 2.66 times in the worst case to 1.73 times in the best case, in comparison to RLE, as it is shown in the Table 6.

Decompression		Dataset					
		a	b	c	d	e	f
RLE	Time [s]	0.007	0.007	0.321	0.037	0.017	0.045
	Data throughput [MB]	124.66	124.04	122.34	146.96	114.67	167.41
ΔRLE	Time [s]	0.018	0.018	0.772	0.084	0.046	0.077
	Data throughput [MB]	49.45	47.22	50.83	64.65	43.17	96.87
Ratio* ¹		2.52	2.63	2.41	2.27	2.66	1.73

Table 6. Decompression time and data throughput for RLE and ΔRLE algorithms for various volume datasets. Data throughput is calculated in relation to uncompressed data amount.

(^{*1}) Ratio represents time of DRLE decompression / time of RLE decompression.

Memory consumption for variables storing includes the use of 64b variable for storing the information on the size of uncompressed data, for both RLE and ΔRLE and another 32b for storing of the data block size in case of ΔRLE. Overall size of the space for storing variables is 12B for both RLE compressor and decompressor and 57B for ΔRLE compressor and 33B for ΔRLE decompressor. ΔRLE compressor and decompressor include also $2 \times n$ bits space for the storage of two data blocks of n -bits size and 32B Look-Up-Table. ΔRLE also uses another 64B data structure for encoding words length optimization.

6. Conclusions

The paper deals with the problematics of data compression and specifically lossless data compression as part of the research of the domain-specific data structures dedicated to volume data representation.

There is an introduction of the Run-Length Encoding compression principle and several modifications of RLE, including bit-level RLE, byte-level RLE, and pixel-

level RLE with scan-line option were mentioned in the first part of the paper. Related works in the field of RLE compression principle and their use in different application areas including medical applications are mentioned in the related works part of the paper.

In the second part of the paper enhanced bit-level Δ RLE algorithm is introduced, which optimizes the RLE packet and brings multi encoding word RLE packets with various number of encoding words and with optimized and variable encoding word lengths. Dissociation of RLEPs for symbol 0 and symbol 1 are part of this modification as well. Δ RLE algorithm includes the possibility to use four different data blocks - raw data block, RLE encoded data block, delta transformed RLE encoded data block, which combines processing of the data block into the form of differential information, which is then encoded similarly as the RLE encoded data block, and last of them is repeating data block, which indicates that the data block is identical with the previous data block. This allows not only to optimize RLE encoding but also to choose the best possibility of how to encode each data block. This results in a better compression ratio.

In the last part of the paper there are results of tests described, in which volumetric datasets that were obtained by medical imaging methods and then thresholded were compressed, using the classical RLE method, alternatively using to the different levels optimized RLE methods and finally using Δ RLE algorithm introduced in this paper. The results show that in all volume dataset cases there was a possibility to compress data with the compression ratio higher than 1. In comparison to the classical RLE compression algorithm, the compression ratio was higher in all cases, when 1.24 to 3.43 times higher compression ratio in comparison to the classical RLE was obtained.

There is a possibility to get potentially even higher compression ratio optimizing the length of data blocks according to a particular dataset when each data block has the same size (except last data block) or optimizing the length of each data block separately. This optimization was not included in this research and proposed data structure and algorithm of its construction.

Acknowledgments

This work was supported by KEGA Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic under Grant No. 003TUKE-4/2017 Implementation of Modern Methods and Education Forms in the Area of Security of Information and Communication Technologies towards Requirements of Labor Market and under Grant No. 077TUKE-4/2015 Promoting the interconnection of Computer and Software Engineering using the KPIkit.

References

- [1] A. Pekár, M. Chovanec, L. Vokorokos, E. Chovancová, P. Fecilák and M. Michalko, "Adaptive Aggregation of Flow Records", *Computing and Informatics*, vol. 37, no. 1, pp. 142-164, Jan. 2018.

- [2] W. Steingartner, V. Novitzká and W. Schreiner, “Coalgebraic Operational Semantics for an Imperative Language“, *Computing and Informatics*, vol. 38, no. 5, pp. 1181–1209, Sep. 2019.
- [3] S. Laine and T. Karras, “Efficient sparse voxel octrees”, In *Proc. of ACM SIGGRAPH 2010 Symposium on Interactive 3D Graphics and Games*, 2010, pp. 55-63.
- [4] V. Kämpe, E. Sintorn and U. Assarsson, “High Resolution Sparse Voxel DAGs”, *ACM Transactions on Graphics*, vol. 32, no. 4, pp. 8, July 2013.
- [5] A. J. Villanueva, F. Marton and E. Gobbetti, “SSVDAGs: Symmetry-aware Sparse Voxel DAGs”, In *Proc. of the 20th ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games (I3D '16)*, 2016, pp. 7-14.
- [6] J. Baert, A. Lagae and P. Dutré, “Out-of-core Construction of Sparse Voxel Octrees”, In *Proc. of the 5th High-Performance Graphics Conference*, 2013, pp. 27-32.
- [7] A. H. Robinson and C. Cherry, “Results of a prototype television bandwidth compression scheme”, In *Proc. of the IEEE, Institute of Electrical and Electronics Engineers (IEEE)*, 1967, pp. 356–364.
- [8] G. M. Morton, “A Computer Oriented Geodetic Data Base and a New Technique in File Sequencing”, *Research Report*. International Business Machines Corporation (IBM), Ottawa, Canada, pp. 20, March 1966.
- [9] S. Akhter and M.A. Haque, “ECG compression using run length encoding”, In *18th European Signal Processing Conference*, 2010, pp. 1645-1649
- [10] S. A. Chouakri, M.M. Benaiad and A. Taleb-Ahmed, “Run length encoding and wavelet transform based ECG compression algorithm for transmission via IEEE802.11b WLAN channel”, In *Proc. of the 4th International Symposium on Applied Sciences in Biomedical and Communication Technologies (ISABEL '11)*, 2011, pp. 1-4.
- [11] M. Alsenwi, M. Saeed, T. Ismail, H. Mostafa and S. Gabran, “Hybrid compression technique with data segmentation for electroencephalography data”, In *2017 29th International Conference on Microelectronics (ICM)*, 2017, pp. 1-4.
- [12] M. Alsenwi, T. Ismail and H. Mostafa, “Performance analysis of Hybrid Lossy/Lossless Compression Techniques for EEG data”, In *2016 28th International Conference on Microelectronics*, 2016, pp. 1-4.
- [13] B. Madoš, A. Baláž, N. Ádám, J. Hurtuk and Z. Bilanová, “Algorithm Design for User Experience Enhancement of Volume Dataset Reading from Storage Using 3D Binary Image as the Metadata”, In *SAMI 2019 -*

- IEEE 17th World Symposium on Applied Machine Intelligence and Informatics, 2019, pp. 269-274.
- [14] B. Madoš and N. Ádám, “Evaluation of Different Encoding Schemas for Optimization of Run-Length Encoding within Lossless Compression of Binary Images”, In 23rd International Conference on Intelligent Engineering Systems (INES), 2019, pp. 75-80.
- [15] P. Komma, J. Fischer and F. Duffner, “Lossless Volume Data Compression Schemes”, In SimVIS Simulation und Visualisierung 2007, 2007, pp. 169-182.
- [16] B. Curless and M. Levoy, “A volumetric method for building complex models from range images”, In Proc. of the 23rd annual conference on Computer graphics and interactive techniques (SIGGRAPH '96), 1996, pp. 303-312.
- [17] B. Houston, M. Wiebe and Ch. Batty, “RLE sparse level sets”, In ACM SIGGRAPH 2004 Sketches (SIGGRAPH '04), Ronen Barzel (Ed.). ACM, New York, NY, USA, 2004, pp. 137.
- [18] D. Xu, S.A. Kurani, J.D. Furst and D.S. Raicu, “Run-length encoding for volumetric texture”, In The 4th IASTED International Conference on Visualization, Imaging, and Image Processing, 2004, pp. 452-458.
- [19] G. Held, *Data Compression: Techniques and Applications, Hardware and Software Considerations*, second edition, John Wiley & Sons, NY, 1987.
- [20] D. Salomon, *Data compression, The Complete Reference*, fourth edition, Springer Science + Business Media, LLC, 2007.
- [21] T. D. Lynch, *Data Compression Techniques and Applications*, first edition, Lifetime Learning Publications, Belmont, CA, USA, 1985.
- [22] J. A. Storer, *Data Compression: Methods and Theory*, Computer Science Press, Rockville, MD, USA, 1988.
- [23] K. Sayood, *Introduction to data compression – fourth edition*, Morgan Kaufmann, Elsevier, 2012.

Publication Ethics; List of Reviewers; Instructions for Authors

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1.1.1. Publication Decisions

The editor is responsible for deciding which manuscripts submitted to JIOS will be accepted for publication. This decision is based on the reviewers' recommendation. The main selection criteria are the contribution's importance, originality and clarity, as well as the study's validity and its relevance. The decision will not be influenced by the authors' race, gender, sexual orientation, religious belief, ethnic origin, citizenship, or political philosophy. The editor may confer with reviewers while making this decision.

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Unpublished materials disclosed in a submitted manuscript will not be used in the editor's own research without the express written consent of the author.

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3. Instructions for Formatting JIOS Articles

Alen Lovrenčić

alen.lovrencic@foi.hr

*Faculty of Organization and Informatics
University of Zagreb, Varaždin, Croatia*

Goran Hajdin

goran.hajdin@foi.hr

*Faculty of Organization and Informatics
University of Zagreb, Varaždin, Croatia*

First Name Middle Name Last Name

email.address@domain

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Keywords: formatting instructions, Microsoft word template, JIOS

3. Introduction

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before publishing date will be included in current volume. All papers that enter copyediting process less than one month from the publishing date will be included in the next volume.

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References to sections (as well as figures, tables, theorems and so on), should be capitalized, as in "In Section 4, we show that...".

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Appendices, if included, follow the acknowledgments. Each appendix should be lettered, e.g., "Appendix A".

References

- [1] IEEEDataPort, "How to Cite References: IEEE Documentation Style" [Online]. Available: http://jios.foi.hr/guidelines/IEEE_Documentation_Style.pdf [Accessed: Jun. 5, 2018].
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Contact

Alen Lovrenčić
Faculty of Organization and Informatics, University of
Zagreb
Pavlinska 2, HR-42000 Varaždin, Croatia
Tel.: +385 42 390 866
Fax: +385 42 213 413
E-mail: alen.lovrencic@foi.unizg.hr
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