

foi

UNIVERSITY OF ZAGREB
FACULTY OF
ORGANIZATION
AND INFORMATICS
VARAŽDIN

UDC 004:005:3

DOI: <https://doi.org/10.31341/jios>



ISSN 1846-3312

e-ISSN 1846-9418

Journal of Information and Organizational Sciences

JIOS

VOL. 47, NO. 2, PP. 255-498, DECEMBER 2023

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

Publisher

University of Zagreb, Faculty of
Organization and Informatics, Varaždin, Croatia

Editor

Alen Lovrenčić, University of Zagreb, Faculty of
Organization and Informatics, Varaždin, Croatia

Editorial Secretary

Goran Hajdin, University of Zagreb, Faculty of
Organization and Informatics, Varaždin, Croatia

Editorial Board

Igor Balaban, University of Zagreb, Faculty of
Organization and Informatics, Varaždin, Croatia
Nina Begičević Redep, University of Zagreb, Faculty
of Organization and Informatics, Varaždin, Croatia
Michael Bosnjak, University of Trier, Germany
Leo Budin, University of Zagreb, Faculty of Electrical
Engineering and Computing, Croatia
Blaženka Divjak, University of Zagreb, Faculty of
Organization and Informatics, Varaždin, Croatia
María José Escalona, University of Seville, Spain
Joaquim Filipe, Polytechnic Institute of Setúbal,
School of Technology of Setúbal, Portugal
Mirta Galesic, Santa Fe Institute, United States
Matjaž Gams, Jozef Stefan Institute, Department
of Intelligent Systems, Slovenia
Veljko Jeremić, University of Belgrade, Faculty of
Organizational Sciences
Mike Joy, University of Warwick, United Kingdom
Dragutin Kermek, University of Zagreb, Faculty of
Organization and Informatics, Varaždin, Croatia
Božidar Kliček, University of Zagreb, Faculty of
Organization and Informatics, Varaždin, Croatia
Douwe Korff, London Metropolitan University,
United Kingdom
Michael Lang, National University of Ireland -
Galway, Ireland
Pavle Mogin, Victoria University of Wellington, School
of Mathematics, Statistics, and Computer Science,
New Zealand

Editor-in-Chief

Marina Klačmer Čalopa, University of Zagreb, Faculty
of Organization and Informatics, Varaždin, Croatia

Advisory Board

Goran Bubaš, University of Zagreb, Croatia
Marina Klačmer Čalopa, University of Zagreb, Croatia
Ivan Magdalenić, University of Zagreb, Croatia
Neven Vrček, University of Zagreb, Croatia

Dirk Neumann, University of Freiburg, Germany
Dijana Oreški, University of Zagreb, Faculty of
Organization and Informatics, Varaždin, Croatia
Ján Paralič, Technical University Kosice, Slovakia
Algirdas Pakstas, London Metropolitan University,
United Kingdom
Rimantas Petrauskas, Mykolas Romeris University,
Lithuania
Roman Povalej, Institute AIFB, University of Karlsruhe
(TH), Germany
Wolf Rauch, University of Vienna, Austria
Slobodan Ribarić, Faculty of Electrical Engineering,
Croatia
Markus Schatten, University of Zagreb, Faculty of
Organization and Informatics, Varaždin, Croatia
William Steingartner, Technical University of Kosice,
Slovakia
Diana Šimić, University of Zagreb, Faculty of
Organization and Informatics, Varaždin, Croatia
Vjerran Strahonja, University of Zagreb, Faculty of
Organization and Informatics, Varaždin, Croatia
József K. Tar, Institute of Intelligent Engineering
Systems, John von Neumann Faculty of Informatics,
Budapest Tech, Hungary
Polona Tominc, University of Maribor, Faculty of
Economics and Business, Slovenia

Publishing Board

Ladislav Cvetko, Darko Grabar, Mladen Konecki,
Bernarda Kos

CONTENTS

<i>From the Editor</i>	III
Lambodara Parabhoi, Rebecca Susan Dewey, Prem Chand, Ajit Kumar Kainchi, Manoj Kumar Verma: Bibliometric Mapping of Gender Disparity in Research Publications in India during 1999-2018: A Case Study of Shimla District, Himachal Pradesh Original Scientific Paper	255-269
Xhelil Bekteshi, Sevdie Alshiqi: Marketing Strategy as Driving Force of Export Performance Small and Medium Enterprises - Case of Kosova Original Scientific Paper	271-281
Maria Ali Yari, Mahmoud Modiri, Kaveh Khalili Damghani, Kiamars Fathi Hafshjani: Measuring Customer Satisfaction Using Multi-Criteria Analysis Model of Customer Satisfaction to Evaluate Product Lines (Case Study: Kaveh Glass Industrial Group) Original Scientific Paper	283-304
Tamara Šmaguc, Ksenija Vuković: Forms and conversions of the economic capital of Croatian entrepreneurs in the computer programming industry with insights into variations of the company's development stages Original Scientific Paper	305-331
Mohammed Abbas Fadhil Al-Husainy, Hamza A. A. Al-Sewadi, Ahmed M. Sayed: Using the 3D Protein Structure as Key to Encrypt Images Original Scientific Paper	333-354
Norzaidi Mohd Daud: The Impact of Transformation in Higher Education: Introductory of New Technology, Is It Good or Bad? Original Scientific Paper	355-372
Riad Sahara, Syahid Abdullah, Muhammad Ikhwan Saputra: Integration Model of Academic Information Systems and Learning Management Systems with REST Web Services Using External Databases Preliminary Communication	373-384
Tomáš Červinka: Digital transformation of strategic management of SMEs in the Czech Republic Original Scientific Paper	385-398
Virtika Singhal, Anurupa B. Singh, Vandana Ahuja, Rajat Gera: Consumer Segmentation in the Fashion Industry Using Social Media: An Empirical Analysis Original Scientific Paper	399-419
Amine El Hadi, Youness Madani, Rachid El Ayachi, Mohamed Erritali: Optimization of the results of a multilingual search engine using a fuzzy recommendation approach Original Scientific Paper	421-441
Nimas Aryany Pratiwi, Siti Fatimah, April Kukuh Susilo: The Impact of Organizational Support and Employee Attitude to Innovative Work Behavior Mediating Role of Psychologic Empowerment Original Scientific Paper	443-470
Mawloud Mosbah: Towards a Combination of Metrics for Machine Translation Original Scientific Paper	471-488
Publication Ethics; List of Reviewers; Instructions for Authors	489-498

From the Editor

Dear readers,

Again, in this issue we are bringing thirteen scientific papers from the wide field of information and communication sciences – three preliminary communications, two survey papers, and eight original scientific papers, authors of which are from Europe, Africa, and Asia.

The papers are on a wide range of topics in information, organizational, and computer sciences, so I expect the issue to be interesting for a wide range of readers.

Alen Lovrenčić

Editor

Bibliometric Mapping of Gender Disparity in Research Publications in India during 1999-2018: A Case Study of Shimla District, Himachal Pradesh

Lambodara Parabhoi

Professional Assistant

Indian Institute of Advanced Study, Shimla

suresh19871987@gmail.com

Rebecca Susan Dewey

Sir Peter Mansfield Imaging Centre,

The University of Nottingham

Rebecca.Dewey@nottingham.ac.uk

Prem Chand

Librarian

Indian Institute of Advanced Study, Shimla

chandprem@gmail.com

Ajit Kumar Kainchi

Indian Institute of Management, Ahmedabad

ajit3131kumar@gmail.com

Manoj Kumar Verma

Department of Library & Information Science

and Coordinator, Career Counselling and Placement Cell,

Mizoram University, Aizawl-796004

manojdilis@mzu.edu.in

Abstract

Gender disparity and gender imbalance are globally pervasive in academia. Research into gender disparity characterizing gender differences uses metrics such as publication rates, author contributions, citation rates and research impact. Previous studies are contradictory in their findings and are limited in scope. As such, the current study examines the research contribution of both men and women in Shimla, Himachal Pradesh, India. A Scopus search was used to identify all articles published over a 20-year period (1999-2018). For each article in the final sample of 2,881 publications, the gender the first author was identified. Both the number and the growth rate of publications by women were lower than those by men. Conversely, the growth in citation rate was higher for women in 2009 and 2016. Gender disparity was found to be highest at the Indian Institute of Wheat and Barley Research and less severe at the HP Govt. Dental College.

Keywords: Gender Disparity, Bibliometric Study, Research Publishing in Shimla, Research Productivity

1. Introduction

Gender disparity or gender imbalance is a pervasive problem in education. It has been seen all over the world. Over the past century, there has been a dramatic increase in research into gender disparity [1], and the main finding was that males dominate in the majority of sectors. Males are reportedly more career-driven than females [1]. However, some researchers reported the inverse; that woman dominated over men. Gender inequality also found in India [2], with reports at the level of student admissions, graduates and qualifications. Traditionally, men have dominated in Higher Education; for example, the renowned Oxford University did not start awarding degrees to women until 1920 [3]. Similarly, Jagiellonian University did not accept females until 1894 [4]. Similarly, women working in science have been reported to be under greater pressure than men [5]. Despite this, women often dominate in fields such as the health sciences [6], and females out-perform males in the lower educational levels [7]. Women make up 60% of graduates in Europe, however the percentage is lower at the level of PhD, where women make up 47% of graduates [8]. Similar gender disparity can also be seen in India [2], with males being over-represented in many sectors. In India, females face problems in education, in society, and feel that they are under great pressure [9]. The literacy rate of women in India is 64.6% (Census of India 2011), compared to a rate of 73% across India as a whole [10]. The highest literacy rates are found in Kerala. The state of Himachal Pradesh was ranked 11th in India with respect to the literacy rate and was placed in 19th position in terms of their gender parity (achieving a score of 0.609658 on a scale from 0 to 1) out of 20 states in India. Himachal Pradesh was reported as one of the three states exhibiting the highest gender disparity in India [11]. Hence, the Government of India has made moves to support women's education by reducing tuition fees and reserving jobs, among other measures [2], [11]–[13].

India is the 5th largest contributor to research worldwide according to the Scopus report [14]. India is a developing country with an educational system that is stratified by gender, caste, class, region, and religion [12]. It has 28 states, of which Himachal Pradesh is one. Himachal Pradesh is a hilly state containing 12 districts [15], including Shimla, the state capital, also known as “queen of hills”. During the British rule, Shimla was referred to as the Summer Capital. There are many educational institutions established in Shimla. There have been a large number of qualitative and quantitative “Scientometric” studies showing evidence of gender disparity and male domination in journals, publishing, education, and literacy. However, there is a lack of such evidence in Shimla, with respect to the association between research publishing and gender. The current study examines gender disparity in research publishing in the district of Shimla. To achieve the research objectives, a number of aspects of academia were examined from a gender perspective, including the association between gender and the growth of literature, the growth of citations, the organizational level, individual academic disciplines, collaboration, authorship patterns, and areas of interest.

2. Scope and Limitation of the study

The current investigation was limited to the research out of Shimla District, Himachal Pradesh and it covered all subject. Further the study limited to the literature published between 1999 and 2018 and indexed in Scopus database. The study also only considered first author of the paper for analysis. The ratio of male and female authors calculated from the publications of the first author rather than whole authors of each the publication. In addition, the study analysed and identify gender gap using bibliometric indicator.

3. Review of related work

Different theories exist in the literature regarding the concepts of “gender disparity” or “the gender gap” or “gender inequality” [4], [13], [16], [17]. A previous study [4] examined science literature published in Polish between 1975 and 2014. The authors reported that out of a total of 56,634 documents published during the study period, female authors outnumbered male authors. A further study [14] analysed the authorship of 186 Indian journals published in 2017 in terms of the gender of just the first author. It was reported that across 26 fields, males outnumbered females by a factor of over 1.5. In the USA, a greater number of female first authors were found in dentistry, economics, and mathematics as compared to males. Similarly publications by females outnumbered those by males in German by 28% between 2010 to 2014 [18]. It was reported [19] that publications by female Norwegian scientists are less cited than those by males, but this was not by a large margin, and may have been related to the finding that females published fewer articles compared to males. A very recent study [20] investigated the gender inequality of citations in six English speaking countries (Australia, Canada, Ireland, New Zealand, UK, and the USA) across twenty-seven research areas between 1996 and 2014. They found that overall, females were more likely to be first authors on research papers, but only by a small margin, and that their work had a tendency to be cited more often than work published by male first authors, again by a non-significant margin. Many studies have documented that females are found to be under-represented in specific domains [21]–[25]. In particular, one study [21] reported that males published more articles than females in the field of library and information science in India between 2008 and 2017, and that one-third of the publications had single-authorship. It has been reported [26] that in neuroscience, the research production of women authors was less than that of men, with men contributing 67.1% compared to 32.9% from women. However, analysis of a sample of 26,783 research publications in the subject of management [27], demonstrated that female authors rank slightly higher than males in the top 10% most highly-cited publications. Similarly, in the field of nanoscience and technology, female authors produced more articles and had greater impact than males between 2005 and 2007 [28]. Another study in library and information science [29] showed that between 2011 and 2018, women researchers contributed fewer publications than men, where the average male authored 1.35 papers compared to an average of 0.54 papers published by females. A similar study [30] reported the vast majority of

literature to have been contributed by males (75.38%), rather than females (24.62 %). [31] Significant differences have been found in research contribution between males and females in Kashmir, India where males contributed 95.31% of published literature across a variety of subjects, compared to the 5.69% contributed by females. Contributions from male academic physicians have been found to outnumber those of females, in addition to males achieving higher h-index scores than their female counterparts [24]. Despite the large number of studies reporting a male domination with regard to research contributions, some studies have reported contradictory findings. In a study comprehensively using many metrics to compare women's contribution to medical research with that of men [32], the study sample comprised 1,910 authors of 223 publications in a single journal between 2000 and 2015. Over the study period, the proportion of female authors significantly ($p < 0.0001$) increased from 32% to 41%. Further, the involvement of female authors in the conception and design of the research rose significantly ($p = 0.0256$) from 55% to 61%. Involvement of female authors in critical revision significantly ($p = 0.0009$) increased from 70% to 81%, in final approval increased from 81% to 86% ($p = 0.0381$) and in securing research funding increased from 16% to 22% ($p = 0.0245$). the workload was different between women and men, with women having greater involvement in roles such as administration and logistics (35% women compared to 26% men; $p = 0.0188$) and data collection (50% women compared to 46% men; $p = 0.0532$). Involvement in tasks such as data analysis and interpretation, drafting of the manuscript, provision of materials/patients and statistical expertise was similar between the genders. Across the study period, a woman researcher was also found to be significantly ($p = 0.0102$) less likely to take the place of last author than a man (9% compared to 16%). Similarly, research by Sotudek and Khoshian [28] used Scientometric methodology to study the performance of women working in nanoscience and technology, in terms of scientific productivity and impact in contrast to males. They found woman researchers to be fewer in number, but to perform equally to men in terms of scientific productivity and impact. [33] conducted a study paper published in SRELS Journal of Information Management between 2011 and 2018. The authors analysed the data using bibliometric indicator and gender identification of papers published in this journal. The study found 464 publications in which 877 authors were contributed their paper. Further author noted that female author was less international collaboration with than male author.

In short, previous research investigating gender differences in publication rates, author contributions, citation rates and research impact has produced many contradictory findings that vary with the field and country of the study. The polarity and magnitude of findings vary to such a degree that no conclusions for general trends can yet be drawn, with the majority of studies being limited in scope to a specific geographical area. Moreover, there is no such research investigating the impact of gender in research in the Shimla district of Himachal Pradesh, India. As such, the current study aims to examine the research contribution of both men and women in Shimla.

4. Research questions

RQ1: Do female researchers produce fewer publications than males?

RQ2: Are the research outputs of women less cited than those of men?

RQ3: Is there an institutional gender imbalance in research productivity?

RQ4: How does gender disparity vary across disciplines?

RQ5: Do women have fewer international collaborators than men?

RQ6: Is there a gender gap in research interests?

5. Materials and methods

5.1. Collection of data

This study utilized the Scopus database as due to it having a wider coverage than Web of Science. Data were exported from Scopus using the advanced search function “Affiliation to City” = Shimla, and the search was performed on the 18th October 2019. The initial search produced 4,952 publications. Further irrelevant entries (i.e. incorrect author affiliation city, district, state or country, or the author being unidentifiable) were removed, such that an only publication where the first author was identifiable and located in Shimla district was included. This resulted in a final sample size of 2,881 publications.

5.2. Gender Identification

Gender identification done of first author of the publication having affiliated to Shimla district. The authors of this study first search each publication in google and extract full name of the author and then collect the first name of the paper. Then manually identify the name gender using various websites such affiliated universities, google Scholar, ResearchGate of the authors. However, the gender was doubt or unidentified the study removed such publication for further study. Finally, 2881 publications found which were affiliated to Shimla district. Out of total 774 (27%) female and 2107 (73%) male first authors found paper published between 1999 and 2018 in Shimla.

5.3. Data analysis

The data analysis used Microsoft Excel and Bibliometrix R Package, a mapping analysis tool, coded in R [34] and Gephi and VoSviewer used to visualize the keywords and collaboration of publications.

6. Results

6.1. Growth of literature

Figure 1 shows growth over times of publications by first author gender between 1999 and 2018. The overall growth of publications by first authors of both genders was not

stable, and fluctuated over time. The growth publications by male first authors dominated over the period. Further, the highest growth rate over a single year of publications authored by men was 179 in 2011, compared to 92 by women, which occurred in both 2015 and 2016. Growth of publications by male authors increased steadily from 2002 to 2007, but in 2008 started to decrease by progressively smaller amounts. Similarly, the growth of publications by female authors increased steadily from 2011 to 2015, and dropped slightly in 2017.

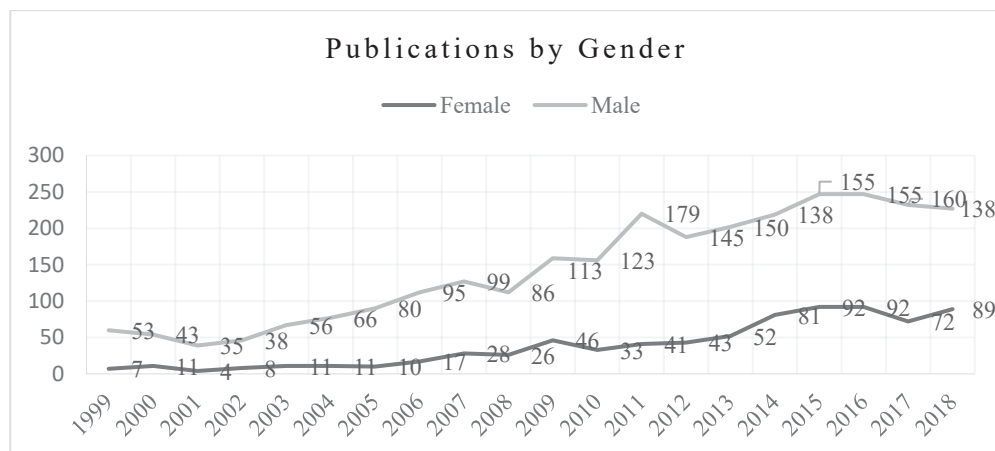


Figure 1. Growth of literature in print by gender of the first author, by year, between 1999 and 2018.

6.2. Citation growth

Figure 2 illustrates the growth of citations both male and female first authors over 20 years in Shimla district. There were a total of 2881 publications reviewed in which the highest citation contributed male first authors 17956 citations in 2107 while female first authors contributed 6148 in 774 publications. Both male and female first authors' citation growth rates fluctuated over a period. The closer inspection of the graph indicated that in the year 2009 and 2016 female first authors' publications received the highest citations than male first authors.

6.3. Publications by organization

Both male and female first authors were categorized into 11 broad categories (Table 1). Small organizations and institutes were merged into a larger group i.e. the group denoted as Government College encompasses all from RKMV, Government College Sanjauli, Govt. PG College Seema, Govt. College of Pharmacy, Govt. College Sunni, Rajiv Gandhi Govt. College, and St. Bede's College Shimla. Table 1 shows a significant gender disparity at the Indian Institute of Wheat and Barley Research (IIWBR), Regional Station, Shimla whereas a lower rate of gender disparity was

found in HP Govt. Dental College (HPGDC) and Hospital, where men were first author to 56% of research outputs and women to 44%.

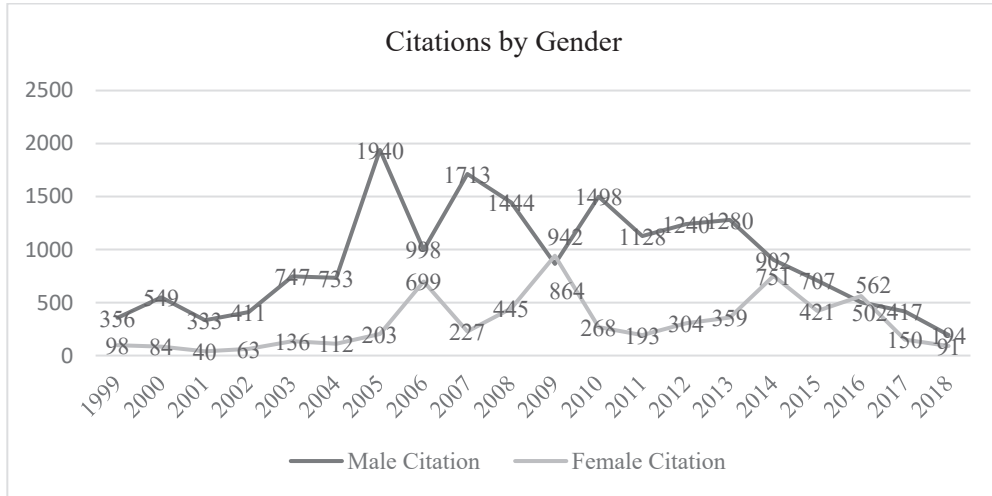


Figure 2. Growth of citations by gender of the first author of the cited paper, by year, between 1999 and 2018.

Organization	# publications with male first author	# publications with female first author	Total	Male (%)	Female (%)
CPRI	190	58	248	77	23
HFRI	14	6	20	70	30
HPGDC	34	27	61	56	44
HPU	1,025	383	1,408	73	27
IARI	16	4	20	80	20
IGMC	587	242	829	71	29
IIAS	28	14	42	67	33
IIWBR	37	0	37	100	0
NBPGR	21	3	24	88	13
Other	114	29	143	80	20
Government College	41	7	48	85	15

Table 1. Organizational gender disparity. N.B. Government College includes RKMV, Government College Sanjauli, Govt. PG College Seema, Govt. College of Pharmacy, Govt. College Sunni, Rajiv Gandhi Govt. College, and St. Bede's College Shimla.

6.4. Number of co-authors by gender

Figure 3 shows the percentage of publications by both male and female first authors to have different numbers of total authors, between 1999 and 2018. There is no visible

association between the number of authors a publication has and the gender of the first author. A slight trend is seen in that the higher number of total authors a publication has, the more likely it was to have been first authored by a male. I.e. in the category of more than three authors, male first authors constituted 73.90% of the publications in this category, whereas female first authors contributed 26.10%. In contrast in outputs with single authorship, males contributed 68.83% and female contributed 31.17%.

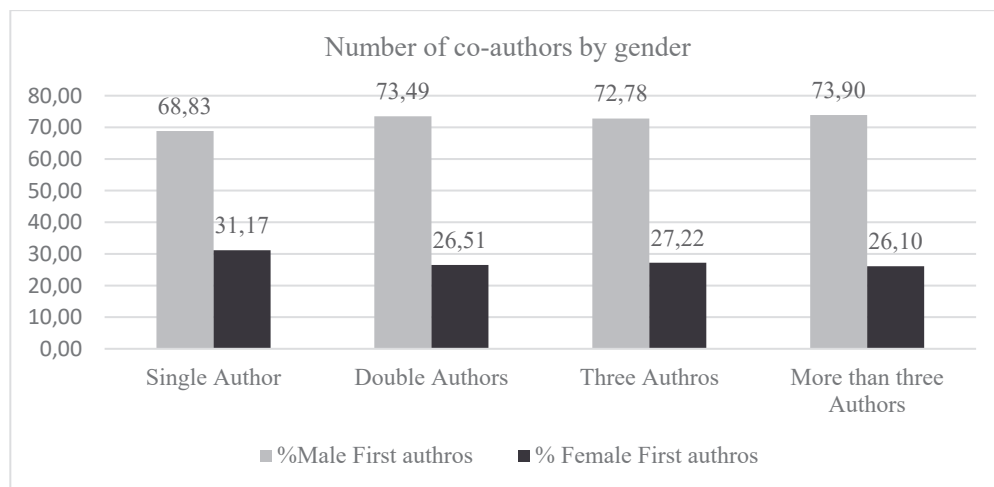


Figure 3. Authorship pattern – number of coauthors on publications first authored by men and women.

6.5. Publications by subject area

Gender disparity exists in all disciplines; however it is even more prominent in some disciplines compared to others. Publications were categorized into four broad disciplines according to the Scopus database. These were health sciences, life sciences, physical sciences and social sciences. The data show that the highest rate of gender disparity was found in physical sciences where male first authors contributed 74.66% of the publications and female first authors contributed only 25.34%. While the lowest gender disparity was found in social sciences (males = 66.67%; and females = 33.33%), this was still significantly different from parity.

6.6. Keywords of articles published by Men and Women

To assess the subject areas of interest of both male and female first authors, the keywords of all publications in the sample were extracted and visualized in the form of a network using the Bibliometrix RPackage. The 23 most-frequently occurring keywords in the sample are shown in Figure 5. The color represents the cluster, and size of the nodes/ font size represent frequency of occurrence. The weight of the line connecting two nodes denotes the strength of the relationship between the two nodes.

For articles first-authored by men, it can be seen that the strongest links found were between the following pairs of terms: potato and yield; wheat and resistance; hydrogel and drug delivery; and immobilization and lipase. For women, the strongest links were between the following pairs or groups of terms: potato and starch; density, speed and viscosity; immobilization and lipase; thermodynamic parameters and critical micelle concentration. The most commonly used keywords in work by men were potato, hydrogels, immobilization and porous medium, for women were potato, density, critical micelle concentration, lipase and immobilization. Closer inspection of the images generated in Figure 5 shows that the overlapping areas of interest, signified by highest frequency of keyword use in publications first-authored by both men and women were potato and immobilization.

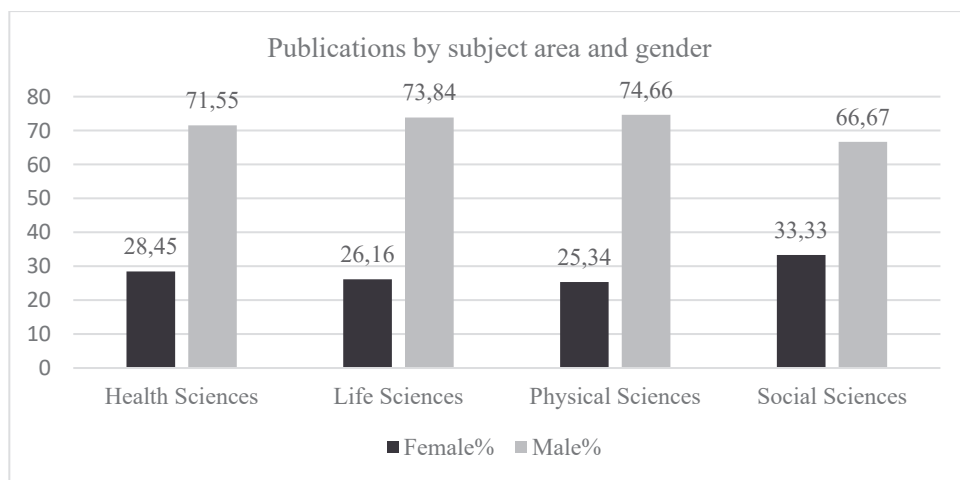


Figure 4. Gender disparity across four broad subject categories of publications. Numbers above columns denote percentages of the publication in that category.

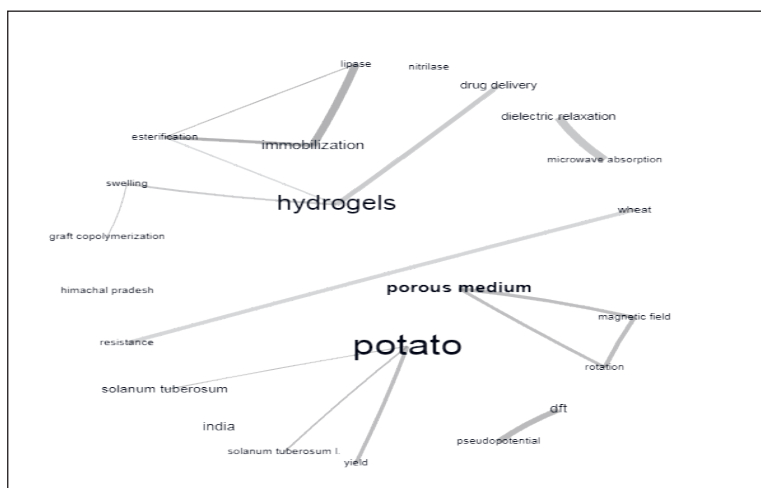


Figure 5 (A). Keywords of articles published by men

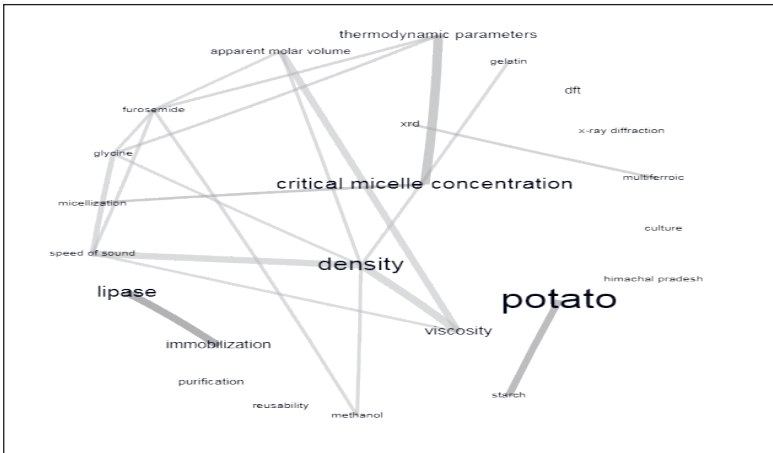


Figure 5 (B). Keywords of articles published by women.

6.7. International collaborations by gender

Figure 6 (A-B) shows the gender disparity of male and female first authors in the existence of international research collaborations, in terms of the strength of collaboration with the other country. The study found that men were more likely to undertake collaborative research and women had fewer collaborations. Male first authors exhibited strong collaborative relationships with researchers in the USA, Saudi Arabia, and South Korea. In contrast, female first authors were strongest with those in Saudi Arabia followed by South Korea, the USA, and Brazil. Closer inspection of the data shows that similar collaborative networks are found in both male and female first authors during the period of 1999 to 2018 in Shimla district.

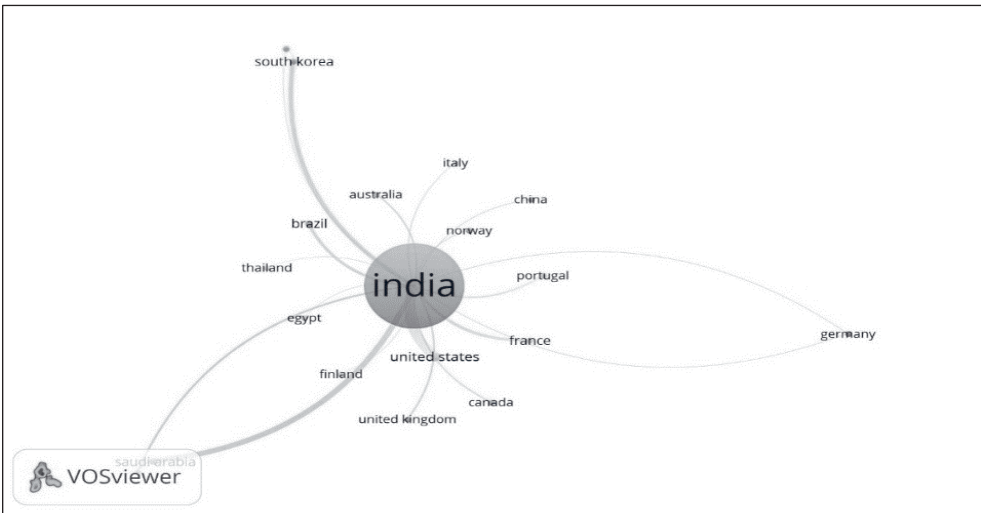


Figure 6 (A). International collaboration of first authors by gender Men.

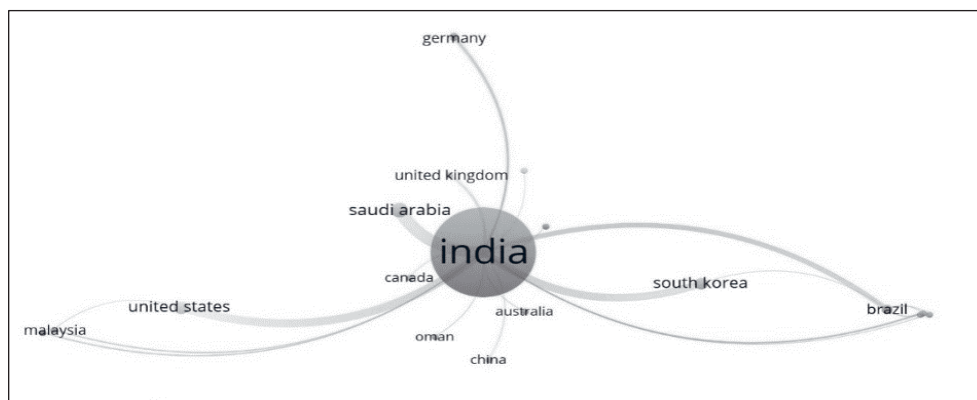


Figure 6 (B). International collaboration of first authors by gender women.

*The thickness of the line denotes the strength of the collaborations with the other country.

7. Discussion and Conclusion

This study investigated gender disparity in research publishing in Shimla over a 20-year period. Our findings show that publications by male researchers outnumbered publications by female researchers overall. The growth rates of publications of both male and female first authors were not stable. However, both the number and the growth rate of publications by female first authors was lower than those by male first authors during the study period. Conversely, the growth in citation rate was higher for female first authors in 2009 and 2016. Significantly, there was a higher gender disparity in research publications found the Indian Institute of Wheat and Barley Research (IIWBR) and a less severe gender disparity found at the HP Govt. Dental College. Similar levels of gender disparity were found in the pattern of the number of separate co-authors each publication has, with a tendency for a greater gender disparity, the greater the number of co-authors listed on a publication. However, this trend was not statistically significant. The degree of gender imbalance in research productivity of both male and female first authors varied across different disciplines. The study found significant differences in research productivity in life sciences, health sciences, and physical sciences while social sciences exhibited the smallest gender disparity of merely a 2:1 male: female ratio among the first author of the sample of publications. In studying the international collaborations within the sample, no significant difference was found, however, male and female first authors both showed strong collaborations with the USA, Saudi Arabia, and South Korea with a trend for stronger collaborations involving male first authors compared to female first authors. In addition, female first authors had less international collaboration than male first authors. The areas of specific research interest, signified by the frequency of publication keywords within the sample, found both men and women to use the keywords potato and immobilization. This may be due to the relatively small sample size and great diversity of subject matter of the publications within the sample.

The study findings are in agreement with previous research reporting that women contribute less to research outputs than men. Indeed, very little of the research outputs in the Shimla district between 1999 and 2018 are attributed to female first authors, as suggested in numerous previous studies. Women in research should receive proper guidance, and institutions should be aware of the needs of the female population in order to reduce and overcome gender imbalance in research activity. This will entail the involvement of multiple research active institutions, in addition to the relevant authorities, UGC, ICMR, and ICAR and other bodies. In conclusion, the gender disparity that is ubiquitous in academia, is shown to be present in Shimla and it not decrease unless proper guidance and resolution is taken.

References

- [1] A. Cooray, R. Verma, and L. Wright, "Does a gender disparity exist in academic rank? Evidence from an Australian university," *Appl. Econ.*, vol. 46, no. 20, pp. 2441–2451, 2014, doi: 10.1080/00036846.2014.904496.
- [2] A. K. Mukhopadhyay, P. Chakrabarti, and S. Marjit, "Measuring gender discrimination: The indian experience and a new index," *J. Interdiscip. Econ.*, vol. 21, no. 1, pp. 53–68, 2009, doi: 10.1177/02601079X09002100105.
- [3] C. Da Wan, "Student enrolment in Malaysian higher education: is there gender disparity and what can we learn from the disparity?," *Compare*, vol. 48, no. 2, pp. 244–261, 2018, doi: 10.1080/03057925.2017.1306435.
- [4] M. Kosmulski, "Gender disparity in Polish science by year (1975-2014) and by discipline," *J. Informetr.*, vol. 9, no. 3, pp. 658–666, 2015, doi: 10.1016/j.joi.2015.07.010.
- [5] World Health Organization, "Africa 's women in science," 2021. [Online]. Available: https://www.who.int/tdr/research/gender/Women_overview_piece.pdf
- [6] E. S. Pietri, I. R. Johnson, E. Ozgumus, and E. Ozgumus, "Maybe she is relatable: increasing women's awareness of gender bias encourages their identification with women scientists," *Psychol. Women Q.*, vol. 42, no. 2, pp. 192–219, 2018, doi: 10.1177/0361684317752643.
- [7] S. Bose, "A contextual analysis of gender disparity in education in India: The relative effects of son preference, women's status, and community," *Sociol. Perspect.*, vol. 55, no. 1, pp. 67–91, 2012, doi: 10.1525/sop.2012.55.1.67.
- [8] National Science Foundation, "Doctorate Recipients from U.S. Universities 2014," 2015. [Online]. Available: <https://www.nsf.gov/statistics/2016/nsf16300/digest/nsf16300.pdf>

-
- [9] A. Sharma, A. Gandhi, C. Kumar, P. Saha, and B. K. Sahoo, "India Human Development Report 2011: Towards Social Inclusion," 2011. [Online]. Available: <https://ideas.repec.org/p/ess/wpaper/id6740.html>
- [10] S. P. Katiyar, "Gender Disparity in Literacy in India," *Soc. Change*, vol. 46, no. 1, pp. 46–69, 2016, doi: 10.1177/0049085715618558.
- [11] N. Ramachandran, "Are women equally unequal in India? looking across geographic space," *Gend. Technol. Dev.*, vol. 15, no. 3, pp. 363–387, 2011, doi: 10.1177/097185241101500303.
- [12] M. S. Alam, "Interrogating gendered inequality in educational attainment in India," *Soc. Change*, vol. 37, no. 4, pp. 153–179, 2007, doi: 10.1177/004908570703700408.
- [13] A. R. Chaudhury and M. Sinha, "Gradual Disappearance of Gender Disparity in Human Capital Accumulation: Evidence from India," *J. Asian Afr. Stud.*, vol. 00, no. 0, 2020, doi: 10.1177/0021909620909492.
- [14] M. Thelwall, C. Bailey, M. Makita, P. Sud, and D. P. Madalli, "Gender and research publishing in India: Uniformly high inequality?," *J. Informetr.*, vol. 13, no. 1, pp. 118–131, 2019, doi: 10.1016/j.joi.2018.12.003.
- [15] Government of India, "india-glance-profile," National Portal of India, 2020. <https://www.india.gov.in/india-glance/profile>
- [16] J. P. Andersen and M. W. Nielsen, "Google Scholar and Web of Science: Examining gender differences in citation coverage across five scientific disciplines," *J. Informetr.*, vol. 12, no. 3, pp. 950–959, 2018, doi: 10.1016/j.joi.2018.07.010.
- [17] K. Prpic, "Gender and productivity differentials in science," *Scientometrics*, vol. 55, no. 1, pp. 27–58, 2002.
- [18] Elsevier, "Mapping Gender in the German Research Arena," 2015.
- [19] D. W. Aksnes, K. Rorstad, F. Piro, and G. Sivertsen, "Are Female Researchers Less Cited? A Large-Scale Study of Norwegian Scientists," *J. Am. Soc. Inf. Sci. Technol.*, vol. 62, no. 4, pp. 628–636, 2011, doi: 10.1002/asi.
- [20] M. Thelwall, "Gender Differences in Citation Impact for 27 Fields and 6 English Speaking Countries 1996-2014," *Quant. Sci. Stud.*, pp. 1–26, 2020.
- [21] B T Sampath Kumar, Vinay R S., M. Vijayakumara, and K. T. Santhoshkumar, "Gender Disparities in LIS Research Productivity: An Exploration," *Int. Conf. Libr. Inf. Sci. Bangkok, Thail.*, no. August, 2018, [Online]. Available: https://www.researchgate.net/publication/327160968_Gender_Disparities_in_LIS_Research_Productivity_An_Exploration
-

- [22] E. Vignola-gagne, C. Villeneuve, P. Ge, and Y. Gingras, "Sex differences in research funding, productivity and impact: an analysis of Quebec university professors," *Scientometrics*, vol. 87, pp. 483–498, 2011, doi: 10.1007/s11192-011-0369-y.
- [23] J. D. West, J. Jacquet, M. M. King, S. J. Correll, and C. T. Bergstrom, "The Role of Gender in Scholarly Authorship," *PLoS One*, vol. 8, no. 7, 2013, doi: 10.1371/journal.pone.0066212.
- [24] J. A. Eloy et al., "Gender Disparities in Research Productivity Among 9952 Academic Physicians," *Laryngoscope*, vol. 123, no. August, pp. 1865–1875, 2013, doi: 10.1002/lary.24039.
- [25] L. Parabhoi, R. R. Sahu, R. S. Dewey, and D. Parabhoi, "Gender Disparity Among Indian Library and Information Science Professionals: a 20-year sample of publications from 1999-2018," *Libr. Philos. Pract.*, 2020.
- [26] J. González-Álvarez and T. Cervera-Crespo, "Research production in high-impact journals of contemporary neuroscience: A gender analysis," *J. Informetr.*, vol. 11, no. 1, pp. 232–243, 2017, doi: 10.1016/j.joi.2016.12.007.
- [27] M. W. Nielsen, "Gender and citation impact in management research," *J. Informetr.*, vol. 11, no. 4, pp. 1213–1228, 2017, doi: 10.1016/j.joi.2017.09.005.
- [28] H. Sotudeh and N. Khoshian, "Gender differences in science : the case of scientific productivity in Nano Science & Technology," *Scientometrics*, vol. 98, pp. 457–472, 2014, doi: 10.1007/s11192-013-1031-7.
- [29] R. Patel and M. Kumar Verma, "Gender Variation in LIS Research Productivity: A Case Study of SRELS Journal of Information Management," *SSRN Electron. J.*, pp. 125–129, 2020, doi: 10.2139/ssrn.3512406.
- [30] G. Bisaria, "DESIDOC Journal of Library and Information Technology : A Gender Pbeerspective," *DESIDOC J. Libr. Inf. Technol.*, vol. 38, no. 6, pp. 410–415, 2018.
- [31] M. A. Kaw and S. Ahmad, "Gender prejudice in the research world : female researchers in a conflict zone , Kashmir," *Libr. Rev.*, vol. 63, no. 8/9, pp. 684–699, 2014, doi: 10.1108/LR-04-2013-0051.
- [32] A. Gayet-ageron, A. Poncet, and T. Perneger, "Comparison of the contributions of female and male authors to medical research in 2000 and 2015 : a cross- sectional study," *BMJ Open*, vol. 9, pp. 1–8, 2019, doi: 10.1136/bmjopen-2018-024436.
- [33] R. Patel and M. K. Verma, "Gender Perspective in LIS Research: A Case Study of SRELS Journals of Library Information Management," in

Transcending Technology A Cognitive Learning Towards Artificial Intelligence, 2019, pp. 113–122.

- [34] M. Aria and C. Cuccurullo, “Bibliometrix: An R-tool for comprehensive science mapping analysis,” *J. Informetr.*, vol. 11, no. 4, pp. 959–975, 2017, doi: 10.1016/j.joi.2017.08.007.

Marketing Strategy as Driving Force of Export Performance Small and Medium Enterprises - Case of Kosova

Xhelil Bekteshi

xhelilbekteshi@gmail.com

Faculty of Economic

St. Clement of Ohrid University of Bitola North Macedonia

Sevdie Alshiqi¹

sevdie.alshiqi@uni-pr.edu

Faculty of Economic

University of Prishtina "Hasan Prishtina", Prishtine, Kosove

Abstract

Kosovo's private sector business is led by small and medium enterprises and shows a crucial role in the economic development and promoting the growth of this sector. Due to the lack of studies in Kosova, related to marketing strategy and export performance, the research aims to explore growth determinants of SMEs in Kosovo by emphasizing exports, revealing the importance of marketing strategy related to the performance of SMEs. Since exporting is becoming more important, it is necessary to understand all the factors that are involved in this booming trade. This research analyses explore the literature dealing with small and medium enterprises' performance to inspect the traditional and modern academic standpoints on estimating the impact of export performance, based on secondary data of five hundred small and medium enterprises, as trade, manufacturing, and services sectors in Kosovo. The data were analysed using both descriptive statistics and inferential techniques, such as logistic regression analysis, and probit model using the SPSS software. Results show a significant linkage of marketing strategy and export performance; managers and policymakers can take some action to improve export performance. On the other hand, the results measure the impact of price, production, promotion and place in export performance incorporate expected future performance. It is argued that enterprises in Kosovo must pay more attention to strategies, and attempt to design and implement better strategies that will be beneficial for developing international trade, especially exports, as one way of trading by SMEs.

Keywords: small and medium enterprises, Kosovo, marketing, price, place, distribution, export, trade

¹ Corresponding author

1. Introduction

Today trading abroad is a fundamental step for the business, reaching the enlargement competitive advantage in competitor's firms. Paper is organized with theoretical background, research methodology, results, discussion and conclusion.

Analysis and gathered data, combined with theoretical background helped in setting the research questions as well as the discussion on the findings of the thesis. This report was used, that gather data from 500 small and medium enterprises, contribute to describing factors that indicate Small and Medium Enterprises in Kosovo. Probit and Tobit analysis was used to test the correlation between the hypothesized relationships. Empirical research has proposed that export performance is determined by firm size, marketing strategy, financial barriers, the experience of the company, knowledge of the foreign language, IT knowledge. Also, some other factors can be considered to be determinants of export performance. This study contributed to the existing knowledge of foreign trade practices by analyzing the problems engaged in, by SME owners in Kosova who participated in this study. Also, recommendations will help to assist in the export sector that may uphold businesses to reach their goals and indicate economic growth. Performance levels can have an impact on marketing strategy decisions, based on the previous results most of the firms can rethink and react to marketing strategy, to improve, redefine and appoint new branding, communication, and relationship marketing strategies. Case studies as British Airways after its 1999 commercial financial disaster, publicity announced that they started rethinking a new marketing strategy.

2. Theoretical background

Due to the fact that variables of marketing strategy show a positive effect on export performance, in some cases is not significant [12]. The results cannot be generalized, if we do not make comparisons between the different products. Export markets and export performance are directly related to each other [20]. Product adaption strategy is viewed as a factor that directly affects export performance; segmentation strategies and world orientation instead of the nearest neighbor approach [10]. For many years, it has been given considerable attention to the influence on the export performance of various product dimensions [14]. In general, it can be seen that products designs have a significant positive effect on performance. Also, products can be differentiated through some advantages that are derived from their attributes as quality, prestige, luxury. Also, products with specific qualifications are very strongly related to product advantages known in the literature as a major export stimulus [9]. The main reasons why we hypothesis to have the positive relationship between product or brand with export performance are: by serving more customer segments it establishes opportunity increasing sales and all these costs including, administrative, marketing and other can distributed in the whole number of products [4]. Research on pricing strategy focused mostly on the effect of setting low prices. Although term sales play an important role in international business, including details of a contract, transporting, and other responsibilities, one factor pursued by the firm in export transactions is currency

strategy; also, if this price quotation minimizes liabilities of international customers, it can have a powerful competitive advantage. Positive relationship between export intensity and pricing approach [4]. This diversity in pricing is necessary for a firm to remain and survive in the competitive market with price adaption. For better exporting, it is quite important to have a proper channel of distribution, regarding this exporter, can use numerous ways of supporting their sales force training, missionary selling, cooperative advertising, market research assistance, dealers, financing [9]. Great caution must have on the delivery time of the products because for importing firms this plays selection criteria and affects competitiveness and success in the market in which these firms operate [16]. Promotion and their effects on export performance are advertising, sales promotion, personal selling, trade fairs, personal visits, and promotion adaption [12]. With advertising, firms can generate more sales by informing, reminding, and pursuing domestic and foreign customers. Personal selling as a way of promotion was analyzed only research by a small number of studies, even if in some studies it is noted a positive relationship their result should be treated with caution. The use of trade fairs as the promoter of exports has been researched in several studies that found a linkage relationship between them [17]. Nevertheless, all these positive effects should be viewed with caution; it depends on which product/service you are a competitor at that fair. It is unrealistic to look for the same results with the use of the same marketing strategy, in all marketing ventures. All these tools of promotion, including participation in trade fairs or personal visits to export markets, help export managers to pursue standardized promotion strategy across all countries, also adaption with new requirements in the competitive market. Which companies are more likely to be active as exporters? Companies that have formal market planning are more likely to be active while lacking this formal plan causing difficulties achieving their goals [5]. And also, companies that spend much more time in selecting foreign target markets have a higher level of export performance than SMEs that are more ad hoc in this process [5]. Moreover, even though the common extension procedure received does not influence export rate, the choice about whether to institutionalize or adjust the advertising mix components affects. All in all, the work endeavored to tackle the issue emerging from the conflicting outcomes on the impact of export rate predecessors utilizing the resource as the hypothetical establishment. For that reason, the authors investigated mutually the elements proposed as potential determinants in this research. Identifying the marketing technique components that impact export rate has been the subject of sizeable observational research [12]. Be that as it may, discontinuity and decent variety portray the discoveries revealed in writing, constraining hypothesis advancement, and change of management practice in the field. The assessment of [12] based on their assessment stated that: there is no significant relationship exists between export performance and marketing strategy. However, this is irrespective of the reality that a significant correlation exists between the whole export performance and the strategy used for marketing; a significant correlation exists between export performance and geographic center, type of product, and the time it was studied; and the export proportion of sales has a stronger effect on exportation performance. The accomplishment of an effective export rate is at the core of the key basic leadership

process for both corporate and open arrangement chiefs. A firm's goals, both economic and non-economic have a significant effect on the importation rate is due to an international context in a given period and also the export strategies used by the company to deal with the problem of the company's environment. A firm determines which export strategy to be used, and that decision varies between industries, time horizons, national firms, and context. Thus, there are plenty of export rate markers utilized as a part of the exporting writing. For instance, [11]. in their analysis of 100 export-related articles recognized 42 distinctive performance markers. All the more as of late, [19], in his investigation of export rate-related articles distributed in the vicinity of 1998 and 2004, recognized 50 different performance indicators. The large exhibit of pointers utilized in the export rate writing is an impression of the troubles in getting to export rate information, and also the ongoing quest for reliable and thorough measures. This makes the studies and approval of the discoveries from various investigations exceptionally troublesome. A diagram of the important writing suggests that a reasonably stable and solid export rate measure ought to satisfy the accompanying criteria. It must be composite and multidimensional, i.e., to incorporate both target and subjective measures; it needs to have an edge of reference, i.e., to be benchmarked against domestic market performance, competitors' performance, or prior performance, [10]. "The objective/subjective divide refers to the type of values used in the export performance assessment, i.e., objective indicators are mainly based on absolute values (e.g., export sales volume, export profit margin, export market share, etc.), while subjective indicators are based on perceptual values (e.g., the manager's perception of success and satisfaction with export sales)." Measures of export performance are usually categorized into two broad groups: financial/economic and non-financial/non-economic measures. The recent astronomical growth of global trade and sales activity in the world, occasioned by social media and other online marketing activities, has increasingly exaggerated the importance of the export business to individuals, estates, and business organizations. The internet, international travel, and other structures portending interconnectedness had blurred the restriction line on the discussions of this magnitude. The whole reveal suggests that the most used financial indicators as measures of export performance are: sales-related indicators. Export sales ratio [6], [9], [13], export sales growth [10], [13]. export sales volume and export sales ratio [14], [2]. Profit-related indicators, such as export profitability, export profitability growth, export profit ratio, and export profit margin [3], [13]. Export intensity (export to total sales ratio), export sales growth, export profitability, export market share, satisfaction with overall performance, and received export success [19]. Faced with the difficulties of acquiring financial data from SMEs, some researchers resort to the use of non-financial/non-economic measures of export performance. This manner advocates the use of perceptual/attitudinal or generic standards of performance, such as perceived export success, achievement of export objectives, satisfaction with export performance, or strategic export performance [21]. Other non-financial measures include product-related and market-related indicators and other miscellaneous actions. Much of the early export performance research has been dominated by single-item measures, either economic or non-economic. Recognizing that export success is "multifaceted and cannot be captured by any single

performance indicator" (Diamantopoulos, 1998: page 3). Recent empirical studies have attempted to develop and validate multi-item measures in the form of more complex and multidimensional performance metrics [12], [7], [21]. Firms that have a developed marketing strategy deem this factor as a driving factor an route for better performance.

3. Research methodology

Identification and measuring the determinants of export performance through the marketing strategy is the main subject of this paper. The data used in this study were obtained from five hundred Small and Medium Enterprises operating in Kosovo, the selected exporting company represents one hundred, which made a total sample of five hundred companies. The respondents were asked for a degree of agreement with a series of statements on an item measure. The LIKERT scale was introduced and deemed to determine the intensity with which respondents feel about asked questions. The descriptive statistics were calculated to give an overview of the distribution, mean, and standard deviation of the data set. Internal consistency and reliability analysis for LIKERT scale variables was performed using Cronbach's Alpha coefficient.

Through these analyses the following hypotheses have been raised, such as:

- The marketing strategy (including price, place, promotion, and distribution) was strongly positively correlated with the export performance of small and medium enterprises.

3.1. Describing the Data used, hypothesis, and Research methods

In this study, the dependent variable is export performance defined by the participation of export in a total sale. The export performance showed a multidimensional formation, validating the complex environment of the structure as suggested by [12], [2], [6].

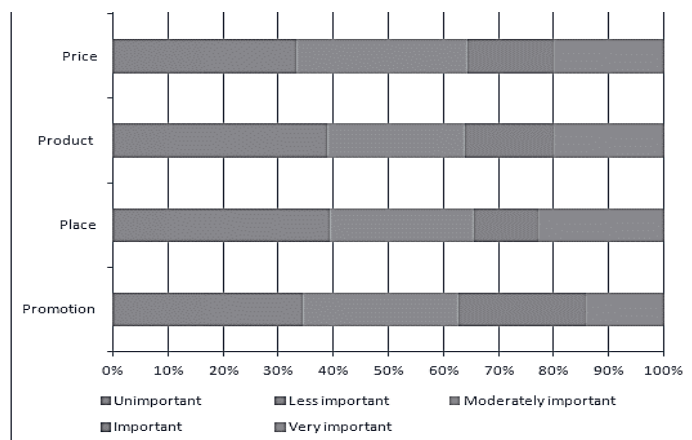


Figure 1. Managers' stated importance for promotion, place, product, price, and innovation

Concerning the marketing strategy, the majority (60.2%) of the interviewed managers perceived marketing strategy as not a less important road map for being engaged in export. Export promotion activities were seen to be important for the export performance of a company. About 66% of the interviewed managers stated that promotion was important to very important for the export of a company. Whereas, less stated importance was given to the place, product, price, and innovation.

Internal factors	χ^2	Df	Age		χ^2	Df	Education	
			Cramer's V	P-value			Cramer's V	P-value
Marketing strategy	19.48	20	0.099	0.491	21.15	12	0.119	0.048
Promotion	37.04	20	0.136	0.012	9.35	12	0.079	0.673
Place	39.38	20	0.140	0.006	17.47	12	0.108	0.132
Product	34.35	20	0.131	0.024	6.42	12	0.065	0.893
Price	40.93	20	0.143	0.004	6.69	12	0.067	0.877

Note: No responses were given for the innovation within the stated category very important.

Table 1. Dependency of the importance of the internal factors with the managers' characteristics

Size of the company (number of employees)				
<i>Internal factors</i>	χ^2	Df	Cramer's V	P-value
Marketing strategy	77.43	8	0.278	0.000
Promotion	16.36	8	0.128	0.037
Place	14.42	8	0.120	0.071
Product	12.70	8	0.113	0.122
Price	13.68	8	0.117	0.090
<i>External factors</i>				
Infrastructure	11.38	8	0.107	0.181
Financial barriers	6.89	4	0.083	0.141

Table 2. Dependency of the importance of the internal and external factors with the firm size

The probit model was performed to find out the relationship between exporting status of the firm and the other explanatory variables presented in Table 2. In the following table, the results from the estimated probit model are reported.

The marketing strategy variable also displays a positive sign at a 1% level of statistical significance, showing that the probability of exporting increases with a better marketing strategy from a company. Four other explanatory variables such as promotion, place, price, and product were omitted in the best-fitted model as they were not proved to be statistically significant determinants of exporting probability. The marketing strategy was positively correlated with the percentage of the export share in the total sale. According to the estimated model, it was shown that if a

company gives higher importance to the marketing strategy the percentage of the export share in the total sale increases by 5.387% (p-value = 0.0000).

Variables	Coefficient	Coefficient
Marketing strategy	0.194110*	0.219870**
Promotion	0.433186*	Omitted
Place	-0.618407*	Omitted
Product	0.885350**	0.217334*
Price	-0.457142	Omitted
Log-likelihood	-105.35	-110.6780
R-squared	0.581	0.560

Note: Significance is denoted as follows: *P < 0.05; **P < 0.01; ***P < 0.001.

Table 3. Results of probit estimation for initial model and with omitted variables

H1: Firms that have marketing strategies are positively associated with export performance.

This hypothesis tries to describe performance differences between small and medium enterprises, why some of them are successful and some are not. What should they improve in their marketing strategy to raise this level of performance? There are two main groups of explanatory variables describing export performance, intervening variables and background variables. In general, it can be seen that product designs have a significant positive effect on performance. Also, products can be differentiated with some advantages that are derived from their attributes as quality, prestige, luxury. All these advantages indicate in export profit contribution. This progress by the firm will lead to export positional advantage, development, and success [2]. Leading to better export it is quite important to have a proper channel of distribution, regarding this exporter, can use numerous ways of supporting their sales force training, missionary selling [12], [9]. From our research, the importance given to the marketing strategy by surveyed companies was strongly positively correlated with export performance.

4. Research results

The importance given to the marketing strategy by surveyed companies was strongly positively correlated with export performance.

	Variables	Pearson Correlation	P-value	H ₁
Marketing strategy	Export share in a total sale (in %)	0.837**	0.000	Accepted

Note: Significance of variations is denoted as follows: *P < 0.05; **P < 0.01; ***P < 0.001.

Table 4. Correlation of marketing strategy with the export share in total sale

The importance given to the marketing strategy by surveyed companies was strongly positively correlated with export performance.

5. Results

This group of variables, including price, distribution, place, and promotion can directly indicate the export performance. During the last years, firms have been paying considerable attention to developing all these variables. Products design has positive effects on better performance, also differentiation attributes as quality, luxury, and prestige can lead to better performance [11]. All these advantages indicate the contribution of export to total profit. From the conducted research, the magnitude given to the marketing strategy by exporter SMEs surveyed was positively and strongly associated with export performance.

The results of this research open new horizons for future research. Understanding the actual situation of SMEs and the ways how they can reach better performance on exporting, helps to increase the relevance of the study and also to attain new findings. Using data from five hundred SMEs can give the best overall picture of exporting. A future research study can be focused on researching the companies from the preliminary step of the beginning of their export, which can help in reaching a better balance and more significant outcomes. The reason why exporting is important is thoroughly explained, however how to use this way of trading so that the companies can become more competitive in the market and show higher performance, stays behind merely as an optional question for further research.

6. Discussion

Based in literature review, this study provides some valuable insights related to marketing strategy. Findings indicate that marketing strategy including price, promotion, place and distribution and export performance have positive relationship. The conclusion identifies significant linkage for small and medium enterprises in Kosova.

7. Conclusion

This paper includes a summary of the contribution and implications of the study including research questions and research methodology. The personal suggestions of the researcher on this study expedition endow with concluding statements of this investigation. This study explores the relationship between some variables of SMEs as firm size, product innovation, and experience of firms in business that is called the age of industry; knowledge of the market in exporting product/services; marketing strategy including price, product, place, and promotion and export performance. To verify whether exporting is the first step in the process of internationalization, the findings of this study are linked with growing literature on exporting aspects. This also offered a more in-depth understanding of the relationship between variables used in the study and export performance. This paper is summarized with some specific

recommendations for the management of SMEs and for government institutions to increase the export performance in Kosovo.

Exporting companies continue to invest in marketing because it has been shown that the marketing variable, including the price, product, place, and distribution, has a positive impact on export performance. This is an excellent way to be closer to the customers, and as a unique way to continue selling products even abroad.

References

- [1] Amine, L., & Cavusgil, T. "Export marketing strategies in the British clothing industry," *European Journal of Marketing*. vol. 20, no. 7, pp. 21 - 33, 1986, doi: 10.1108/EUM0000000004653.
- [2] Axinn, C. "Export performance: do managerial perceptions make a difference?" *International marketing review*, vol. 5, no. 2, pp. 61 – 71, 1988 doi:10.1108/eb008353.
- [3] Bilkey, W. "An attempted integration of the literature on the export behaviors of firms" *Journal of International Business studies*, vol. 9, no. 1, pp. 33 -43. 1978, doi: www.jstor.org/stable/154631.
- [4] Beamish, P., & Munro, H. "The export performance of small and medium-sized Canadian manufacturers" *Canadian journal of administrative sciences/revue canadienne des sciences de l'administration*, vol. 3, no 1, pp. 29 – 45, 1983, doi: 10.1111/j.1936-4490.1986.tb00416.x.
- [5] Brouthers, L., & Nakos, G. "The role of systematic international market selection on small firms export performance". *Journal of small business management*, vol. 43, no. 4, 2005, doi: 10.1111/j.1540-627X.2005.00142.x.
- [6] Czinkota, Michael; Johnston, Wesley. "Exportin: does sales volume make a difference". *Journal of International Business Studies*, vol. 14, no. 1, 1983, pp. 147–53. JSTOR, <http://www.jstor.org/stable/154334>. Accessed 12 June 2022.
- [7] Causgil, T. "Differences among exporting firms based on their degree of internationalization". *Journal of business research*, vol. 12, no. 2, pp. 195 – 201, 1984, doi: 10.1016/0148-2963(84)90006-7.
- [8] Causgil, Tamer; Naor, Jacob. "Firm and management characteristics as discriminators of export marketing activity". *Journal of Business Research*, vol. 15, no. 3, pp. 220 – 240, 1987, doi: 10.1016/0148-2963(87)90025-7.
- [9] Cavusgil, T., & Zou, S. "Marketing strategy - performance relationship: an investigation of the empirical link in export market ventures". *The Journal of Marketing*, Vol. 58, no. 1, pp. 1-21, 1994. doi: 10.1177/002224299405800101.

- [10] Cooper, R. G., & Kleinschmidt, E. J. "The impact of export strategy on export sales performance". *Journal of International Business Studies*, Vol. 16, no. 1, pp. 35-37, 1985, <https://www.jstor.org/stable/154483>.
- [11] Czinkota, M., & Johnston, W. "Exporting: does sales volume make a difference?" *Journal of international business studies*, vol. 14, no. 1, 1983, pp. 147–53. JSTOR, <http://www.jstor.org/stable/154334>. Accessed 12 June 2022.
- [12] Diamantopoulos, A., & Schlegelmich, B. "Can Socio-Demographics still play a role in profiling green consumers? A review of the evidence and an empirical investigation". *Journal of Business Research*, 56(6), vol. 56, no. 6, pp. 465-480, 2003 doi: 10.1016/S0148-2963(01)00241-7.
- [13] Katsikeas, C. S., Leonidas, L., & Morgan, N. "Firm level export performance assessment review, evaluation and development". *Journal of the Academy of Marketing Science*, Vol. 28, no. 4, pp. 490-511, 2000. doi:/10.1177/0092070300284003.
- [14] Leonidou, L., Katsikeas, C., & Saeed, S. "Marketing strategy determinants of export performance: a meta analysis". *Journal of business research*, vol. 55, no. 1, pp. 52-62, 2002. doi:10.1016/S0148-2963(00)00133-8.
- [15] Madsen, K. "Successful export marketing management: some empirical evidence". *International Marketing Review*, vol. 6, no 4, pp. 13-18, 1989. doi: /10.1108/EUM0000000001518.
- [16] McGuinness, N., & Little, B. "The influence of product characteristics on the export performance of new industrial products". *The journal of marketing*, vol. 45, no 2, pp. 110-120, 1981, doi: 10.1177/002224298104500211.
- [17] McGuinness, N., & Little, B. "The influence of product characteristics on the export performance of new industrial products". *The journal of marketing*, vol. 45, no. 2, pp. 115-123, 1981, doi: 10.1177/002224298104500211.
- [18] Piercy, N., Kalela, A., & Katsikeas, C. "Sources of competitive advantage in high-performing exporting companies". *Journal of world business*, vol. 33, no. 4, pp. 183 – 185, 1999. doi: 10.1016/S1090-9516(99)80081-9.
- [19] Seringhaus, R., & Rosson, P. "Management and performance of interantional trade fair exhibitoria: government stands vs independent stands". *International marketing review*, vol. 15, no. 5, pp. 395-415, 1998, doi: 10.1108/02651339810236425.
- [20] Sousa, C., Martinez-Lopez, F. J., & Coelho, F. "The determinants of export performance: A review of the research in the literature between 1998 and 2005". *International journal of management reviews*, vol. 10, no. 4, pp. 343 – 374, 2008, doi: 10.1111/j.1468-2370.2008.00232.x.

- [21] Sousa, C., Martinez-Lopez, F. J., & Coelho, F. “The determinants of export performance: A review of the research in the literature between 1998 and 2005”. *International journal of management reviews*, vol. 10, no. 4, pp. 340 – 379, 2008, doi: 10.1111/j.1468-2370.2008.00232.x.
- [22] Wang, Q., Wang, Z. and Zhao, X. “Strategic Orientations and Mass Customization Capability: The Moderating Effect of Product Life Cycle”. *Int. J. Pro. Res.*, vol. 53, no. 17, pp. 5278 -5295, 2015, doi: 10.1080/00207543.2015.1027012.
- [23] Zou, S., Taylor, C. R., & Osland, G. E. “The EXPERF scale: a cross-national generalized export performance measure”. *Journal of international Marketing*, vol. 6, no. 3, pp. 37 – 58, 1998, doi: 10.1177/1069031X9800600307.

Measuring Customer Satisfaction Using Multi-Criteria Analysis Model of Customer Satisfaction to Evaluate Product Lines (Case Study: Kaveh Glass Industrial Group)

Maria Ali Yari

AliYari3@gmail.com

Ph.D. Student, Department of Management, South Tehran Branch, Islamic Azad University, Tehran, Iran

Mahmoud Modiri

mahm.modiri2@gmail.com

Assistant Professor, Department of Management, South Tehran Branch, Islamic Azad University, Tehran, Iran

Kaveh Khalili Damghani

Khalili.Damghani@gmail.com

Associate Professor, Department of Industrial Engineering, South Tehran Branch, Islamic Azad University, Tehran, Iran

Kiamars Fathi Hafshjani

k.FathiHafshjani@gmail.com

Assistant Professor, Department of Management, South Tehran Branch, Islamic Azad University, Tehran, Iran

Abstract

Today, customer retention and growth is the first goal. Companies have taken a heavy toll on each customer, and competitors are constantly seeking to steal them. Satisfied customers have many benefits for the company, they are less sensitive to prices, will be a customer for a long period of time, and give a favorable view of the company and its products and services to others. Paying attention to the factors that are less important from the customer's point of view and evaluating these factors leads to spending resources in areas that have less impact on customer behavior, so understanding the factors that have the greatest impact on customer satisfaction to the organization to move in this will help. In this study, we intend to use the operational data of the lines and customer satisfaction scales to evaluate the relative efficiency of product lines using the network data envelopment analysis method. In order to achieve this goal and quantify the data obtained from the questionnaire, another linear programming method called multi-criteria satisfaction analysis will be used. Another innovation of this research is the application of customer expectations in the data envelopment analysis mole because most researchers that focus on quality do not consider this component in their evaluation model. The results indicate that the distribution system is the most effective factor and resources and supply is the most effective factor affecting customer satisfaction.

Keywords: Customer Satisfaction, Multi-Criteria Satisfaction Analysis, Manufactured Products

1. Introduction

Currently, customer retention and growth are the first objectives. Companies have endured a heavy exaction to achieve each customer, and competitors are continuously attempting to steal them. Missing a customer does not mean losing next sales, but missing every customer provides a loss for the purchase of his/her whole life, and we also should regard the cost of obtaining a replacement customer [1], [2]. Customers experience various degrees of satisfaction and dissatisfaction after each experience based on the level of realizing their expectations or receiving services and goods that are beyond their expectations. Satisfaction is an emotional state, reactions after the purchase can include anger, dissatisfaction, excitement, impartiality, happiness, or passion [3], [4]. Considering the factors that are less important in terms of the customer and paying attention to these factors cause to spend resources in fields that insignificantly affect customer behavior, therefore, understanding properly the factors that significantly affect customer satisfaction will help the organization to move in this direction [5]. Findings explain that higher than 90% of a company's dissatisfied customers do not attempt to communicate with the company to provide a comment or criticism. These customers refer to competitors in order to satisfy their requirements and express their dissatisfaction with interest to other potential customers [6], [7]. Masters et al conducted several studies on 124 large American companies and the achieved results explained that 75% of these companies have explicitly stated the word customer satisfaction in their organization's mission statement. Customer satisfaction and the quality of an organization's product or service imply concepts that are truly related to each other, almost 65% of these statements utilized customer satisfaction more than the word quality of product or service. More than half of the mission statements (56%) have paid attention to customer service and approximately 46% of the statements have stressed the principle of customer orientation [8]. Studies conducted by Juran Institute in 1994 showed that about 90 percent of top executives in more than 200 large US companies accept that "improving customer satisfaction will increase our profitability and develop our market share in the competitive market." Approximately 90% of these companies have designated high capital and taken organized measures in order to follow up and improve customer satisfaction and have presented objective evidence for this claim [9], [10].

If paying attention to the satisfaction is increased and the methods of attracting and retaining them are identified and increased, in fact, we could take useful and beneficial steps in terms of the prosperity and dynamism of the company. Customer satisfaction results in repeated purchases or increases the visits for the purchase, and this customer loyalty increases the market share and profitability of the organization. Increasing customer loyalty will increase sales and will result in better financial performance [11], [12]. Currently, customer satisfaction has become a significant issue for organizations. The organization's success or failure is determined by the percentage of customers who the organization has retained [13]. Customer satisfaction is essential in shaping customers' future purchasing wishes. It is also possible that satisfied customers share their experiences with others, which is particularly important when social life has been designed in such a way to improve social interactions with

others in the population [14]. It is more beneficial to retain good customers in the long term compared to constantly attracting new customers in order to replace customers who have missed their relationship with the company. Customers who are extremely satisfied with the organization communicate their positive experiences to others and consequently, advertise for the organization. Consequently, it reduces the cost of attracting new customers. This is particularly valuable for professional service providers because others explain self-awareness and reputation and its advantages and positive points that can be a key source of information for new customers [15]. In fact, organizations and institutions' most significant task is customer satisfaction because it has a direct relationship with customer retention, market share, and the interests of the organization ([16]. Kadic et al. (2017) believe that customer satisfaction is one of the main columns in any business, particularly in the marketing division. Customer satisfaction is the best indicator of understanding the issue of the customer's future purchase and makes the company expected that it can count on satisfied customer's purchases in the future. A similar study conducted by Chang (2016) showed that loyal customers make 2.6 times more profits than customers with relative loyalty. Satisfaction plays a significant role in purchasing more and investing more customers in the product and declares that successful businesses are able to recognize the significance of the customer's life value. It has also been confirmed that obtaining a new customer costs 6 to 7 times higher than retaining a current customer. Consequently, all companies first attempt to make their current customers loyal in order to reduce their marketing costs, then think of new customers [17]. Although every successful marketer requires to provide a service that satisfies customers, this is not his/her only purpose. Companies are required to consider other main objectives of the businesses, such as producing a competitive profit or creating profits. Customer satisfaction provides many advantages to the company and higher levels of customer satisfaction make customers more loyal. Subsequently, it is more beneficial to retain good customers compared to constantly attracting new customers in order to replace a customer who has not purchased from the company anymore. Highly satisfied customers publish positive verbal advertisements and accordingly, become a moving spoken advertisement for the company, therefore, reduce the cost of attracting new customers. This is particularly significant for specialized service providers such as dentists, lawyers, and engineers because reputation and word of mouth are considered as the main sources of information for new customers [18].

Customer satisfaction extends the length of the customer survival period. Also, the spread of negative messages by dissatisfied customers of the organization will be minimized by concentrating on the principle of customer satisfaction. The disadvantage of missing a customer or the loss of a dissatisfied customer is much more serious because a dissatisfied customer can talk to many people and explain his/her dissatisfaction in a bad way. Also, as studies conducted by Melinda Goddard explain, expanding mass communication instruments and particularly, developing the World Wide Web communicate the negative verbal message of dissatisfied customers to everyone much faster than previously and with great exaggeration. Customers frequently choose suppliers to satisfy their requirements, consciously or unconsciously, who create the most customer satisfaction for the amount of money

paid for the product. Organizations will take a significant step in order to establish a customer-oriented business by spending the time and cost to evaluate current customer satisfaction [16]. Feedback is one of the essential factors in any process. Feedback can enable a process to adapt to environmental requirements and adjust its structure, production, and services. Accordingly, the organization to be able to guarantee the customers' satisfaction and apply their opinions and demands in the competition field to proceed with high self-confidence. It is possible that customer feedback directs us to optimal performance, therefore, it is required to establish a notable feedback mechanism in the first stage in order to identify the positive and effective points of the organization and also the negative and destructive points. Consequently, successful organizations are mainly required to establish feedback as one of their most basic necessities [15], [18].

There are limited resources of firms, hence, it is highly significant to apply these resources. Also, the way to spend these resources in order to satisfy customers' needs to identify the factors that have an effect on their satisfaction. Profitability is the ultimate objective of all companies and also there is a clear and substantial relationship between product quality, service, customer satisfaction, and profitability. Consequently, it is possible for the organization to meet its objective by considering the product and its customers and it is also highly significant for most companies to identify factors affecting customer satisfaction and the survival of organizations depends on identifying these factors and strengthening them [16].

The following table shows the summary of the research conducted in the fields of applying data envelopment analysis (DEA), fuzzy data envelopment analysis (FDEA), MUSA multi-criteria analysis, and satisfaction.

Satisfaction of Client	MUSA	FDEA	DEA	Year	Topic of Study	Reference
✓				2019	Determining the impact of employees' social identity on customer satisfaction in the hotel industry applying structural equation modeling	Rajabi
✓				2019	Surveying the classification of insurance customers in terms of satisfaction with insurance services applying data mining	Pooyan Far
✓				2018	Evaluating the status of communication skills of administrative staff and its relationship with customer satisfaction (teachers) Education and upbringing District 1 of Ardabil	Hosseini Nasab and Azimi Kohan
✓				2018	Surveying and determining the difference among the attitudes of regular customers and unstable customers to accurately determine satisfied and loyal customers	Fakhr Hosseini et al
			✓	2017	Evaluation of production lines of Iran Khodro Press Factory with data envelopment analysis technique	Maghsoud Amiri et al
			✓	2017	Evaluating the efficiency of Golbarg Baharan Company products with product development approach applying DEA data envelopment analysis	Reza Habibollah Garmabaki et al

			✓	2017	"Measuring the relative efficiency of forestry plans applying various hybrid scenarios in DEA data envelopment analysis	Majid Zad Mirzaei Soleimandara rabi
			✓	2017	Measuring the efficiency of bank branch management applying three-stage data envelopment analysis (Case study: Bank Melli Iran(	Roghayeh Mozaffari et al
		✓		2017	Evaluation of chosen performance of Iranian sports federations applying data envelopment analysis with approach to fuzzy systems	Simin Eskandari Dastgiri et al
		✓		2017	New model of fuzzy two-stage data envelopment analysis with variable-scale returns	Mohammad Javad Glij
✓				2020	Surveying the reasons for turning away from customers and finally canceling the insurance policy by customers	Parastoon et al
✓				2019	Development, analysis and applications of quantitative methods for evaluating customer satisfaction utilizing evolutionary optimization	Bandura et al
✓				2019	Time 1: Strategic utilization of the formal conscious half to improve customer satisfaction	Ford
✓				2018	The objective of determining customer satisfaction for the organization	Omayan et al
✓				2016	The field of business to increase customer satisfaction in academic libraries	Jayasandra
	✓			2015	Title of applying national component satisfaction analysis in the health care sector	Demitrus Doruy
	✓			2015	Multivariate customer satisfaction analysis with interaction metrics	Silvia
	✓			2013	Job Satisfaction of University Teachers: Multi-Criteria Satisfaction Analysis (MUSA) Method	Avadin
			✓	2011	Integration of data envelopment analysis, artificial neural network and anomalous set algorithm to measure the efficiency of bank staff	Alizadeh et al
✓	✓	✓	✓	2021	Present Study	

Table 1. Summary of research background studies

The studies conducted in papers related to the research subject explain that customer expectation components are applied as one of the inputs in the data envelopment analysis model. The multi-criteria customer satisfaction analysis model of evaluation is a hierarchical Analytical Hierarchy process in studies. In this analysis, the evaluation will be performed based on the combined model of Fuzzy DEMATEL Analytical Network Process networks. Because Analytical Network Process considers the complex relationships between decision elements by replacing the hierarchical structure and the network structure. Fuzzy sets are additionally utilized to cover uncertain decision-making states. The innovation of this research is to apply customer expectations in the data envelopment analysis model because most studies that concentrate on quality do not consider this component in their evaluation model.

Consequently, this study mainly aims to measure customer satisfaction employing a multi-criteria analysis model of customer satisfaction of Kaveh Industrial Group.

2. Research methodology

This study is applied in terms of the objective and is a kind of descriptive-analytical survey in terms of the type of research and data collection. Descriptive research describes and interprets everything and considers current circumstances, various approaches, current processes, tangible effects, or developing trends. It focuses fundamentally on the present, although it additionally examines past events and effects relate to the current circumstances. Descriptive research includes collecting information for the test by responding to questions related to the current studied circumstances. The survey research is conducted based on the generalization of information. The research method is a definite survey because it has been collected in a certain period of time. The spatial scope of this research is Kaveh Industrial Group in Iran. The time scope of this research is 25 months from 2019 to April 2020. The following four methods were applied in order to collect information and data:

1. This study is field research, consequently, the library method has been applied in order to collect information.

2. We also used interviews with academic and industry experts and also examined the content validity of the factors.

3. Three questionnaires were applied in order to collect research data using a field method.

- A. The first questionnaire is to select the effective factors in the customer survey in which experts responded to the significance of each factor based on the 5-point Likert scale and the fuzzy Delphi method was applied to screen them.

- B. The second questionnaire was employed to determine the relationships between the effective factors to solve the fuzzy dimethyl.

- C. The third questionnaire was employed to determine each index in which customers responded based on a 5-option scale and the method of multi-criteria satisfaction analysis was applied in order to solve it.

4. Data related to the past year and also customer surveys were employed in order to evaluate the product lines and data envelopment analysis technique was used to solve.

2.1. Validity and reliability of data collection instruments

Experts examined the validity of the questionnaire. To this end, the identified indices were referred to 10 university professors and 11 industry managers as a questionnaire. At this stage, some of the factors identified by experts were mixed, modified, removed, and added. A self-control mechanism was employed in order to examine the reliability of the fuzzy Delphi screening questionnaire with the difference in responses at 0.2 based on the experts' opinions. Two methods have been used to examine the reliability of the DEMATEL questionnaire. (Wang, 2012) with the response error less than 5% and it is possible to confirm it:

$$\frac{1}{n(n-1)} \sum_{i=1}^n \sum_{j=1}^n \frac{|t_{ij}^p - t_{ij}^{p-1}|}{t_{ij}^p} \times 100\% = 4.97\% < 5\%$$

Where, n is the number of sub-factors and t_{ij} is the aggregation of 21 expert's opinions.

The questionnaires were sent to customers in the form of 1000 questionnaires compared to the customers in the country after extracting the criteria and indices and organizing the questionnaire. 500 questionnaires were analyzed and other questionnaires that could not be analyzed were collected and deleted.

Data analysis method: Four fuzzy Delphi approaches, fuzzy DEMATEL approach, Fuzzy Analytical Network Process, and multi-criteria analysis of multi-criteria customer satisfaction analysis is used in this study. In general, Figure 1 shows the process of the DANP hybrid method:

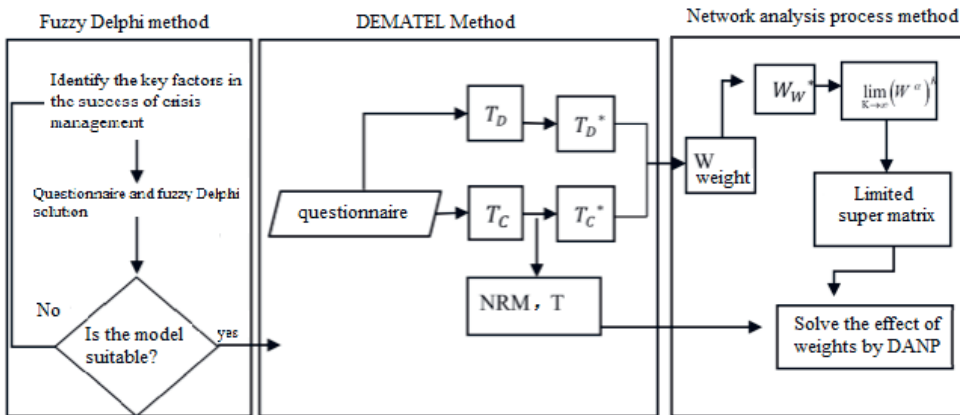


Figure 1. DANP hybrid problem-solving process

2.2. Multi-criteria analysis model of customer satisfaction

The multi-criteria satisfaction analysis model mainly aims to aggregate individual decisions in a set of value performances. Assuming that the customer satisfaction based on a set of criteria or variables indicates the dimensions of service features, each customer is invited to explain his/her opinion on the overall satisfaction with the services provided based on this model and also explain his/her opinion based on a set of separately defined criteria in order to measure satisfaction (Haghighi Nasab, 2008).

The main objective of the MUSA method (multi-criteria customer satisfaction analysis) is to combine customer judgment into a collective value function assuming that overall customer satisfaction is based on a set of n criteria that create customer satisfaction criteria. The set of criteria is presented with $X = (x_1, x_2, \dots, x_n)$. Six criteria have been utilized in this research to measure customer satisfaction of Kaveh Glass Industrial Group as follows:

x_1	x_2	x_3	x_4	x_5	x_6
Customer Communication	Price	Customer complaint	Loyalty	Product quality	The quality of service

Table 2. Customer Satisfaction Criteria

Accordingly, customers reveal their judgment about the general satisfaction of Kaveh Glass Industrial Group and also a set of satisfaction criteria (x_i) in the form of a questionnaire with distance scales. The multi-criteria customer satisfaction analysis method that observes the rules of sequential regression analysis tries to create the maximum agreement between general customer satisfaction and satisfaction criteria by inferring the collective value function of total satisfaction (Y^*) and the set of functions of satisfaction criteria (X_i^*) (Mehregan et al. 2013). The multi-criteria customer satisfaction analysis sequential regression analysis equation has the following model:

$$Y^* = \sum_{i=1}^n b_i X_i^* \quad (1)$$

$$st: \sum_{i=1}^n b_i = 1 \quad (2)$$

Where, the values of the functions Y^* and X_i^* have been normalized in the range [0-100] and b_i is the i th standard weight.

According to the presented model and introducing a pair of error variables, the sequential regression equation will be as follows:

$$Y^{\sim*} = \sum_{i=1}^n b_i x_i^* - \sigma^+ + \sigma^- \quad (3)$$

Where, $Y^{\sim*}$ are the estimations of some general functions of Y^* , σ^+ , and σ^- are high estimation error and low estimation error, respectively. Formula (3) is considered for each customer and explains a set of satisfaction judgments. Accordingly, it is required that a pair of error variables be assessed separately for each customer (Grigoroudis & Siskos 2010).

y	General customer satisfaction
α	Number of levels (response options) General customer satisfaction
y^m	Level (option) of m th in general satisfaction ($m = 1, 2, \dots, \alpha$)
z_m	Distance between m and $m + 1$ levels in total satisfaction
n	Number of satisfaction criteria (dimensions)
x_i	Partial customer satisfaction in the i th criterion ($i = 1, 2, \dots, n$)
α_i	Number of levels (response options) of satisfaction in the i th criterion
x_i^k	Level (option) of k th in the i th criterion ($k=1, 2, \dots, \alpha_i$)
w_{ik}	The distance between the levels k and $k + 1$ in the i -th criterion
y^*	The value of the function y
y^{*m}	value of y^m (level m th in total satisfaction)
x_i^*	The value of the x_i function

x_i^{*k}	Value x_i^k (kth level in ith standard)
M	Number of customers
y^j	Selection option of customer jth in total satisfaction ($j = 1, 2, \dots, M$)
x_i^j	Selection option of customer jth in the ith criterion ($j = 1, 2, \dots, M$)
σ^+	High estimation error
σ^-	Low estimation error

Table 3. Variables used in the multi-criteria customer satisfaction analysis method

The model of multi-criteria satisfaction analysis in the form of ideal linear programming is ultimately presented as follows, in which the variables of deviation from the ideal determine the degree of deviation of the combination of satisfaction criteria of total satisfaction per jth customer. (Mehregan et al., 2013)

$$\text{Min} F = \sum_{j=1}^M \sigma_j^+ + \sigma_j^- \quad (4)$$

$$S \cdot t \cdot$$

$$\sum_{i=1}^n \sum_{k=1}^{x_j^{i-1}} w_{ik} - \sum_{m=1}^{y_j^{j-1}} z_m - \sigma_j^+ + \sigma_j^- = 0 \quad \text{for } j = 1, 2, \dots, M \quad (5)$$

$$\sum_{m=1}^{\alpha-1} z_m = 100 \quad (6)$$

$$\sum_{i=1}^n \sum_{k=1}^{\alpha_j^{j-1}} w_{ik} = 100 \quad (7)$$

$$z_m \geq 0, w_{ik} \geq 0 \quad \forall m, i, k \quad (8)$$

$$\delta_j^+ \geq 0, \delta_j^- \geq 0 \quad \text{for } j = 1, 2, \dots, M \quad (9)$$

This model uses the distances between the response options instead of using the response values of the questions due to the rank of the scale of the data obtained from the questionnaire. Consequently, the first response option of each question has a value of zero and from the second option, the distance variable (w_{ik}) between the ith standard options ($k + 1$) indicates the w_{ik} distance variable. It is considered that the sum of all distance variables in the ith criterion is 100%. The measuring scale is normalized at a distance of 0 to 100 for the ith satisfaction criterion and also total satisfaction.

$$x_i^1 = 0 \quad w_{i1} \quad x_i^2 \quad w_{i2} \quad x_i^3 \quad \dots \quad x_i^k$$

$$w_{ik} x_i^{k+1} = 100$$

According to the results, if the respondent prefers an option in the range completely disagree to completely agree for the ith criterion, w_{ik} will be considered relevant to his/her option. For example, if the option of the somewhat agree is selected for the ith criterion, the intervals $w_{i1} + w_{i2}$ will be considered. In this model, a constraint is generated for each customer, in which, jth customer's response has been considered to all n criteria in the form of a linear combination and its deviation from the value of the intervals of the criterion of total satisfaction (z_m) that has been exactly developed like w_{ik} , is recognized by the deviation of the ideal variables (σ_j^+, σ_j^-). The

model aims to minimize deviations from the ideal of total customers by specifying proper values to the intervals of the scale. In this model, M denotes the number of customers. The variable y^j describes the option that the customer j th has been selected in the criterion of total satisfaction and x_i^j describes the option that the customer j th has been selected for the criterion i th. For example, if the fifth customer ($j = 5$) adopts the option of somewhat agree for the first criterion ($i = 1$), the value model $x_{i=1}^{j=5}$ will be equal three, which describes the sum of the first two distance variables of criterion 1 that means $w_{11} + w_{12}$. The model has been solved optimally solving and the optimal values of the distance variables have been determined and a distance measurement scale has been then obtained in which the final value of all levels of satisfaction and total satisfaction criteria have been determined in the optimal state with the least deviation in terms of all customers. The value of the value per k th level in the i th criterion is calculated through the Equation $x_i^{*k} = 100 \sum_{t=1}^{k-1} w_{it} / \sum_{t=1}^{\alpha_j-1} w_{it}$ and is calculated through the Equation $Y^{*m} = \sum_{t=1}^{m-1} z_t$ to measure the total satisfaction (Grigoroudis & Siskos, 2010).

This $M + 2$ linear programming model is a variable constraint of $2m + (\alpha - 1) + \sum_{i=1}^n (\alpha_i - 1)$. Accordingly, the multi-criteria customer satisfaction analysis method creates a value system between satisfaction and total customer satisfaction criteria and estimates the distances of the scale and the weight values of satisfaction criteria using the equation $b_i = \sum_{t=1}^{\alpha_i-1} w_{it} / 100$. (Mehregan et al., 2013)

The initial variables of the model are calculated based on the optimal solution of the previous LP (Grigoroudis & Siskos, 2010).

$$b_i = \frac{1}{100} \sum_{t=1}^{\alpha_i-1} w_{it} \text{ for } i = 1.2. \dots n \quad (10)$$

$$y^{*m} = \sum_{t=1}^{m-1} z_t \text{ for } m = 2.3. \dots \alpha \quad (11)$$

$$x_i^{*k} = 100 \frac{\sum_{t=1}^{k-1} w_{it}}{\sum_{t=1}^{\alpha_i-1} w_{it}} \text{ for } i = 1.2. \dots n \text{ and } k = 2.3. \dots \alpha_i \quad (12)$$

3. Results

3.1. Evaluating and selecting the factors

Customer satisfaction indices were extracted by examining the theoretical literature and various papers and holding meetings with experts in order to identify the effective factors. To this end, a questionnaire with 41 questions (each question represents a variable) was designed and 21 questionnaires were provided to the respondents that all questionnaires were collected comprehensive and complete. These questionnaires have been designed qualitatively based on 5 Likert scales from extremely high to extremely low. Currently, the fuzzy Delphi method is applied after distributing and collecting the questionnaire in order to determine the most significant factors that we have explained its steps in the following part.

Accordingly, experts selected 6 main factors with 24 effective indices in customer polling, and we drew a model with a network structure in three rounds of polling, which Figure 2 shows it.

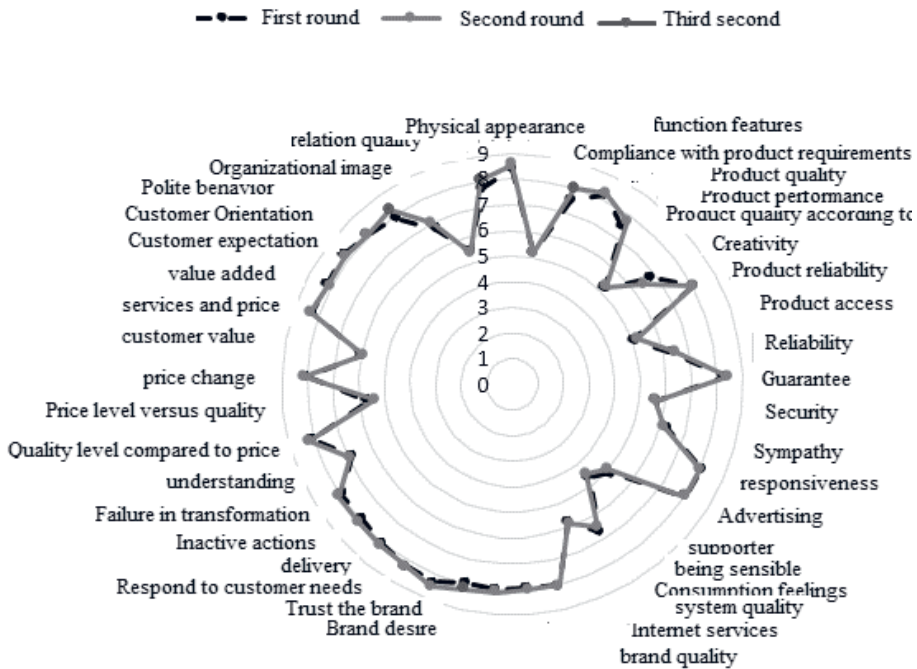


Figure 2. Average of expert opinions using fuzzy Delphi for screening customer satisfaction indices

Also, Table 4 shows the effective factors and sub-factors in improving customer satisfaction performance in order to evaluate product lines.

Sign	Subscribers	Main factors
C11	Physical appearance	C1 Product quality
C12	Product quality produced	
C13	Compliance with product requirements	
C14	Product reliability	
C21	Guarantee	C2 Services quality
C22	Security	
C23	responsiveness	
C24	Internet services	
C31	Brand quality	C3 loyalty
C32	Brand loyalty	
C33	Willingness to repurchase	
C34	the trust	
C41	Lack of response to customer needs	C4

C42	Timely delivery Delivery failure Passive and irresponsible action	Client complaint
C43		
C44		
C51	Price versus quality Price change Price Value Added	C5 price
C52		
C53		
C54		
C61	Customer expectation Customer Orientation Polite behavior Quality of relationships	C6 Relation with client
C62		
C63		
C64		

Table 4. Factors affecting the performance of customer satisfaction in order to evaluate product lines

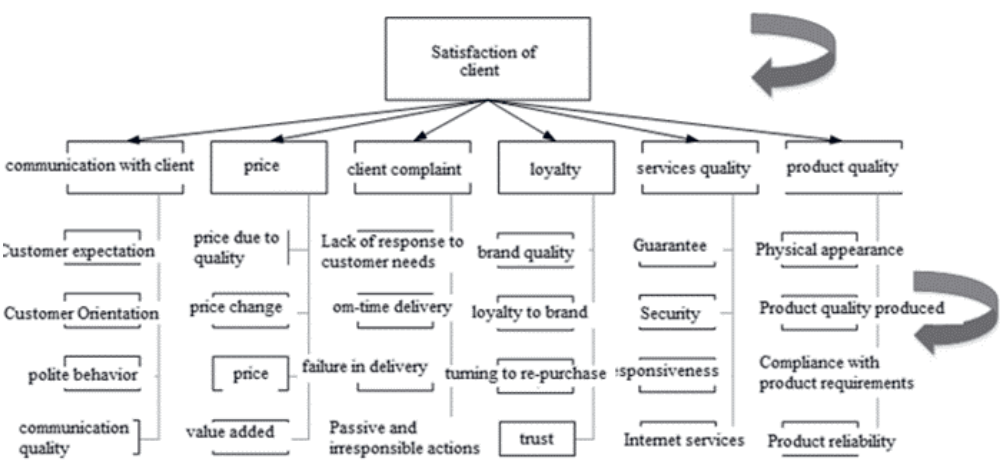


Figure 3. Network structure model

3.2. Results of fuzzy DEMATEL

5 verbal expressions have been used to compare factors with each other that Table 5 shows the names of these expressions and their equivalent fuzzy values.

Triangular fuzzy numbers	Definitive numbers	Language options
(0/75 ,1 ,1)	4	Too much impact
(0/5 ,0/75 ,1)	3	high impact
(0/25 ,0/5 ,0/75)	2	Low impact

(0 ,0/25 ,0/5)	1	Very little impact
(,0 ,0 ,0/25)	0	No effect

Table 5. Language options and fuzzy numbers in order to measure the intensity of effects

9 experts' opinions have been used in order to investigate the factors. In these matrices, $\tilde{x}_{ij} = (l_{ij}, m_{ij}, u_{ij})$ are triangular fuzzy numbers and $\tilde{x}_{ii} = (i = 1, 2, 3, \dots, n)$ are considered as Fuzzy numbers (0,0,0). We take an arithmetic average to consider the opinion of all experts according to the formula 1-4.

$$\tilde{z} = \frac{\tilde{x}^1 \oplus \tilde{x}^2 \oplus \tilde{x}^3 \oplus \dots \oplus \tilde{x}^p}{p} \quad (1-4)$$

In this formula, p is the number of experts and $\tilde{x}^1, \tilde{x}^2, \dots, \tilde{x}^p$ are the matrix comparison pairs of expert 1, expert 2 and expert p, respectively, and $\tilde{z}$ is a triangular fuzzy number in the form of $\tilde{z}_{ij} = (l'_{ij}, m'_{ij}, u'_{ij})$. Table 7 presents the average pairwise comparisons for the main factors and Table 8 for the following factors: We use formulas 2-4 and 3-4 in order to normalize the achieved matrix.

$$\tilde{H}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left(\frac{l'_{ij}}{r}, \frac{m'_{ij}}{r}, \frac{u'_{ij}}{r} \right) = (l''_{ij}, m''_{ij}, u''_{ij}) \quad (2-4)$$

Where r is obtained using the following equation:

$$r = \max_{1 \leq i \leq n} (\sum_{j=1}^n u_{ij}) \quad (3-4)$$

After calculating the above matrices, the matrix of fuzzy total equations is obtained using formulas 4-4 to 7-4.

$$T = \lim_{k \rightarrow +\infty} (\tilde{H}^1 \oplus \tilde{H}^2 \oplus \dots \oplus \tilde{H}^k) \quad (4-4)$$

A fuzzy number is as $\tilde{t}_{ij} = (l^t_{ij}, m^t_{ij}, u^t_{ij})$ in each element and is calculated as follows:

$$[l^t_{ij}] = H_l \times (I - H_l)^{-1} \quad (5-4)$$

$$[m^t_{ij}] = H_m \times (I - H_m)^{-1} \quad (6-4)$$

$$[u^t_{ij}] = H_u \times (I - H_u)^{-1} \quad (7-4)$$

In these formulas, I is a single matrix, and H_l, H_m and H_u are $n \times n$ matrices whose elements are the lower number, middle number, and an upper number of the triangular

fuzzy numbers of the H matrix, respectively. Table 10 presents the t-matrix for the principal factors and for the sub-factors.

The next step is to calculate the sum of the rows and columns of the matrix $\tilde{T}$. The sum of rows and columns is calculated according to formulas 8-4 and 9-4.

$$\tilde{D} = (\tilde{D}_i)_{n \times 1} = [\sum_{j=1}^n \tilde{T}_{ij}]_{n \times 1} \quad (8-4)$$

$$\tilde{R} = (\tilde{R}_i)_{1 \times n} = [\sum_{i=1}^n \tilde{T}_{ij}]_{1 \times n} \quad (9-4)$$

Where $\tilde{D}$ and $\tilde{R}$ are the matrices $n \times 1$ and $1 \times n$, respectively.

The next step is to determine the significance of the indices $(\tilde{D}_i + \tilde{R}_i)$ and the relationship between the criteria $(\tilde{D}_i - \tilde{R}_i)$. If $\tilde{D}_i - \tilde{R}_i > 0$, the relevant criterion will be effective, and if $\tilde{D}_i - \tilde{R}_i < 0$, the relevant criterion will be effective. In the next step, we will perform the defuzzification of the fuzzy numbers $\tilde{D}_i + \tilde{R}_i$ and $\tilde{D}_i - \tilde{R}_i$ achieved by the previous step according to the formula 10-4.

$$B = \frac{(a_1 + a_3 + a_2)}{3} \quad (10-4)$$

B is diffused form of the number $\tilde{A} = (a_1, a_2, a_3)$. Table 10 shows the diffused numbers of values of effect ($\tilde{D}$), effectiveness ($\tilde{R}$), significance ($\tilde{D} + \tilde{R}$) and net effect and effectiveness ($\tilde{D} - \tilde{R}$) for the main factors and for the sub-factors.

Result	$\tilde{D} - \tilde{R}$	$\tilde{D} + \tilde{R}$	$\tilde{R}$	$\tilde{D}$	Main factors
Effective	0.167	5.436	2.635	2.802	Communicational
Effective	0.222	5.018	2.398	2.62	Manpower
The most effective	-0.81	5.312	3.063	2.25	Distribution system
Influential	-0.12	5.961	3.043	2.918	Production system
The most effective	0.369	4.072	1.851	2.221	Resources and supplies
Effective	0.18	5.447	2.634	2.813	Environmental

Table 6. Significance and effectiveness of the main injury

As Table 6 shows, if the value of $\tilde{R} - \tilde{D}$ is positive for an index, that index will be effective, and if the value of $\tilde{R} - \tilde{D}$ is negative, that index will have affectability; consequently, "price" with an effective value of 0.369 is the most effective among the main factors and "loyalty" with a net effect value of -0.81 has the most affectability. In general, positive $\tilde{R} - \tilde{D}$ is considered the causal factor and negative $\tilde{R} - \tilde{D}$ is considered the effected factor. Accordingly, the factors of "price", "service quality", "customer relationship", "and product quality" are the cause and which direct more and are less dependent. The factors of "customer complaint" and "loyalty" are affected factors, which are affected by causal factors. These factors are highly dependent and direct in less value. Table 7 also shows the value $\tilde{R} - \tilde{D}$ for the sub-factors.

Main factors	Sub-factors	Abbreviation	0.094	0.069	0.164	0.0253	Result
Product quality	Physical appearance	C11	0.094	0.069	0.164	0.0253	effective
	Product quality produced	C12	0.201	0.193	0.393	0.0078	effective
	Compliance with product requirements	C13	0.19	0.218	0.409	-0.028	influential
	Product reliability	C14	0.176	0.181	0.357	-0.0051	influential
the quality of service	Guarantee	C21	0.119	0.152	0.271	-0.0328	influential
	Security	C22	0.125	0.115	0.24	0.0107	effective
	responsiveness	C23	0.1	0.081	0.181	0.0196	effective
	Internet services	C24	0.039	0.037	0.076	0.0025	effective
Loyalty	Brand quality	C31	0.214	0.189	0.403	0.0248	effective
	Brand loyalty	C32	0.203	0.223	0.427	-0.0201	influential
	Willingness to repurchase	C33	0.249	0.289	0.539	-0.0404	influential
	trust	C34	0.244	0.208	0.452	0.0358	effective
Customer complaint	Lack of response to customer needs	C41	0.172	0.243	0.415	-0.0714	influential
	On-time delivery	C42	0.208	0.194	0.403	0.0142	effective
	Delivery failure	C43	0.247	0.216	0.462	0.031	effective
	Inactive and irresponsible actions	C44	0.263	0.236	0.499	0.0262	effective
Price	Price versus quality	C51	0.173	0.155	0.328	0.0179	effective
	Price change	C52	0.164	0.174	0.338	-0.0104	influential
	price	C53	0.163	0.175	0.338	-0.012	influential
	Value added	C54	0.042	0.037	0.079	0.0045	effective
Communi- cation with client	Customer expectation	C61	0.236	0.248	0.484	-0.0115	influential
	Customer Orientation	C62	0.226	0.235	0.462	-0.0091	influential
	Polite behavior	C63	0.186	0.179	0.365	0.0074	effective
	Quality of relationships	C64	0.186	0.173	0.359	0.0132	effective

Table 7. Significance and effectiveness of sub-injuries

Figure 4 also shows the significance and effectiveness between factors. The horizontal axis of the diagram shows the significance of the factors and the vertical axis shows the effectiveness or affectability of the factors. In this figure, the diagram shows the center of relationships and the way to interact between the main factors that the way

of the interactions between their sub-factors have been also determined. As this figure shows, price affects other factors and affects "service quality", "customer relationship", "product quality", "customer complaint" and "loyalty", respectively.

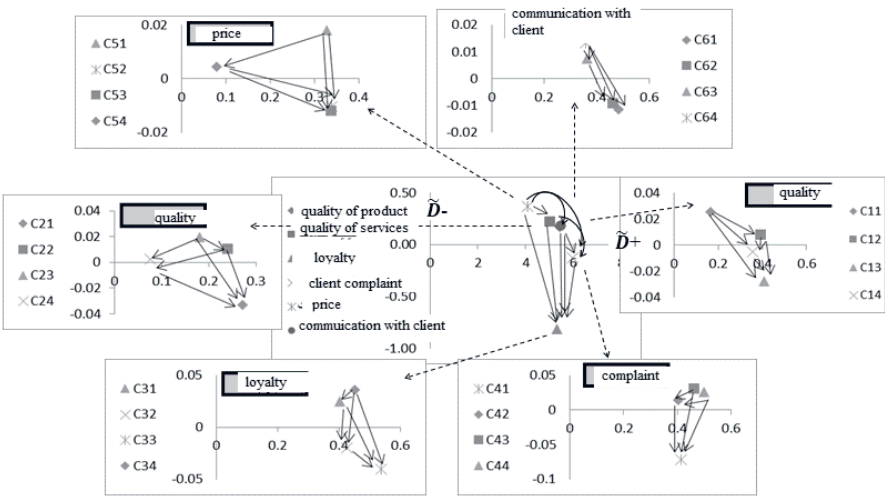


Figure 4. cause-and-effect-relationships diagrams and relationships among the following factors

3.3. Results of the fuzzy network analysis process

Finally, we calculated the weight of factors and sub-factors by obtaining the limit supermatrix, which is shown in Table 8.

Weight and priority of the main factors	Sub-factors	Code	Weight and relative priority under the factors		Weight and final priority under the factors	
Product quality 0.156 (4)	Physical appearance	C11	0.0682	4	0.0116	22
	Product quality produced	C12	0.3094	2	0.0528	8
	Compliance with product requirements	C13	0.3397	1	0.0579	6
	Product reliability	C14	0.2828	3	0.0482	10
Services quality 0.172 (5)	Guarantee	C21	0.3965	1	0.0598	5
	Security	C22	0.2645	3	0.0399	14
	responsiveness	C23	0.2961	2	0.0447	12
	Internet services	C24	0.0429	4	0.0065	23
Loyalty 0.182 (2)	Brand quality	C31	0.1817	4	0.0361	15
	Brand loyalty	C32	0.2048	3	0.0406	13
	Willingness to repurchase	C33	0.3823	1	0.0759	2

	trust	C34	0.2312	2	0.0459	11
Client complaint 0.2 (1)	Lack of response to customer needs	C41	0.2409	3	0.0495	9
	On-time delivery	C42	0.172	4	0.0354	16
	Failure in delivery	C43	0.3263	1	0.0671	3
	Inactive and irresponsible actions	C44	0.2608	2	0.0536	7
Price 0.177 (6)	Price versus quality	C51	0.2907	3	0.0288	19
	Price change	C52	0.3271	2	0.0324	18
	price	C53	0.3324	1	0.0329	17
	Value added	C54	0.0498	4	0.0049	24
Communication with client 0.112 (3)	Customer expectation	C61	0.4731	1	0.083	1
	Customer Orientation	C62	0.3491	2	0.0612	4
	Polite behavior	C63	0.0898	3	0.0158	20
	Quality of relationships	C64	0.088	4	0.0154	21

Table 8. The weight and significance of improving the factors affecting the performance of customer satisfaction in order to evaluate product lines

As Table 8 shows, the factor of "customer complaint" with a weight of 0.206 has the most weight and significance among the main factors. Furthermore, the highest weight is related to the "customer expectation" factor among the sub-factors, which has the first priority. The factor of "willingness to repurchase" has the second priority, "failure to deliver" has the third priority, "customer orientation" has the fourth priority and guarantee has the "fifth priority" and eventually, "conformity with product requirements" has the sixth priority among 24 sub-factors that approximately allocated 40.49% of the total weight of the sub-factors and this issue explains the high significance of these sub-factors.

3.4. Results of the modified multi-criteria customer satisfaction analysis method

One of the main assumptions of the multi-criteria customer satisfaction analysis method is that the satisfaction sub-criteria have no interfering effects on each other and are completely independent and while in fact, the satisfaction sub-criteria have interfering effects on each other and are not independent of each other and influence each other. Consequently, it is required to determine these interference effects in the model and it is possible to determine these interference effects in two ways. A) by asking customers and b) by asking experts in the field of satisfaction.

It is possible that customers have no information about the way of the interaction and effects of sub-criteria in a multi-criteria decision problem and it is also possible that customers do not consider attractive completing separate questionnaires in order to determine the interaction effects between criteria, hence, we use method b in this

study that is, questioning experts in order to determine the interactions of the satisfaction sub-criteria.

Consequently, DEMATEL and FANP techniques are applied in order to calculate relative weights of the satisfaction sub-criteria. Presently, we experience a problem including that if we use the standard multi-criteria customer satisfaction analysis method to calculate the sub-criteria weights of satisfaction, we will only consider the customers' opinion (which is correct and reasonable) and if we employ the mixed method of DEMATEL and FANP, we will only consider the experts' opinion.

We plan to modify the MUSA method in such a way in this section that it can consider the opinion of experts and also the experts' opinions. In fact, we enable it to achieve information from customers outside the organization as input, and also from the interference effects of these sub-criteria hidden in the output of DEMATEL and FANP and displayed in W_i , $i = 1, \dots, n$ values in order to determine the weights of satisfaction criteria. To this end, we should maintain all the previous definitions for the parameters and we are also required to consider the decision variables of the modified MUSA mixed model as follows.

$$\text{Min } F = \sum_{j=1}^M (\sigma_j^+ + \sigma_j^-) + \sum_{i=1}^n (d_i^+ + d_i^-)$$

s.t.

$$Y_j^* = \sum_{i=1}^n b_i X_{ij}^* - \sigma_j^+ + \sigma_j^-, \quad j = 1, \dots, M$$

$$a_{i'i} \times b_i - d_i^+ + d_i^- = 0, \quad i', i = 1, \dots, n, i' \neq i$$

$$\frac{w_{i'}}{w_i} = a_{i'i}, \quad i', i = 1, \dots, n, i' \neq i$$

$$\sum_{i=1}^n b_i = 1$$

$$\sigma_j^+ \geq 0, \quad j = 1, \dots, M$$

$$\sigma_j^- \geq 0, \quad j = 1, \dots, M$$

$$b_i \geq 0, \quad i = 1, \dots, n$$

The parameters and symbols are introduced as follows in the above model.

Indices and sets:

j: is the customer counter

M: Number of customers who have completed the satisfaction questionnaire.

i: The satisfaction counter

n: Number of satisfaction sub-criteria

Parameters: Y_j^* : The level of overall satisfaction of customer jth about the product or service (quality values that are obtained through a questionnaire and quantified with a range between 0 and 100).

X_{ij}^* : The level of overall satisfaction of customer j th in I sub-criterion about the product or service (quality values that are obtained through a questionnaire and quantified with a range between 0 and 100).

w_i : The weight of criterion i th that has been obtained using FANP method.

$a_{i'i}$: : The weight ratio of criterion i th and criterion i' that have been obtained using FANP.

Decision variables:

b_i : Decision variables indicate the weight or relative significance of the i -th sub-criterion of satisfaction

σ_j^+ : The decision variable is the amount of positive deviation in terms of the customer's opinion j th about the sub-criteria of satisfaction (overestimation)

σ_j^- :: The decision variable is the amount of negative deviation in terms of the customer's opinion j th about the sub-satisfaction criteria (underestimation)

d_i^+ :: The decision variable is the amount of positive deviation from the weight obtained from the i th criterion of FANP output (overestimation)

d_i^- : : The decision variable is the amount of negative deviation from the weight obtained from the i th criterion of FANP output (overestimation)

The weights achieved by the above-modified model consider both opinions explained by goods and services customers who are the final consumers of goods and services and their opinions on the significance of satisfaction sub-criteria are important and also consider the opinions explained by satisfaction experts that examined the network structure between satisfaction sub-criteria and try to minimize the total deviation in terms of the different opinions explained by customers and the judgments explained by experts.

The optimal value of decision variables $b_i^*, i = 1, \dots, n$ is calculated after solving the above model. This value really shows the weight of the satisfaction sub-criteria in such a way that the target variance is calculated at its lowest value. This means, the amount of positive and negative deviations in terms of the j th customer's opinions and the amount of positive and negative deviations according to the outputs of the weights obtained from FANP in the case of satisfaction sub-criteria is the minimum possible value and in fact, the weights of the satisfaction sub-criteria have been determined in such a way that a collective decision has been made according to the opinion of all customers and experts and paying attention to the network structure and interaction between the sub-criteria. Using the optimal amount $b_i^*, i = 1, \dots, n$

and using the formula
$$Y_j = \sum_{i=1}^n b_i X_{ij}, \quad j = 1, \dots, M$$
, it is possible to calculate the

total satisfaction of each customer according to the mentioned conditions, and also calculate the amount of overall satisfaction using the formula:

$$Y = \frac{\sum_{j=1}^M Y_j}{M}$$

3.5. Measuring customer satisfaction

After gathering data due to the questionnaire completed by 500 customers in 4 kinds of products of Kaveh Industrial Group, the modified MUSA model was implemented applying LINGO 11 software and the average findings of customer satisfaction were separately presented. In the figure below, the numbers on the right are due to the weight of criteria and the numbers on the left are due to the average (geometric) scores of the customers of criteria.

Customer satisfaction	Evaluation period	Customer satisfaction	Evaluation period	Customer satisfaction	Evaluation period
0.88	19	0.90	10	0.90	1
0.90	20	0.88	11	0.88	2
0.85	21	0.85	12	0.86	3
0.88	22	0.89	13	0.89	4
0.90	23	0.87	14	0.88	5
0.89	24	85.	15	0.84	6
0.88	25	0.88	16	0.87	7
Total satisfaction 0.88		0.90	17	0.89	8
		0.84	18	0.87	9

Table 9. Results of Method

4. Conclusion

Nowadays, customer survey is so significant in evaluating product lines. The objective of this research was to identify the appropriate hybrid model of DEA/MCDM to identify the relationship between customer satisfaction, employee assessment and financial performance in Kaveh Industrial Group. First, reviewing the theoretical literature of study, the dimensions of customer satisfaction were determined and dimensions were determined. Then, the dimensions were screened by university and industry experts applying fuzzy Delphi method and finally 6 indicators and 24 criteria were chosen. These indicators are as follows:

- Product quality (physical appearance, product quality, compliance with product requirements, product reliability)
- Quality of service (guarantee, security, accountability, internet service)
- Customer loyalty (brand quality, brand loyalty, willingness to repurchase, trust)

- Customer complaint (lack of response to customer needs, timely delivery, failure to deliver, irresponsible and irresponsible actions)
- Price (price against quality, price change, price, value added)
- Customer relationship (customer expectation, customer orientation, polite behavior, quality of relationships)

References

- [1] Bendaru, F., Berry, M. J. A., Gordon, L. (2019). Customer Support Modeling Approach for Measuring Demands. *Wiley publishing Inc.*
- [2] Chang, J. C. (2016). Customer satisfaction with tour leaders' performance: A study of Taiwan's package tours. *Asia Pacific Journal of Tourism Research*, 11(1), 97-116.
- [3] Cheng, Ching-Hsue & Lin, Yin. (2002). Evaluating the best mail battle tank using fuzzy decision theory with linguistic criteria evaluation, *European Journal of Operational Research*, vol.142, p.147.
- [4] Dabestani, R., Shahin, A., Saljoughian, M., Shorouyезд, H., (2016). Importance-performance analysis of service quality dimensions for the customer groups segmented by DEA, *International Journal of Quality & Reliability Management*.
- [5] El-Adly, (2018). M.I. Modelling the relationship between hotel perceived value, customer satisfaction, and customer loyalty, *Journal of Retailing and Consumer Services*.
- [6] Fecikova, D. A. (2019). Competing on the eight dimensions of quality, *Harvard Business Review*, Vol. 65 No. 6, pp. 101-109.
- [7] Ford, D. A. (2019). Competing on the eight dimensions of quality, *Harvard Business Review*, Vol. 65 No. 6, pp. 101-109.
- [8] Grigoroudis, E. Siskos, Y. (2010). Customer Satisfaction Evaluation: Methods for Measuring and Implementing Service Quality. *London*, Springer.
- [9] Hao, S., Shi, F., Hao, Q., (2019). Research on the Optimization of DEA Based on the Perspective of Customer Satisfaction, *Advances in Social Science, Education and Humanities Research*, volume 385.
- [10] Howar, D., Assakar, T. Y. (2013). Using data envelopment analysis to measure hotel managerial efficiency change in Taiwan, *Tourism Management*, Vol. 24 No. 4, pp. 357-369.
- [11] Iglesias, O., Markovic, S., Rialp, J., (2019). How does sensory brand experience influence brand equity? Considering the roles of customer satisfaction, *Journal of Business Research*, Volume 96, March 2019, Pages 343-354.

- [12] Kumar, A. & Dixit, G. (2018). Evaluating critical barriers to implementation of WEEE management using DEMATEL approach. Resources. *Conservation & Recycling*, 131, 101-121.
- [13] Lovelock, S. (2020). The co-creation continuum: From tactical market research tool to strategic collaborative innovation method. *Journal of Brand Management*, 24(4), 310–321.
- [14] Omayan, A. C., Smith, K. A., Willis, R. J., Brooks, M. (2018). Modelling the Effect of Premium Changes on Motor Insurance Customer Retention Rates Using Neural Networks. *PUBLISHED IN: Proceeding ICCS '01 Proceedings of the International Conference on Computational Science-Part II* Pages 390-399.
- [15] Preston, E., Bailom, F., Hans, H. (2020). Hinterhuber -The kano model: how to delight your customers - *International working seminar on production economics* - Innsbruck/igls/Austria, vol. 1, no.4, pp. 313-327.
- [16] Serhan, M., Serhan, C., (2019). The Impact of Food Service Attributes on Customer Satisfaction in a Rural University Campus Environment, *International Journal of Food Science* Volume 2019, 12-24.
- [17] Yussof, N. M., Nayan, M., Syafigah, S., (2020). Review on customer satisfaction, *Journal of Undergraduate Social Science and Technology*, 2 (2).
- [18] Wang, F. K., Hsu, C. H. & Tzeng, G. H. (2012). The best vendor selection for conducting the recycled material based on a hybrid MCDM model combining DANP with VIKOR. Resources. *Conservation and Recycling*, 66, 95-111.

Forms and conversions of the economic capital of Croatian entrepreneurs in the computer programming industry with insights into variations of the company's development stages

Tamara Šmaguc

tamara.smaguc@foi.unizg.hr

*University of Zagreb, Faculty of
Organization and Informatics, Varaždin, Croatia*

Ksenija Vuković

ksenija.vukovic@foi.unizg.hr

*University of Zagreb, Faculty of
Organization and Informatics, Varaždin, Croatia*

Abstract

The paper examines traditional knowledge about the role of financial and physical resources in entrepreneurship. Based on Bourdieu's theory, we search for an answer to the question of which forms of economic capital are used by Croatian entrepreneurs in the computer programming industry and what their value in the context of accessing other forms of capital is. The study is based on a qualitative methodological approach. In-depth interview technique accompanied by unstructured observations was used in data collection. In addition to primary data, research includes the use of qualitative and quantitative secondary data. Research suggests that in the computer programming industry, economic capital is just one tool in the conversion game of entrepreneurial capital. Moreover, the interviewed entrepreneurs attach the least importance to it in business, favoring the value of intangible resources such as specialized knowledge, business connections and personal acquaintances. The company's start-up phase is characterized by the entrepreneur's reliance on personal savings, which is replaced by financing based on retained earnings in the later stages of business. Other forms of growth financing, such as bank loans and recapitalization of external investors, are used by a minority of larger companies, with a good base of symbolic capital. The results on capital conversions indicate relatively easy conversion of economic capital into cultural capital and symbolic capital, and less frequent use of economic capital to create social capital. Fresh insights into the entrepreneurs' perceptions provided by the study expand existing knowledge about entrepreneurship within the computer programming industry, suggesting that it is an industry with huge potential for young talents without a personal financial base that is commonly considered a precondition for entering entrepreneurship.

Keywords: economic capital, capital conversions, entrepreneurship, computer programming industry, Croatia

1. Introduction

Economic capital has traditionally been one of the most critical forms of entrepreneurial assets [1]–[5]. Decomposed of cash and material resources such as buildings, equipment and machinery, it is an integral part of daily business activities and is a basic element of the smooth implementation of the process of production and provision of enterprise services [6]–[8]. In addition to influencing the quantitative and qualitative performance of established organizations [9], having an appropriate level of economic capital is a good predictor of starting a business, potentially facilitating the early stages of building entrepreneurial legitimacy [1], [10]–[13]. As found by Lee *et al.* [14], in the non-absence of financial capital, a “young” high-tech company is able to acquire better employees and invest sufficiently in the development of innovative products and initial marketing activities. It is also able to sneak into more cost-effective niches that are more attractive regarding profit [14], and is able to create a more attractive physical environment that sends signals of “financial health” and facilitates the creation of a business reputation [15], [16].

Understanding the capital of entrepreneurs as a contextually specific set of different tangible and intangible resources [17]–[19], the paper examines traditional knowledge about the role of economic capital in entrepreneurship. With conceptual support in Pierre Bourdieu's theory of capital [6], we search for an answer to the question of the role of economic capital in the business of Croatian entrepreneurs in the field of computer programming. From the perspective of the entrepreneurs themselves, it is deeply researched in which forms and in what way economic capital is engaged in the selected industry and how it is used in the acquisition of other valuable forms of capital. The continuation of the paper provides an overview of the current knowledge on the role of economic capital in the entrepreneurial process on the basis of which research questions are asked. The second part of the paper presents the methodological framework of empirical research and elaborates the main research findings. The paper ends with a conclusion discussing the scientific contribution of research, the implications for practice, and the limitations and recommendations for future studies.

2. The role of economic capital in the entrepreneurial process

The amount of financial capital of an individual (measured by personal wealth and/or personal income) is traditionally considered a good predictor of the decision to start your own business and the company's growth opportunities [1], [10]–[13]. The predefined risk of a new entrepreneurial venture imposes cost and other restrictions on access to formal sources of financing, so for many start-ups, acquiring financial capital through institutions is less attractive compared to a cheaper alternative to investing family savings in business. In addition, having an adequate level of personal physical and financial resources increases the ability to borrow for business purposes, as new entrepreneurs often use their own assets to guarantee the return of business loans. Consequently, individuals with a lack of personal financial and physical capital faced with liquidity constraints are potentially discouraged or disabled in their

intention to take advantage of entrepreneurial opportunities and ultimately do not decide to start their own business [20]. This is confirmed by quantitative empiricism, which generally finds a positive relationship between the likelihood of an individual entering entrepreneurship and growth opportunities, and the financial capital available to him [1], [10]–[13], [21]–[23].

In addition to the above, traditional scientific opus mainly based on the isolated study of economic capital, a somewhat subtler research direction is gradually developing which examines the importance of economic capital relatively, putting its value in relation to other manifestations of capital, and respecting the nature of (industrial and other) context within which the entrepreneur acts. Brush *et al.* [24] were among the first to adopt such an approach examining entrepreneurs' perceptions of the relative value of several different types of resources, with respect to particular stages of a company's life cycle. The authors include physical, financial, human, social and organizational resources in the analysis and conclude that compared to other forms of capital, entrepreneurs, regardless of the age of the company, consider financial resources the least important for business.

The dependence of the relative value of physical and financial capital on the nature of industry is also acknowledged by Kim *et al.* [20], [25], Lam *et al.* [16], Stringfellow and Shaw [26], Pret *et al.* [17] and Vuković *et al.* [19]. For example, Kim *et al.* [25] expectedly notice that financial resources are not necessarily a predictor of the realization of entrepreneurial intent within low-capital intensity industries (such as service and professional) since new entrepreneurs predominantly invest some other forms of capital in such ventures. Their empiricism indicates that most new entrepreneurs do not decide to buy or rent office space but start entrepreneurial activity in their own home, which in turn further reduces the importance of initial business costs. Stringfellow and Shaw [26] also come to similar conclusions in the conceptual discussion of the components of entrepreneurial capital. As they note, the source of company value within industries with low entry barriers related to the necessary financial resources is most often specialized knowledge and reputation of entrepreneurs, and such industries are characterized by weaker influence of economic capital on entrepreneurial performance. Finally, similar is confirmed by Brush *et al.* [27] who discuss the challenge of creating a capital platform in a "nascent" enterprise in the information and communication technology industry. As their study shows, the hotbed of the ICT company's resource base is primarily not money but the intangible personal resource configuration of the future entrepreneur (his expertise, reputation in the industry and acquaintances).

Contemporary approaches to entrepreneurial capital as a mix of entrepreneurs' different, tangible and intangible resources [17]–[19], [28], [29] recognize conceptual appropriateness in the theory of capital by the French philosopher and sociologist Pierre Bourdieu. By economic capital Bourdieu [6] means money and all material resources convertible directly into money, and mentions that labour can be materialized in several forms. He adds social capital (formal and informal networks and acquaintances), cultural capital (education, experience, manners, cultural property in physical form) and symbolic capital (status in the society, prestige, reputation) to economic capital and considers the concept of capital from the perspective of its

conversion nature. According to Bourdieu's theory, namely, every form of capital under certain conditions is subject to transformation into some other resource manifestation [6]. For example, a high level of economic capital can be converted into cultural capital (financial investment in education) [16], [30], [31] and used to acquire social capital (financing the access to elite social networks) [17], [32], just as, for example, cultural capital (rare knowledge and style) can be mobilized for the purpose of acquiring symbolic capital (community reputation) [17], [19]. Starting from the assumption of multiple manifestations of entrepreneurial capital and the conversion nature of capital discussed by Bourdieu [6], this paper seeks to answer the question of which forms of economic capital are important for entrepreneurial activity in the Croatian computer programming industry. The interpretive paradigm [33] and the accompanying qualitative research approach [34] deeply explore the manifestations of economic capital in the chosen industry, the practices of economic capital conversion and its relative value for entrepreneurs. More succinctly, the paper examines the following research questions:

- 1) What forms of economic capital are used by Croatian entrepreneurs in the computer programming industry?
- 2) How do Croatian entrepreneurs in the computer programming industry value economic capital compared to other forms of capital?
- 3) How do Croatian entrepreneurs in the computer programming industry convert economic capital into social, cultural and symbolic capital?

3. Methodology

Consistent with the philosophical starting point based on interpretivism as a research paradigm [33], an empirical study based on a qualitative methodological approach was conducted [34]. An in-depth interview technique accompanied by unstructured observations was used to collect primary data. The participants in the interviews were entrepreneurs whose companies were registered and active in the Republic of Croatia at the time of the research under the main activity J62.0 - Computer programming, consultancy and related activities. The study was conducted as part of a more comprehensive, multi-year research project from September 2015 to March 2019. Interviewing entrepreneurs (predominantly in the form of fieldwork throughout Croatia) was organized in three phases over three years (October 2015 - November 2017). Each phase of interviewing was accompanied by the secondary data collection, and the data analysis procedure (ending in September 2018). The total sample of interview participants included 77 respondents from 70 companies based in Zagreb and 10 counties throughout the Republic of Croatia (the number of companies involved is different from the number of respondents as several interviews were conducted in group interviews with two or three respondents).

The selection of respondents in the sample in the initial phase of the research was based on mixed purposeful sampling [34], so that three respondents from three companies based in Varaždin County were selected according to the criterion of convenience (the researcher knows them and asked them to participate in the research), one respondent from a company from Primorje-Gorski Kotar County and

Virovitica-Podravina County each were selected according to the snowball technique (other respondents suggested them as potential future respondents) while twenty-three companies, i.e. twenty-eight respondents were selected using a random number generator. The researcher's intention was not to form a random sample as used in quantitative research, but to use a random number generator to simplify the choice of entrepreneurs to contact in order to participate in the research, as the researcher previously had no contacts or other resources to select a different selection process. According to Patton [34], the logic of purposeful sampling is completely different from the principle of sample design in quantitative research. Since the intention is not to generalize the results to the population but to examine the phenomenon in depth, the goal of purposeful sampling is to select those units that are information rich cases.

Based on the results of previous research, it was initially assumed that the company's location is a potentially significant criterion for selecting respondents in the purposeful sample. As Spigel states [35], the capital conversions of entrepreneurs are influenced by local fields that are connected to local populations and institutions and are anchored in a specific geographical area. Therefore, the diversity of respondents in terms of local areas in which companies operate can enable the examination of the impact of local and regional processes on the practices of entrepreneurs and contribute to practical implications for the local and regional entrepreneurial policies. Considering the available data on the research population, the location criterion is defined in terms of the regional self-government unit (i.e., county of company headquarters). The counties covered by the research were selected according to the criterion of appropriateness and the criterion of approximate distribution of the number of enterprises from the population by counties. The intention of using these criteria was not to form a statistically representative sample but to cover different local areas with a higher concentration of entrepreneurial activity in the selected industry. As shown in Table 1, the total sample includes regional self-government units in which 84.18% of companies from the defined research population had their headquarters in the year before the beginning of the research (since the study is based on purposeful sampling, statistical data on the share of companies by county are purely informative). The number of entrepreneurs from each county to be included in the sample has not been defined in advance, as it has been estimated that this criterion will not contribute to increasing the degree of variation in the data.

In the later stages of the research the respondents were selected on the basis of theoretical sampling [34], [36]. Based on the results of the initial phase of the research desirable characteristics of future respondents and their companies were identified. For example, one of the identified variations in existing data relates to the practice of acquiring economic capital using bank loans. This practice was identified in only one company, and thus represented a variation in the data (the category of economic capital was not saturated and required further examination). Based on the other characteristics of the company in question, it was assumed that the mentioned practice of acquiring economic capital is a consequence of the need to finance extremely high revenue growth rates of that company. Therefore, in the further phase of the research,

other companies that achieve very high growth rates measured by the growth of operating revenues were included in the added sample.

All interviews were conducted in person (face-to-face) predominantly in the business premises of the company or a nearby cafe. The average duration of one interview was 66 minutes. Prior to the interview, each respondent was provided with a statement on the anonymity and confidentiality of the data collected during the interview, and a request was made for an audio recording of the interview. Observations during the interviews were made according to the principle of unstructured observation [37] and included the collection of data on the appearance of the entrepreneur and their business premises and the physical location of the company.

Regional self-government unit	Share of enterprises from the county in the population in 2014¹	Number of respondents / companies in the research	Share of enterprises in the research
City of Zagreb	53.36%	37 / 33	47.14%
Primorje-Gorski kotar County	6.51%	11 / 9	12.86%
Split-Dalmatia County	6.82%	6 / 6	8.57%
Osijek-Baranja County	3.43%	6 / 5	7.14%
Istria County	4.26%	4 / 4	5.71%
Varaždin County	3.67%	4 / 4	5.71%
Međimurje County	2.42%	3 / 3	4.29%
Koprivnica-Križevci County	0.83%	3 / 3	4.29%
Karlovac County	1.42%	1 / 1	1.43%
Zadar County	1.11%	1 / 1	1.43%
Virovitica- Podravina County	0.35%	1 / 1	1.43%
TOTAL	84.18%	77 / 70	100.00%

Table 1. Share of enterprises by counties in the population and in the conducted research

Table 2 shows the basic data on the companies involved and the demographic data on the interview participants. Regarding the number of employees, 46 companies (or 65.72%) included in the research had less than ten workers, 22 companies (or 31.42%) employed between 10 and 49 people, while only two companies (2.86%) had 50 or more employees. To consider data on the number of employees, as well as other indicators of company size, it can be concluded that the research sample refers exclusively to micro, small, and medium-sized enterprises (SMEs). Such a structure

¹ The shares of enterprises by counties in the research population were calculated on the basis of data from the Financial Agency of the Republic of Croatia [38]. The data refer to the year 2014 since the study was conducted as part of a multi-year research project which began in 2015.

is not surprising since only 2 companies (or 0.06%) in the computer programming industry in Croatia in 2015 belonged to the category of large companies (there were 31 (or 1.00%) medium-sized enterprises, 266 (or 8.58%) small enterprises, and 2,802 (or 90.36%) micro enterprises) [38].

At the time of the research, the business entities were in different stages of their life cycle. More precisely, out of a total of 70 business entities, 17 (or 24.28%) were 20 or more years old, 17 (or 24.28%) were between 10 and 19 years old, while 36 companies (or 51.44%) started business less than 10 years ago. Additionally, the sample includes 9 business entities that had been operating for less than 42 months (new entrepreneurs), and the average age of all companies included in the sample is 11 years. Likewise, in some cases, business activity started earlier than the year of company registration, which refers to entrepreneurs who previously had a craft or unregistered entrepreneurial activity. The fact is incorporated in the interpretation of the results since the respondents' earlier involvement in entrepreneurship implied a previously accumulated resource base.

Characteristics of the companies		Percentage / number
Company's age	Less than 10	51.44% / 36
	10 - 19	24.28% / 17
	20 or more	24.28% / 17
Number of employees	0 - 1	14.29% / 10
	2 - 9	51.43% / 36
	10 - 19	15.71% / 11
	20 - 49	15.71% / 11
	50 or more	2.86% / 2
Characteristics of the participants		Percentage / number
Gender	Women	9.09% / 7
	Men	90.91% / 70
Participants' age	Less than 35	27.27% / 21
	35 - 40	18.18% / 14
	41 - 50	25.97% / 20
	51 - 60	15.59% / 12
	More than 60	7.80% / 6
	No data	5.19% / 4
Level of education	High school	14.29% / 11
	Bachelor's and master's degree	81.82% / 63
	Doctorate	3.89% / 3

Table 2. Data on companies and interview participants

Regarding the gender structure of interview participants, men predominate among the interviewees (70 or 90.91% men versus 7 or 9.09% women). Moreover, 6 out of 7 women who participated in the research share the function of ownership and/or

management of the company with a male person, whether the man is exclusively a business partner (3 female entrepreneurs) or the husband of the research participant (3 female entrepreneurs). The significant underrepresentation of women in the sample is not surprising given the small share of women in the ICT industry workforce [39], and ICT entrepreneurship [40], [41]. According to the Global Entrepreneurship Monitor, women entrepreneurs are much less likely to be involved in ICT startups than men (according to recent data, in 2021 the global ratio is 2.7% women vs. 4.7% men, while the gap for Croatia is even more pronounced (3.7% women vs. 9.8% men)) [41]. This large gender gap is persistent and was also present during the period of conducting the research [40].

The most represented age group in the sample is entrepreneurs younger than 35 (21 or 27.27%), followed by 20 respondents (or 25.97%) between the ages of 41 and 50. The smallest age group of respondents was over 60 years old (6 or 7.80%). The youngest respondents in the sample were aged 30, and the oldest respondent was 72. The average age of the respondents expressed by the arithmetic mean is 43, while the median is 42. Regarding the level and type of education of the interview participants, most of them graduated from university (81.82%). The exception is eleven respondents (or 14.29%) with high school education. Nine of them were included in the higher education system but left the college before graduation, which is related to work and/or starting a company during their studies. It should also be added that two interviewees have the title of Master of Science, three are PhDs, and one interviewee was involved in the educational process of a post-graduate doctoral study at the time of the interview. The formal education of the majority of respondents is related to technical sciences (electrical engineering, mechanical engineering) or social sciences (information sciences, economics). The majority of respondents graduated from the Faculty of Electrical Engineering and Computing in Zagreb, followed by the Faculty of Economics in Zagreb and the Faculty of Organization and Informatics in Varaždin.

In addition to primary data, research empiricism includes qualitative and quantitative secondary data. Quantitative secondary data refer to data from the financial statements of entrepreneurs included in the research. The analysis includes positions of assets, operating revenue and net profit/loss from the financial statements of the company initially for the period from 2007 to 2015 (obtained from the database of the Financial Agency of the Republic of Croatia and the Court Register of the Republic of Croatia). To deepen the picture of the economic capital of companies during and after the period of primary data collection, quantitative secondary data from the company's financial statements was subsequently collected also for the period from 2016 to 2021. The analysis of quantitative secondary data identified the amount of assets and the amount, intensity and direction of the movement of operating revenue and profit/loss of the company during the observed period (2007-2021). The obtained data were used to support primary data in drawing conclusions about the role of tangible assets in business, (own) sources of financing and financial self-sufficiency of the company. Also, the financial data served as a support in identifying the relations between individual practices of conversion of economic capital and financial strength of the company.

The qualitative data collected from secondary sources include all information about the entrepreneur and the company that was available on the Internet at the time of the search by typing the following keyword combinations into Google: "name surname of the entrepreneur company name". The search was conducted for each respondent and company immediately after the interview, and some of the data collected in this way include data on the appearance, content and up-to-dateness of the company's website, data on awards and accolades received, and data related to negative news about entrepreneur/company in the media.

Data analysis was based on the application of techniques characteristic of the constructivist grounded theory [42]. Accordingly, initial, focused and axial coding was performed on the empirical data, followed by the application of the constant comparison method. The analysis was preceded by the completion of transcripts of interviews, followed by repeated reading of empirical material and initial coding. It is a process by which interview segments are assigned codes that represent the meaning of a group of data. Thousands of source codes were identified in this phase, after which we moved on to the next coding phase. Focused coding referred to the identification of significant codes and their grouping into more abstract particles, the so-called categories. In the last phase, axial coding determined the relationships between data and previously defined categories [43]. The entire coding process was performed manually. Due to that, it was a very time-consuming and exhausting process. Although computer programs can speed up and simplify the lengthy process of multiple reading, constant comparison, and cross-checking of data, relying solely on computer analysis impoverishes rich qualitative material and creates some form of methodological anomie [44].

To provide insights into the relations between the form of capital and the capital conversions with the characteristics of companies and entrepreneurs, the qualitative analysis was supplemented by statistical indicators. More precisely, the correlations between the characteristics of companies (company's age, number of employees) and the characteristics of entrepreneurs (gender, participant's age, level of education), and the frequencies of codes related to certain forms of economic capital and capital conversion were calculated. Since the data on code frequencies was measured on an ordinal scale, Spearman's correlation coefficient was used [45]. The results of the analysis are presented in Appendix A, and the interpretations of the results are included in the corresponding segments within Section 4.

4. Results

4.1. Forms and relative value of economic capital

The structure and value of economic capital of entrepreneurs are recognized by examining the source of financial capital invested in starting a business and financing further business, analysing the level and dynamics and direction of business revenue and profit or loss and identifying physical capital owned by companies [17], [31]. Table 3 shows quantitative data on the absolute and relative representation of certain

forms of economic capital among the interviewed entrepreneurs and data on the frequency of the associated codes. The data from the table were obtained by counting the number of entrepreneurs from the sample who use particular identified form of economic capital in business. Frequencies were calculated by counting codes related to a particular form of economic capital obtained by interview analysis.

Form of economic capital	Number of entrepreneurs (N=70)	Share of entrepreneurs	Frequency of associated codes
Financial capital to start a business			
– savings of entrepreneurs	61	87.14%	61
– loans from family and friends	11	15.71%	11
– bank loans	6	8.57%	6
Financial capital to support growth and survival			
– operating profit	65	92.86%	104
– bank loans and leasing	15	21.43%	15
– recapitalization of external investors	9	12.86%	12
Physical capital			
– computer and other equipment (interviews)	20	28.57%	32
– computer and other equipment (other sources)	65	92.86%	-
– business space (owned)	9	12.86%	-

Table 3. Forms of economic capital among interviewed entrepreneurs

When it comes to the impact of economic capital on the birth of entrepreneurial intent and financing start-ups, although valuable, for most entrepreneurs it is not a scarce resource. This is a result of the nature of the industry related to the low level of capital intensity [46], [47] which reduces the initial financial requirements to the legally defined amount of share capital and relatively modest initial investment in computers and other equipment. Therefore, in the early stages of business, the predominant source of economic capital of our respondents (87.14% of them) are their own funds in the form of personal savings. Formal third-party sources were used by only six entrepreneurs to finance the start-up, while only eleven of them (or 15.71%) engaged connecting social capital [48] embodied in "strong", parental and kinship ties:

That initial capital practically, like... I came to my parents, told them to lend me those, as much as it was, cca 1000 euros. ... After that I practically did all the rest myself... with those initial 1000 euros I moved on. (Bruno, 34, Pula)²

In addition to social capital engagement, some actors have found a way to overcome the liability of newness [49] in the beginning of entrepreneurship in the

² In order to protect the anonymity of the respondents, the real names of persons and the names of companies and institutions have been replaced by pseudonyms.

form of unregistered activity, in the form of a freelancer or by establishing a more financially favourable legal framework. Thus, Leon (33, Čakovec) overcame the financial requirements of the early stages of business much easier, since he had previously acquired some economic capital by moonlighting, while Nada (43, Zagreb) entered formal entrepreneurship with partners by founding a company after five years in business.

Although relatively scarce, economic capital is a valuable resource in the early stages of business, especially from the perspective of the fact that combating the liability of newness in some cases (more precisely for 14.29% of entrepreneurs) involved sacrificing entrepreneurs' personal income in order to maintain financial stability. Commitment to entrepreneurship, at the cost of personal financial gain, is beautifully illustrated by the statement of Anita (30), an ambitious young entrepreneur, co-owner and director of a young fast-growing company from Zagreb:

Now I will be completely honest... So,... I sacrificed my finances for Softmax. So, it was a much lower salary than I used to have or that I could have if I went somewhere to work, especially abroad... but it didn't [discourage] me... I never had a problem with it because I knew why I was doing it... (Anita, 30, Zagreb)

In addition to not being a barrier to starting a business, economic capital is a predominantly scarce form of capital in the later stages of the life cycle of an entrepreneurial venture. Namely, a large number of companies (more precisely, 68.57%) quickly reached the level of financial self-sufficiency, securing a position in which the realized profit is used as the only source of capital for the maintenance and growth of business. This was due to the practice of concluding long-term contracts with clients which was identified for 90.00% of actors, and, of course, doing business in more financially generous foreign markets (which is practiced by 54.29% of companies). As indicated by the correlation data in Appendix A, the latter practice is potentially characteristic of younger entrepreneurs ($\rho=-0.611$, $p<0.01$), younger companies ($\rho=-0.386$, $p<0.01$), and as expected, the one with a larger number of employees ($\rho=0.252$, $p<0.05$).

The financial stability and growth of most of the companies included in the research are confirmed by descriptive indicators of data from the financial statements. As suggested by the data in Table 4, more than half of the companies observed from one to the other accounting period recorded an increase in operating revenue, which in many cases exceeded 10%. It is also important to point out that in all the years included in the analysis, about 80-90% of companies were operating with a positive financial result.

The "peak" of the share of companies with profit in 2018 and 2019 and a decline in 2020 and 2021 potentially indicate the negative impact of the COVID-19 crisis on the economic capital of some of the observed companies. The primary data of the study refer to the pre-crisis period and do not allow reliable estimates. However, descriptive statistical findings by Konecki *et al.* [53] based on the data set of 2,069 companies suggest that the profitability of the industry was generally not affected negatively by the crisis, but quite the opposite (in 2020 and 2021 the sector shows an increase in ROA, ROE, and EBITDA margin).

Year	Operating revenue (in HRK)			
	Min	Max	Median	Arithmetic mean
2007	23,168	9,429,808	1,087,005	1,723,639
2008	23,150	9,076,656	1,164,457	1,565,418
2009	0	8,050,310	1,076,864	1,477,609
2010	21,795	8,118,121	1,018,352	1,507,150
2011	33,077	9,894,353	1,003,224	1,767,736
2012	0	12,796,033	1,021,121	1,838,054
2013	21,110	12,833,993	958,141	1,889,891
2014	0	22,992,372	1,156,973	2,332,567
2015	2,200	47,639,748	1,270,074	3,078,581
2016	3,497	55,633,153	1,251,734	3,542,194
2017	3,200	50,669,941	1,739,058	3,985,595
2018	14,441	135,389,127	1,736,096	6,246,226
2019	1,428	196,437,080	1,888,315	7,857,207
2020	230	398,265,987	2,533,666	12,165,830
2021	1,000	300,932,790	3,049,174	11,436,674
Year	Standard deviation (oper. rev. in HRK)	Share of comp. with rev. growth ³	Share of comp. with rev. growth of more than 10%	Share of comp. with profit
2007	2,007,217	-	-	81.82%
2008	1,877,889	57.89%	52.63%	86.84%
2009	1,708,112	51.16%	46.51%	83.72%
2010	1,700,712	52.08%	41.67%	85.42%
2011	2,130,394	52.94%	45.10%	84.31%
2012	2,502,306	58.93%	37.50%	87.50%
2013	2,413,570	66.15%	50.77%	92.31%
2014	3,655,007	59.42%	47.83%	92.75%
2015	6,382,184	71.43%	60.00%	91.43%
2016	7,481,084	57.14%	34.29%	85.71%
2017	7,590,426	57.35%	42.65%	89.71%
2018	17,715,518	60.00%	50.77%	95.38%
2019	25,470,802	60.94%	46.88%	95.31%
2020	51,249,653	59.38%	42.19%	84.38%
2021	40,095,842	53.23%	40.32%	83.87%

Table 4. Descriptive indicators of financial statements data of companies included in the research (Source: Own calculations according to the data of the Financial Agency and the Court Register of the Republic of Croatia [38], [50]–[52])

³ Revenue growth was determined compared to the previous accounting period included in the analysis.

This is one of the industries characterized by great heterogeneity of companies regarding the nature of products and services, and the character of markets, implying potential differences in the impact and direction of the impact of the COVID-19 crisis on the financial results of different companies. Anyway, the issue is an interesting ground for future, quantitative and longitudinal studies of the computer programming industry in Croatia.

Given the financial self-sufficiency of most entrepreneurs, formal foreign sources of financing are a rare instrument for obtaining economic capital, not only in starting a business but also in financing its survival and growth. Moreover, a large number of surveyed entrepreneurs show an aversion to the risk of borrowing, which, according to Ante (34) from Split, can be stimulated only by specific financial requirements in business:

Own resources, yes... exclusively [we used our own funds to finance business], in fact, it's kind of something I believe in...it is actually the best way to do something because first it's a matter of responsibility and everything that is done, which is still greatest if you work with your own money, and I don't like loans, so in fact, there really should be some specific situation that would have to be financed in such a way... (Ante, 34, Split)

Despite the propensity for self-financing and the enviable financial strength accumulated so far in business activities, for several (fast) growing entrepreneurs it still does not provide a sufficient financial injection to the business. One of the few such examples is a fast-growing company run by Ivan (40-50) from Varaždin, which finds support for extreme growth in bank capital. For this company, bank credit is a very common financing mechanism and is easily accessible thanks to the symbolic capital in the form of a positive reputation with banks based on the strength and "financial health" of the company. In addition to bank loans, this entrepreneur (and several other growing companies) does not refrain from frequent recapitalizations by strong foreign investors, who, by investing economic capital, strengthen the company's symbolic capital and make it easier for entrepreneurs to penetrate new markets. In addition to this entrepreneur, access to financial capital in the form of recapitalizations of external investors or business angels was found in several other companies (12.86% on the level of the entire research). These are entrepreneurs who have attracted investors thanks to a software product that represents an influential innovation or those who decided to start a new, attractive niche by founding a spin-off company and found an investment partner thanks to the company's existing legitimacy. The data on statistically significant correlations from Appendix A confirm that financing through investors' recapitalizations is potentially used by larger companies (measured by the number of employees), characterized by higher revenues and profits, as well as a higher level of symbolic capital.

No respondents reported funding through other alternative sources, such as venture capital and crowdfunding. It can be assumed that this is a consequence of the still weaker availability of risk capital in Croatia [54] and the potential reluctance of ICT entrepreneurs to crowdfunding [55]. It should also be noted that as many as 40 companies in the sample offer software as a service and/or other related services on

behalf of the client, so they have no financial needs related to product development or market testing, which are common motives for crowdfunding [56].

Like financial capital, the material form of economic capital in most enterprises does not belong to the category of VRIN resources [57]. Namely, compared to other industries, the equipment is easily available and does not involve a significant financial investment, and the same is true for business premises, which almost 90% of entrepreneurs provide by rent. The burden of investing in physical assets is recognized by only three entrepreneurs, primarily as a result of the company's current financial difficulties or financial instability in the earlier stages of business. As expected, the size of physical capital has a significant positive correlation with the number of company employees, since larger companies require higher investments in different forms of business equipment ($p=0.387$, $p<0.01$).

The relations between the form of economic capital and the demographic characteristics of entrepreneurs (gender, participant's age, level of education) cannot be identified by the findings of the study. The corresponding correlation coefficients in Appendix A are mostly statistically insignificant or significant but suggest only a slight correlation ($p<0.250$). The exceptions are the data on the significant negative correlation between the participant's age and operations on foreign markets ($p=-0.611$, $p<0.01$), as well as the amount of the company's profit ($p=-0.273$, $p<0.05$). Accordingly, younger entrepreneurs, compared to older ones, are potentially more inclined to expand their business to foreign markets, which results in better financial results for the company. Nevertheless, the assumptions need to be confirmed by quantitative research based on inferential statistics.

Valuing it relatively, in relation to other resource manifestations, most entrepreneurs (61.43% of them) consider economic capital to be the least significant in business (Table 5). As illustrated by Andrija (30) from Virovitica, this is the result of the already mentioned small entry barriers regarding financial capital, and generally low levels of capital intensity of industry:

I would put finances only in the third place, because when a company grows... it is not finances that are crucial, but that people should believe... those who come to the company... that they come not only for money but because they believe that there is a way for them in that company...the finances are honestly the least necessary for us because we are not buying machines worth € 100,000 to expand our business...(Andrija, 30, Virovitica)

Table 5 shows quantitative data on the absolute and relative representation of certain combinations of ranking of forms of capital among the interviewed entrepreneurs. The data from the table were obtained by counting companies, i.e. entrepreneurs who in the interview opted for a certain combination of ranking of certain forms of capital.

To sum up, regarding the forms of economic capital that lead us to the answer to the first research question from Section 2, the results suggest that the company's start-up phase is characterized by the entrepreneur's reliance on personal savings and, more rarely, loans from family and friends, which is replaced by financing based on retained earnings in the later stages of business.

Entrepreneur's response	Number of entrepreneurs (N=70)	Share of entrepreneurs
– cultural, social, economic capital	26	37.14%
– social, cultural, economic capital	17	24.29%
– economic, social, cultural capital	5	7.14%
– social, economic, cultural capital	4	5.71%
– economic, cultural, social capital	1	1.43%
– cultural, economic, social capital	1	1.43%
– other responses	16	22.86%
Total	70	100.00%

Table 5. Ranking of forms of capital according to their role in business

Other forms of growth financing, such as bank loans and recapitalization of external investors, are used by a minority of larger companies, with a good base of symbolic capital. Larger companies also invest more in business premises and equipment as a physical form of economic capital. When it comes to the second research question, the findings show that economic capital, compared to social capital and cultural capital, is the least valuable form of capital. Preference in the industry is given to intangible forms of capital such as specialized knowledge, business connections and personal acquaintances of entrepreneurs.

4.2. Conversions of economic capital into other types of capital

An examination of the conversion nature of economic capital revealed that it is subject to conversion into all three remaining forms of capital, being most easily converted into cultural resources and then symbolic ones, while being seldom engaged in acquiring social resources.

Table 6 shows examples of identifying capital conversions from excerpts from interviews with respondents. The table review demonstrates the logic of qualitative data analysis that follows the analytical procedures used in previous research on capital conversions in entrepreneurship (for example, see the demonstration of identifying capital conversions in research by Pret *et al.* [17] and Hill [28]).

When it comes to transforming economic into symbolic capital, they are mainly related to building a reputation through financial investments in marketing, participation in humanitarian actions, sponsorship of events, financing of new, promising start-ups and other investment activities in the symbolic identification of entrepreneurs and companies. These practices are characteristic of the largest and most financially powerful companies and are in the function of strengthening entrepreneurial legitimacy in the eyes of different categories of constituents (clients, business partners, potential employees, media). This finding is supported by the identification of the relations between entrepreneurial practices and the financial strength of the company determined on the basis of data from the financial statements.

Conversions of economic into symbolic capital are also reflected in the form of waiving companies' financial gains in order to create or maintain the trust of existing customers. It is about providing free first services to new clients, suffering financial losses due to an incident on the project or delaying the collection of services from clients who are in financial difficulties. In contrast to the previously stated practice, this practice is characteristic of companies regardless of their size and financial strength, and is especially popular among new entrepreneurs. For them, it is a kind of mechanism to dampen the liability of newness [49], a strategy by which newcomers work hard to build the trust of their first clients, gradually creating outlines of moral legitimacy in the marketplace [58], [59]. This process reflects the experience of Zoran, the owner of a micro company from Zagreb, which gradually gained the trust of foreign clients through the practice of free first services:

... Let's say we managed to gain that trust from these kind of companies, as these external ones are called, where we offered them to make them something for free for the first time. So it means totally for free, as it is called, and they also hesitated here and there, and in principle, when we did it once, then it [started] for you... (Zoran, 45, Zagreb)

In addition to easy conversion into symbolic resources, economic capital is convertible into all manifestations of cultural capital. This is reflected in the investment of entrepreneurs in further formal education and certification (cultural capital in the institutionalized state), investment in non-formal forms of education (cultural capital in the embodied state) and financing the arrangement of business premises (cultural capital in the objectified state) [6]. Among them, the most popular is the latter conversion, typical of (fast)growing companies (17.14% of them) that arrange business premises in the mission of producing symbolic resources—reputation in the market and the industry [60], a kind of symbolic advantage in the fight for scarce labour force. The data in Appendix A confirm that the practice of converting economic capital into cultural capital in the objectified state, to create symbolic capital, is characteristic of larger enterprises ($\rho=0.386$, $p<0.01$). Additionally, significant negative correlations of this entrepreneurial practice with the company's age ($\rho=-0.375$, $p<0.01$) and the entrepreneur's age ($\rho=-0.494$, $p<0.01$) were found. It seems that younger entrepreneurs and larger companies have a higher level of symbolic capital in the form of exposure in the media, local recognition, and reputation in the industry, which is potentially the result of the engagement of economic capital.

Table 7 shows quantitative data on the absolute and relative representation of economic capital conversions among the interviewed entrepreneurs and data on the frequency of the associated codes. The data in the table were obtained by counting the companies or entrepreneurs with whom a certain conversion of economic capital was found. Frequencies were calculated by counting the codes from the interviews related to each conversion of economic capital.

Economic capital conversions - illustrative excerpts from interviews		
Social capital	Cultural capital	Symbolic capital
<i>We were [members of associations], but we stopped it a month ago... because some membership fees had to be paid so I concluded... given in which direction the company is going, it is better to stop '... than... wherever you join, you have to pay for something, so we concluded that we don't want it anymore ... we paid a lot somehow ... we are members of the Oracle group, we paid some money there, and that's where it went the most, right ... that's how I stopped it...</i> (Božo, 65, Split)	<i>What should I say, we had to give 80,000 kuna to be able to certify the product, you have to earn this 80,000 kuna, and these certificates could be given for free, but still, at a marketing show, it says that I have a certificate, when you act like that, then it's much better than when you don't have it. (Zoran, 45, Zagreb)</i>	<i>... Well, one [should] be present to some, some level in society and with some ideas and advice support some other entrepreneurial stories. Maybe even financing... companies... now it's maybe... even a matter of social responsibility, but it's hard to say 'what social responsibility is and what purposeful propaganda. I mean... through these [activities] we also get quality people from the faculty... so it's a combination of both, a kind of symbiosis... isn't it? (Robert, 30, Zagreb)</i>
<i>If your hour costs more, it means you will be able to go to foreign conferences. If you go to foreign conferences, you will meet new people ... (Bruno, 34, Pula)</i>	<i>...Now we have reserves and some funds that we will try to invest [in business premises]... to be, like, top. ...or a little better and to leave that good impression, and so that... the employees are comfortable and proud to be working here. (Josip, 36, Osijek)</i>	<i>... if there is an incident on the project, and that is not uncommon, or something is done that may not be right or we make a mistake, in these situations we take everything on ourselves, even at the cost of loss... to initially gain some trust and start seriously working... (Dušan, 36, Zagreb)</i>

Table 6. Examples of identification of economic capital conversions

Conversions of economic capital into social capital have been observed among 5.71% of entrepreneurs, and are mainly related to the payment of membership in formal associations and the financing of participation in conferences and related events. Given the importance that respondents attach to them and the amount of financial resources involved, they do not have a crucial role in business. Moreover, social resources that require the investment of economic capital are forms of capital that entrepreneurs can easily give up in case of financial difficulties and the need to rationalize costs. This is especially true for start-ups and micro-enterprises, for which the most valuable social capital is acquired through informal networking within an industry that does not require a direct outflow of economic capital.

Economic capital conversions	Number of entrepreneurs (N=70)	Share of entrepreneurs	Frequency of associated codes
Social capital			
- payment of membership in associations	3	4.29%	3
- financing of conferences	1	1.43%	1
Total	4	5.71%	4
Cultural capital			
- investments in business premises	12	17.14%	13
- investing in education and training	10	14.29%	11
- financing of certificates	1	1.43%	1
Total	21	30.00%	25
Symbolic capital			
- investing in marketing activities	8	11.43%	9
- waiver of financial gains in order to maintain customer confidence	7	10.00%	8
- investments in philanthropy and social responsibility	3	4.29%	3
Total	15	21.43%	21

Table 7. Data on economic capital conversions among interviewed entrepreneurs

Finally, it should be added that the results do not confirm related findings regarding the relations between local business environments and entrepreneurial practices [35]. The forms and conversions of economic capital could not be brought into relation with specific local fields. The potential justification of such results should be sought in the fact that Croatia is a smaller, and thus more homogeneous, national context compared to the national environment of the previous study conducted in Canada [35]. For this reason, variations in local practices in this case do not exist or are so small that they cannot be identified.

Summarizing the answer to the third research question, it is concluded that the industry is characterized by relatively easy conversion of economic capital into cultural capital and symbolic capital, and less frequent use of economic capital to create social capital. The most popular engagement of economic capital refers to financing the arrangement of business premises (production of cultural capital in the objectified state). The practice is potentially specific to larger and younger companies that are led by younger entrepreneurs, who use economic capital and cultural capital

to create symbolic capital. Somewhat more prevalent capital conversions are also investments in education and training (accumulation of cultural capital in the embodied state), and investments in marketing to create symbolic capital.

5. Discussion and conclusion

The insight into the relational nature of capital provided by our research indicates that in the computer programming industry, economic capital is only one tool in the conversion game of entrepreneurial capital. Moreover, the interviewed entrepreneurs attach the least importance to it in business, favouring the value of intangible resources such as specialized knowledge, business connections and personal acquaintances. Our findings are consistent with the empirical findings of Greene *et al.* [61], Brush *et al.* [27] and Lam *et al.* [16] and more recent research by Pret *et al.* [17] and Vuković *et al.* [19], pointing out that physical and financial resources are not dominant in all forms of entrepreneurship and their relative value is conditioned by the characteristics of the industry and the size of the enterprise. In low capital intensity sectors, such as computer programming or cultural industries, the skill in creating economic value of new and small entrepreneurs is not primarily driven by the level of personal and business financial capital but by the ability to mobilize specific social and cultural resources. Only in larger companies does the accumulated economic capital become a significant pool of symbolic capital as financial investments in marketing activities and tangible cultural assets (for example, elite business premises) contribute to strengthening the reputation and attracting a better workforce. Weak representation of economic capital investment in formal social capital (membership in associations) and institutionalized cultural capital (certification) is also evident and suggests their lower value in industry compared to informally created social networks and knowledge accumulated through independent learning and experience.

When it comes to sources of financing for companies, the results show that these are mostly traditional methods, primarily informal ones. The causes of the underrepresentation of modern funding mechanisms such as crowdfunding, although they can be assumed [55], [56], are an open question for future research. Also, it would be interesting to examine the impact of the aversion to the risk of indebtedness of these entrepreneurs on the possibility of taking advantage of new business opportunities in the industry.

The topic of the paper is important as it expands saturated approaches based on isolated research of financial, and possibly social and human capital in entrepreneurship. This research, in addition to being one of the few studies conducted among entrepreneurs in the field of computer programming in Croatia, is important because it contributes to the recent and still modest work that approaches entrepreneurs' capital from the perspective of resource dynamics in entrepreneurship [17], [28]. Further development of knowledge in the narrower field would be facilitated by expanding research with a comprehensive quantitative analysis of the relationship between sources of financing, forms of economic capital and capital conversion practices, and company characteristics (number of employees, revenue and profits, subsectors, market and others) as well as demographic and other

characteristics of entrepreneurs. Research findings of this type, based on a representative sample and inferential statistics, produce more precise conclusions regarding the structure and characteristics of economic capital with regard to the characteristics of entrepreneurs and enterprises, and by extending the study to other activities they provide the possibility of sectoral comparisons.

The study presented in the paper provides several relevant contributions to the theory of entrepreneurship. The research provides a systematic overview of existing knowledge about the role of economic capital in entrepreneurship and expands it with empirical findings for a specific, hitherto unexplored context. Fresh insights into the practices and perceptions of Croatian entrepreneurs expand existing knowledge about entrepreneurship within the computer programming industry, suggesting that it is an industry with huge potential for entrepreneurial young talents without a personal financial base that is commonly considered a precondition for entering entrepreneurship. Therefore, future research on entrepreneurial capital in knowledge-based industries should emphasize the role of social, cultural and symbolic resources of entrepreneurs, their relational nature, as well as changes in the value of individual forms of capital as companies progress through development stages. In addition to new empirical insights, the contribution of the study is also given in the conceptual framework which is characterized by the rich Bourdieu theory as an excellent tool for defining different forms of capital and analysing the use and management of resources in entrepreneurship [17].

When it comes to the implications for entrepreneurial practice, the research suggests that the lack of certain personal resources (especially economic capital) in this industry is not a reason to be discouraged from starting a business, especially if they are individuals with a broad informal social network and rich knowledge and experience. The education system also has a role in strengthening entrepreneurial self-efficiency, with the task of pointing out to ICT students the benefits of entrepreneurship as a profession and teaching about alternative ways to use and influence economic, cultural, social and symbolic capital for business management and development [17]. Finally, it is also the responsibility of entrepreneurship policy makers to complement traditional and universal measures of financial support for entrepreneurship with support in accessing intangible forms of capital.

The fundamental limitation of the research stems from the fact that empirical results relate to a specific industry within a national environment and should not be generalized outside the research context [62]. In addition to examining the results in the new contextual conditions, it is desirable that future research be of a longitudinal type, which would contribute to creating a clearer picture of the role of each form of capital given the size of the company and life cycle stage. Moreover, this research was conducted from 2015 to 2019 (with the addition of financial data for 2020 and 2021), and the results do not provide empirically-based insights into the reflection of new circumstances on the observed industry (more precisely, the impact of the COVID-19 crisis on the economic capital of entrepreneurs). Collecting more recent data would bring a fresher understanding of the research issue. Finally, related research conducted within different national environments would provide comparisons of findings for

countries where the activity of computer programming is at different stages of development, which would expand knowledge about the industry.

Appendix A

	Characteristics of the companies		Characteristics of the participants		
	Company's age	Number of employees	Gender	Participant's age	Level of education
Financial capital to start a business					
– savings of entrepreneurs	0.054 n.sig.	0.095 n.sig.	0.187 n.sig.	0.092 n.sig.	0.094 n.sig.
– loans from family and friends	0.056 n.sig.	-0.030 n.sig.	-0.008 n.sig.	0.046 n.sig.	-0.158 n.sig.
– bank loans	0.152 n.sig.	0.020 n.sig.	0.094 n.sig.	0.210*	0.087 n.sig.
Financial capital to support growth and survival					
– operating profit	-0.033 n.sig.	0.422***	0.133 n.sig.	-0.229*	-0.019 n.sig.
– bank loans and leasing	0.147 n.sig.	0.215*	-0.089 n.sig.	0.073 n.sig.	-0.017 n.sig.
– recapitalization of external investors	-0.090 n.sig.	0.243**	-0.183 n.sig.	-0.163 n.sig.	-0.003 n.sig.
Physical capital					
– computer and other equipment (interviews)	0.021 n.sig.	0.127 n.sig.	-0.124 n.sig.	-0.081 n.sig.	-0.272**
– computer and other equipment (other sources)	0.235 n.sig.	0.387***	-0.085 n.sig.	0.057 n.sig.	0.053 n.sig.
Doing business on foreign markets	-0.386***	0.252**	-0.076 n.sig.	-0.611***	-0.237**
Operating revenue (2015)	0.203*	0.752***	-0.071 n.sig.	-0.120 n.sig.	-0.001 n.sig.
Profit/Loss (2015)	-0.008 n.sig.	0.342***	0.058 n.sig.	-0.273**	-0.015 n.sig.
Conversions of economic capital into social capital (total)	0.072 n.sig.	-0.087 n.sig.	0.075 n.sig.	0.114 n.sig.	-0.077 n.sig.
Conversions of economic capital into cultural capital (total)	-0.037 n.sig.	0.255**	0.092 n.sig.	-0.147 n.sig.	0.083 n.sig.
Conversions of economic capital into symbolic capital (total)	-0.072 n.sig.	0.120 n.sig.	0.019 n.sig.	-0.127 n.sig.	0.020 n.sig.
Conversions of economic capital into objectified cultural capital and symbolic capital	-0.375***	0.386***	0.045 n.sig.	-0.494***	-0.169 n.sig.
Social capital (total)	-0.207*	0.350***	-0.080 n.sig.	-0.223*	-0.176 n.sig.
Cultural capital (total)	0.012 n.sig.	0.346***	-0.065 n.sig.	-0.113 n.sig.	-0.159 n.sig.
Symbolic capital (total)	-0.130 n.sig.	0.576***	-0.013 n.sig.	-0.399***	-0.077 n.sig.

Note: *p<0.1; **p<0.05; ***p<0.01

Table 8. Data on correlations between frequencies of codes related to forms of economic capital and capital conversions, and characteristics of the companies and characteristics of the research participants (the data refer to Spearman's correlation coefficient)

References

- [1] D. Cetindamar, V. K. Gupta, E. E. Karadeniz, and N. Egrican, "What the numbers tell: The impact of human, family and financial capital on women and men's entry into entrepreneurship in Turkey," *Entrep. Reg. Dev.*, vol. 24, no. 1–2, pp. 29–51, 2012, doi: 10.1080/08985626.2012.637348.
- [2] P. Firkin, "Entrepreneurial Capital: A Resource-Based Conceptualisation of the Entrepreneurial Process," Labour Market Dynamics Research.

- Programme, Massey University Auckland, Working Paper No. 7, Auckland, 2001.
- [3] Y. Sefiani, "Factors for success in SMEs: A perspective from Tangier," PhD thesis, University of Gloucestershire, 2013.
 - [4] E. Shaw, J. Wilson, and T. Pret, "The process of embedding a small firm in its industrial context," *Int. Small Bus. J.*, vol. 35, no. 3, pp. 219–243, 2017, doi: 10.1177/0266242616671170.
 - [5] M. A. Wdowiak, E. J. Schwarz, R. J. Breiteneker, and R. Harms, "Linking Cultural and Financial Capital of the Entrepreneur in a New Venture Creation Context: A Cross-Country Comparison," *Zeitschrift für Betriebswirtschaft*, no. 5, pp. 25–51, 2009.
 - [6] P. Bourdieu, "The forms of capital," in *Handbook of Theory and Research for the Sociology of Education*, J. Richardson, Ed. New York: Greenwood, 1986, pp. 241–258.
 - [7] M. J. Dollinger, *Entrepreneurship: strategies and resources*, 4th ed. Lombard: Marsh Publications, 2008.
 - [8] C. W. Hofer and D. Schendel, *Strategy Formulation: Analytical Concepts*. St. Paul, New York, Los Angeles, San Francisco: West Publishing Company, 1978.
 - [9] A. C. Cooper, J. F. Gimeno-Gascón, and C. Y. Woo, "Initial Human and Financial Capital as Predictors of New Venture Performance," *J. Priv. Equity*, vol. 1, no. 2, pp. 13–30, 1997, [https://doi.org/10.1016/0883-9026\(94\)90013-2](https://doi.org/10.1016/0883-9026(94)90013-2).
 - [10] T. Dunn and D. Holtz-Eakin, "Financial capital, human capital, and the transition to self-employment: Evidence from intergenerational link," *J. Labor Econ.*, vol. 18, no. 2, pp. 282–305, 2000, doi: 10.1017/CBO9781107415324.004.
 - [11] D. Holtz-Eakin, D. Joulfaian, and H. S. Rosen, "Sticking It Out: Entrepreneurial Survival and Liquidity Constraints," *J. Polit. Econ.*, vol. 102, no. 1, pp. 53–75, 1994, <https://doi.org/10.1086/261921>.
 - [12] D. Holtz-Eakin, D. Joulfaian, and H. S. Rosen, "Entrepreneurial Decisions and Liquidity Constraints," *Rand J. Econ.*, vol. 23, no. 2, pp. 340–347, 1994.
 - [13] B. D. Meyer, "Why are there so Few Black Entrepreneurs?," National bureau of economic research, Cambridge, Working Paper 3537, 1990. [Online]. Available: https://www.nber.org/system/files/working_papers/w3537/w3537.pdf [Accessed Jan. 10, 2017].

- [14] C. Lee, K. Lee, and J. M. Pennings, "Internal capabilities, external networks, and performance: A study on technology-based ventures," *Strateg. Manag. J.*, vol. 22, no. 6–7, pp. 615–640, 2001, doi: 10.1002/smj.181. <https://doi.org/10.1002/smj.181>.
- [15] S. Helm, "Designing a Formative Measure for Corporate Reputation," *Corp. Reput. Rev.*, vol. 8, no. 2, pp. 95–109, 2005, <https://doi.org/10.1057/palgrave.crr.1540242>.
- [16] W. Lam, E. Shaw, and S. Carter, "Entrepreneurial Capital : Convertibility, Personal Reputation and Firm Performance," in *Institute for Small Business & Entrepreneurship (ISBE) 30th National Conference*, 2007, pp. 1–15.
- [17] T. Pret, E. Shaw, and S. Dodd Drakopoulou, "Painting the full picture: The conversion of economic, cultural, social and symbolic capital," *Int. Small Bus. J.*, vol. 34, no. 8, pp. 1004–1027, 2016, doi: 10.1177/0266242615595450.
- [18] T. Šmaguc and K. Vuković, "Entrepreneurs' social capital in struggles within market field: The case of the Croatian software industry," *Manag. - J. Contemp. Manag. Issues*, vol. 25, no. 2, pp. 83–110, 2020, doi: 10.30924/mjcmi.25.2.5.
- [19] K. Vuković, I. Fojs, and K. Detelj, "Konverzije kapitala poduzetnika u kreativnim i kulturnim industrijama Sjeverozapadne Hrvatske," *Ekonom. Pregl.*, vol. 72, no. 4, pp. 597–618, 2021, <https://doi.org/10.32910/ep.72.4.5>.
- [20] P. H. Kim, H. E. Aldrich, and L. A. Keister, "If I were rich? The impact of financial and human capital on becoming a nascent entrepreneur," in *Annual Meeting of the American Sociological Association*. The American Sociological Association, Atlanta, 2003.
- [21] D. G. Blanchflower and A. J. Oswald, "What Makes an Entrepreneur?," *J. Labor Econ.*, vol. 16, no. 1, pp. 26–60, 1998, doi: 10.1086/209881.
- [22] A. LaFerrere, "Self-employment and intergenerational transfers: Liquidity constraints and family environment," *Int. J. Sociol.*, vol. 31, no. 1, pp. 3–26, 2001, [Online]. Available: <http://www.jstor.org/stable/20628609>.
- [23] J. Nykvist, "Entrepreneurship and Liquidity Constraints : Evidence from Sweden," *Scand. J. Econ.*, vol. 110, no. 1, pp. 23–43, 2008, <https://doi.org/10.1111/j.1467-9442.2008.00523.x>.
- [24] C. G. Brush, P. G. Greene, M. M. Hart, and L. F. Edelman, "Resource Configurations Over the Life Cycle of Ventures," in *Frontiers of Entrepreneurship Research, 1997: Proceedings of the 17th Annual Entrepreneurship Research Conference*, 1997, pp. 315–329.

- [25] P. H. Kim, H. E. Aldrich, and L. A. Keister, "Access (Not) Denied: The Impact of Financial, Human, and Cultural Capital on Entrepreneurial Entry in the United States," *Small Bus. Econ.*, vol. 27, no. 1, pp. 5–22, 2006, doi: 10.1007/s11187-006-0007-x.
- [26] L. Stringfellow and E. Shaw, "Conceptualising entrepreneurial capital for a study of performance in small professional service firms," *Int. J. Entrep. Behav. Res.*, vol. 15, no. 2, pp. 137–161, 2009, <https://doi.org/10.1108/13552550910944557>.
- [27] C. G. Brush, P. G. Greene, M. M. Hart, and H. S. Haller, "From initial idea to unique advantage: The entrepreneurial challenge of constructing a resource base," *Acad. Manag. Exec.*, vol. 15, no. 1, pp. 84–80, 2001, doi: 10.1109/EMR.2002.1022409.
- [28] I. R. Hill, "Spotlight on UK artisan entrepreneurs' situated collaborations: through the lens of entrepreneurial capitals and their conversion," *Int. J. Entrep. Behav. Res.*, vol. 27, no. 1, pp. 99–121, 2021, <https://doi.org/10.1108/IJEBr-11-2019-0642>.
- [29] S. R. M. Reid, "The generative principles of lifestyle enterprising: dialectic entanglements of capital-habitus-field," *Int. J. Entrep. Behav. Res.*, vol. 27, no. 3, pp. 629–647, 2021, <https://doi.org/10.1108/IJEBr-10-2018-0688>.
- [30] D. De Clercq and M. Voronov, "Entrepreneurial legitimacy as a set of discursive practices," in *Second Conference on Rhetoric and Narratives in Management Research: Management and Persuasion*, 2011, pp. 125–146.
- [31] E. Shaw, W. Lam, and S. Carter, "The role of entrepreneurial capital in building service reputation," *Serv. Ind. J.*, vol. 28, no. 7, pp. 899–917, 2008, doi: 10.1080/02642060701846820.
- [32] P. J. DiMaggio, "Review: On Pierre Bourdieu," *Am. J. Sociol.*, vol. 84, no. 6, pp. 1460–1474, 1979.
- [33] G. Burrell and G. Morgan, *Sociological Paradigms and Organisational Analysis: Elements of the Sociology of Corporate Life*. Burlington: Ashgate Publishing Company, 1979.
- [34] M. Q. Patton, *Qualitative Research and Evaluation Methods*, 3th ed. Thousand Oaks London New Delhi: Sage Publications, 2002.
- [35] B. Spigel, "The Emergence of Regional Cultures and Practices: A Comparative Study of Canadian Software Entrepreneurship," PhD thesis, Graduate Department of Geography and Program in Planning, University of Toronto, 2013.
- [36] B. G. Glaser and A. L. Strauss, *The Discovery of Grounded Theory: Strategies for Qualitative Research*, 7th ed. New Brunswick and London: Aldine Transaction, 2012.

-
- [37] A. Tkalac Verčić, D. Sinčić Ćorić, and N. Pološki Vokić, *Priručnik za metodologiju istraživanja u društvenim djelatnostima*, 2nd ed. Zagreb: M.E.P. d.o.o., 2014.
- [38] Republic of Croatia - Financial Agency, "Data base," Purchased data on companies from selected industries, 2017.
- [39] OECD, "Going digital: The future of work for women," Policy brief on the future of work. Paris, 2017. doi: 10.1787/9789264281318-26-en. [Online]. Available: <https://www.oecd.org/employment/Going-Digital-the-Future-of-Work-for-Women.pdf>. [Accessed: Jul. 29, 2023].
- [40] D. J. Kelley et al., "Global Entrepreneurship Monitor 2016/2017, Report on Women's Entrepreneurship," Global Entrepreneurship Research Association (GERA), London, 2017. [Online]. Available: <https://www.gemconsortium.org/report/gem-20162017-womens-entrepreneurship-report>. [Accessed: Jul. 18, 2023].
- [41] A. B. Elam et al., "GEM 2021/22 Women's Entrepreneurship Report From Crisis to Opportunity," Global Entrepreneurship Research Association (GERA), London, 2022. [Online]. Available: <https://www.gemconsortium.org/file/open?fileId=51084>. [Accessed: Jul. 18, 2023].
- [42] K. Charmaz, "Constructing grounded theory: a practical guide through qualitative analysis," in *Handbook of constructionist research*, J. A. Holstein and J. F. Gubrium, Eds. New York: The Guilford Press, 2008, pp. 397–412.
- [43] A. L. Strauss and J. M. Corbin, *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*, 4th ed. Los Angeles, London and New Delhi: Sage Publications, 2015.
- [44] C. Goulding, *Grounded theory: A practical guide for management, business and market researchers*. London, Thousand Oaks, New Delhi: SAGE Publications, 2002.
- [45] M. Udovičić, K. Baždarić, L. Bilić-Zulle, and M. Petrovečki, "Što treba znati kada izračunavamo koeficijent korelacije?," *Biochem. Medica*, vol. 17, no. 1, pp. 10–15, 2007.
- [46] T. Šmaguc and K. Vuković, "The possibility of using the grounded theory method in the research of software entrepreneurship," in *International Scientific Symposium "Economics, Business & Finance", Proceedings*, 2016, pp. 5–12.
- [47] K. Vuković, "Enterprise size distribution in the Croatian software industry," *Int. Sci. Publ. Econ. Bus.*, vol. 6, no. 4, pp. 43–51, 2012.
-

- [48] R. D. Putnam, *Bowling Alone: The Collapse and Revival of American Community*. New York London Toronto Sydney: Simon & Schuster Paperbacks, 2000.
- [49] J. Wiklund, T. Baker, and D. Shepherd, "The age-effect of financial indicators as buffers against the liability of newness," *J. Bus. Ventur.*, vol. 25, no. 4, pp. 423–437, 2010, doi: 10.1016/j.jbusvent.2008.10.011.
- [50] Republic of Croatia - Court Register, "Search for subjects," *Republic of Croatia - Court Register*, 2018. [Online]. Available: <https://sudreg.pravosudje.hr/registar/f?p=150:1>. [Accessed: Dec. 2, 2018].
- [51] Republic of Croatia - Court Register, "Search for subjects," *Republic of Croatia - Court Register*, 2021. [Online]. Available: <https://sudreg.pravosudje.hr/registar/f?p=150:1>. [Accessed: Oct, 8, 2021].
- [52] Republic of Croatia - Financial Agency, "InfoBizz data base," *Republic of Croatia - Financial Agency*, 2022. [Online]. Available: <https://infobiz.fina.hr/Login?ReturnUrl=%2F>. [Accessed: Jun., 6, 2022].
- [53] I. Konecki, D. Oreški, and N. Kadoić, "Clustering of Croatian Software Development Companies Based on Their Financial Indicators," in *46th MIPRO ICT and Electronics Convention (MIPRO)*, K. Skala, Ed. Croatian Society for Information, Communication and Electronic Technology – MIPRO, 2023, pp. 1682–1687, doi: 10.23919/MIPRO57284.2023.10159898.
- [54] S. Singer, N. Šarlija, S. Pfeifer, and S. Oberman Peterka, "Što čini Hrvatsku (ne)poduzetničkom zemljom GEM HRVATSKA 2019-2020.," Centar za politiku razvoja malih i srednjih poduzeća i poduzetništva, Zagreb, Hrvatska, 2021.
- [55] C. Ingram and R. Teigland, "Crowdfunding among IT entrepreneurs in Sweden: a qualitative study of the funding ecosystem and ICT entrepreneurs' adoption of crowdfunding," Stockholm School of Economics, Stockholm, 2013. [Online]. Available: <https://ssrn.com/abstract=2289134>. [Accessed: Jan., 9, 2022].
- [56] A. Moritz and J. H. Block, "Crowdfunding: A literature review and research directions," in *Crowdfunding in Europe - State of the Art in Theory and Practice*, D. Brüntje and O. Gajda, Eds. Springer, 2016, pp. 25–53.
- [57] J. B. Barney, "Firm Resources and Sustained Competitive Advantage," *J. Manage.*, vol. 17, no. 1, pp. 99–120, 1991, <https://doi.org/10.1177/014920639101700108>.

- [58] L. Stringfellow, E. Shaw, and M. Maclean, "Apostasy versus legitimacy: Relational dynamics and routes to resource acquisition in entrepreneurial ventures," *Int. Small Bus. J.*, vol. 32, no. 5, pp. 571–592, 2014, doi: 10.1177/0266242612471693.
- [59] M. C. Suchman, "Managing Legitimacy : Strategic and Institutional Approaches," *Acad. Manag. Rev.*, vol. 20, no. 3, pp. 571–611, 1995, doi: 10.2307/258788.
- [60] C. Zott and Q. N. Huy, "How Entrepreneurs use Symbolic Management to Acquire Resources," *Adm. Sci. Q.*, vol. 52, no. 1, pp. 70–105, 2007, <https://doi.org/10.2189/asqu.52.1.70>.
- [61] P. G. Greene, C. G. Brush, and T. E. Brown, "Resources in small firms: An exploratory study," *J. Small Bus. Strateg.*, vol. 8, no. 2, pp. 25–40, 1997.
- [62] J. Vickers, "Exploring Engagement: A Grounded Theory Study of Young People's Interactions with Healthcare Professionals," PhD thesis, College of Health and Social Care, University of Salford, 2016.

Using the 3D Protein Structure as Key to Encrypt Images

Mohammed Abbas Fadhil Al-Husainy

dralhusainy@gmail.com

Department of Cyber Security

Irbid National University, Irbid, Jordan

Hamza A. A. Al-Sewadi

alsewadi@hotmail.com

Department of Computer Technology Engineering

Iraq University College, Basra, Iraq

Ahmed M. Sayed

ahmedpharma8530@gmail.com

Department of Pharmacognosy

Nahda University, Beni-Suef, Egypt

Abstract

In the digital world, information is exposed anytime, anywhere, to everybody, hence its privacy is a crucial matter. No matter how complicated the encryption algorithm is, it requires a strong and hard-to-break encryption key. Since the three-dimensional protein sequence structures are usually highly conserved, even better than DNA sequences, this work presents an innovative scheme for implementing the protein sequence and structural to build protein data tables that are then used to generate extremely strong encryption-keys. An image-encryption scheme designed to implement such encryption keys is developed and produced compatible security strength with existing encryption schemes. Prototype experiments resulted in an average normalized mean absolute error of 66.84%, an average peak signal to noise ratio of 6.85 dB, and comparable entropy with other cryptosystems. The obtained results make this scheme a promising color image protection technique for various applications.

Keywords: Image-encryption, Data-security, Cryptography, Protein Structure

1. Introduction

The fast advancement of digital computing capabilities and communications networks has resulted in an ever-increasing volume of multimedia data (i.e., images, video, and audio) being stored or transmitted across insecure communication channels. Because user data typically contains confidential and private information, their security has become critical for protecting and defending users against various harmful assaults, such as preventing data loss and ensuring data integrity. Many technologies, such as steganography [1], [2], watermarking [3], and encryption are currently suitable for assuring a high level of security for medical images. Encryption techniques can turn an identifiable image into something unrecognizable, defending the security of personal information on public networks from malicious assaults [1].

Any cryptosystem consists of two main components; an encryption algorithm and encryption keys. The currently available cryptosystems are classified into two types: symmetric cryptosystems require the same secret key for both encryption and decryption. And, asymmetric cryptosystems require a pair of keys, one for encryption (public key) and one for decryption (private key). The symmetric cryptosystem is faster and achieves a satisfactory level of security but suffers from the key distribution problem, while the asymmetric cryptosystem is slower and solves the key distribution problem, sometimes attackers may exploit the existence of a relationship between the pair of keys to break the security of the cryptosystem. No matter how hard and sophisticated the encryption algorithm is, it is usually publicly available. Hence, the encryption key represents the most important factor, as it is the only secret component in the system for providing strong information protection. Therefore, a strong and hard-to-guess encryption key is sought, and researchers are continuously searching for new approaches to generate strong and hard-to-break keys. The main feature that determines the key strength is its key-space. Taking design cues from biological systems and processes has resulted in some beneficial problem-solving approaches [4], [5]. Previous studies of biology-inspired computing, such as the artificial immune system and ant colony optimization, have focused on extracting computing models from a high-level understanding of biological processes. Recently, many academics have begun to investigate biology-inspired computing at a much lower level, gaining insights into the evolutionary roots of biological information systems by studying how small cellular organisms' function [6]. Accordingly, a number of biology-inspired cryptographic approaches have also been introduced. For example, deoxyribonucleic acid (DNA) -based cryptography is an emerging cryptographic field as a result of research into DNA computing. DNA computing technology has been advanced and is now being employed in various applications, including cryptography [7].

The motivation of utilizing the three-dimensional (3D) proteins to generate secure encryption key since their structures are extremely conserved, even better than DNA sequence, from which data tables can be constructed using their sequence alignment and template structural similarity. Besides, it is anticipated that such implementation could be suitable for secure data processing, storage, and communication applications. Hence, the work in this paper presents a novel protein-based cryptographic method that was inspired by the complex and random structures of natural proteins. It is an image encryption technique adopting a symmetric cryptographic system based on the 3D-protein structure features, where the encryption keys are generated by utilizing these features.

Accordingly, this presented cryptographic method is more efficient than those previously described e.g., DNA-based ones.

After this brief definition in section 1, section 2 gives a brief explanation of the 3D protein structure, then Section 3 summarizes the related work review. Section 4 outlines the methodology of the proposed image cryptography algorithm. Section 5 describes the implementation of the algorithm, lists experimental results, and includes the discussion. Finally, the conclusion of the paper is presented in Section 6.

2. 3D Protein Structure

To clarify how to utilize the three-dimensional (3D) structure of a protein to generate and implement the secret key for the proposed image-encryption technique, a brief introduction is given below.

It has been shown that 3D protein structure is evolutionarily more conserved than expected based on sequence conservation alone [8]. The sequence alignment and template structure are used to produce a structural model of the target. Since the protein structures are usually more conserved than DNA sequences, detectable sequence similarity levels usually imply significant structural similarity [9].

Protein structure is a polymer of amino acids (i.e., polypeptide) with secondary, tertiary, and quaternary complex structures; an example of the 3D protein structure is shown in Fig 1-a. Structures of different proteins depend mainly on their amino acid sequence, where 20 different amino acids are employed as building blocks, see Fig 1-b [10].

Generally, proteins are expressions of DNA genetic codes, and hence, they have the same natural randomness as DNA. Additionally, they have other elements of randomness and complexity resulting from their secondary, tertiary, and quaternary structures. As a result, there are no two identical proteins in nature [10], [11]. Random Sequence Complexity (RSC), Ordered Sequence Complexity (OSC), and Functional Sequence Complexity (FSC) are three qualitative features of protein linear sequence complexity defined by Abel and Trevors [21]. Accordingly, proteins can be considered highly complex, random and chaotic. Using such complex and chaotic systems in cryptography will be of great interest, particularly if it is combined with other efficient cryptographic methods. Additionally, this protein-based encryption method is superior to that of the previously reported DNA-based one in utilizing the very complex 3D structure of proteins in the encryption algorithm.

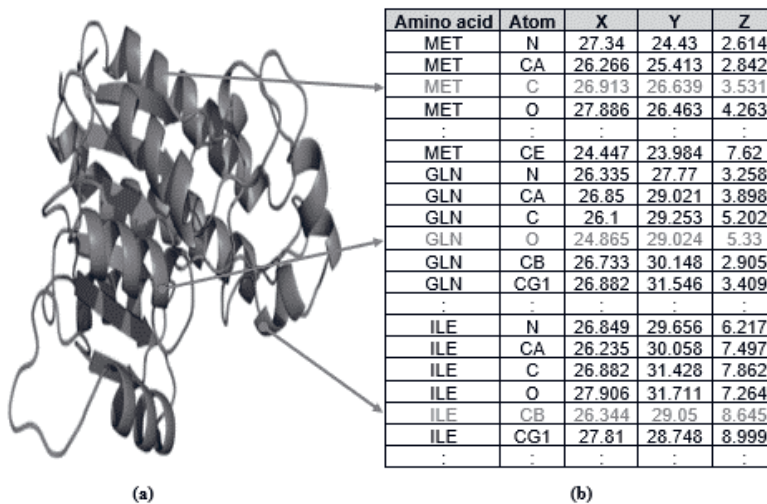


Figure 1. (a) An example of the protein structure, (b) the detailed representation of the protein in the PDB structure file. (MET: methionine, GLN: Glutamine, ILE: Isoleucine).

3. Related Works

DNA was utilized in the field of cryptography and steganography. For example, Gehani et al. in 2000 [12] introduced this concept with XOR operation to produce strong indexed, random key strings. Then several schemes were reported for incorporating the DNA concept for cryptography, as summarized Al-Husainy et al. [13]. These schemes were secret-key cryptosystems such as the so-called molecular sticker developed by Chen J. [14] and Bibhash Roy et al. [15], while others were public-key cryptosystems, such as the one developed by Tanaka K. [16] and Cui G. et al. [17]. Moreover, many DNA-based image-encryption schemes were developed, see Al-Husainy et al. [13], Zhang et al. [18], and Khan et al. [19].

Image encryption through ribonucleic acid (RNA) sequence approach assisted with neural key sequences is reported by Davi et al. [20]. It transcribes messenger ribonucleic acid (mRNA) sequence to train a binary associative memory neural network (BAM NN), producing transfer ribonucleic acid (tRNA) sequences. Then these sequences provide the processes of change and diffusion for the pixels in colour digital imaging and communications in medical images. The authors claim considerable robustness through various decryption quality analyses, statistics and differential attack analyses.

Herein, we introduced a novel protein-based image encryption scheme inspired by the natural protein due to its random and complex properties. It is based on the three-dimensional protein structure features. Considerably strong encryption keys were generated and tested for the designed encryption scheme. This design benefits from the protein databases currently available to the public, these databases contain thousands to millions of different protein structures, such as the protein data bank ([21]; <https://www.rcsb.org/>) and Alpha Fold protein structure database ([22]; <https://alphafold.ebi.ac.uk/>). Hence, users can easily access these protein structures.

Accordingly, the combination of genetically acquired and structural-based codes of proteins makes them an exceptional biology-inspired coding and encryption model. The protein-based code that the end-user can use as a key or generate a secret key for a cryptographic system can be extracted from the protein structure file in the Protein Data Bank format (PDB). Such structure files can be easily downloaded from any protein database and represented in a table as listed in Fig 1-b. The most important five columns of data will be used to construct a protein-based key consisting of five different parameters. The first column represents the amino acid sequence in the chosen protein. Each one is referred to by three letters and represents the corresponding genetic code in the DNA.

The second column is the amino acids elements, which represents the elemental composition of each amino acid in the protein sequence. The alphabet, composed of 38 different characters, represents the type and position of each element in each amino acid in the protein sequence. The last three columns are the X, Y, and Z coordinates of each character (i.e., element) in the previous column within the 3D protein structure in Fig 1-a.

In the proposed study, different proteins will be used as keys; ubiquitin, Pim kinase, and DNA gyrase. These three proteins represent three different structures of different sizes and are hosted in Protein Data Bank.

Taken together, this protein structure-based five-as columns key can be considered a very strong and readily available key model to start our encryption algorithm with. Additionally, each obtained key is unique, as are no two identical keys in all currently available databases. Even similar proteins, of the same sequences, differ slightly in their structures (i.e., The coordinates of each amino acid).

4. Proposed Encryption Technique

In the proposed technique, the table of Fig 1-b will be used as the primary key and shall be filled by the user. The first two parameters; the amino acid sequence in the chosen protein (i.e., MET, GLN, and ILE) and the elemental composition of each amino acid in the protein sequence (i.e., N, CA, C, O, CB, GB1) will be used to perform the substitution operation. The last three parameters (i.e., The coordinates X, Y, and Z) will be used to perform the transposition operation.

The user of the proposed encryption technique enters two digital files: the source color image S to be encrypted and the protein data table shown in Fig. 1-b, which is used as the primary key K to encrypt the source image.

The source color image S is treated as a 3D matrix of red, green, and blue colors, and each color is treated as a byte. To describe the technique, consider the simple example of the 3D representation of the color image illustrated Fig. 2, where (a) an example of a source image and (b) the image pixel diagram showing a pixel value in the red, green, and blue (RGB) matrix.

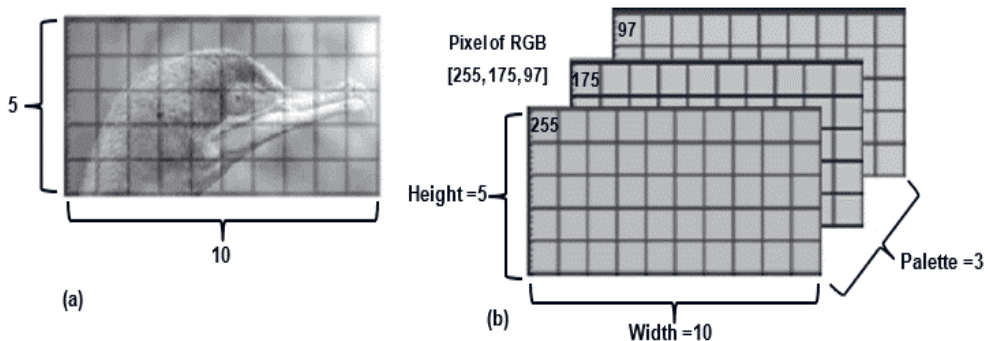


Figure 2. (a) Source image, (b) Illustration of a pixel and its value in the RGB matrix.

4.1. Preparation Stage

Initially, the size (in byte) of the source image S is calculated using Equation (1), where Palette equals 3 for RGB color image.

$$n = \text{Width} \times \text{Height} \times \text{Palette} \quad (1)$$

Change the size of the primary key (protein) K so that it has a number of rows equal to the n . Two cases have to be dealt with:

- If the size of $K < n$, add more rows by repeating the rows starting with the first row in the protein table.
- If the size of $K > n$, delete the unnecessary rows at the end of the protein table.

Use n as a seed for a pseudorandom number generator used in the proposed encryption technique to:

- Assign a unique non-repeating random value between (0...255) for each different amino acid as shown in Table 1.
- Assign a unique non-repeating random value between (0...255) for each different atom as shown in Table 2.

Generate a random sequence of row numbers in the key (protein) data table K . This will produce a new protein table containing a random sequence of rows as shown in Table 3.

Change the range of values for the X , Y , and Z coordinates in the protein data table K to equal the Width, Height, and Palette ranges, respectively for the source image S . Then use equations (2), (3), and (4) to determine new values for each X , Y , and Z .

$$X_{new} = Round \left(\frac{X_{old} - Min_X}{Max_X - Min_X} \times Width \right) \quad (2)$$

$$Y_{new} = Round \left(\frac{Y_{old} - Min_Y}{Max_Y - Min_Y} \times Height \right) \quad (3)$$

$$Z_{new} = Round \left(\frac{Z_{old} - Min_Z}{Max_Z - Min_Z} \times Palette \right) \quad (4)$$

4.2. Encryption Stage

Two main operations (Substitution and Transposition) are performed to encrypt the source image S and create the encrypted image E . The proposed encryption technique treats the source image S as a single 3D block and implements the substitution and transposition operations on every byte of the source image S . The key (protein) data table K produced from the preparation stage is used in these two operations.

1. Substitution Operation

Two different implementations of the substitution operation are performed on each byte of the source image S . These implementations are explained below:

A. XOR Operation with Amino Acid Code

In the 3D block of the source image S , perform the XOR logical operation between each byte in S with the amino acid code in the key (protein) data table K . The following programming code shows the substitution operation.

Amino acid		Amino acid Code between (0...255)
Name	Abbreviation	
Alanine	ALA	237
Arginine	ARG	82
Asparagine	ASN	242
Aspartic acid	ASP	171
Cysteine	CYS	189
Glutamine	GLN	24
Glutamic acid	GLU	162
Glycine	GLY	112
Histidine	HIS	60
Isoleucine	ILE	15
Leucine	LEU	137
Lysine	LYS	179
Methionine	MET	160
Phenylalanine	PHE	208
Proline	PRO	55
Serine	SER	249
Threonine	THR	4
Tryptophan	TRP	119
Tyrosine	TYR	17
Valine	VAL	38
Asparagine	ASX	78
Glutamine	GLX	183
Any amino acid	XAA	81
Isoleucine	XLE	184

Table 1. Amino acid abbreviations and their random code.

Amino acid	Atom	X	Y	Z
15	89	26.235	30.058	7.497
162	82	24.865	29.024	5.33
4	222	26.882	31.546	3.409
208	19	27.886	26.463	4.263
189	219	26.85	29.021	3.898
4	82	27.906	31.711	7.264
:	:	:	:	:

Table 3. The key (protein) data table *K* contains a random sequence of rows.

Atom Abbreviation	Atom Code between (0...255)
N	81
C	167
O	82
CB	165
CG	19
CD	32
NE	127
CZ	163
NH1	216
NH2	126
OD1	114
ND2	75
OD2	41
SG	209
OE1	130
OE2	159
NE2	92
ND1	235
CE1	148
CD2	46
OD	103
CG1	55
CD1	207
CG2	195
CE	222
NZ	2
SD	0
CE2	26
CZ	245
CA	89
OG	219
OG1	244
NE1	60
CZ2	96
CH2	56
CZ3	35
CE3	239
OH	49

Table 2. Amino acid abbreviations and their random code.

```

 $K_{index} = 0$ 
For ( $X: 0 \dots Width_S - 1$ )
  For ( $Y: 0 \dots Height_S - 1$ )
    For ( $Z: 0 \dots Palettes_S - 1$ )
       $S(X, Y, Z) = S(X, Y, Z) \text{ XOR } K_{Amino\ acid}[K_{index}]$ 
       $K_{index} = K_{index} + 1$ 

```

B. XOR Operation with Atom Code

In the 3D block of the source image S , perform the XOR logical operation between each byte in S with the one of the atom code in the key (protein) data table K . The following programming code shows the substitution operation.

```

 $K_{index} = 0$ 
For ( $X: 0 \dots Width_S - 1$ )
  For ( $Y: 0 \dots Height_S - 1$ )
    For ( $Z: 0 \dots Palettes_S - 1$ )
       $S(X, Y, Z) = S(X, Y, Z) \text{ XOR } K_{Atom}[K_{index}]$ 
       $K_{index} = K_{index} + 1$ 

```

The substitution operation is used to satisfy as much as possible of the confusion effect in the data of the source image S . Choosing the XOR logical operation aims to implement a fast operation where using a mathematical formula would slow the encryption process. Also, the random values of the amino acid code are used to certainly add more difficulties for attackers to know the key and break the encrypted data.

2. Transposition Operation

For more protection to the encrypted data produced from the substitution operation and to fulfil Shanons' criteria, transposition operation is implemented to cause the diffusion effect on the contents of the source image S . This is conducted by performing swap operations between the bytes of S . The following programming code is implemented for the transposition operation.

```

 $K_{index} = 0$ 
For ( $X: 0 \dots Width_S - 1$ )
  For ( $Y: 0 \dots Height_S - 1$ )
    For ( $Z: 0 \dots Palettes_S - 1$ )
       $S(X, Y, Z) \leftrightarrow S(K_X[K_{index}], K_Y[K_{index}], K_Z[K_{index}])$ 
       $K_{index} = K_{index} + 1$ 

```

The nature of the 3D structure of the protein that has random X , Y , and Z coordinates helps to achieve a high level of distribution of the bytes over the whole content of the image S . Besides, the swapping operations cause more difficulty for the attackers to predict the key.

4.3. Construct Encrypted Image E

After completing the substitution and transposition operations, the resulting byte values are combined to produce an encrypted image E .

4.4. Decryption Stage

The same primary protein key K and the encrypted image E are used in this stage to recover the source image S . The perpetration stage is performed here in the same procedure as described earlier. Then the substitution and transposition operations are performed but in reverse order.

5. Implementation and Discussion

To evaluate the performance of the proposed encryption technique, a set of measurements is used in the experiments to test the proposed encryption technique, such as statistical and visual tests, information entropy, avalanche effect, key space, encryption execution time, and correlation analysis. In addition, a comparison is made between the proposed encryption technique with commonly used cryptosystems (such as DES, AES, and DNA-based methods) based on some criteria. These criteria are an encryption execution time, normalized mean absolute error (NMAE), peak signal-to-noise ratio (PSNR), Information Entropy, correlation, number of changing pixel rates (NPCR), the unified averaged changed intensity (UACI), and key space (Brute force attack) [23].

In the experiments, various images of different contents and sizes were selected and used to evaluate the performance of the proposed technique. The strengths and weaknesses of the proposed technique are determined by comparing the results of the proposed technique with the existing cryptosystems. Some of these images are shown in Fig. 3, and their results are listed afterward.

5.1. Statistical and Visual Tests

Attackers can use an image histogram to get information about the distribution of the color/byte intensity in the image. The efficiency of any image encryption technique depends on achieving a high degree of flatness in the color/byte histogram of the encrypted image. This factor plays an important role in achieving a high level of protection for encrypted images against statistical analysis attacks. This will add more difficulties for the attackers. Figure 4 shows the histograms of the source and the encrypted image of two selected images as examples, namely Bridge and the Monument images of Fig. 3.

Figure 4 indicates that the proposed image encryption technique succeeded in producing a high level of flatness in the encrypted image histogram compared to the source image histogram.

The peaks shown at the same locations in both, the source and the encrypted images may leak some information which presents a drawback of the algorithm.

However, the overall histogram presented no serious threat as was manifested by the results of the information entropy, avalanche effect, NMAE, and the PSNR tests.

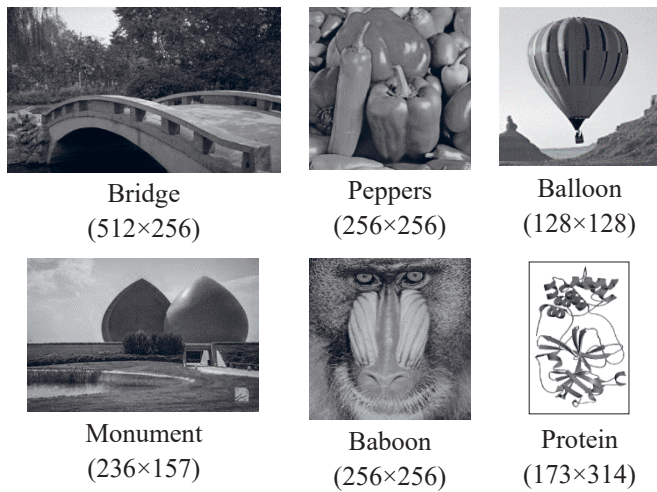


Figure 3. Source images used in the experiments.

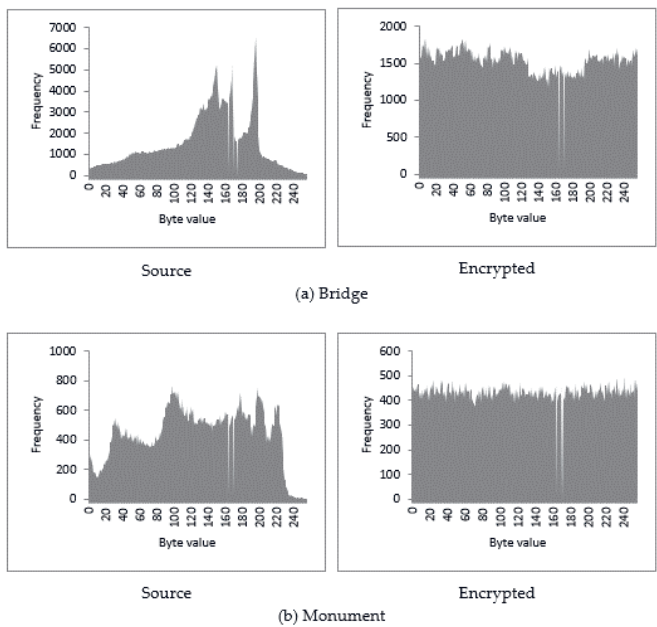


Figure 4. Histograms of the source and encrypted images, (a) Bridge (b) Monument.

Achieving a high level of diffusion and confusion effects in the encrypted image is the major objective of any proposed image encryption technique. The performance efficiency of the image encryption technique depends on the distortion rate generated in the encryption image, which will prevent any attacker from guessing the nature of

the source image. The encrypted images that resulted in the testing experiments proved that the proposed image encryption technique produces a high level of distortion in the encrypted images. Figure 5 shows the encrypted images generated using the proposed image encryption technique for the images in Fig. 3.

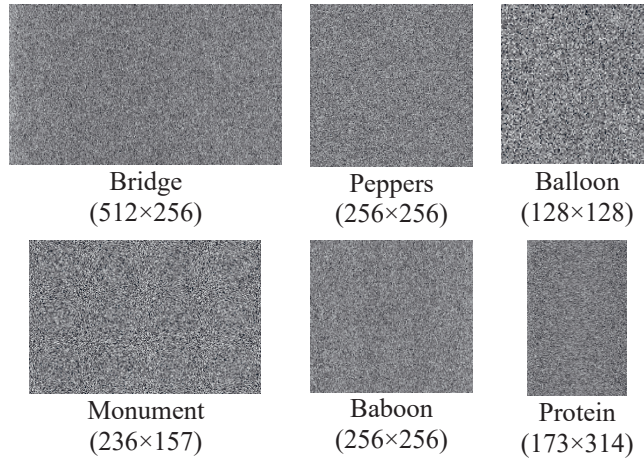


Figure 5. The encrypted images generated from the source images in Fig. 3.

5.2. Information Entropy

The property of randomness of any image is called Information entropy. Entropy is the average (expected) amount of information from the data. When the information entropy of an image is high, it becomes difficult to predict the content of that image. Equation (5) is used to calculate the information entropy [24], [25].

$$Entropy = - \sum_{i=1}^n P_i \cdot \log_2(P_i) \quad (5)$$

Where n is the number of different data values and P_i is the probability of the data value occurring.

Table 4 lists and compares the information entropy of the source and encrypted images with that well-known encryption techniques; DES and AES, and DNA-based encryption algorithm [25].

From Table 4, it is obvious that the proposed encryption method produces an acceptable level of randomness in the encrypted image compared with the other well-known encryption techniques.

The average entropy value of the three encryption techniques is about 8, which indicates that the proposed image encryption technique is comparable to the other techniques and indicates that it is difficult to implement a successful attack.

From Table 4, it is obvious that the proposed encryption method produces an acceptable level of randomness in the encrypted image compared with the other well-known encryption techniques.

The average entropy value of the three encryption techniques is about 8, which indicates that the proposed image encryption technique is comparable to the other techniques and indicates that it is difficult to implement a successful attack.

Image	Entropy				
	Source	Proposed	DES	AES	DNA
Bridge	7.5422	7.9945	7.9995	7.9995	7.9769
Peppers	7.6772	7.9967	7.9990	7.9991	7.9636
Balloon	7.1668	7.9815	7.9967	7.9963	7.9653
Monument	7.7973	7.9981	7.9982	7.9982	7.9950
Baboon	7.7788	7.9978	7.9990	7.9990	7.9941
Protein	2.8616	7.8934	7.9988	7.9991	6.4184
Average Entropy value	6.8040	7.9770	7.9990	7.9985	7.7189

Table 4. Entropy values of the source and encrypted images.

5.3. Avalanche Effect

The avalanche effect is a numerical and a visual measure used to test the sensitivity of the proposed encryption technique to any small changes in its parameters. The main goal is to develop an encryption technique with high sensitivity characteristics, i.e., any small change in the key or the source data causes a considerable change in the encrypted data.

The test is conducted for different number of bits variations in the encryption key, and the effects of these changes are calculated in the generated encrypted image and the recovered source image.

5.3.1. Avalanche effect on the encrypted image

During the experiments, equation (6) [26] was used to calculate the avalanche effect (AE), the percentage of the number of bits in the encrypted image that changes when a few bits in the used encryption key are changed.

$$\text{Avalanche Effect} = \frac{\text{Number of changed bits in key used}}{\text{Total number of bits in encrypted image}} \times 100 \quad (6)$$

The avalanche test was performed by changing different number of bits in the encryption key between 1 bit to 7 bits. Table 5 lists the avalanche test values recorded in the experiments of the example images in Fig 3.

5.3.2. Avalanche effect on the recovered source image

Another use of the avalanche effect is in the source image recovery, where any changes in the encryption key bits will affect the recovered source image. An effective image encryption technique is that when some bits in the encryption key are changed and then use the key to decrypt the encrypted image, it will create an image completely different from the source image. Figure 6 shows the recovered

images after changing a number of bits in the encryption key for some images in Fig. 5. The recovered images in Fig. 6 are completely different from the source images of Fig. 3. This means that the key used by the proposed image encryption technique is very sensitive to the avalanche effect.

Image	Number of changed bits in the encryption key (%)		
	1 bit	4 bits	7 bits
Bridge	50.015	50.017	50.029
Peppers	50.008	50.009	50.010
Balloon	50.043	50.044	50.045
Monument	50.053	50.054	50.081
Baboon	49.989	49.991	50.014
Protein	50.043	50.044	50.051

Table 5. Avalanche test results during experiments.

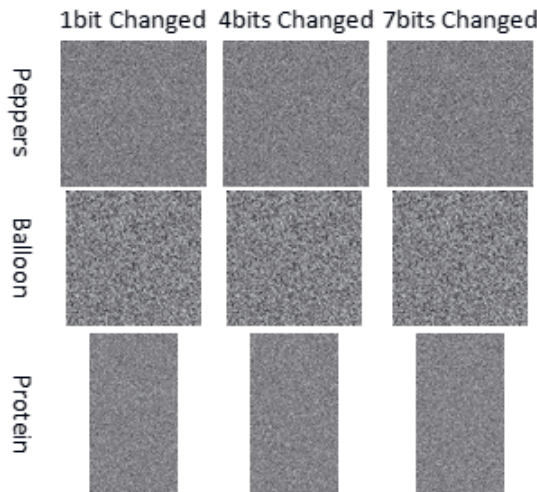


Figure 6. The effect of changing bits in the encryption key on the recovered images.

5.4. Key Size and its Complexity

The success and failure of a brute force attack mainly depend on the length and randomness of the encryption key. Using a larger key length means the attackers need more time to breach the security. Moreover, a high degree of randomness in the key increases the difficulty of guessing the key. The length of the key used is normally measured in bits.

For the proposed image encryption technique, its key-length depends on the number of bits required for the protein structure representation as well as the number of bytes (n) in the source image, and can be clarified as follows; 8 bits to represent the random value between (0...255) for each one of the 24 amino acids and 8 bits to represent the random value between (0...255) for each one of the 38 atom types. Then,

if an image with width (W), height (H), and color palette (P) is to be encrypted, the total number of bytes in the image shall be $n = (W \times H \times P)$.

Therefore, the key length in bits (K_{bit}) for this image encryption technique is calculated by equation (7).

$$K_{bit} = \left((8 + 8) + \left(\frac{\log W + \log H + \log P}{\log 2} \right) \right) \times n \quad (7)$$

In the proposed image encryption technique, the user can select any digital protein file of any size to be used for the encryption key. The primary key (protein file) used in this technique is usually large, as illustrated by the following example.

The encryption key in the proposed algorithm results in a huge key space compared with other encryption algorithms, such as 3DES, AES, Twofish, Blowfish, and RC4, as listed in Table 6 [27], [28], which indicates strong security.

Algorithm	Encryption key	
	Key Size (bits)	Key space
3DES	168	2^{168}
AES	256	2^{256}
Twofish	256	2^{256}
Blowfish	448	2^{448}
RC4	2048	2^{2048}
Proposed Technique	K_{bit}	$> 2^{K_{bit}}$

Table 6. Key size and key space comparison.

Where: K_{bit} is defined in equation (7)

Example: Consider the (236×157 pixels) monument color image shown in Fig 3. The width, $W = 236$, and the height, $H = 157$, $P = 3$, hence $n = (W \times H \times P)$ then, the encryption key length is:

$$K_{bit} = \left((8 + 8) + \left(\frac{\log 236 + \log 157 + \log 3}{\log 2} \right) \right) \times 111156$$

$$\therefore K_{bit} > 6924493.102 \text{ bits}$$

5.5. Encryption Execution Time

The speed of the encryption process is one of the important metrics for evaluating the performance of an encryption method. The same images have been encrypted using the proposed technique and other known encryption methods (DES, AES, DNA), the recorded results are listed in Table 7.

It can be seen from Table 7 that the encryption process time, including the time required for the preparation stage, of the proposed technique is relatively close to the

known encryption methods. This means that the proposed encryption technique can be used effectively to protect the images.

Image	Encryption Time ET (sec)			
	<i>Proposed</i>	<i>DES</i>	<i>AES</i>	<i>DNA</i>
Bridge	0.762	0.629	0.592	0.632
Peppers	0.402	0.328	0.307	0.301
Balloon	0.117	0.157	0.140	0.150
Monument	0.245	0.208	0.134	0.172
Baboon	0.400	0.347	0.258	0.306
Protein	0.365	0.379	0.361	0.375
Average ET value	0.382	0.341	0.299	0.323

Table 7. Encryption process time for encryption methods.

5.6. NMAE and PSNR Metrics

Two numerically determined metrics can be determined to reflect the amount of distortion produced in the encrypted images to thwart the attackers, namely the normalized mean absolute error NMAE and peak signal to noise ratio PSNR. These metrics are calculated by Equations (8) and (9), respectively [29] as follows:

$$NMAE = \frac{\sum_{k=0}^{n-1} |S(k) - E(k)|}{n} \times 100 \quad (8)$$

$$PSNR_{db} = 10 \cdot \log_{10} \left(\frac{Max_S^2}{NMAE} \right) \quad (9)$$

Where S is the source image and E is the encrypted image, and Max_S is the maximum possible pixel value of S .

Tables 8 and 9 show the resulting NMAE and the PSNR values for the proposed technique and for DES, AES, and DNA encryption methods. The NMAE and PSNR values of the proposed technique are competitive values with well-known DES, AES, and DNA encryption methods. Moreover, the NMAE and PSNR values in Tables 8 and 9 are represented graphically in Fig. 7 and Fig. 8, respectively.

Image	NMAE (%)			
	<i>Proposed</i>	<i>DES</i>	<i>AES</i>	<i>DNA</i>
Bridge	58.57	57.60	57.69	58.15
Peppers	83.53	83.40	83.37	82.56
Balloon	66.33	66.19	65.99	65.72
Monument	65.47	65.19	65.11	65.45
Baboon	67.19	66.78	66.93	66.34
Protein	53.35	55.41	55.34	46.67
Average NMAE value	65.74	65.76	65.74	64.15

Table 8. NMAE values for encryption methods.

Image	PSNR (dB)			
	<i>Proposed</i>	<i>DES</i>	<i>AES</i>	<i>DNA</i>
Bridge	7.86	7.99	7.99	7.89
Peppers	6.77	6.78	6.79	6.85
Balloon	6.77	6.84	6.84	6.89
Monument	7.49	7.54	7.55	7.51
Baboon	7.53	7.58	7.56	7.63
Protein	5.62	5.30	5.32	5.46
Average PSNR value	7.01	7.01	7.01	7.04

Table 9. PSNR values for encryption methods.

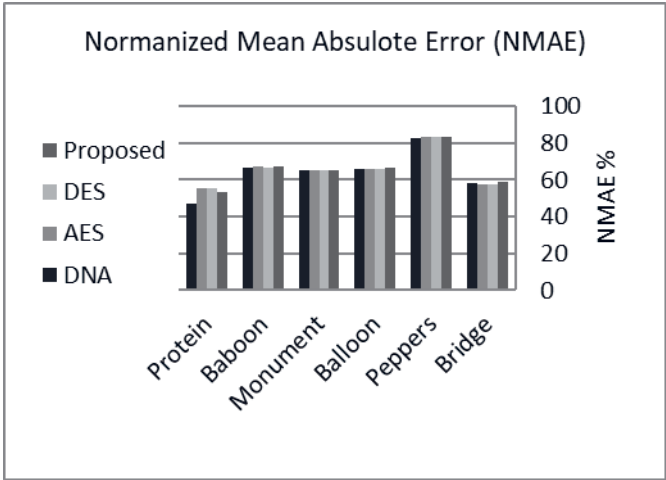


Figure 7. The graphical representation of NAME values of Table 8.

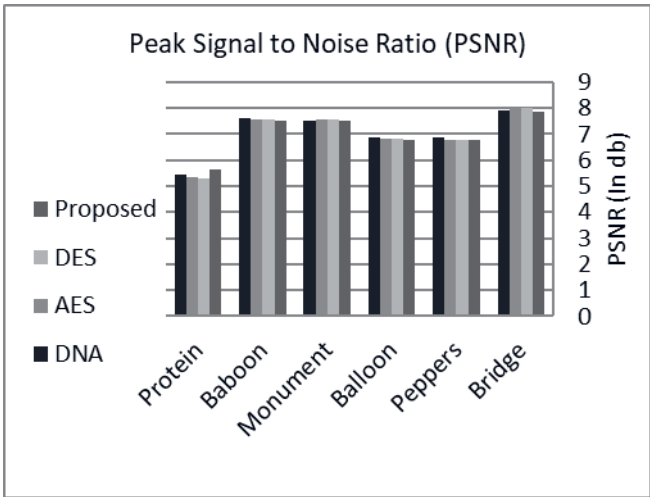


Figure 8. The graphical representation of PSNR values of Table 9.

5.7. Correlation Metric

One of the distortion effects that the encryption method aims to achieve in the encrypted image leads to minimizing the relationship between the values of the adjacent pixels in the encrypted image. Equation (10) is used to calculate the correlation between two adjacent pixels in the diagonal orientations.

$$C = \frac{N \sum_{j=1}^N (X_j \times Y_j) - \sum_{j=1}^N X_j \times \sum_{j=1}^N Y_j}{\sqrt{\left(N \sum_{j=1}^N X_j^2 - \left(\sum_{j=1}^N X_j \right)^2 \right) \times \left(N \sum_{j=1}^N Y_j^2 - \left(\sum_{j=1}^N Y_j \right)^2 \right)}} \quad (10)$$

Where X and Y are the values of the colors of two adjacent pixels in the encrypted image and N is the number of adjacency pixels selected in the image that are used to calculate the correlation.

During the experiments, 3000 pairs of adjacent pixels were randomly selected. Equation (10) is used to test the correlation between two adjacent pixels in the vertical, horizontal, diagonal, and anti-diagonal orientations. Tables 10-13 show the correlation values of the proposed technique and the known DES, AES, and DNA encryption methods in the vertical, horizontal, diagonal, and anti-diagonal orientations, respectively.

The recorded correlation values in Tables 10-13 indicate that the proposed techniques achieved a competitive average correlation value with other methods.

Image	Correlation Values – Vertical Orientation			
	<i>Proposed</i>	<i>DES</i>	<i>AES</i>	<i>DNA</i>
Bridge	0.0104	0.0031	0.0052	0.0108
Peppers	0.0344	0.0141	0.0194	0.0485
Balloon	0.0221	0.0571	0.0195	0.0278
Monument	0.0041	0.0649	0.0023	0.0476
Baboon	0.0535	0.0205	0.0145	0.0394
Protein	0.0123	0.0251	0.028	0.0134
Average correlation value	0.0228	0.0308	0.0148	0.0313

Table 10. Correlation values for encryption methods in vertical orientation.

Image	Correlation Values – Horizontal Orientation			
	<i>Proposed</i>	<i>DES</i>	<i>AES</i>	<i>DNA</i>
Bridge	0.0547	0.0317	0.0014	0.0645
Peppers	0.0286	0.0221	0.0281	0.0481
Balloon	0.0022	0.0531	0.0076	0.0201
Monument	0.0467	0.0349	0.0565	0.0709
Baboon	0.0816	0.0023	0.0223	0.0711
Protein	0.0114	0.0066	0.0223	0.0122
Average correlation value	0.0375	0.0251	0.023	0.0478

Table 11. Correlation values for encryption methods in horizontal orientation.

Image	Correlation Values – Diagonal Orientation			
	<i>Proposed</i>	<i>DES</i>	<i>AES</i>	<i>DNA</i>
Bridge	0.0093	0.0372	0.0056	0.0139
Peppers	0.0384	0.0166	0.0026	0.0305
Balloon	0.047	0.0083	0.0422	0.0768
Monument	0.0321	0.008	0.0418	0.0411
Baboon	0.0666	0.0033	0.0242	0.0089
Protein	0.0385	0.0235	0.0412	0.0102
Average correlation value	0.0387	0.0162	0.0263	0.0302

Table 12. Correlation values for encryption methods in diagonal orientation.

Image	Correlation Values – Anti-diagonal Orientation			
	<i>Proposed</i>	<i>DES</i>	<i>AES</i>	<i>DNA</i>
Bridge	0.0246	0.0181	0.0455	0.0167
Peppers	0.0109	0.0112	0.0243	0.0109
Balloon	0.014	0.0674	0.0287	0.0835
Monument	0.0348	0.0065	0.0019	0.0018
Baboon	0.0078	0.025	0.0507	0.0422
Protein	0.0229	0.0094	0.0048	0.0442
Average correlation value	0.0192	0.0229	0.026	0.0332

Table 13. Correlation values for encryption methods in anti-diagonal orientation.

5.8. NPCR and UACI Randomness Tests

The strength of image encryption algorithms for differential attacks can be assessed using NPCR and UACI metrics. The NPCR and UACI are calculated using equations (12) and (13), respectively.

$$D(i, j) = \begin{cases} 1, C_1(i, j) \neq C_2(i, j) \\ 0, C_1(i, j) = C_2(i, j) \end{cases} \quad (11)$$

$$NPCR = \frac{\sum_{i=1}^{Width} \sum_{j=1}^{Height} D(i, j)}{Width \times Height} \times 100\% \quad (12)$$

$$UACI = \frac{\sum_{i=1}^{Width} \sum_{j=1}^{Height} |C_1(i, j) - C_2(i, j)|}{Width \times Height \times 255} \times 100\% \quad (13)$$

Where C_1 and C_2 represent the encrypted images before and after one pixel change in a source image, $Width \times Height$ represents the image size. The calculated values of NPCR and UACI between the two encrypted images C_1 and C_2 are listed in Table 14 and 15, respectively.

It is clear from Tables 14 and 15 that the proposed image encryption algorithm succeeded in creating two different encrypted images when only one pixel in the source image changed, which means that the algorithm has a high sensitivity to any small changes in the source image.

Image	NPCR (%)			
	<i>Proposed</i>	<i>DES</i>	<i>AES</i>	<i>DNA</i>
Bridge	99.33	99.60	99.61	99.21
Peppers	99.40	99.58	99.61	99.30
Balloon	99.00	99.60	99.61	99.01
Monument	99.53	99.60	99.60	99.44
Baboon	99.50	99.64	99.62	99.50
Protein	99.00	99.62	99.59	99.10
Average correlation value	99.29	99.61	99.61	99.26

Table 14. NPCR values between the two encrypted images C_1 and C_2 .

Image	UACI (%)			
	<i>Proposed</i>	<i>DES</i>	<i>AES</i>	<i>DNA</i>
Bridge	33.03	33.44	33.54	33.12
Peppers	33.26	33.39	33.52	33.01
Balloon	33.17	33.66	33.50	33.24
Monument	33.33	33.40	33.48	33.07
Baboon	32.92	33.48	33.39	33.56
Protein	32.90	33.43	33.37	33.27
Average correlation value	33.1	33.47	33.47	33.21

Table 15. NPCR values between the two encrypted images C_1 and C_2 .

6. Conclusions

A new symmetric image encryption scheme based on 3D protein structure is developed, producing a considerably strong encryption key with huge key - spaces. Utilizing the randomness of protein sequences along with their chaotic and very complex 3D structures led to the construction of random data tables from which extremely strong encryption keys were generated. Various security tests that included statistical and visual tests, avalanche tests, entropy, normalized mean absolute error, peak signal to noise ratio, and values were satisfactory compared to other cryptosystems, such as DES, AES, and DNA methods. The proposed cryptographic scheme can also be linked to any other cryptosystem to provide a more efficient hybrid security technique suitable for various applications.

There is no limit to the type of images used as the proposed algorithm can encrypt any images (e.g., RGB, RGBA, etc.). Different images of different sizes were used in the experiment to evaluate the proposed algorithm. The proposed algorithm treats the source image as a single block. This makes it difficult to encrypt very large images. Therefore, in future work, the source image will be divided into a set of small segments and encrypt each one separately.

Acknowledgments

- Mohammed Abbas Fadhil Al-Husainy is grateful to the Irbid National University, Irbid, Jordan for the financial support granted to cover the publication fee of this research article.
- Hamza A. A. Al-Sewadi is grateful to the Iraq University College, Basra, Iraq for the financial support granted to cover the publication fee of this research article.
- Ahmed M. Sayed is grateful to the Nahda University, Beni-Suef, Egypt for the financial support granted to cover the publication fee of this research article.

References

- [1] Saračević, M. H., Adamović, S. Z., Miškovic, V. A., Elhoseny, M., Maček, N. D., Selim, M. M., & Shankar, K. Data encryption for Internet of Things applications based on catalan objects and two combinatorial structures. *IEEE Transactions on Reliability*, 2020, 70(2), 819-830.
- [2] Ahani, S., & Ghaemmaghami, S. (2015). Color image steganography method based on sparse representation. *IET Image Processing*, 9(6), 496-505.
- [3] Zong, T., Xiang, Y., Guo, S., & Rong, Y. (2016). Rank-based image watermarking method with high embedding capacity and robustness. *IEEE Access*, 4, 1689-1699.
- [4] Afek, Y., Alon, N., Barad, O., Hornstein, E., Barkai, N., & Bar-Joseph, Z. (2011). A biological solution to a fundamental distributed computing problem. *science*, 331(6014), 183-185.
- [5] Kroeker, K. L. (2011). Biology-inspired networking. *Communications of the ACM*, 54(6), 11-13.
- [6] Tero, A., Takagi, S., Saigusa, T., Ito, K., Bebber, D. P., Fricker, M. D., & Nakagaki, T. (2010). Rules for biologically inspired adaptive network design. *Science*, 327(5964), 439-442.
- [7] Xiao, G., Lu, M., Qin, L., & Lai, X. (2006). New field of cryptography: DNA cryptography. *Chinese Science Bulletin*, 51(12), 1413-1420.
- [8] Debora S. Marks, Lucy J. Colwell, Robert Sheridan, Thomas A. Hopf, Andrea Pagnani, Riccardo Zecchina, and Chris Sander. (2011). Protein 3D Structure Computed from Evolutionary Sequence Variation. *Plos One*.
- [9] Pearson W. R. (2013). An introduction to sequence similarity ("homology") searching. *Current protocols in bioinformatics*, Chapter 3, Unit3.1.
- [10] Whitford, D. (2013). *Proteins: structure and function*. John Wiley & Sons.

-
- [11] Agrawal, A., Sarkar, C., Dwivedi, S. K., Dhasmana, N., & Jalan, S. (2014). Quantifying randomness in protein–protein interaction networks of different species: a random matrix approach. *Physica A: Statistical Mechanics and its Applications*, 404, 359-367.
 - [12] Hassan, R., Pepic, S., Saracevic, M., Ahmad, K., Tasic, M. A Novel Approach to Data Encryption Based on Matrix Computations. *Comput. Mater. Contin*, 2020, 66, 1139-1153.
 - [13] Al-Husainy M. A., Al-Sewadi H. A, and Masadeh S. R. (2022) Using DNA Tape as a Key for Image Encryption. *International Journal of Electronic Security and Digital Forensics*, Vol 14, No. 4.
 - [14] Chen J. (2003). A DNA-based, biomolecular cryptography design. *Proceeding of the IEEE International Symposium on Circuits and Systems (ISCAS)*, Vol. 3, PP 822–825
 - [15] Roy B., Singha P. (2011). An improved symmetric key cryptography with DNA based strong cipher”. *Devices and Communications (ICDeCom)*, IEEE, International Conference on 24-25 Feb. 2011.
 - [16] Tanaka K., Okamoto A., and Saito I. (2005). Public-key system using DNA as a one-way function for key distribution. *Biosystems*, Vol. 81, N0 1, PP 25–29. <https://doi.org/10.1016/j.biosystems.2005.01.004>
 - [17] Cui G.Z., Qin L. M., and Wang Y. F. (2008). An Encryption Scheme using DNA Technology. *Computer Engineering and Applications*, PP 37-42.
 - [18] Zhang Y., Fu B., and Zhang X. (2012). DNA cryptography based on DNA Fragment assembly. *IEEE International Conference on Information Science and Digital Content Technology (ICIDT)*, Vol. 1, PP 179-182.
 - [19] Khana J. S., Ahmadb J., Ahmeda S. S., Siddiqac H. A., Abbasid S. F., and Kayhana S. K. (2019). DNA key based visual chaotic image Encryption. *Journal of Intelligent & Fuzzy Systems*, IOS press, DOI:10.3233/JIFS-18277
 - [20] Devi R. S., Aravind A.R. N., Vishal J. C, D. Amritha D., Thenmozhi K., Rayappan J. B. B., Rengarajan A., Padmapriya P. (2020). Image encryption through RNA approach assisted with neural key sequences. *Multimedia Tools and Applications*, Springer Science+Business Media, LLC, part of Springer Nature. <https://doi.org/10.1007/s11042-019-08562-5>
 - [21] Berman, H. M., Westbrook, J., Feng, Z., Gilliland, G., Bhat, T. N., Weissig, H., ... & Bourne, P. E. (2000). The protein data bank. *Nucleic acids research*, 28(1), 235-242.
 - [22] Jumper, J., Evans, R., Pritzel, A., Green, T., Figurnov, M., Ronneberger, O., ... & Hassabis, D. (2021). Highly accurate protein structure prediction with AlphaFold. *Nature*, 596(7873), 583-589.
-

- [23] Atiewi, S., Al-Rahayfeh, A., Almiani, M., Yussof, S., Alfandi, O., Abugabah, A., & Jararweh, Y. (2020). Scalable and secure big data IoT system based on multifactor authentication and lightweight cryptography. *IEEE Access*, 8, 113498-113511.
- [24] H. Zhang, J. E. Fritts, and S. A. Goldman (2003). Entropy-based objective evaluation method for image segmentation. in *Storage and Retrieval Methods and Applications for Multimedia 2004*, vol. 5307, pp. 38–49.
- [25] Zhang W., Wang S., Han W., Yu H., and Zhu Z. (2020). An Image Encryption Algorithm Based on Random Hamiltonian Path,” *Entropy*, vol. 22, no. 1, p. 73.
- [26] Alabdullah B., Beloff N., and White M. (2021). E-ART: A New Encryption Algorithm Based on the Reflection of Binary Search Tree.” *Cryptography*, Vol. 5, No. 4.
<https://doi.org/10.3390/cryptography5010004>.
- [27] Tagashira M, and Nakagawa T. (2020). “Biometric Authentication Based on Auscultated Heart Sounds in Healthcare,” *IAENG International Journal of Computer Science*, vol. 47, no. 3.
- [28] Kushwaha P. K., Singh M. P., and Kumar P. (2014). A survey on lightweight block ciphers. *International Journal of Computer Applications*, vol. 96, no. 17.
- [29] Al-Husainy M. A. F. and Al-Sewadi H. A. A. (2018). Full Capacity Image Steganography Using Seven-Segment Display Pattern as Secret Key. *Journal of Computer Science*, Vol. 14, No. 6, pp 753-763.
<https://doi.org/10.3844/jcssp.2018.753.763>.

The Impact of Transformation in Higher Education: Introductory of New Technology, Is It Good or Bad?

Norzaidi Mohd Daud

norza544@uitm.edu.my

*Faculty of Business and Management
Universiti Teknologi MARA, Malaysia*

Abstract

This study examines the impact of transformation in higher education, in particular on the introduction of new technology to students in Malaysia. This study is unique as it focuses on usage and technology resistance. Another uniqueness of the study is that technology resistance is measured by non-technology and post-technology antecedents, which have yet to be discovered by existing studies. These factors could potentially influence students to refrain from using technology in their studies, as many previous studies only focus on usage. Furthermore, prior research should have classified different types of resistance that cause significant knowledge gaps in technology education. A survey of 156 respondents concluded that antecedents of non-technology usage do lead to resistance. Post-technology usage, similarly, does influence resistance. As expected, the usage of technology influenced students' performances. Finally, resistance to technology did not affect students' performance. This is likely the first study to examine the impact of transformation in education and classify the antecedents of technology resistance into two categories: non-technology usage and post-technology usage. This research will help policymakers understand how students react to educational transformations. Adding technology could improve how well students do in university, but it could also hurt how well they do in university.

Keywords: Non-technology usage, post-technology usage; technology resistance, students' performance, Malaysia universities

1. Introduction

Introducing new technology in higher education in Malaysia is another milestone in the transformation of education. For instance, since COVID-19 has plagued Malaysian higher learning institutions and schools for the past two years, most universities and schools have mandated online learning classes for students and academicians. This decision stands to keep COVID-19 from spreading quickly in physical education classes. Even though online classes are new to students and academicians, they do have the option of not taking them if it is the only way for them to graduate, as there is no evidence that COVID-19 will end. As a result, education based on cutting-edge technology is critical in assisting students in completing their education. Besides, students' ability to use technology effectively is now critical for locating relevant data and information for assignments, projects, and thesis writing on

the Internet. Malaysian university students, in particular, use an online library and the Internet to download academic articles, proceedings, reports, and videos for academic purposes and other media content for recreational purposes [19].

Furthermore, technological advancements have given students a new way to engage their memories actively, excitement, stories, images, and modes of communication with their physical and virtual friends and families through social networking sites (e.g. Facebook, Twitter, LinkedIn), social review sites (e.g. Yelp and TripAdvisor), image sharing sites, video hosting sites, community blogs (e.g. Medium and Tumblr), and discussion sites (e.g. Reddit, Quora, Facebook) [17].

However, these technologies have a few unintended consequences or potential drawbacks after years of use. Students complained that online classes made them bored, tired, and red-eyed and that they had agronomic problems in a few cases. As a result, these students believe that online classes could be more flexible and suitable for them. Furthermore, online classes are highly reliant on high-speed networks, and the most up-to-date I.T. gadgets, which are costly and only some students can afford them. As a result of the COVID-19 pandemic, many families' incomes and budgets have suffered a deficit because economic downturned, making it impossible to lease faster Internet or purchase new laptops. As a result, these students must share a laptop with their siblings, and a bad internet connection will undoubtedly affect their academic performance. As a result, these incidents may have a negative impact on students' perceptions of technology as a burden because it is expensive and does not support their need to study. Hence, the introduction of new technology will lead students to develop technology resistance [13, 20].

In general, there are two kinds of technology resistance. For illustration, technology resistance may arise due to the environment or the individual, referred to as non-technology usage. People who used technology that was classified as post-technology usage were another example.

The following is an example of non-technology usage: A few students believe certain technologies will harm their academic performance. They believe that by utilizing specific social media platforms, they will be able to waste time and money on new technology and app subscriptions. The allure of technology will not entice these students. When wealthy colleagues are involved, another scenario where technological resistance may arise. Students, especially inexperienced students who rely on close friends for support, tend to follow their peers. They will follow suit if their peers are less tech-savvy than they are. Technology resistance will undoubtedly increase if students follow their peers to avoid using technology [3, 12, 24]. These are two examples of non-technology applications that contribute to technology resistance. Technology has been the primary focus for the past decade, resulting in increased effectiveness, efficiency, and quality.

On the other hand, post-technology usage is the next category that could lead to technology resistance. Negative prior experience with technology, poor system design, and security systems are three significant antecedents that may influence technology resistance. Students may be hesitant to use technology if they have had bad experiences with it in the past [9]. Students may believe similar technologies will impair their performance if they have difficulty using new devices or information

technology appliances. As a result, they will reject new technology for fear of having to go through the same thing again.

Furthermore, some students will only use technology if it is well-designed. If students are proficient in information technology but it needs to meet their needs and desires for a certain level of design, this scenario may arise. Last, most technology, including social media, must be adequately protected. Students may fear confronting cyberbullying, which has become a threat and jeopardized their lives. The university's systems must be free of viruses and resistant to attacks from various information technology adversaries. Users can only use systems and social media platforms if they are adequately secured. As a result, technological resistance will rise [8]. In a nutshell, these three scenarios occur when students have used a piece of technology and, as a result of negative experiences, poor system design, and a lack of security systems, are more likely to resist technology.

According to the aforementioned data, it follows that students may become both users and opponents of the changing technology. According to numerous earlier studies, using technology will increase performance while resisting it will decrease performance [1, 5, 14]. However, given how quickly technology advances change, the conclusions of these studies are out of date, and more recent discoveries are essential.

Additionally, the majority of current studies distinguish between technology use and resistance while it is essential to correlate every component of technology use and resistance in one place, indicating a significant knowledge gap. Additionally, it seems crucial to uncover fresh data on education given that the majority of studies focus on the manufacturing, maritime, and logistics sectors [5, 19]. At the time, a study in this field addressed the following research questions:

1. Does a colleague's affluence affect student resistance to technology?
2. Does one's expectation of efficacy affect student resistance to technology?
3. Does technology usage affect negative prior experiences?
4. Does technology usage affect system security?
5. Is technology usage a predictor of poor system design?
6. Is prior negative experience a predictor of technology resistance?
7. Is poor system design a predictor of technology resistance?
8. Is system security a predictor of technological resistance?
9. Does students' resistance to technology affect their performance?
10. Is it possible to predict students' performance based on their use of technology?

The following section reviews the literature and formulates propositions for testing in this study.

2. Review of Literature

2.1. Colleagues' Affluence and Technology Resistance

The majority of failed technology implementations, between 50% and 70%, resulted from organizational and people-related issues. The following characteristic of user

resistance is the influence of peers [14, 19]. This trait has been extensively studied regarding how colleagues affect an individual's perception of a job. This situation occurs when initially resistant employees observe their colleagues adapting their work behaviors to a new technology system with ease. They are also likely to believe that they are capable of mastering new technology [15].

Additionally, additional research demonstrates that colleagues influence technological resistance. For example, Markus [14] discovered that an individual's level of technological resistance could be influenced by the expectations of others (co-workers). Joshi [12] demonstrates that people recognize cues in their environment and may react to them, even more so when the cues originate from highly regarded colleagues. Thus, if colleagues oppose the new information technology and place-specific blame for failure, the individual may do the same [11]. According to the current study, students may avoid using specific technology devices to keep up with their friends. As is the case with their friends, they are the most influential people in their lives, and due to their separation from their families, they will make decisions on their behalf. The situation is legitimate because their friends mean the world to them, and their lives would be in jeopardy without them.

Additionally, if their friends have previously had negative experiences with similar technology, they will be less likely to use it in the future. As a result, students will pay attention to their peers and avoid using technology. Unmistakably, this is a rejection of technology. Thus, to support this argument, the following hypothesis is advanced:

H1: Colleagues' affluence is a predictor of technology resistance

2.2. Efficacy Expectation and Technology Resistance

An efficacy expectation is users' hostile attitude toward new technology [2]. Most technophobes believe that utilizing technology, such as the Internet, will impede their ability to perform necessary tasks. This notion is problematic in many departments of corporate companies that were previously government agencies. However, it has morphed into private businesses, where a sizable portion of their staff is unwilling to explore and adopt new technologies. For example, many middle managers at terminal operators in Port Klang place a premium on intranet effectiveness. This situation occurred during the intranet's initial stage of development. Some senior IT executives believed they could excel at their jobs by utilizing traditional technologies, such as telephones and fax machines, except intranets [23].

According to Nguyen et al. [17] research, students resist using the intranet due to unfamiliarity. They discovered that most of them needed to be more familiar with performing specific intranet tasks and believed using it would impair their performance. Additionally, they believed traditional technologies such as fax machines and telephones would improve their performance. One could argue that efficacy expectations originate from specific sources. For instance, Kim [13] believes efficacy expectations develop due to prior failures, reinforcing anxiety and negative attitudes. As a result, this end-user is opposed to introducing new computer-based

technology (CBT) or modifying existing CBT, regardless of the degree of difficulty associated with the CBT's learning. As a result, we generate the following hypothesis:

H2: Efficacy expectation a predictor of technology resistance

2.3. Technology Usage and Negative Prior Experience

According to Martinko et al. [15] there is empirical evidence that prior negative experiences with information technologies are associated with the rejection of information technologies. Norzaidi et al. [24] studied user satisfaction and technology resistance. A few officers refused to use the Internet due to prior negative experiences with similar technologies. These students believed that using the Internet would have a detrimental effect on their lives. As a result, one of the characteristics of user resistance is a prior negative experience with technology.

On the other hand, Dishaw and Strong [7] take a contrary position on the issue of technology experience in other studies. They investigated the effect of increasing exposure to maintenance tools and tasks on the TTF model for software maintenance tool use. They investigated two hypotheses in their research: (1) familiarity with maintenance tools and (2) familiarity with the maintenance task. They found substantial support for the first part of their initial hypothesis but could not determine the direction of the effect. Furthermore, hypothesis two is unsupportable in any way. Dishaw and Strong assert that the fit between a tool's functions, the task's requirements, and the maintainer's experience with the tool are excellent predictors of the tool's use for a particular maintenance project. As a result, experience with the task does not affect the fit models.

According to this study, students who struggle with technology may avoid similar technologies in the future. The same students will believe that similar technology, regardless of brand or functionality, is challenging and insufficient for the assigned tasks or projects. When technology is required or mandatory, students are compelled to use it, resulting in incomplete assignments or projects. Indirectly, poor assignments and projects will have a detrimental effect on their academic performance. This action is also comparable to the situation in which students who are careless with the software or systems they use produce substandard assignments or projects. As a result, their academic performance will suffer due to this condition. To summarize, empirical research on user resistance to technology use and prior negative experiences with technology use is inconsistent and contradictory [3]. According to this argument, the following hypothesis is formed:

H3: Negative prior experience is a predictor of technology resistance

2.4. Technology Usage and Systems Security

There is a condition in which students use specialized technology to devastate their work assignments and final project papers. This situation invariably occurs when these particular systems need to have adequate security measures in place. When powerful trojans or viruses attack students' assignments, the students' files and work are jeopardized. The affected file could not be opened, and the sentences in the

assignments were not editable [8]. Almost invariably, this results in substandard writing. As a result, students must redo their assignments or find alternate solutions to complete them. This situation will undoubtedly cause them stress and apprehension regarding technology.

Moreover, it may be related to a prior negative experience, as students who have had a negative experience with a particular technology, information, or technology device are more likely to avoid it in the future and instead use alternative technologies or none. That is why most universities will ensure that all devices, particularly lab computers and online classes, are adequately protected by cutting-edge security systems. University networks, like intranet networks, will be protected by two or three layers of firewalls [2]. It is difficult to imagine universities being unconcerned about security systems, as this would have impacted both students' academic performance and the university's overall performance. The following proposition is made as a result of this study:

H4: Systems security is a predictor of technology resistance

2.5. Technology Usage and Poor Systems Design

One of the reasons for people's adverse reactions to computers is poor system design (Markus, 1983). Poor systems can be defined as those that lack functionality, interface design, modes of presentation, and accessibility of two insufficient response times are insufficient, all of which amplify adverse reactions and frustrate those who initially exhibit positive ones [6, 11]. Gebauer and Shaw (2004) found that inadequate system documentation has a detrimental effect on usage. While systems may perform well on all performance measures, they may be underutilized due to user dissatisfaction with the systems and their interface. Kim [13] discovered the source of resistance to computer-based technology (CBT) in one of his studies. According to his research, many professionals believe that end users may blame specific features of CBT for workplace problems. Resistance to CBT-determined explanations focuses on specific features of the CBT that the end-user finds challenging to learn or operate.

Additionally, Henry indicated that the causes of unsuccessful performance, such as the difficulty of using CBT, are likely to increase resistance among current CBT users and may serve as the initial cause for new CBT users. This situation may be especially true for users who exert great effort with little success. Norzaidi et al. [20] discovered that poor system design is a factor in managers' resistance to technology. The respondents contended that it would be rejected if the technology lacked an adequate system (i.e., difficult to use, had a slow operating system, and was incompatible with certain technologies). This argument constructs the following hypothesis:

H5: Poor systems design is a predictor of technology resistance

2.6. Negative Prior Experience and Technology Resistance

Until now, little research has been conducted on the relationship between prior negative experiences with technology and the subsequent development of technology resistance. However, for this study, it is possible that if students or users have had a bad experience with technology, they will be less likely to use similar technology in the future [8, 10]. For instance, if students encounter difficulties downloading free software from the university's network due to a slow internet connection, they will abstain from doing so in the future. Even worse, if students attempt to download for several hours and are suddenly unable to do so due to a slow internet connection. Moreover, if students are required to attend online classes, and the lines connecting their homes or hostels to the university's network are problematic, this situation will cause them stress and make them less likely to attend online classes [4, 11]. As such, the purpose of this study is to address this assertion.

H6: Negative prior experience will influence technology resistance

2.7. Security Systems and Technology Resistance

Another point of contention for students is whether the technology is sufficiently secure. This condition is critical because the system's security level will influence its perception of its safety [13, 19]. They are concerned that viruses or trojans will infect their assignments or final reports, jeopardizing their academic performance. This concern is a concern unique to universities. This situation is analogous to the situation in which many students are now required to attend classes online and must place some trust in the platform they use to ensure their data is secure from any technology adversaries.

On the other hand, businesses rely on electronic commerce, or e-commerce, to attract customers. Online banking, for example, is critical because each financial transaction must be valid and entirely protected by sophisticated security systems. If customers lose trust in online banking systems due to easy hacking or cracking, they will use them less. That is why many banks are currently upgrading their security measures by adding one or two additional layers of password protection to ensure the system remains secure [16, 18]. Thus, customers will trust online systems because they are simple to use and secure and eliminate the need for customers to visit banks to check their accounts, make money transfers, and conduct other related transactions. As a result, learning about this prediction is fascinating.

H7: Security systems will predict technology resistance

2.8. Poor Systems Design and Technology Resistance

Another factor contributing to students' resistance to technology use is ineffective system design. Most recent students are familiar with cutting-edge information technology, experimenting with and learning through social media platforms such as YouTube. Their fundamental understanding of information technology is significant, which is why any device or system introduced should, at the very least, match their technology knowledge [16, 20].

For example, if a university's registration system is challenging due to poor design, students will complain and may even avoid using it. This scenario occurs when the online education platform is incompatible with a computer or an iPad. This condition complicates their ability to follow in class and adds to stress [19, 20, 25]. Finally, students' performance on quizzes, mid-term tests, and final examinations will be subpar. As with online banking, a user may be discouraged from using a menu or system that is overly complicated. For example, a user wishing to make an online payment must adhere to numerous instructions until they become bored and decide not to use the service again. As such, the purpose of this study is to address this assertion.

H8: Poor systems design will affect technology resistance

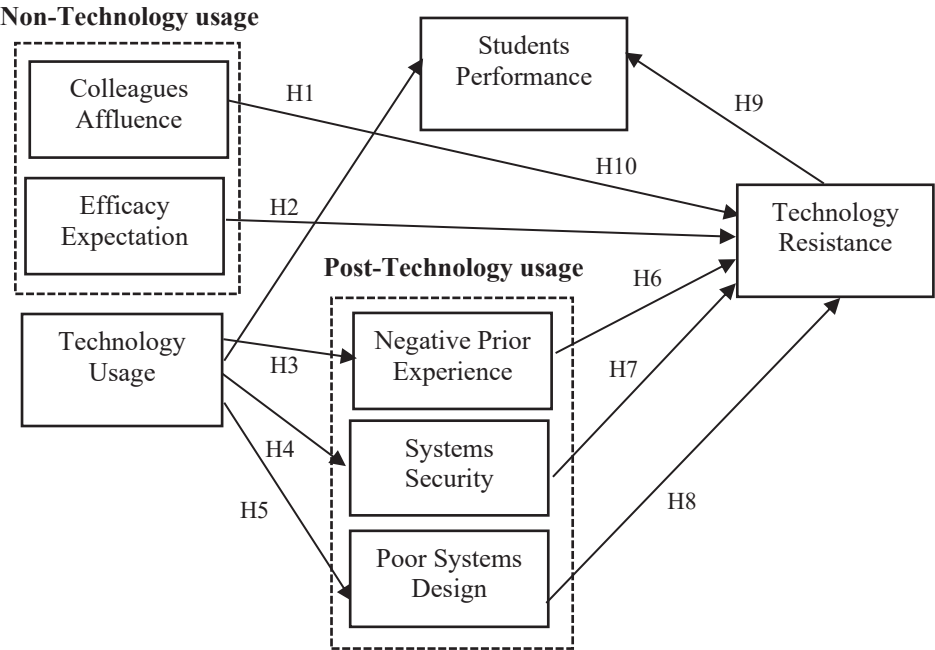


Figure 1. Research Framework and Hypotheses of the Study

2.9. Technology Resistance, Technology Usage, and Students’ Performance

The literature has thus far provided scant information about students' technological resistance and academic performance. Norzaidi and Intan Salwani [18], for instance, investigated the effect of internet use on student performance. As a result, the study concluded that student resistance to technology affects their performance. Furthermore, another study discovered no correlation between intranet use and resistance to technology. Hence, most managers will regard the intranet as necessary to motivate them to improve their performance [28].

Utilizing technology will result in increased performance, resolving the issue of technological resistance. Numerous studies have shown that implementing technology

increases productivity, improves quality, and lowers operating and production costs. Simultaneously, students will benefit from using technology by minimizing their errors. For instance, there is a plethora of proofreading software available. Students will proofread their work using this trial version of the software. Students, particularly those who are not native English speakers, can produce better writing with the assistance of this software than they could on their own.

Additionally, students may complete their work and theses using data analysis software such as SPSS or AMOS. With this software, students can quickly formulate and finalize their interpretations of data and validate them for their research findings. In short, students who utilize technology will benefit from increased productivity and academic performance [24]. We proposed the following to test these hypotheses:

H9: Technology resistance will predict students' performance

H10: Technology usage will influence students' performance

In summary, Figure 1 shows the research framework developed and the ten hypotheses proposed to be stated in this study.

3. Research Methodology

3.1. Sampling

The target population included 4,500 diploma and bachelor's degree students from a Malaysian university. The students in this study were chosen because they are recognized as users who rely on technology to complete assignments and final reports. Around 354 self-reporting questionnaires were distributed in the computer labs of the university library. Of the 354 questionnaires distributed, 156 (44 percent) were returned. The response rate exceeds expectations and is representative of the population studied. Sekaran [27] recommends that the questionnaire distribution method's response rate be greater than 10% to avoid sample bias and that at least 30% of responses be collected for analysis [26]. This calculation enables the results to be generalized [27].

3.2. The instrument

The questionnaire is divided into nine sections, each addressing one of the study's ten hypotheses. The first section contains five questions that elicit demographic information about respondents, such as their gender, age, current program, and faculty. The remaining sections include three items measuring respondents' perceptions of their colleagues' affluence [7]; three items measuring respondents' efficacy expectations [23]; three items measuring negative prior experience [20]; three items measuring poor system design [15]; three items measuring system security [1], three items measuring technology usage [5], three items measuring technology resistance [14, 20, 22] and six items measuring students' performance [5]. All items (except the demographic section) were evaluated using a seven-point Likert scale, with 1 indicating strong disagreement and 7 indicating strong agreement.

3.3. Analysis of Data

This section will go over the sample's characteristics and the results of the student's participation in the survey questionnaire study. The next step is to construct validity, which determines how well a test measures what it is supposed to measure. Hence, the test is designed to effectively test what it claims to test [26]. In addition, a reliability test is created to see if the instrument used or questionnaire can perform flawlessly for the current study. Correlation analysis, on the other hand, computes and measures the strength of the linear association between two variables. Finally, hypotheses testing is used to see if the alternative hypotheses proposed in this study can be accepted or rejected [27].

3.4. Sample characteristics

The current study was conducted at a university in Malaysia with the participation of 156 students. According to the data collected, most respondents are female, between 18 and 29, and enrolled in a diploma program at the Faculty of Business and Management. Each respondent has used technology for at least three months (see Table 1). Following that, the discussion will turn to validity and reliability evaluations.

Gender	
<i>Male</i>	30
<i>Female</i>	126
Age	
<i>18-29</i>	156
Current program	
<i>Diploma</i>	104
<i>Bachelor Degree</i>	52
Faculty	
<i>Business and Management</i>	111
<i>Accountancy</i>	34
<i>Information Studies</i>	10
<i>Computer and Mathematics</i>	1

Table 1. Profile of Respondents

3.5. Assessing validity and reliability

A general rule in determining the instrument's reliability is that the indicators should have a Cronbach's alpha of 0.5 or more [26]. With the range of Alpha scores between 0.51 and 0.93 obtained in this study, we can conclude that the questionnaire is reliable and the data can be applied for the analysis [27] (see Table 2). The initial findings show that most of the respondents perceived that antecedents of technology resistance, such as colleagues' affluence, efficacy expectation, negative prior experience, poor systems design, and systems security, influence them to resist technology usage.

Construct	Mean	Standard Deviation	Cronbach's Alpha
Colleagues affluence	2.53	1.55	0.55
Efficacy expectation	2.29	1.34	0.53
Negative prior experience	2.53	1.44	0.53
Poor systems design	2.70	1.75	0.51
Systems security	2.81	1.55	0.52
Technology usage	5.24	1.20	0.68
Technology resistance	2.57	1.52	0.83
Students' performance	5.41	1.17	0.93

Table 2. Descriptive analysis and model fit test

This study considers construct validity besides content validity [4]. In order to measure construct validity, data were extracted using principal component analysis and rotated using the Varimax method. None of the attributes were dropped when the cut-off loading was 0.40, and the eigenvalues were more significant than 1.0. (see Table 3).

Construct	Kaiser-Meyer-Olkin Measure of Sampling Adequacy	Eigenvalue	Percent of total variance explained
Colleagues affluence	0.63	1.24	61.99
Efficacy expectation	0.62	1.60	69.95
Negative prior experience	0.65	1.54	67.07
Poor systems design	0.73	1.71	61.52
Systems security	0.69	1.83	61.02
Technology usage	0.65	1.86	61.88
Technology resistance	0.82	3.00	60.02
Students' performance	0.87	4.45	74.18

Table 3. KMO and Eigenvalue Results

3.6. Correlation

The correlation matrix between the constructs is shown in Table 4. There is a positive association between poor systems design and affluent colleagues ($r = 0.244$). Notably, there is an association between efficacy expectations and poor systems design ($r = 0.599$). Following that, prior negative experiences were found to be significantly associated with efficacy expectations ($r = 0.712$). Additionally, security systems and prior negative experiences have a positive association ($r = 0.622$). There is, as expected, an association between technology usage and security systems ($r = 0.591$). Following that, there is an association between student performance and technology usage ($r = 0.359$). Finally, there is a negative association between student performance and technology resistance ($r = -0.109$).

	Poor Syst.	Eff Expec.	Prior Exp.	Security	Usage	Perform.	Resist
Coll Aff.	0.244**						
Poor Syst.		0.599**					
Eff Expec.			0.712**				
Prior Exp.				0.662**			
Security					0.591		
Usage						0.359**	
Perform.							- 0.109

Note: * *correlation is significant at the 0.01 level

Table 4. Correlation among constructs

4. Results

The findings in Table 5 are summarised the ten hypotheses that were constructed. According to the analysis, colleagues' wealth is a significant predictor of technology resistance; thus, hypothesis 1 is not rejected (p-value = 0.000). Similarly, efficacy expectations are predicted to be technologically resistant (p-value = 0.000), rejecting hypothesis 2. However, hypothesis 3 is rejected because technology usage does not predict negative prior experiences (p-value = 0.088). Next, technology usage does not affect system security (p-value = 0.539), rejecting hypothesis 4. This study concluded that poor system design is unrelated to technology usage (p-value = 0.983), effectively rejecting hypothesis 5. On the other hand, individuals who have negative experiences with technology are more likely to be resistant to it (p-value = 0.000), so hypothesis 6 should not be discarded.

Hypothesis	Causal Relationship		Factor	β	Sig.	Result
H1	Colleagues affluence	→	Technology resistance	0.590	0.000	Accepted
H2	Efficacy expectation	→	Technology resistance	0.859	0.000	Accepted
H3	Technology usage	→	Negative prior experience	-0.137	0.088	Rejected
H4	Technology usage	→	Systems security	0.043	0.539	Rejected
H5	Technology usage	→	Poor systems design	-0.022	0.983	Rejected
H6	Negative prior experience	→	Technology resistance	0.810	0.000	Accepted
H7	Poor systems design	→	Technology resistance	0.800	0.000	Accepted
H8	Systems security	→	Technology resistance	0.707	0.000	Accepted
H9	Technology resistance	→	Students' performance	-0.109	0.174	Rejected
H10	Technology usage	→	Students' performance	0.359	0.000	Accepted

Table 5. Hypotheses testing

Furthermore, hypothesis 7 is not rejected because poor system design strongly predicts resistance to technology (p-value = 0.000). Do not reject hypothesis 8 because

systems security strongly predicts technology resistance ($p\text{-value} = 0.000$). Additionally, student performance is unrelated to technology resistance ($p\text{-value} = 0.174$); thus, hypothesis 9 is rejected. Finally, technology students perform significantly better academically ($p\text{-value} = 0.000$). This indication does not mean that hypothesis 10 should be discarded. The discussion and practical implications will be expanded in the following section.

5. Discussion and Practical Implementations

By examining the causal relationships between dimensions of technology resistance and student performance, this article adds to the body of knowledge by narrowing the research gap. This study is unique in holistically examining the critical factors affecting non-technology and post-technology usage in light of technology resistance and student performance. The model is based on a unified framework that incorporates theories about colleagues' affluence, efficacy expectations, negative prior experience, poor system design, and system security identified through an extensive literature review. Additionally, the model is intended to aid decision-makers in comprehending the relationships between variables, which have recently received scant attention in the literature. These variables were combined and tested in one location to understand better how they were related.

The current study is unique in that it examines the effects of students' perceptions of non-technology usage and post technology usage. Students with negative prior experience, insufficient security systems, and poor system design are more likely to be rejected due to their use of similar or identical technology. Thus, this study seeks to ascertain whether students will feel this way after a negative technology experience.

The current study recruits students with no prior experience with specific technologies but is prone to reject them due to their peers' affluence and efficacy expectations. The findings indicate that there is no such correlation between students who use technology to have a negative prior experience, insufficient system security, or insufficient system design and those who use technology to have a positive prior experience. Thus, even if a small percentage of students have negative experiences with technology, their numbers are insignificant and do not reflect overall outcomes. Due to the mandatory nature of technology, students may be compelled to use it. This suggestion ensures that those who use technology have no negative prior experiences, insufficient security, or poorly designed systems.

Additionally, this study discovered that all antecedents of technology resistance, such as negative prior experience, insufficient security systems, and poor system design, contribute significantly to technology resistance. Similarly, two additional technology resistance antecedents, colleague affluence, and efficacy expectations, significantly affect technology resistance. As a result, students believed these antecedents had the most significant influence on technology resistance. There is no doubt that technology resistance does not affect students' performance. This result is logical, given that most students must use technology to complete assignments, final projects, and other related assignments. They will only be able to perform if this

technology is used. This argument is determined by the amount of technology used, which significantly impacts how well students perform.

Figure 2 displays the finished model. Colleagues' affluence is one factor that predicts aversion to technology. In order to plan, coordinate, direct, and control the company's strategies, students and coworkers usually work together. Colleagues may therefore have an impact on students' decisions to use technology. Coworkers who abstain from using technology are likely to influence pupils to follow suit. These results are consistent with research by Joshi (2005) and Markus (1993).

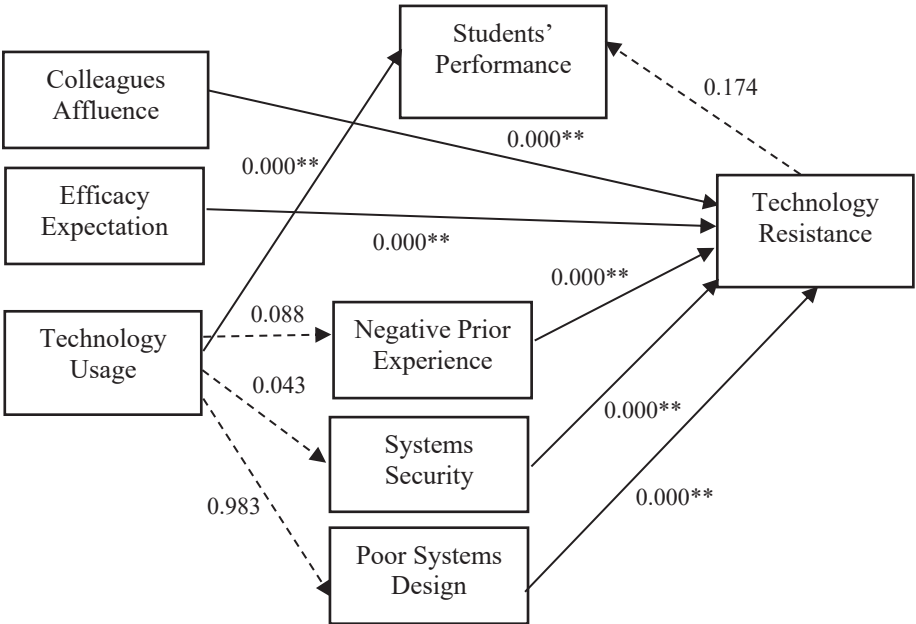


Figure 2. The Final Model of a Study

This study also came to the conclusion that students' performance can be influenced by their earlier experiences. Students who have had a bad encounter with technology, for instance, can be resistant to it. They will think that using technology will always have a similar outcome and that its functioning is always equivalent. As such, the present study demonstrated its support for the earlier research conducted by Friedman et al. (2021) and Elisi et al. (2021).

Another intriguing conclusion is that efficacy expectation is a significant factor that contributes to technology resistance, and this study supported the findings of Kim (2021), Nguyen et al. (2021), and Norzaidi et al. (2011). The rationale is that pupils would not use technology if they believe they are incapable of using it properly.

Several practical implications may assist decision-makers in achieving the above objectives, including the following: (1) support and commitment from university top management and lecturers; (2) ensuring a match between task requirements and technology functionalities; and (3) providing appropriate training to students.

Nothing is more critical than top management leadership and commitment to such an initiative regarding technology implementation. Because a more significant proportion of technology acceptance is attributed to the university's cultural component, university administrators and lecturers play a critical role in shaping the organizational culture and promoting organizational change. University leaders and lecturers must understand the benefits of implementing technological changes to accomplish organizational goals and how students perceive and use technology to improve their performance. It makes no sense to establish a new system to assist students with their assignments if they do not desire it.

A critical consideration, for instance, is communicating with all students to earn their trust and understanding. Another strategy for communicating the system's importance is to incorporate its use and an individual's performance into the university's vision and mission statements. Students will be persuaded to use the system when they see their lecturers' commitment. On the other hand, usage would enhance individual and institutional performance [11]. Along with emphasizing the value of such systems to the organization, leaders must educate students about the benefits of using technology in their daily jobs. Lecturers must set an example by utilizing technology themselves. Suppose lecturers encourage students to use technology while they continue to browse information on the desktop when they can do so via technology. In that case, trust is eroded, and successful technology implementation is unlikely. In short, the support of university administration and lecturers for the spread of technology usage can be operationalized through the lecturer's communication with students. Additionally, university top management and lecturer support for the infusion of technology can be operationalized through university top management's communication regarding integrating technology into organizational and class processes.

Second, the critical nature of adapting information technology to students' needs cannot be overstated. Efforts must be made to ensure that task requirements and technology functionalities are compatible. In other words, the system must be intuitive enough to capture all task specifications. There is a reason that the task-technology fit of an individual is a predictor of their performance [9]. Students who have worked at the same company for an extended period are accustomed to traditional communication and information retrieval methods. This condition may find new systems frightening and desire to discover technical flaws in the technology. In this case, students may be unwilling to manipulate their technology. use if the task and the technology are not a good match.

Thirdly, training in information technology is regarded as a time-honored method of increasing usage and perceived usefulness. This situation may occur because users may also need a thorough understanding of the capabilities of the technology, resulting in less-than-optimal utilization of the systems' functionalities. Thus, training has been connected to the issue of implementing innovative technologies. The authors discovered during a pre-study that students do not receive any technology training [12, 25]. If they do, they receive training only once or twice a year. As a result, many of them lacked technology proficiency.

Additionally, it has been observed that students' level of technology literacy still needs to be below expectations. For instance, some students interviewed have difficulty performing piecemeal tasks on computers, such as creating histograms or using Microsoft Office PowerPoint. The university must provide a range of computer training to its students, from basic to intermediate to advanced. One can only expect users to understand how to use technology. if they can operate a simple application on a computer [24, 25]. When such an environment is created, users will feel at ease interacting with technology.

6. Conclusion, Limitation, and Future Research

The survey findings are hoped to shed some light on the university's ability to recover from its technology implementation through the recommendations made in this paper. Additionally, it is hoped that the recommendations will serve as a guide for other industries in implementing new technology most effectively. Nonetheless, given the survey's small sample size and scope, the results have been interpreted cautiously. For prospect studies, it is recommended that a larger sample size be used across multiple industries. Future research should also examine two additional critical issues (attention to withdrawal from the program and withdrawal from work) and correlate them with student performance. A cross-cultural study can also be conducted to determine whether the findings are unique or consistent across cultures.

References

- [1] Al-Gahtani, S., "Computer Technology Acceptance Success Factors in Saudi Arabia: An Exploratory Study", *Journal of Global Information Technology Management*, Vol. 7, no.2, pp. 5-29, 2004.
- [2] Alqurashi, E., "Self-Efficacy in Online Learning Environments: A Literature Review", *Contemporary Issues in Education Research*, Vol. 9, no.1, pp. 45-52, 2016.
- [3] Amri, Z., and Alasmari, M., "Self-Efficacy During The COVID-19 Pandemic", *International Journal of Higher Education*, Vol. 10, no. 3, pp. 127-137, 2021.
- [4] Browne, M.W. and Cudek, R., "Alternative Ways of Assessing Model Fit", in Bollen, K.A., and Long, J.S. *Testing Structural Equation Models*, Newbury Park, CA, Sage, 1993.
- [5] Davis, F.D., Bagozzi, R.P. and Warshaw, P.R., "User Acceptance of Computer Technology: A Comparison of Two Theoretical Models", *Management Science*, Vol. 35, no. 2, pp. 982-1003, 1989.
- [6] DeLone, W.H. and McLane, E.R., "Information Systems Success: The Quest for the Dependent Variable", *Information System Research*, Vol. 3, no. 3, pp. 60-95, 1992.

- [7] Dishaw, M.T. and Strong, D.M., “Assessing Software Maintenance Tool Utilization Using Task-Technology Fit and Fitness-For-Use Models”, *Journal of Software Maintenance Research and Practice*, Vol. 10, no. 2, pp. 151-179, 1998.
- [8] Elsisi, M., Tran, M-Q., Mahmoud, K., Lehtonen, M., and Darwish, M.M., “Deep Learning-Based Industry 4.0 And Internet of Things Towards Effective Energy Management for Smart Buildings”, *Sensors*, Vol. 21, no. 4, pp. 1038-1047, 2021.
- [9] Friedman, J., York, H., Mokdad, A.H., and Gakidou, E., “U.S. Children 'Learning Online' During Covid-19 Without the Internet or A Computer: Visualizing the Gradient by Race/Ethnicity and Parental Educational Attainment”, *Socius*. Vol. 7, no. 1, pp. 1-3, 2021.
- [10] Goodhue, D.L. and Thompson, R.L., “Task-Technology Fit and Individual Performance”, *MIS Quarterly*, Vol.19, pp. 213-236, 1995.
- [11] Jeyaraj, A., “A Meta-Regression of Task-Technology Fit in Information Systems Research”, *International Journal of Information Management*. Vol. 65, pp. 102493-102506, 2022.
- [12] Joshi, K., “Understanding User Resistance and Acceptance During The Implementation Of An Order Management System: A Case Study Using The Equity Implementation Model”, *Information Technology Cases and Application Research*, Vol.7, no.2, pp. 6-20, 2005.
- [13] Kim, S.S., “Motivators and Concerns for Real-Time Online Classes: Focused on The Security and Privacy Issues”, *Interactive Learning Environment*, Vol.13, no.2, pp. 1-13, 2021.
- [14] Markus, M.L., “Power, Politics and MIS Implementation”, *Communication of the ACM*, Vol.25, no.6, pp. 430-444, 1993.
- [15] Martinko, M.J., Henry, J.W., and Zmud, R.W., “An Attribute Explanation of Individual Resistance to the Introduction of Information Technologies in The Workplace”, *Behaviour and Information Technology*, Vol.15, pp. 313-330, 1996.
- [16] Moustafa, N., “A New Distributed Architecture for Evaluating AI-Based Security Systems At The Edge: Network TON-IOT Datasets”, *Sustainability Cities and Society*, Vol.72, pp. 102994-103008, 2021.
- [17] Nguyen, D.C., Ding, M., Pathirana, P.N., Seneviratne, A., Li, J., and Poor, V., “Federated Learning for Internet of Things: A Comprehensive Survey”, *IEEE Communication Surveys & Tutorials*, Vol.23, no. 3, pp. 1622-1658, 2021.
- [18] Norzaidi M.D., and Intan Salwani, M., “Evaluating the Post-Intranet Usage: Empirical Study in Malaysian Port Industry”, *Australian Journal Basics and Applied Research*, Vol.5, no.7, pp. 336-345, 2011.

- [19] Norzaidi, M.D., Fathur, R., Intan Salwani, M., Ali, M., Ahmad, S., and Lulu, A.F., "Examining the Connection Between Mandatory Technology Usage and Technology Withdrawal in The Maritime Industry", *Journal of Maritime Research*, Vol.19, no.2, pp. 22-30, 2022.
- [20] Norzaidi, M.D., Chong, S.C, and Intan Salwani, M., "Perceived Resistance, User Resistance and Managers' Performance in The Malaysian Port Industry", *Aslib Proceedings: New Inform. Perspectives*, Vol.60, no.3, pp. 242-264, 2008.
- [21] Norzaidi, M.D., Chong, S.C., and Intan Salwani, M., "Intranet Usage, Managerial Satisfaction and Performance Impact: An Empirical Analysis", *International Journal of Business Science Research*, Vol.3, no.3, pp. 481-496, 2009.
- [22] Norzaidi, M.D., Chong, S.C., Intan Salwani, M, and Rafidah, K., "A Study of Intranet Usage and Resistance in Malaysia's Port Industry", *Journal of Computer Information Systems*, Vol.49, no.1, pp. 37-47, 2008.
- [23] Norzaidi, M.D., Chong, S.C., Intan Salwani, M., and Bishan, L., "The Indirect Effects of Intranet Functionalities on Middle Managers' Performance: Evidence from the Maritime Industry", *Kybernetes*, Vol.40, no.½, pp. 166-181, 2011.
- [24] Norzaidi, M.D., Chong, S.C., Murali, R., and Intan Salwani, M., "Intranet Usage and Managers' Performance in The Port Industry", *Industrial Management and Data System*, Vol.107, no.8, pp. 1227-1250, 2007a.
- [25] Norzaidi, M.D., Chong, S.C., Azizah, A., Intan Salwani, M., Rafidah, K., and Ruhana, Z., "The Effects of Students' Backgrounds and Attitudes on Computer Skills in Malaysia", *International Journal of Management in Education*, Vol.1, no.4, pp. 371-389, 2007b.
- [26] Nunnally, J.C., "Psychometric Theory", New York, NY: McGraw Hill, 1978.
- [27] Sekaran, U., "Research Methods for Business", New York, NY: John Wiley and Son, 2003.
- [28] Tzu, T.W. and Yin, T.L., "Key Factors for Small and Medium Enterprises in Taiwan To Successfully Implement Information Systems", *International Journal of Management and Enterprise Development*, Vol.2, no.3, pp. 106-121, 2005.

Integration Model of Academic Information Systems and Learning Management Systems with REST Web Services Using External Databases

Riad Sahara

Informatics Study Program

Universitas Siber Asia, Indonesia

riadsahara@lecturer.unsia.ac.id

Syahid Abdullah

Informatics Study Program

Universitas Siber Asia, Indonesia

syahidabdullah@lecturer.unsia.ac.id

Muhammad Ikhwani Saputra

Informatics Study Program

Universitas Siber Asia, Indonesia

muhammadikhwani@lecturer.unsia.ac.id

Abstract

ICT products like Academic Information Systems (AIS) and LMS are commonly utilized in Indonesian universities. These two ICT tools will be of tremendous use to higher education institutions in managing their academic business procedures. The two systems are still not connected in many higher institutions, nevertheless, for example when it comes to handling academic data. If the management and integration process is carried out conventionally, it will be challenging and inefficient due to the massive volume of data and complexity of these two systems. Observing these issues, the researcher plans to study the two REST-based Web Service systems' connection and make use of the External Database functionality, which will be utilized to synchronize data in real-time from AIS to E-Learning. It is hoped that the integration model resulting from research can be a solution for integration between AIS and LMS and can be implemented in many higher education institutions.

Keywords: AIS, External-database, Integrations, LMS, Web-Services

1. Introduction

The current paradigm calls for students to be active learners and to be provided with the necessary resources to be applied in Indonesia's educational system, particularly in higher education given the availability of information and communication technologies (ICT). ICT is crucial in creating a variety of teaching and learning materials that are easier for students to understand, have highly interactive components, and are much more engaging to follow [1]. E-learning is one of the ICT tools that is frequently utilized in universities.

E-learning is not well-known or utilized in Indonesia, particularly in rural regions. Vice President Ma'ruf Amin went so far as to clarify that just over 20 of Indonesia's 4,741 postsecondary institutions had adopted electronic learning, or e-learning [2]. E-learning saw a spike in use until after the Covid-19 pandemic, when the government advised doing activities for teaching and studying at home.

Moodle is one of the extensively used E-Learning solutions, sometimes known as the Learning Management System (LMS). not just in Indonesia but globally as well. As seen in the graphic below, there are approximately 250,000,000 registered users and approximately 251 nations that are already using Moodle. When it comes to continuing the necessary teaching and learning activities, even during the Covid-19 pandemic, the use of the Moodle for LMS is a very beneficial answer. circumstances in which everyone must maintain social isolation [3]. A solution for distance learning is Moodle, since it has all the features needed for instructional and learning activities. The Moodle software itself can be used on a wide range of hardware, including mobile phones, with varying screen resolutions, platforms, and operating systems. Thus, proper fulfilment of activities for teaching and studying can be achieved through fair access to teaching resources [1].

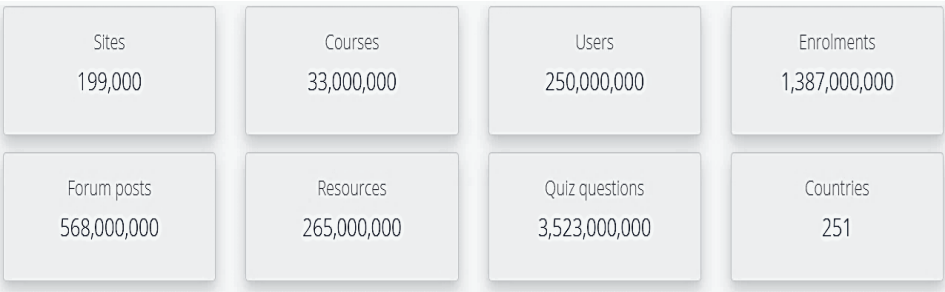


Figure 1. The Statistics of Moodle LMS Usage [4]

An additional ICT product that is frequently utilized in universities is the Academic Information System (SIA) as it is more commonly called. A tertiary institution's use of SIA, a data management system, is essential for processing data related to student grades, courses, lecturers, faculty/department administration, and other topics [5]. It is crucial for higher education institutions to adopt SIA since failing to do so would result in the following outcomes:

1. Wasteful of human resources
2. Difficult to divide schedules and classes
3. Difficult to control
4. Difficult to handle data for staff, students, and lecturers
5. Will require a lot of paper papers, etc.

The two ICT products—E-Learning and SIA—will be of tremendous assistance to higher education institutions in managing their academic business operations. Of course, if the two work effectively together, particularly in terms of handling current academic data. The two systems are still not integrated at many higher education institutions, though, for example in the administration of academic data. Particularly

since these two systems undoubtedly include a large amount of data and complexity, which will make traditional methods of management and integration challenging and ineffective.

The researcher plans to carry out an integration design between the SIA and the E-Learning system after realizing this issue. Real-time data synchronization from SIA to E-Learning will be facilitated by the External Database functionality, which will be leveraged in the Web Service REST-based interface of the two systems.

2. Literature review

2.1. Research Review

Numerous scholars have studied the integration of LMS and SIA. The primary source of information for researchers undertaking study is a review of prior studies, which is provided below:

There were various issues with the initial prior study. The first issue is that the program needs to be updated each time there is a modification to the SIA data format pertaining to lectures or an upgrade to the LMS system itself because it needs to adapt to the new structure once more. The second issue is that human work is required at both the SIA and the LMS when there is a change in data in the middle of the semester, such as when a user modifies their passwords, lecturers, or student Study Plan Cards. This forces lecturers to manually backup their content on the LMS before the current semester ends so that it can be used again in the following semester, in addition to other issues with the disappearance of all teaching and learning activity data when the LMS will be used again in the following semester. To synchronize and transfer data in real time from the Academic Information System and/or to the LMS, researchers utilize the External Database capability [6].

The application of the LMS (Moodle) and Academic Information System for the issue of managing current data is still not integrated in the second prior study. In Moodle, data entry is still done by hand rather than automatically scheduled. These two systems contain vast and complex amounts of data, which will undoubtedly make management and integration challenging and ineffective. By using a data integration paradigm between the Academic Information System and the Moodle-based e-learning system, researchers can solve these issues. Because it can integrate systems and databases, the web service REST (Representational State Transfer) method is the most suitable approach used by researchers [7].

Several issues were present in the third earlier research, including the professors' practice of creating courses each semester, manually enrolling and disengaging students, and registering new students for online courses. Because course data for e-learning can be derived from already-existing course data in the Academic Information System, as well as student and lecturer data from already-existing SSO data, the presence of these issues would undoubtedly result in extremely inefficient data management. In order to solve the issue, researchers include Moodle features or

web service modules that can be utilized as instruments for data integration with other systems already in place [8].

It was clarified in the fourth previous research that the LMS's use will be inextricably linked to the SIA. The two applications had not been integrated when they were implemented in the teaching and learning environment, which made it difficult for users—in this case, students—to take advantage of both systems at the research site where the researcher conducted his study. Researchers developed SIA plus E-Learning applications and other applications as a solution to the current issues. PHP is a programming language used in the design and development of additional applications, also known as bridge apps [9].

It was discovered in the fifth earlier survey that many higher education institutions still do not have Academic Information Systems and e-learning integrated. The procedure demonstrates that when new student information is uploaded into the Academic Information System, it is not immediately registered in the e-learning system. This leads to additional issues and renders administrative tasks like manually entering data into the e-learning system ineffective. It may increase the likelihood of data redundancy, data entry errors, and other issues. In the research that was done, researchers employed the data level integration method. The goal of this data level integration is to share the same data among multiple apps by focusing on data transfer between applications. A new database structure that unifies the two applications is created by merging the databases of the two current systems [5].

The researcher will perform research that is broadly like the research conducted by Ajib Hanani in 2020 [7] and the research conducted by Muhammad Bunyamin and Ahmad Syazili in 2019 [6] based on literature reviews from prior studies with similar themes. Researchers will design the integration between the SIA and the e-learning system. Real-time data synchronization from SIA to E-Learning will be facilitated by the External Database functionality, which will be leveraged in the Web Service REST-based interface of the two systems. Researchers will, however, create a more comprehensive integration of the two systems, for example, integrating Moodle value data that may be entered into the SIA value data.

2.2. Basic theory

2.2.1. *Web Services REST*

According to Gottschalk and Eric Kurniawan, Web Services are interfaces that specify groups that are reachable across a network by utilizing a common XML message format. Web services carry out duties. A common XML notation type called services description is used to define web services [12]. A web server designed particularly to meet the requirements of other websites or apps is called a web service. Application Programming Interfaces (APIs) are used by client programmers to talk to Web services. An API, in general, exposes a collection of functions and data to allow computer programmers to communicate with one another and share information. The Web API is the face of the Web Service; it directly receives and processes requests

from clients, as seen in Figure 2.4. The technical description of the operation of the World Wide Web* is called Representational State Transfer, or REST. REST explains how the Web became so popular. If there is a "operating system" for the Web, it is the REST architectural style. Modern online services usually use APIs that are designed using the REST architectural approach. REST API is a Web API that complies with the REST architectural style [10].



Figure 2. Web API [10]

Any Web Service that has a REST API is considered "RESTful." The REST API is made up of a collection of connected resources. REST API model resources are the collections of resources that go by this name. The use of web services by client developers can be encouraged by a well-designed REST API. In the current competitive industry, where Web Service rivals vie for users' attention, visually appealing REST API designs are an essential component [10].

Resource	Method			
	Get	Post	Put	Delete
/api/student	<i>Get a list of all students</i>	<i>Create a new list of students</i>	<i>Update a list of students</i>	<i>Delete all student</i>
/api/student/1	<i>Get a student by student's ID</i>	<i>Treat as a collection. Create a new student in it.</i>	<i>If student exists, update the student. If student does not exist. Create a new student.</i>	<i>Delete the student.</i>

Table 1. Example of REST API [11]

The utilization of REST Architecture has the following five benefits. [12]:

1. Light RESTful for Web Services
2. RESTful simplicity
3. RESTful architecture is closer in design to the Web
4. Scalability
5. Expose API as HTTP Service

2.2.2. Moodle External Databases

The Moodle LMS has a functionality called External Database that is helpful for syncing user and enrolment data with databases hosted outside of Moodle. This capability allowed Moodle to read information from other databases that it had mapped [6]. The graphic below shows an example of how to register teaching participants at a university utilizing an external database in Moodle.

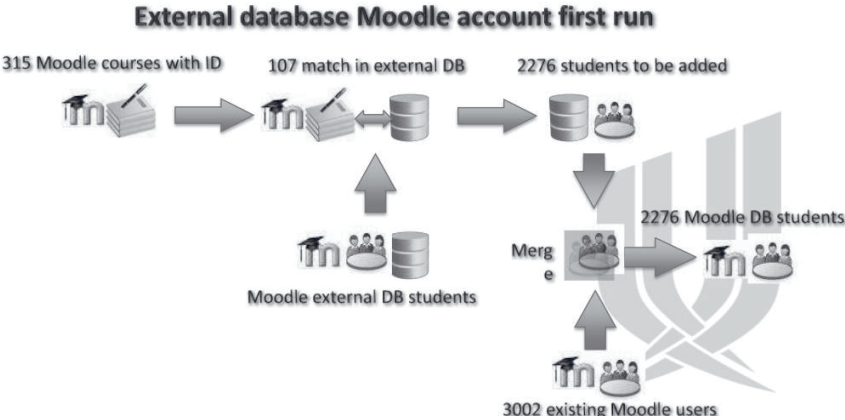


Figure 3. External Database Moodle account first run [13]

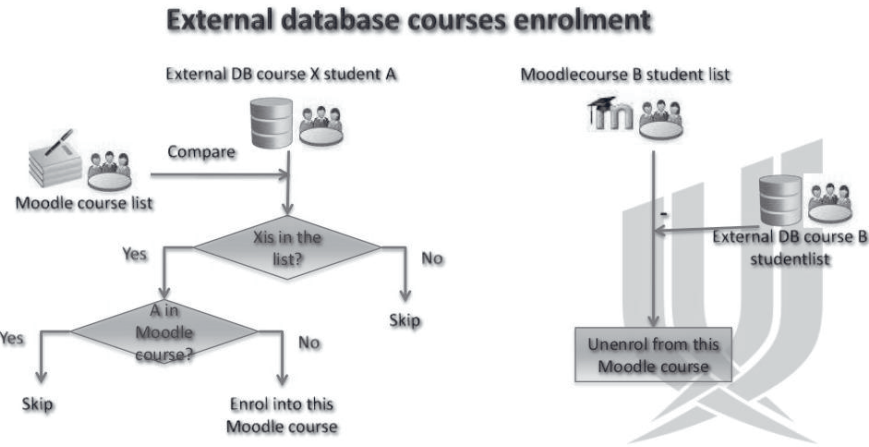


Figure 4. External database course enrolment [13]

3. Research Methods

3.1. Web service REST method

In several studies, researchers integrated AIS with Moodle LMS utilizing the Web Service REST technique. Web service servers and web service clients make up REST

web services [7]. An architectural methodology for creating network applications is called REST. The concept is that simple HTTP can be used to carry out machine-to-machine communication in place of more complicated techniques like CORBA, RPC, or SOAP. RESTful apps retrieve data (by making queries, for example), write data (by creating and/or updating data), and remove data via HTTP requests. Consequently, REST use HTTP for each of the four CRUD (Create, Read, Update, and Delete) actions [12].

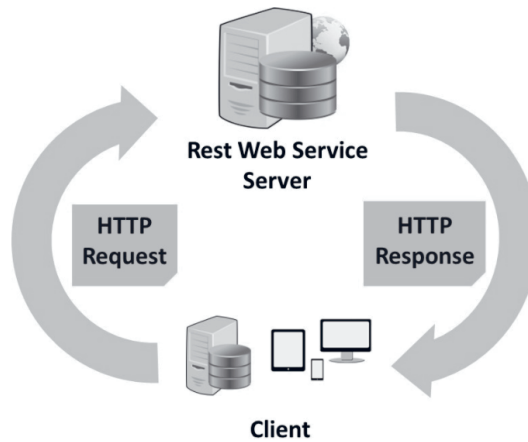


Figure 5. Architecture of REST [12]

REST is an architecture for software applications that is based on how data is accessed, changed, and represented online. It is a distributed hypermedia system architectural style. Data and functionality are viewed as resources in the REST architecture, and they can be accessed using a Uniform Resource Identifier (URI), which is typically a web link [14].

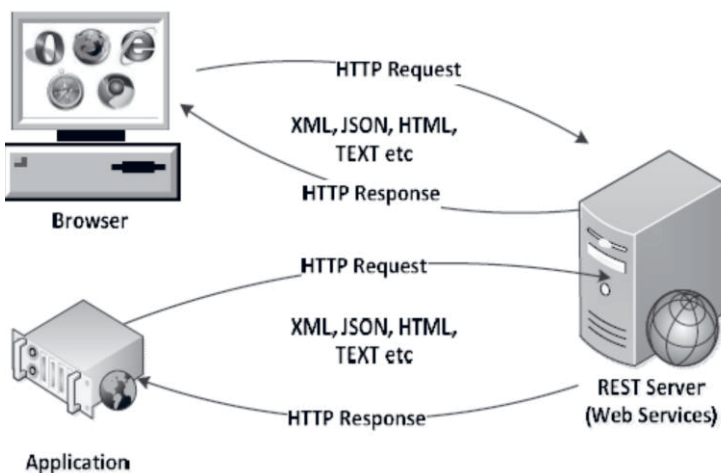


Figure 6. Architecture of RESTful Web Service [14]

3.2. Research Stages

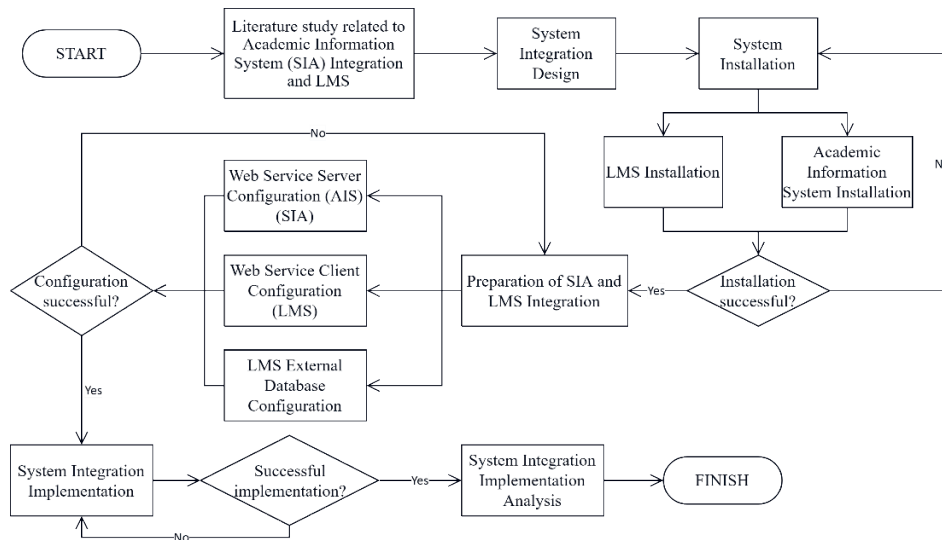


Figure 7. Research Stages Flowchart

4. Results And Discussion

4.1. System Integration Design

4.1.1. Design of Web Services Architecture

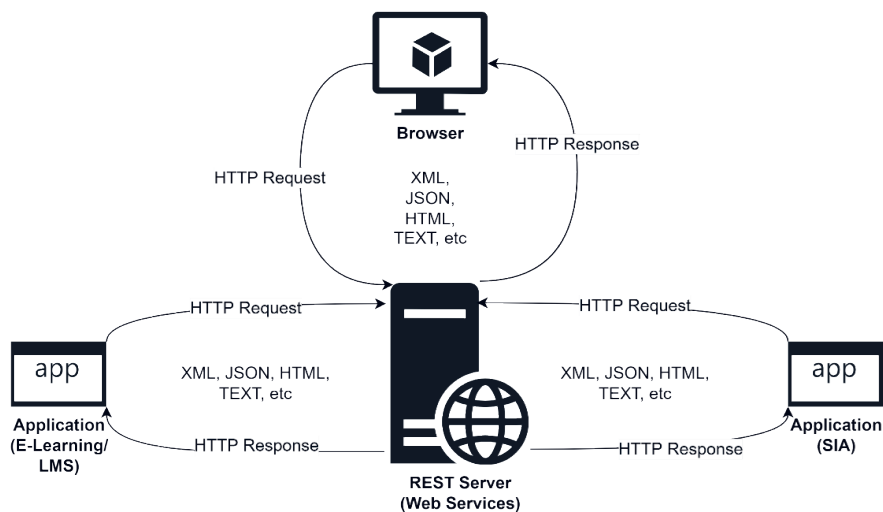


Figure 8. Design of Web Services Architecture

The Architecture of Web Services in Figure 8 is an example of the key architectural designs that will be used in integration. The Web services that are utilized include REST, which use plain HTTP for data publishing, reading, and deletion when facilitating communication between devices or applications.

4.1.2. External Database Architecture Design for System Integration.

An early version of the External Database Architecture, which would serve as a tool for the LMS and SIA systems' integration, is shown below. There are two applications, the SIA application and the LMS application, as shown in Figure 9 below. By an external database built on REST Web Services, the two applications can communicate.

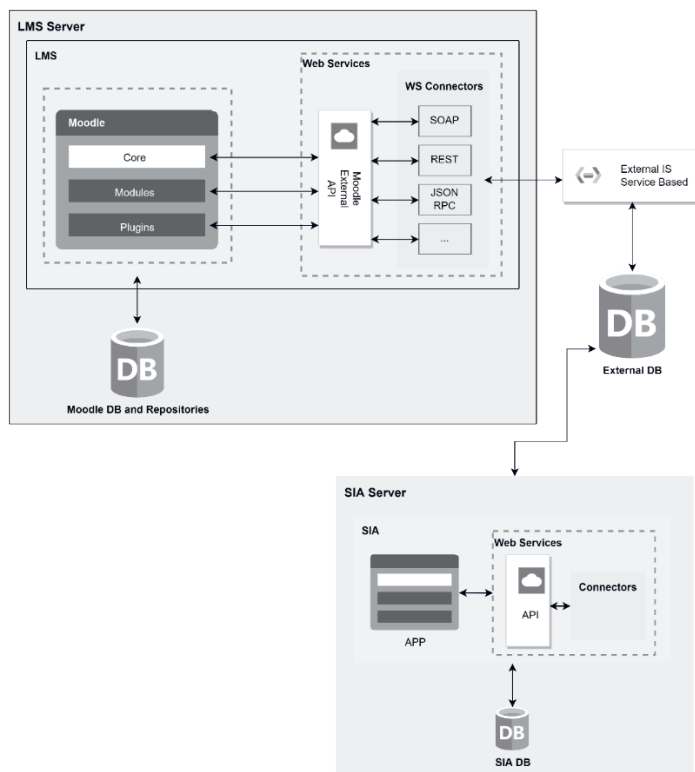


Figure 9. External Database Architecture Design for System Integration.

The following are a few ways that the External Database is used in system integration:

1. Link current LMS users with the SIA and LMS apps.
There won't be any duplicate users with the same identity thanks to this integration; if there are, a merger procedure will be initiated. There will always be a procedure to verify if a new user is registering or entering the system for the first time, using the technique depicted in Figure 10 below.

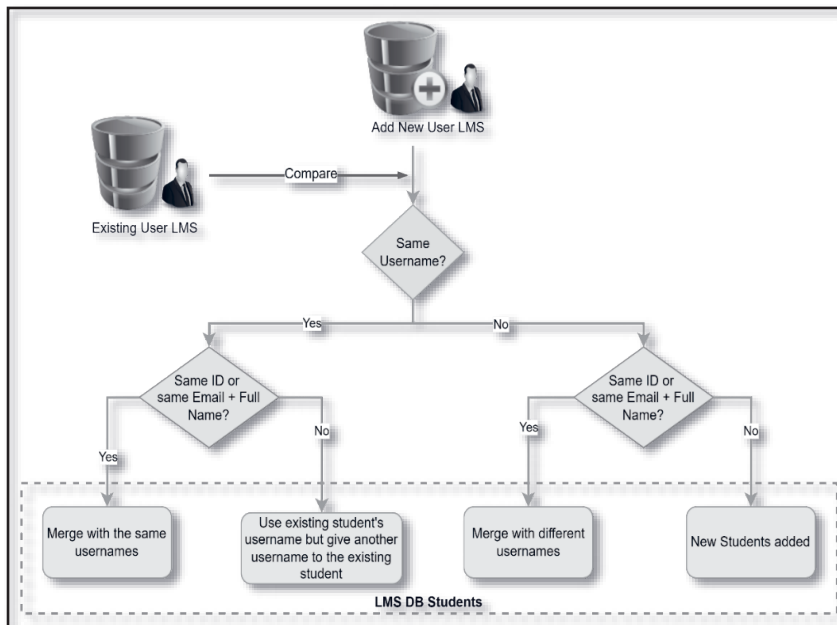


Figure 10. Integration of existing LMS users in the SIA and LMS applications

2. Controlling Enrolments and Un-enrolments

When the student user logs into the LMS, the External database enrolling event will take place. According to the information in the external database, the LMS plugin will attempt to automatically register student users in all courses and classes. It may also create empty courses and classes in which the user student is not enrolled. If the student user's data is no longer in the database, this step will also terminate their registration. However, this plugin for an external database can only unenroll student users who have already registered with it. Figure 10 below illustrates the enrolment and unenrollment control system.

5. Conclusions And Recommendations

5.1. Conclusion

From the research that has been carried out, some research conclusions are obtained as follows:

1. The Academic Information System and LMS have an integration design that can serve as a prototype for system integration and a point of reference for its implementation.
2. The fact that the Academic Information System and LMS are integrated via REST Web-Service and the External Database functionality allows for real-time data synchronization between the two systems.

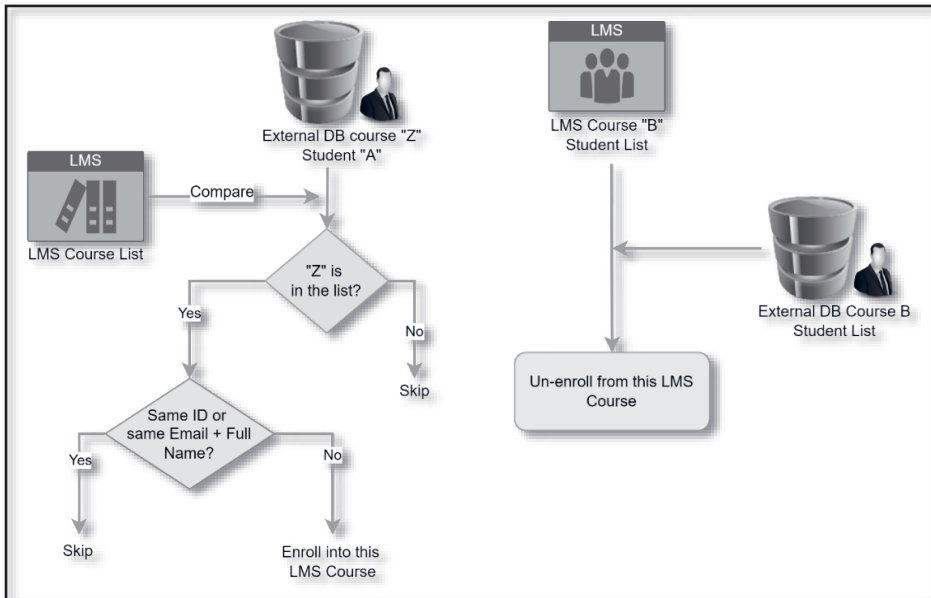


Figure 11. Controlling Enrolments and Un-enrolments

5.2. Suggestion

To obtain the best possible outcomes from this preliminary research, integration between the LMS and AIS platforms must be implemented. It will be possible to test whether real-time, delay-free data synchronization between the LMS system and AIS is possible after system integration is achieved. It will also be possible to identify potential obstacles to this process.

References

- [1] R. Sahara, "Analisa Performansi Mobile Learning dengan Konten Multimedia pada Jaringan Wireless Studi Kasus pada Fakultas Ilmu Komputer Universitas Mercu Buana," *Jurnal Telekomunikasi dan Komputer*, vol. 5, no. 3, pp. 251-274, September 2014.
- [2] "CNN Indonesia," 23 September 2020. [Online]. Available: <https://www.cnnindonesia.com/nasional/20200923001725-20-549651/maruf-amin-baru-20-dari-4741-kampus-terapkan-e-learning>. [Accessed 11 December 2020].
- [3] E. J. Wicaksana, P. Atmadja, W. Lestari, L. A. Tanti and R. Odrina, "EFEKTIFITAS PEMBELAJARAN MENGGUNAKAN MOODLE TERHADAP MOTIVASI DAN MINAT BAKAT PESERTA DIDIK DI TENGAH PANDEMI COVID -19", *Jurnal Edukasi dan Teknologi Pembelajaran*, vol. 1, no. 2, pp. 117-124, Juni 2020.

- [4] "Moodle Statistics," 11 December 2020. [Online]. Available: <https://stats.moodle.org/>. [Accessed 11 December 2020].
- [5] D. W. Utomo, G. R. Alsyah and D. A. Prabowo, "INTEGRASI SISTEM INFORMASI AKADEMIK DAN E-LEARNING BERBASIS WEB," *Jurnal Sistem Informasi Dan Bisnis Cerdas (SIBC)*, vol. 11, no. 1, pp. 18-24, Februari 2018.
- [6] M. Bunyamin and A. Syazili, "External Database Sebagai Media Integrasi Sistem Informasi Akademik dengan E-Learning," *Jurnal Bina Komputer*, pp. 73-81, 2019.
- [7] A. Hanani, "Integrasi Sistem Informasi Akademik dan E-Learning UIN Maulana Malik Ibrahim Malang berbasis Web Service REST," *SMARTICS Journal*, vol. 6, no. 1, pp. 17-24, 2020.
- [8] R. Saptono, M. E. Sulistyono and J. Susilo, "UTILIZATION OF MOODLE WEB SERVICE BASED SYSTEM TO SYSTEM WITH SIAKAD AND SSO UNS," *TELEMATIKA*, vol. 13, no. 2, pp. 107-122, JULI 2016.
- [9] B. D. Bernadhi and S. Saptadi, "PERANCANGAN INTEGRASI SISTEM INFORMASI AKADEMIK DENGAN E-LEARNING (Studi Kasus : Program Studi XYZ)," *Jurnal Teknik Industri*, vol. XI, no. 3, pp. 177-186, September 2016.
- [10] M. Masse, *REST API Design Rulebook: Designing Consistent RESTful Web Service Interfaces.*, O'Reilly Media, Inc., 2011.
- [11] E. Kurniawan, "IMPLEMENTASI REST WEB SERVICE UNTUK SALES ORDER," *Jurnal EKSIS*, vol. 07, no. 01, pp. 1-12, Mei 2014.
- [12] A. Ozlu, "Medium," 30 July 2018. [Online]. Available: <https://medium.com/@ahmetozlu93/mastering-rest-architecture-rest-architecture-details-e47ec659f6bc>. [Accessed 12 December 2020].
- [13] Y. Liu, "SlideShares," 26 July 2011. [Online]. Available: https://www.slideshare.net/yong_liu/moodle-external-database-enrolment-8696784. [Accessed 12 December 2020].
- [14] E. E. Thu and T. N. Aung, "Developing Mobile Application Framework By Using RESTful web service with JSON parser.," in *International Conference on Genetic and Evolutionary Computing*, Springer, Cham, 2015.

Digital transformation of strategic management of SMEs in the Czech Republic

Tomáš Červinka

cervinka@utb.cz

Faculty of management and economics

Tomas Bata University in Zlin, Czech Republic

Abstract

Strategic management of SMEs is perceived as crucial backbone of their business, as it impacts their business models and internal processes all the way up to digital innovation measured by the level of digital maturity. How do the strategic management factors influence the digital maturity? Through quantitative analysis of 76 respondents representing SMEs in the Czech Republic, the research data was collected and statistically tested. Results imply that strategic management factors affect the level of digital maturity. This paper contributes to prior literature by practical implementation of modified digital maturity model and by addressing the correlation of strategic management factors and the level of digital maturity. Limitations springing from sample site and environment are addressed and discussion on the results is conducted. Author proposes a conclusion that strategic management factors can be perceived as a driver of digital transformation, emphasizing the need for future research and practical discussion.

Keywords: strategic management, digital transformation, digital maturity, strategic management factors

1. Introduction and literature review

Digital innovation is one of the key attributes in business administration and other substantial fields and can be seen as one of the primary elements of entrepreneurship (Schumpeter & Backhaus, 2003 [1]; Davidsson, 2016 [2]).

As globalized market is a competitive environment, we can perceive high pressure on process efficiency (Nawanir et al., 2016 [3]). As companies need to achieve higher performance to attract new customers and retain current customers by achieving long-term customer satisfaction (Aguwa et al., 2012 [4]), they are ought to continuously improve and innovate mainly by improving their production quality, costs, and flexibility (Singh & Singh, 2015 [5]). Fitzgerald et al. (2014 [6]) define the digital transformation as an enabler of major business improvements such as creating new business models, raising performance, and enhancing customer experience. Therefore, digital transformation leads to gaining advantage in competitive environment. As digital transformation is clearly an imperative to strategic management, and business model innovation is a solution for firms to survive a thrive

in nowadays competitive markets (Kim & Mauborgne, 2015 [7]), it is vital to search for the best ways of harnessing the innovation potential. Entrepreneurial success can be derived from identification of innovative products or service, processes, and business models.

The digital innovation perspective changes the nature of business models and firm management, as we can draw from information system literature (Yoo et al., 2010 [8]; Yoo et al., 2012 [9]; Nambisan et al., 2017 [10]; Tilson et al., 2010 [11]). The role of digital technology on firms' strategies was examined during past years (Hess et al., 2016 [12]; Bharadwaj et al., 2013 [13]), regarding the possible disruptive impact on business models and organizations. As Sing & Hess (2020) [14], imply, the holistic approach must be projected in connection to the strategic management, overall strategy, and digital transformation to compensate for disruptive impact of digital innovation of organizations (El Sawy and Pereira, 2013 [15]).

In order to innovate, companies are ought to take up digital transformation to open new paths to gaining competitive edge. Although there are many different approaches to digital transformation, digital maturity is one of the cornerstones of its success.

As can be drawn on (Sommer, 2015) [16] the research regarding the SMEs in Germany, digital transformation, and industry 4.0 approach can be perceived as a challenge, mainly from the point of view of knowledge, readiness, and capability to face unexpected challenges. It can be established that the capability and adaptability depend on either size or revenue, but also on deriving factors such as strategic management, financial and human capital, and internal compatibility of embracing change, which originates from digital maturity and level of necessary competencies (Werner & Wäger, 2019) [17]. Motivation, capability of adaptation to change and level of digital maturity is vital in for reaching success in complicated and costly process of digital transformation (Ghobakhloo & Iranmanesh, 2021) [18].

Maturity refers to a state of readiness and perfection (Simpson & Weiner, 1989) [19] and provides an insight to the level of development of a system. Maturity can be measured quantitatively and qualitatively in different manners (Kohlegger et al., 2009) [20]. by using different models. Maturity models dealing with the digital maturity are used to evaluate the starting point of a company and help to set up the pace and plan of digital transformation and innovation process, e.g., PriceWaterhouseCoopers Digital Operations Self-Assessment or Deloitte maturity model (2018) [21]. Yet, how do the SMEs perceive their strategic management approach and its impact on the level of digital maturity? Can the digital maturity be coherent with the strategic management approach?

Nearly two-thirds of manufacturing CEOs claim that agility, in hand with strategic innovation is the new currency of business. Being slow leads to the bankruptcy. Yet, one third points out that their organization is struggling to keep the pace with technological and digital innovation (KPMG, 2018) [22].

Drawn from the Tech Pro survey (The Tech Pro Research, 2019) [23], 70% of business leaders claim to be investing more time and resources into digital strategy and digital transformation. It can be stated that businesses seek digital transformation to harness innovative potential and achieve sustainable growth and competitive

advantage. General public opinion sees greater promise in smaller firms investing heavily in strategic approach rather than large incumbents (Lee & Chen, 2009) [24]. It can be stated that SMEs are prone to conclusion that strategic business model innovation is a means to achieve success, and new normal is to make the most of digital transformation. Without digital maturity, transformation is more likely to fail or to be rather costly experiment. So how does the strategic management help to evolve the level of digital maturity? More than a hundred different maturity models have been created (de Bruin et al., 2005) [25] , and new ones are constantly being published. But the authors rarely reveal the development of their model and the results of evaluation, as it is usually contained in their knowhow and a part of a business product. For the purpose of this research, modified maturity model was drawn from the pivots of Deloitte maturity model to assess the SMEs participating in the survey. Aim of this paper is to find out if there is a correlation between the level of SME's digital maturity and the strategic management factors including business model innovations and to explore and measure the influence of strategic management factors on the level of digital maturity in the SMEs in the Czech Republic.

2. Methods

As a member of digital transformation projects, the author observed the connection between the digital maturity and the strategic management approach. Therefore, the author used quantitative methods to collect and analyze the data to address the main aim of this study. In terms of the aim stated above, following research questions were proposed:

RQ1: Does the strategic management factors affects the level of digital maturity in SME's?

RQ2: Do the SMEs managers evaluate their strategic management factors as strongly positioned?

Following zero hypothesis were formulated:

H0A: The factors of strategic management do not affect the level of digital maturity.

H0B: More than 50% of SME's managers evaluate their strategic management factors as strongly positioned.

Following alternative hypothesis were formulated:

HAA: The factors of strategic management affect the level of digital maturity.

HAB: Less than 50% of SME's managers evaluate their strategic management factors as strongly positioned.

A research project based on conducting a quantitative study to address the research problem was carried out in selected SMEs in the Czech Republic. To obtain the necessary data, a structured survey was performed. Closed question survey contained basic questions regarding the company stats as revenue, number of employees. Auto evaluation assessing the level of digital maturity followed, closing with the questions regarding the approach to strategic management and perceived influence of strategic management on digital maturity.

2.1. Structure of the survey sample

Research survey contained 76 responses. The number of respondents was evaluated using the G-power programme through power sample analysis proportion sign binomial test with effect size 0,2 (deriving from 70% expected result minus 50% zero hypothesis starting point) on with error probability 0,05, with the result of 67 total sample size, as can be seen in Fig. 1.

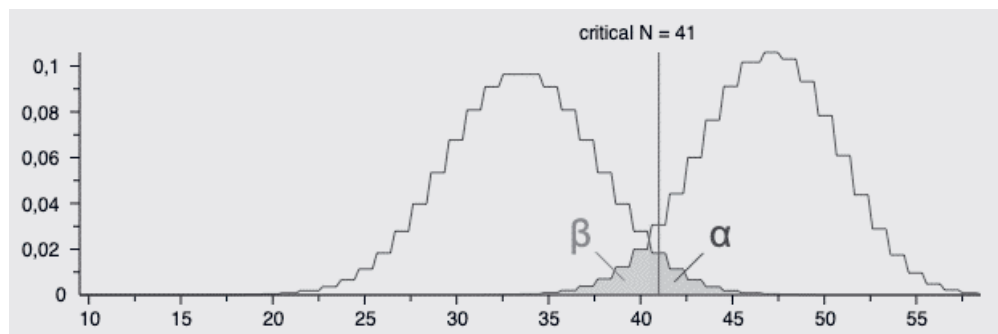


Figure 1. Power analysis

In terms of stated above, the number of participants was deemed sufficient.

SMEs respondents' structure was identified followingly:

- As for the size of companies included:
 - 0 – 9 employees – 21 % of the research sample.
 - 10 – 49 employees – 34 % of the research sample
 - 50 – 249 employees – 45% of the research sample.
- As for the revenue value proportion:
 - 2 mil. Euro – 30 % of the research sample.
 - 2 – 10 mil. Euro – 57 % of the research sample.
 - 10 – 50 mil. Euro – 13 % of the research sample.

2.2. Evaluation of digital maturity

As for the digital maturity evaluation, research drew on the Deloitte maturity model (2018) [21], and modified version of the assessment was prepared. Following pivots were evaluated:

- Flexible, secure infrastructure – implementing technology that balance security and privacy.
- Complex data management – aggregating and activating of data embedded into products, services, and operations to increase efficiency and revenue growth.
- Digital excellency support – training programs and empowering talents with focus on digital competencies.

- Ecosystem engagement – external business partners, universities, tech incubators.
- Intelligent workflows – continuous improvement and calibration of processes to produce positive outcomes.
- Customer experience – digital coordination and interaction with customers to deliver fast and transparent experience.
- Business model adaptability – change and expansion of business models and revenue streams through optimization and agility in changing markets.

Evaluation was based on 1-10 scale, where value 1 stood for minimum level, and value 10 for maximum level. Pivots were marked as variable x_i , ($i=1;7$). Results were collected from top-management of SME's. To ensure the reliability of data collected, the same set of questionnaires was used. Addressing the ethical rules of research, full anonymity was guaranteed to each participant and organization.

For the purpose of categorizing the respondents, digital maturity index (DMI) was used. Digital maturity index (DMI) was calculated thusly:

$$DMI = \frac{\sum x_i}{n} * 100 \quad (1),$$

Where x_i represents variable, whereas n represents the value of maximum sum of variables ($n=7*10$). The classification of the results was based on summary score of the responses:

Intervals	Evaluations
LDMI (0; 0.3)	Low digital maturity index
MDMI (0.3;0.7)	Medium digital maturity index
HDMI (0.7; 1)	High digital maturity index

Figure 2. Digital maturity index groups

Following intervals were used:

- LDMI = low digital maturity index
- MDMI = medium digital maturity index
- HDMI = high digital maturity index

2.3. Evaluation of influence of strategic management coefficient on the level of digital maturity

The strategic management was analysed through the following factors:

- Perceived level of strategic management (LSM).
- Shared common vision of strategic management (SCV).
- Digitalization to strategic business model (SBM) innovation (DSBM).

Strategic management factors coefficient ratio spans in interval (0;1) calculated via the summary of measured factor variables to total max sum of the variable. Average ratio (avg.SMR) for DMI categories was calculated followingly:

$$avg.SMR = \frac{avg.LSM + avg.SCV + avg.DSMB}{n} (2).$$

Average strategic management ratio was examined in context to the level of digital maturity to evaluate the correlation between digital maturity and strategic management factors.

The perception of strategic management position was measured using Likert 3-point scale with 0/+2 range based on personal evaluation of the respondents, where:

- 0 = not at all/low
- +1 = moderate
- +2 = strong

Following questions were used:

- How do you perceive the level of strategic management in your organisation?
- Do you perceive the shared common vision of management in strategic management?
- How did digitalization change your approach to strategic business model innovation?

Responses were sorted to categories using DMI as main criterion with aim to analyse possible difference in responses in different DMI categories. For the purpose of hypothesis evaluation, average numbers of responses representing value +1/+2 were calculated. Relative frequency was used to express the portion of respondents opinion evaluating the influence of strategic management on the level of digital maturity.

The data acquired was analysed using 1-sample proportion test with continuity correction using following formula in the R statistical programme:

$$prop.test(n, x, p = 0.5, alternative = greater) (3),$$

Where n (number of responses total), x (variable), p (zero hypothesis probability). Zero hypothesis was tested on three different categories divided by DMI criterion.

3. Results and discussion

After the data collection and evaluation, it was possible to comment on the fact that the level of digital maturity strongly depends on SMEs capability to assess their position. After initial collection, the data was cleared and prepared for statistical processing. Firstly, SMEs were sorted out to categories using the digital maturity index using formula (1), as stated in chapter 2.2.

3.1. Level of digital maturity

As it is shown in Fig. 2, lesser portion of the sample is represented by SME's identified with high digital maturity index. Overall number of companies was 76, from which 31 were identified with LDM index, 26 with MDM index and 19 with HDM index. Respondents evaluated their level of digital maturity in 7 categories, as stated chapter 2.2.

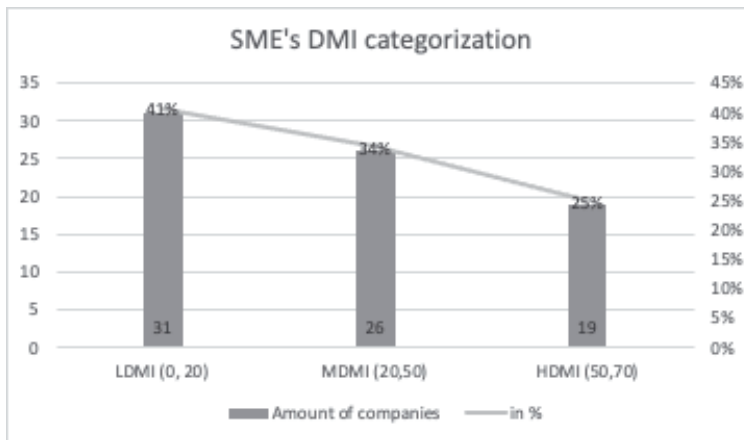


Figure 3. Categorization through DMI criterion

Fig. 2. shows declining tendency of digital maturity index in our research sample, revealing that state of digital maturity amongst SMEs is a matter of national market importance, that is to be addressed in future years in terms of rising the companies' level of digital maturity to reach competitive edge and to maximize the potential of digital transformation. As the digital transformation is an actual and important topic, SMEs are ought to continuously measure their level of digital maturity, as it is one of the key markers interlacing the journey to maximum digital readiness and successful digital transformation. Based on the processed data, it can be stated that there is still vast space for SMEs to improve and develop their digital position in internal and external environment.

3.2. Influence of strategic management factors on the level of digital maturity

In Fig. 4., a model is represented that shows the correlation of average digital maturity index to strategic factors ratio. It can be stated that higher strategic management factors ration is projected in higher digital maturity index.

Partial strategic factors ratio was measured according to chapter 2.3 and average innovation ration was calculated using formula (2), as stated in chapter 2.3. As an organisation progresses and develops strategic management approach, the influence pattern on higher digital maturity level can be perceived clearly. It can be stated that although there are many factors influencing the digital maturity level, in terms of our research sample, the relationship between the level of digital maturity and strategic management leads to consideration of the fact, that more developed and digitally advanced organisations apply more evolved strategic management approach. Thus, can be recommended that SMEs should nurture strategic management approach and invest in managerial talents and improve their employees' competencies as well as invest in appropriate technological background to rise their level of digital maturity. Based on basic frequency analysis, we can imply that zero hypothesis H_{0A} is rejected in favour of alternative H_{A_A} , resulting in a fact that the strategic management factors affect the level of digital maturity.

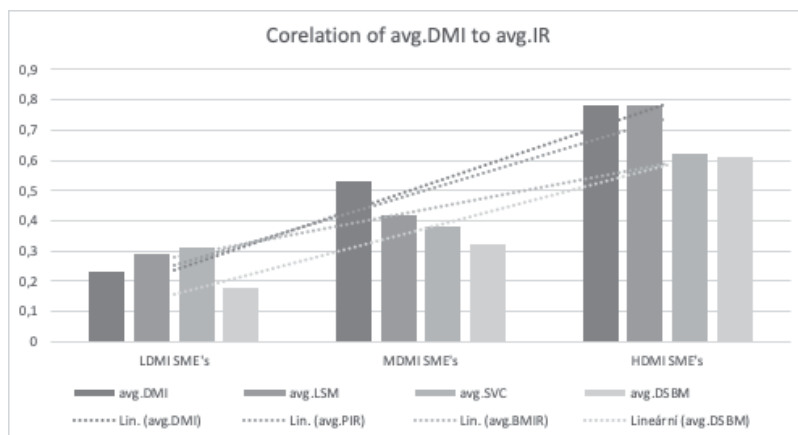


Figure 4. Correlation of average digital maturity index to average innovation ratio

3.3. The perceived position of strategic management of SMEs managers

The position of strategic management was measured according to the methods stated in chapter 2.3. For the purpose of distinction of categories with different digital maturity index, data was divided into three different groups. Results were statistically tested using the formula (3) with focus on the responses marked as **b** and **c**, as it is represented in Fig. 5., standing for the variable value evaluated in the calculations.

LDMI responses overview						
Question	Variable meaning	variable marker	variable value x	relative frequency	relative frequency x(b+c)	p value
How do you perceive the level of strategic management in your organisation?	low	1a	19	61,29%		
	moderate	1b	8	25,81%		
	high	1c	4	12,90%		
	x(b+c)		12		38,71%	
Do you perceive the shared common vision of management in strategic management?	not at all	2a	21	67,74%		
	moderately	2b	6	19,35%		
	strongly	2c	4	12,90%		
	x(b+c)		10		32,26%	
How did digitalization change your approach to strategic business model innovation?	not at all	3a	20	64,52%		
	moderately	3b	7	22,58%		
	strongly	3c	4	12,90%		
	x(b+c)		11		35,48%	
	avg.value x(b+c)		33			
	n.total		93			
	avg.relative frequency x(b+c)				35,48%	0,9965

Figure 5. LDMI SMEs evaluation of influence of digital maturity on innovation process

As can be seen in Fig. 4., companies categorized with low digital maturity index don't evaluate their strategic management factors as high or moderate.

MDMI responses overview						
Question	Variable meaning	variable marker	variable value x	relative frequency	relative frequency x(b+c)	p value
How do you perceive the level of strategic management in your organisation?	low	1a	11	35,48%		
	moderate	1b	8	25,81%		
	high	1c	7	22,58%		
	x(b+c)		15		60,00%	
Do you perceive the common vision of management in strategic management?	not at all	2a	13	41,94%		
	moderately	2b	7	22,58%		
	strongly	2c	6	19,35%		
	x(b+c)		13		52,00%	
How did digitalization change your approach to strategic business model innovation?	not at all	3a	13	41,94%		
	moderately	3b	7	22,58%		
	strongly	3c	6	19,35%		
	x(b+c)		13		52,00%	
	avg.value x(b+c)		41			
	n.total		78			
	avg.relative frequency x(b+c)				54,67%	0,367

Figure 6. MDMI SMEs evaluation of influence of digital maturity on innovation process

It can be stated that those companies are on the brink of implementation of digital environment, struggling with many pitfalls on the way to reach at least an average level of digitalization.

On the contrary, data in Fig. 6 shows that with rising level of digital maturity, the perception shifts to more firm position of strategic management and the companies are prawn to see the pattern between strategic management and digital maturity.

As for the companies listed in category with high digital maturity index, as represented in Fig. 7., the results are clear and can lead to confirmation of the assumption, that companies with developed strategic management approach, high level of digital competencies and in the state of advanced development are much likely to connect their position in the digital world with their strong strategic approach.

HDMI responses overview						
Question	Variable meaning	variable marker	variable value x	relative frequency	relative frequency x(b+c)	p value
How do you perceive the level of strategic management in your organisation?	low	1a	4	12,90%		
	moderate	1b	8	25,81%		
	high	1c	7	22,58%		
	x(b+c)		15		88,24%	
Do you perceive the common vision of management in strategic management?	not at all	2a	6	19,35%		
	moderately	2b	9	29,03%		
	strongly	2c	4	12,90%		
	x(b+c)		13		76,47%	
How did digitalization change your approach to strategic business model innovation?	not at all	3a	3	9,68%		
	moderately	3b	11	35,48%		
	strongly	3c	5	16,13%		
	x(b+c)		16		94,12%	
	avg.value x(b+c)		44			
	n.total		57			
	avg.relative frequency				86,27%	<0,01

Figure 7. HDMI SMEs evaluation of influence of digital maturity on innovation process

The zero hypothesis was tested secluded for each category. As can be seen in Fig. 8., the zero hypothesis is rejected in LDMI and MDMI SMEs in favour of alternative hypothesis. On the contrary, in category HDMI the zero hypothesis is accepted.

SME category	p H0	p-value	confidence interval	evaluation
LDMI SME's	0,5	0,9965	0,95	H0 rejected
MDMI SME's	0,5	0,367	0,95	H0 rejected
HDMI SME's	0,5	3.54e-05	0,95	H0 accepted

Figure 8. Results of zero hypothesis prop.test

From the data presented in Fig. 8., we can draw a conclusion, that zero hypothesis stating that more than 50% of SMEs managers perceive that their strategic management is strongly positioned is only viable in more evolved and advanced enterprises, that already reached the necessary breakpoint of digital maturity to be able to assess its influence on innovation processes.

4. Conclusion

The aim of the paper was to examine the influence of strategic management factors on the level of the digital maturity in SMEs and the perception of said factors of SME's managers in order to conceptualize the approach to strategic management and the digital maturity in the process of gaining a competitive edge in the ongoing thrive for sustainability and competitiveness. According to the obtained data and discussed results, number of conclusions can be drawn regarding the research questions.

It has been found that level of digital maturity and its connection to strategic management is a matter of importance for included SMEs, and the influence can be perceived as measurable. More developed strategic management serves as an accelerator of digital transformation process and contributes to a higher level of digital maturity. As last years were somewhat turbulent and SMEs had to deal with the perplexity caused by covid19 pandemic, strategic management could be their means to survive in the difficult times and evolve and gain competitive advantage.

SMEs with lower digital maturity index do not report the same level of strategic management as more digitally advanced enterprises. As for the number of SMEs and its division into categories according to the digital maturity index, higher number of respondents was categorized as lowly digitally mature. It opens space for both scholarly and practical discussion about SMEs journey to digital maturity. It can be stated that there are still future goals to reach in terms of digital maturity and digital transformation process for SMEs in the Czech Republic.

Through raising the level of digital competencies and building up viable technological environment based on the firm's strategic approach, SMEs can maximise the effect of digital transformation process, helping the enterprises to reach sustainable revenue growth and competitive edge.

As one of the limitations of this research we can state that strategic management factors are not the only thing affecting the digital maturity level, although this fact

opens space for future research on the topic of factors influencing the innovations ratio and describing the position of strategic management among them.

It can be stated that digital maturity index has risen, as the SMEs reported more developed strategic management approach and shared vision, as well as the perception of their strategic management firmness and position. Thus, results of the study recommend that SMEs build up their strategic management approach to reach higher level of digital maturity if they strive for more digitalized and innovative company. As the digital maturity evaluation can vary depending on the point of view of respondents, the author aims to develop more detailed evaluation protocols for digital maturity in future research.

This research contributes to prior literature and practical digital maturity models via application of modified digital maturity model used to measure level of digital maturity and linking its impact to the amount of innovation ratio and innovation processes.

As this study has an exploratory character with limited sample, there are natural limitations. Yet, those limitations provide impulses a create possibility for future research.

As responses often depend on time and conditions (Baxter & Jack, 2008) [26], it can be stated that one limitation is the impossibility to control the environment. By executing multiple studies with larger samples, this limitation could be addressed by future researchers. Future research could also explore the position of strategic management among other factors with impact on the level of digital maturity and innovation processes, and the means of building up the digital maturity and training necessary competencies needed to successful digital transformation (Zhou et al., 2021) [27]. Another research gap can be seen in comparison between various SME divided by fields of business, size, revenue, and other performance indicators, concerning their role and purpose in building dynamic capabilities for digital transformation (Barreto, 2010) [28].

Acknowledgements

The author would like to express his gratitude to the organizations involved, as well as to the Tomas Bata University in Zlin and Faculty of management and economy for providing the support and research background.

References

- [1] Schumpeter, J., & Backhaus, U. (2003). The Theory of Economic Development. In J. Backhaus (Ed.), Joseph Alois Schumpeter (pp. 61-116). Kluwer Academic Publishers. https://doi.org/10.1007/0-306-48082-4_3
- [2] Davidsson, P. (2016). Researching entrepreneurship. Springer Science+Business Media.

- [3] Nawanir, G., Lim, K.T., & Othman, S.N. (2016). Lean Manufacturing Practices in Indonesian Manufacturing Firms. *International Journal of Lean Six Sigma*, 7(2), 149-170
- [4] Aguwa, C.C., Monplaisir, L., & Turgut, O. (2012). Voice of the customer: Customer satisfaction ratio-based analysis. *Expert Systems with Applications*, 39 (11), 10112-10119.
- [5] Singh, J., & Singh, H. (2015). Continuous Improvement Philosophy. *Benchmarking: An International Journal*, 22 (1), 75-119
- [6] Fitzgerald, M., Kruschwitz, N., Bonnet, D., & Welch, M. (2014). Embracing digital technology: A new strategic imperative. *MIT Sloan management review*, 55(2), 1.
- [7] Kim, W. C., & Mauborgne, R. (2015). *Blue ocean strategy: how to create uncontested market space and make the competition irrelevant* (Expanded edition). Harvard Business Review Press.
- [8] Yoo, Y., Henfridsson, O., & Lyytinen, K. (2010). Research commentary—the new organizing logic of digital innovation: an agenda for information systems research. *Information systems research*, 21(4), 724-735.
- [9] Yoo, Y., Boland, R. J., Lyytinen, K., & Majchrzak, A. (2012). Organizing for Innovation in the Digitized World. *Organization Science*, 23(5), 1398-1408. <https://doi.org/10.1287/orsc.1120.0771>
- [10] Nambisan, S., Lyytinen, K., Majchrzak, A., & Song, M. (2017). Digital Innovation Management: Reinventing innovation management research in a digital world. *MIS quarterly*, 41(1)
- [11] Tilson, D., Lyytinen, K., & Sørensen, C. (2010). Research commentary—Digital infrastructures: The missing IS research agenda. *Information systems research*, 21(4), 748-759.
- [12] Hess, T., Matt, C., Benlian, A., & Wiesböck, F. (2016). Options for formulating a digital transformation strategy. *MIS Quarterly Executive*, 15(2).
- [13] Bharadwaj, A., El Sawy, O. A., Pavlou, P. A., & Venkatraman, N. (2013). Digital Business Strategy: Toward a Next Generation of Insights. *MIS Quarterly*, 37(2), 471-482. <https://doi.org/10.25300/MISQ/2013/37:2.3>
- [14] Singh, A., & Hess, T. (2020). How chief digital officers promote the digital transformation of their companies. In *Strategic Information Management* (pp. 202-220). Routledge.
- [15] El Sawy, O. A., & Pereira, F. (2013). *Business modelling in the dynamic digital space: An ecosystem approach*. Heidelberg: Springer.
- [16] Sommer, Lutz, 2015. Industrial revolution - industry 4.0: Are German manufacturing SMEs the first victims of this revolution? *Journal of*

- Industrial Engineering and Management [online]. 8(5), 1512-1532 [cit. 2022-02-14]. ISSN 2013-0953. <https://doi.org/10.3926/jiem.1470>
- [17] Warner, K. S. R., & Wäger, M. (2019). Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal. *Long Range Planning*, 52(3), 326-349. <https://doi.org/10.1016/j.lrp.2018.12.001>
- [18] Ghobakloo, Morteza a Mohammad IRANMANESH, 2021. Digital transformation success under Industry 4.0: a strategic guideline for manufacturing SMEs. *Journal of Manufacturing Technology Management* [online]. 32(8), 1533-1556 [cit. 2022-02-14]. ISSN 1741-038X. <https://doi.org/10.1108/JMTM-11-2020-0455>
- [19] Simpson, J. A., & Weiner, E. S. C. (1989). *The Oxford English dictionary* (2nd ed.). Oxford University Press.
- [20] Kohlegger, M. Maier, R., and Thalmann, S. "Understanding Maturity Models Results of a structured Content Analysis," presented at the IKNOW '09 and I-SEMANTICS '09, Graz, Austria, 2009.
- [21] Deloitte. (2018). Digital maturity pivot model. <https://www2.deloitte.com/us/en/insights/focus/digital-maturity/digital-maturity-pivot-model.html>
- [22] the KPMG Global Manufacturing Outlook. (2018). *Global Manufacturing Outlook: Transforming for a digitally connected future*. Publication number: 135443-G. London.
- [23] The Tech Pro Report (2019). Special report: Digital transformation: A CXO's guide. Tech republic. Retrieved May 15, 2022, from <https://www.techrepublic.com/resource-library/whitepapers/digital-transformation-a-cxo-s-guide-free-pdf/>
- [24] Lee, R. P., & Chen, Q. (2009). The immediate impact of new product introductions on stock price: the role of firm resources and size. *Journal of Product Innovation Management*, 26(1), 97-107.
- [25] de Bruin T, Rosemann M, Freeze R, Kulkarni U (2005) Understanding the main phases of developing a maturity assessment model. In: 16th Australasian conference on information systems (ACIS). Sydney
- [26] Baxter, P., & Jack, S. Qualitative Case Study Methodology: Study Design and Implementation for Novice Researchers. *The Qualitative Report*. <https://doi.org/10.46743/2160-3715/2008.1573>
- [27] Zhou, J., Liu, C., Xing, X., & Li, J. (2021). How can digital technology-related acquisitions affect a firm's innovation performance? *International Journal of Technology Management*, 87(2/3/4). <https://doi.org/10.1504/IJTM.2021.120931>

- [28] Barreto, I. (2010). Dynamic Capabilities: A Review of Past Research and an Agenda for the Future. *Journal of Management*, 36(1), 256-280.
<https://doi.org/10.1177/0149206309350776>

Consumer Segmentation in the Fashion Industry Using Social Media: An Empirical Analysis

Virtika Singhal

virtikasinghalvs@gmail.com

*Amity Business School, Amity University
Noida, India*

Anurupa B. Singh

absingh@amity.edu

Amity Business School, Amity University

Vandana Ahuja

director@sibmnoida.siu.edu.in

*Symbiosis Institute of Business Management
Noida, India*

Rajat Gera

rajat.gera@woxsen.edu.in

*School of Economics and Commerce and
School of Social Sciences and Humanities, CMR University, Bangalore*

Abstract

Social media has developed into a symbolic channel that affects consumer behavior due to the remarkable marketing and ecommerce opportunities that the internet has provided. This study is based on segmentation of consumers into different categories in the world of fashion using social media. This paper proposes two conceptual models (the FC-CBR model of consumer brand relationship and the FC-CBP model of consumer brand perception) for exploring further into these constructs and developing a more coherent theoretical framework. The study identifies factors of Consumer Brand Relationship (CBR) and Consumer Brand Perception (CBP) using social media in the fashion world. Subsequently, the manuscript groups fashion consumers into clusters using K-means cluster analysis based on consumer brand relationship and consumer brand perception. The manuscript demonstrates how the clusters can be used in the development of efficient targeting and positioning strategies by practitioners.

Keywords: Digital Networking, Social Networking Sites, Consumer Behavior, Fashion, Fashion Industry, Cluster Analysis

1. Introduction

Due to demanding consumers, globalization and fierce competition, marketing on social media is currently experiencing a number of challenges. Therefore, in order to address their own advantages and drawbacks in respect to competition, fashion

businesses must first evaluate the existing scenario [1]. In light of the fantastic opportunities that the internet has opened up for marketing and commerce, social media has refined into a symbolic channel that influences consumer behavior [2]. Numerous inputs that integrate both qualitative and quantitative factors are used to make judgments.

One of the most prominent online evolutions is the adoption of social media. More over 3.6 billion individuals globally or approximately half of the world's population used social media in 2022 [2]. Social media is especially noticeable in the fashion industry because fashion, lifestyle goods and beauty items dominate online consumer behavior for commodities related to fashion. In many countries throughout the world, fashion consumers start their search on digital sites, which helps them develop relationships with brands and shape perceptions of those brands. Access to knowledge about a variety of fashion goods is made possible by social media platforms, which also offer a number of advantages like customer assistance and systemization. Due to the increased elucidation channels and infinite opportunities for product differentiation that social media has brought about, it had a symbolic impact on fashion marketing [3]. Researchers have recently been attempting to better understand the connections that some brands consumers flourish with them [4]. However, both consumers and brands place a high value on brand relationships. While a fragile brand relationship between the consumer and brand leads to churn and brand switching, a good brand relationship emboldens repurchase intent [5].

Additionally, businesses can lessen the likelihood that clients switch to a competitive brand by implementing well-defined customer retention strategies [6]. As a result, it is crucial for fashion firms to regularly measure the status of their consumer brand relationship, as well as to shape consumer perception in order to improve the equation. This study proposes conceptual models to explain the significance of social media in understanding consumer behavior in the fashion world. The models serve as the foundation for developing a research tool to assess the contribution of social media to the progression of consumer behavior in the fashion sector.

The paper concentrates on explicating social media usage in segmenting fashion consumers according to two aspects of customer behavior, namely consumer brand relationship (CBR) and consumer brand perception (CBP). The manuscript attempts to conduct an exploratory factor analysis on the data collected with the research instrument in order to validate the below mentioned factors. Consumer segmentation, consumer profile extraction, and proposed targeting strategies are researched using k-means cluster analysis. Using the information acquired, the fashion CBR index (FCBRI) and fashion CBP index (FCBPI) were constructed.

2. Literature Review

The literature review section explores the impact of social media in the world of fashion and consumer behavior that has always been a contemporary marketing topic that has been widely discussed over the years. In order to explain the principles of consumer behavior, the most common strategy discusses customer brand relationship and consumer brand perception.

2.1. Social Media and Fashion Industry

Social media is categorized by self-presentation/self-disclosure and social presence/richness of media [7]. Consumers typically use a variety of channels and touch points throughout their consumer journey [8]. Consumers might use fashion business app to look up information and prescreen selections, purchase the goods online from their laptop at home, pick it up in-person and then post their happiness on social media once they've received it [9]. Fashion brands must comprehend what motivates omni-channel consumers behavior in this cut throat omni-channel environment. If they hope to retain these consumers as well as provide each with the services they need since they do not all behave in the same way [10]. Fashion brands are better able to comprehend the needs of their consumers because to the communication opportunities provided by social networks [11]. The key point is that while doing social network marketing campaigns, many consumer demographic, cultural, geographic and behavioral groupings must be taken into account [12]. Despite this, research reveals that many fashion companies have joined social media platforms and invested a significant amount of money in social media marketing without having specific marketing objectives or strategies [9].

2.2. Consumer Behavior

With increased media coverage, the assistance of social activists and a number of rigorous government regulations being applied to the business, fashion brands have also noticed changes in consumer behavior [13]. Numerous studies from all over the world have suggested that consumers are becoming more conscious of social media's role in impacting consumer behavior in the fashion world [11]. Where one-on-one connections would be challenging to maintain and improve, brand communities play a significant role [14]. Since the intimate act of self-disclosure might put oneself and others at risk, trust is necessary and essential [15]. Additionally dedication is necessary to the partnership, which includes working together as a team rather than independently, sharing tasks and assisting one another [16]. Due to their desire to interact with other users and share their brand experiences, this can either diminish or strengthen customer engagement [17]. A digital marketing strategy consequently offers a platform for others with similar interests [18].

2.3. Consumer Brand Relationship

The ability to properly establish brand meaning in consumers' minds is essential to the consumer brand relationship [19]. In order to build a relationship and familiarity with consumers, brands might have a particular relevance [20]. For this study, we draw on the research in which the relationship between the consumer and the brand is viewed as a function of the brand's engrossment, reliability, engagement and conviction [21]. The consumer and brand may develop strong, positive emotional attachments as a result of the brand relationship [13]. Relationships are characterized as interactions across time. The interdependence that exists between the parties involved constitutes the essence of a relationship [5]. Consumer brand relationship

marketing also refers to keeping valuable clients through collaboration and participation [22].

2.4. Consumer Brand Perception

Consumer brand perception tells us about consumer awareness, perception or opinion about a product or brand. Consumers' past experiences, beliefs, habits, likes, dislikes and moods can all influence how they perceive products and services today. Any individual who encounters a stimulus analyses it in light of knowledge they already have about their behavioral intentions, beliefs, and emotions [20]. These evaluations help create a general viewpoint or orientation toward a specific subject within a predetermined frame of reference. For this study, we draw on the research in which the perception between the consumer and the brand is viewed as a function of the brand's impression, bonding, recognition, and dependability [19].

Through the review of the literature, a brief summary of the determinants identified in the research is included along with a discussion of the theoretical frameworks for the investigation. First, the factors affecting CBR and CBP are discussed followed by two conceptual models (Figures 1 and 2) for analyzing CBR and CBP in relation to the world of fashion. Readers will gain a complete grasp of the conceptualization and identification of important determinants in the research study from the thorough review of literature. This helped in grouping the factors mentioned in Figures 1 and 2, depending on the specific role they had in the development of CBR and CBP.

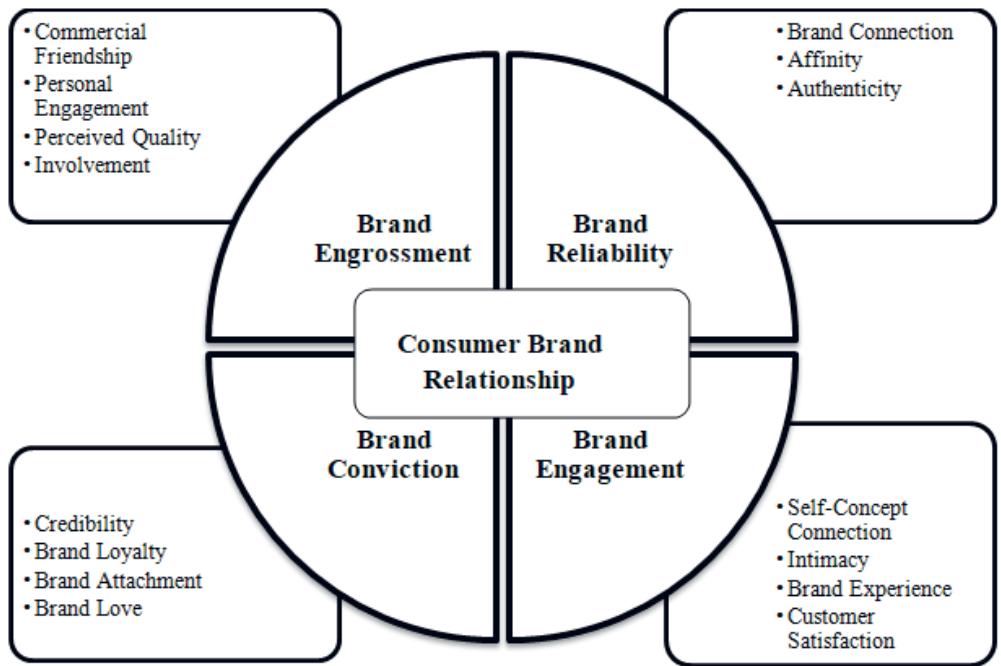


Figure 1. Fashion Consumers under CBR (FC-CBR)

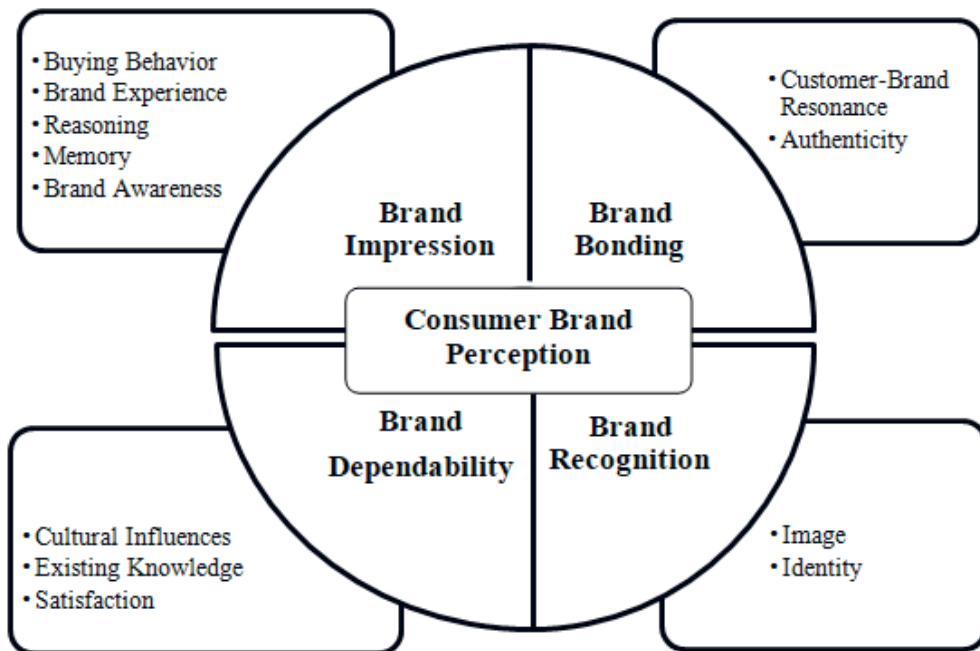


Figure 2. Fashion Consumers under CBR (FC-CBP)

3. Research Methodology

The research takes a theoretical and empirical approach to examine the social media's impact on consumer behavior with reference to fashion brands. This study uses exploratory factor analysis and k-means cluster analysis to attempt to quantify the social media's impact on fashion consumers. The goal of the manuscript is to validate the components listed below by performing an exploratory factor analysis on the data gathered using the research instrument. Using the information acquired, the fashion CBR index (FCBRI) and fashion CBPI index (FCBPI) were constructed. This study's research technique was organized as follows:

3.1. Research Objectives

Based on the above literature review, the following research objectives are proposed for this manuscript:

1. Identification of factors for establishing relationships using social media in the fashion world.
2. Identification of factors for forming perceptions using social media in the fashion world.
3. Formulation of conceptual models to determine the use of social media in the fashion business in creating relationships and forming perceptions.
4. Extraction of fashion consumer clusters using cluster analysis method.

3.2. Research Instrument Formulation

In order to better understand how social media affects CBR and CBP in the fashion world, a questionnaire was developed with the help of a thorough analysis of literature. The research tool was bifurcated into three sections. The first section was proposed with the intention of gathering demographic data. The questionnaire's second and third sections were constructed to support research on the ways that social media can be used to evaluate CBR and CBP in the fashion sector, respectively. Additionally, the second section included 39 statements, while the third section contained 30 statements.

3.3. Establishing Reliability of the Instrument

Through the Cronbach's alpha test, the research instrument's dependability was determined. A result of more than 0.60 denotes the scale's acceptability [23]. The reliability test was carried out using the SPSS software after the data was gathered from 500 fashion consumers. It was determined that the values of Cronbach's Alpha (Table 1) for CBR and CBP were 0.909 and 0.891, respectively. As a result, it was decided that the research instrument may be used for data collection.

	CBR	CBP
Cronbach's Alpha	.909	.891
Cronbach's Alpha Based on Standardized Items	.910	.892
N of Items	39	30

Table 1. Results of the Pilot Study using Cronbach's Alpha

3.4. Proposed Data Collection and Analysis

The research instrument had 39 statements of CBR and 30 statements of CBP. Out of 575 respondents, 500 respondents administered the study of segmenting fashion consumers on the basis of consumer behavior using social media. On a scale of 1 to 5, the respondents were asked to rate each statement (1-Strongly Disagree to 5-Strongly Agree).

3.5. Sampling Method and Data Collection

The data was collected through snowball sampling. Researchers recruit fresh respondents for a test or study by using the snowball sampling approach. The researcher develops an online self-completion questionnaire for a group of people who are relevant to the study's subject, and then leverages contacts from that group to track down additional people for interview [24]. Ages of the interviewees ranged from 18 to 55 years. 500 out of the 575 responses were useful for this study.

3.6. Exploratory Factor Analysis

The method of factor analysis entails the mathematical expression of fictitious constructions utilizing a variety of observable indicators that may be precisely assessed. Exploratory factor analysis is a statistical method for data reduction and investigation of the occurrences underlying theoretical framework. This method is used to determine the type of association between the variable and the respondent. Data reduction entails breaking down large sets of measured variables into more manageable groups of constructs. Strongly correlated variables can be grouped together using the factor analysis technique. Latent constructs are the names given to these collections of variables.

3.7. K-Means Cluster Analysis

Cluster analysis is a typical technique for classifying objects or illustrating the structure of data. Data items are grouped together in fragmented clusters during the clustering process so that the data within the same cluster are similar while the data within separate clusters differ [25]. This tool is used to observe the properties of clusters and to zero in on a specific cluster for more investigation. By calculating the distance between each pair of things, it helps to determine how unlike two objects are. In a big data set, it aids in recognizing homogenous clusters of data. This indicates that data are divided into distinct groups, with data belonging to related categories sharing commonalities while having differences.

4. Data Analysis and Results

4.1. Factor Analysis

SPSS 26.0 was used for data analysis. Factor analysis utilizing the rotating component method was conducted on the complete set of data from 500 fashion consumers (Tables 2 and 3). The significant communalities in the data allowed us to conclude that the variables were depicted logically in the retrieved components. Thus, we were able to reduce the data while retaining component context (Figures 1 and 2). To identify associated factors that each item represented, the items with the highest loading were chosen. A factor loading of at least 0.5 was required for several of these elements in order to be maintained. As a result, two factors and ten items were removed from Table 2. Since seven items failed to load onto any factors, they were excluded from Table 3 altogether.

	Component					
	1	2	3	4	5	6
Brand is trustworthy	.274	.201	.364	.187	.146	.628
Fashion brand's credibility	.271	.271	.608	.277	.102	.002
Building consumer loyalty	.207	.186	.594	.322	.156	.207
Closer to my preferred fashion brand	.353	.136	.638	.371	.107	.212

Love content of social media	.111	.134	.602	.179	-.231	.003
I identify myself if I love its social media content	.112	.341	.184	.587	.017	.288
Consumer value for a fashion brand	.216	.407	.623	.192	.140	.243
Brand Connection	.332	.408	.315	.420	.116	.182
Intimate with a fashion brand	.143	.416	.212	.414	.222	.390
Enriching my experience with a fashion brand	.284	.330	.472	.442	.029	.178
Feel positive about my preferred fashion brand	.408	.345	.478	.392	-.052	-.015
Advertising a fashion brand	.497	.280	.461	.337	.066	-.021
Contact with my preferred fashion designer	.298	.503	.234	.283	.160	-.044
Positive ecosystem for my preferred fashion brand	.273	.472	.316	.361	.321	-.099
Positive relationship on social media with preferred fashion brand	.289	.430	.435	.174	.352	.142
I feel satisfied by the social media content	.345	.455	.429	.299	.067	.060
Evaluating and comparing offerings of fashion brands	.340	.634	.120	.207	.074	.069
Building a fashion brand's authenticity	.241	.591	.317	.197	.201	.094
Consumer affinity towards fashion brand	.230	.723	.251	.110	.177	.166
Fashion brand in cultivating a consumer-focused business environment	.302	.495	.510	- .073	.331	.246
Retaining and attracting consumers better than rivals	.113	.625	.310	- .048	.490	.061
Engaged with my preferred fashion brand	.325	.592	.190	.298	.038	.332
Strong and dynamic relationship with preferred fashion brands	.521	.453	.230	.188	.174	.246
Commercial friendship with a fashion brand	.673	.325	.329	.054	.250	.149
Personal engagement with a fashion brand	.740	.150	.331	.062	.171	.140
Excellence and superiority of a fashion brand	.591	.138	.345	.113	.265	.169
Develops interest towards a fashion brand	.446	.650	.080	.351	.161	-.055
Endorses a fashion brand	.550	.343	.137	.241	.166	.245
Belief backed my good experience	.593	.311	.161	.224	.313	.071
Happiness towards the same fashion brand	.264	.062	.316	.653	.097	.146
Following a fashion brand on social media	.158	.172	-.065	.687	.234	.001
I feel happy to praise my choice of social media content	.553	.233	.320	.200	.128	.216
Fashion brands are trendy and relevant on social media sites	.671	.263	.143	.291	.439	.078
Trust social media content posted by a fashion brand	.258	.342	.038	.003	.123	.103
Experiences shared by my peers on social media	.337	.111	.324	.219	.443	.368
Time researching fashion brand before I	.259	.308	.182	.417	.539	-.141

decide to make my purchase						
Good brand advertisements attract me on social media sites	.335	.198	.255	.552	.203	.140
Good quality of social media images and content posted by a fashion brand	.396	.375	.304	.545	.154	-.115
A regular practice to search fashion brand items on social networking sites	.004	-.060	.267	.754	.019	-.189

Table 2. Rotated Component Matrix under CBR

	Component			
	1	2	3	4
Makes me feel happy	.172	.260	.601	.210
Peers and family	.346	.181	.673	.139
Cultural influences on social media	.106	.111	.590	.383
Existing information on social media	.407	.218	.753	.227
The social media content influences consumer's mind	.010	.198	.122	.154
Decisions building	.495	-.016	.409	.486
Social media content created by a brand	.451	.003	.297	.362
I feel overjoyed	.642	.164	.294	.313
Brand purchase	.571	.260	.215	.184
Happy memories associated with the social media	.704	.302	.268	.034
Confident of the social media's content	.610	.106	.247	.183
Fashion brand experience	.598	.278	.164	.303
Content satisfaction	.434	.277	.368	.378
Fashion brands behaviors and characteristics	.090	.169	.107	.826
Search for fashion brand	.311	.367	.296	.779
Unhappy to leave my search	.056	.190	.263	.739
Fashion brand adds to my Self-esteem	.227	.871	.189	.175
In sync	.283	.756	.344	.219
Fashion brands keeps its promises	.401	.643	.059	.254
Impulsive buying	.565	.201	.308	.309
Affinity	.341	.233	.115	.103
Quality products	.008	.483	.067	.296
Memories that are happy	.665	.002	.250	.345
Brand's personality	.329	.750	.160	.228
Brand awareness	.896	.009	.007	.348
Use of fashion brands	.109	.290	.174	.563
Preferred fashion brand adds to my status	.621	.006	.208	.186
Content liking	.446	.492	.237	.110
Feel happy on people's comment	.412	.651	.231	.120
Content sharing	.002	.101	.390	.163

Table 3. Rotated Component Matrix under CBP

A focus group of six fashion industry experts was employed to help determine a numerical weight for each of the four aspects of CBR (Table 4): brand engrossment, brand reliability, brand conviction and brand engagement and four aspects of CBP

(Table 5): brand bonding, brand impression, brand dependability and brand recognition aspects using the weighted averages calculation method. The following weights (Tables 4 and 5) were retrieved for each of the parameters based on their rating employing the formula:

$$\text{Weight of each variable} = \Sigma Ni / \text{Total score}$$

Where, ΣNi = Number of focus group responses for each scale component

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Total	Weight
Brand Engrossment	3	3	4	5	5	4	24	0.27
Brand Reliability	5	4	2	4	3	3	21	0.23
Brand Conviction	4	5	3	3	3	4	22	0.25
Brand Engagement	2	5	5	4	3	3	22	0.25
							89	1

Table 4. Weighted Average Calculation (CBR)

The factor scores for the four components of brand engrossment, brand reliability, brand conviction and brand engagement of CBR were combined from each respondent in the sample. The expert weight under each of the four component categories was multiplied by the acquired total. The final fashion consumer brand relationship index (FCBRI) for each respondent was calculated by adding the resultant multiplied scores for the four categories brand engrossment, brand reliability, brand conviction and brand engagement. This FCBRI value currently illustrates the four elements of consumer brand relationship and exemplifies the strength of the bond between consumers and fashion companies. The strength of the relationship increases as the index score rises.

Equation Formation for Calculating Fashion Consumer Brand Relationship Index (FCBRI):

$$\text{FCBRI} = (0.27 * E_i + 0.23 * R_i + 0.25 * C_i + 0.25 * En_i)$$

Where,

E= Engrossment;

R= Reliability;

C= Conviction;

En= Engagement;

i= individual respondent

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Total	Weight
Brand Bonding	2	5	4	3	5	2	21	0.25
Brand Impression	3	2	3	5	2	4	19	0.23
Brand Dependability	5	2	4	2	3	5	21	0.25
Brand Recognition	4	4	5	3	4	3	23	0.27
							84	1

Table 5. Weighted Average Calculation (CBP)

From each respondent in the sample, the factor scores for the four aspects of CBP: brand bonding, brand impression, brand dependability and brand recognition were

combined. The collected total was multiplied by the expert weight under each of the four component categories. The resultant multiplied scores for the four areas of brand bonding, brand impression, brand dependability and brand recognition were added to determine the final fashion consumer brand perception index (FCBPI) for each respondent. This FCBPI score currently exhibits the form of consumer perceptions of fashion companies and the four components of consumer brand perception. As the index score grows, the perception's strength also rises.

Equation Formation for Calculating Fashion Consumer Brand Perception Index (FCBPI)

$$\text{FCBPI} = (0.25 * B_i + 0.23 * I_i + 0.25 * D_i + 0.27 * R_i)$$

Where,

B= Bonding; I= Impression;
D= Dependability; R= Recognition;
i= individual respondent

4.2. Fashion Consumer Brand Relationship Index (FCBRI) Data

K-means was used to analyze the Fashion Consumer Brand Relationship Index (FCBRI) data. Four consumer clusters (Table 6) were derived using cluster analysis. The final cluster centers are shown in Table 6, which demonstrates that cluster 2 and cluster 4 are similar since there is a small distance between them. However cluster 1 and cluster 3 are very different because there is a large gap between them. It is thought that each consumer segment represents a uniform group of fashion consumers who have a comparable level of social media usage in improving relationship with the brand.

Cluster	1	2	3	4
1		12.077	5.869	10.398
2	12.077		8.535	5.441
3	5.869	8.535		9.565
4	10.398	5.441	9.565	
	28.344	13.976	18.1	15.006

Table 6. K- Means Cluster Analysis- Final Cluster Centers of CBR

Cluster	1	100.000
	2	135.000
	3	75.000
	4	190.000
Valid		500.000
Missing		0.000

Table 7. Number of Cases in each Cluster: CBR

4.3. Fashion Consumer Brand Perception Index (FCBPI) Data

Data from the Fashion Consumer Brand Perception Index (FCBPI) was analyzed using K-means. Four customer clusters were determined using cluster analysis (Table

8). Table 8's final cluster centers reveal that clusters 1 and 3 are similar since there is not much space between them, whereas clusters 2 and 4 are extremely different because there is a lot of space between them. Each consumer category is believed to reflect a consistent group of buyers who use social media to influence perceptions of the fashion brand to a similar extent.

Cluster	1	2	3	4
1		3.875	6.958	6.099
2	3.875		5.813	8.813
3	6.958	5.813		11.534
4	4.099	5.813	10.534	
	14.932	11.626	16.347	20.347

Table 8. K- Means Cluster Analysis- Final Cluster Center of CBP

Cluster	1	178.000
	2	84.000
	3	42.000
	4	200.000
Valid		500.000
Missing		0.000

Table 9. Number of Cases in each Cluster: CBP

5. Results

With the help of this study, members of the sample population were successfully grouped into clusters (Tables 7 and 9) that have distinct connections and viewpoints. These clusters shared traits provide light on the fundamental role that social media plays in influencing consumer behavior and how they interact with and perceive fashion businesses. With the use of this data, brands may create marketing plans that will improve their connections to the various clusters.

On the basis of the discussion above, we were able to develop the model for our study, which is the model for fashion consumers under CBR (FC-CBR) (Figure 1). This model will make it easier for us to comprehend the consumer psychology elements of brand engagement, reliability, conviction and engrossment. This would further help us to determine the impact that social media has in establishing relationships with fashion consumers. Using the literature review, we have categorized the following factors:

1. Commercial friendship, personal connection, perceived quality and involvement are all grouped together by the brand engrossment component of the model, which forms a relationship between brand engrossment and consumer brand relationship.
2. Brand reliability is a category that includes brand connection, affinity and authenticity.
3. Brand conviction will include the concepts of credibility, loyalty, attachment and love, establishing a link between brand conviction and consumer brand

relationships. As a result, brand engagement and customer brand relationships are created.

4. Self-concept connection, intimacy, brand experience and consumer happiness make up brand engagement. As a result, there is a connection between consumer brand relationship and brand engagement.

The model for fashion consumers under CBP (FC-CBP) was created based on the discussion above and provides a framework for our study (Figure 2). Understanding the components of brand impression, brand bonding, brand recognition and brand dependability from the perspective of consumer psychology will be made simpler by this model. By doing so, we would be better able to assess how a fashion consumer contributes in forming perception in the social media world. Using the literature review, we have categorized the following factors:

1. The buying behavior, brand experience, reasoning, memory and brand awareness factors are all included in the model's brand impression component, which establishes a link between brand impression and consumer brand perception.
2. Authenticity and customer-brand resonance could be categorized under brand bonding.
3. Brand dependability, which is grouped with cultural influences, prior knowledge and satisfaction, creates a link between brand dependability and consumer brand perception.
4. Brand recognition, which is grouped with image and identity, establishes a link between brand recognition and consumer brand perception. As a result, there is a connection between customer perception of a brand and brand recognition.

5.1. Consumer Segmentation, Consumer Profile and Social Media Content Strategies

Consumer categories were created from the consumers using the two indexes using K-means cluster analysis (Figure 3). Additionally, the development of efficient targeting and positioning strategies will benefit from a comprehensive consumer cluster analysis of each of the consumer groups.

Profiles of the consumer cluster are shown in Table 9. The model that was eventually developed is shown in Figure 3. This illustrates the framework that fashion brands may use to comprehend how social media plays a role in establishing relationships and forming perceptions in a positive way.

5.1.1. Consumer Brand Relationship

Based on the state of their relationship with the fashion brands, consumers were split into 4 segments. Table 6 presents a complete consumer profile. Additionally, using this profile, appropriate marketing plans were created to target each of the four consumer segments (Table 10).

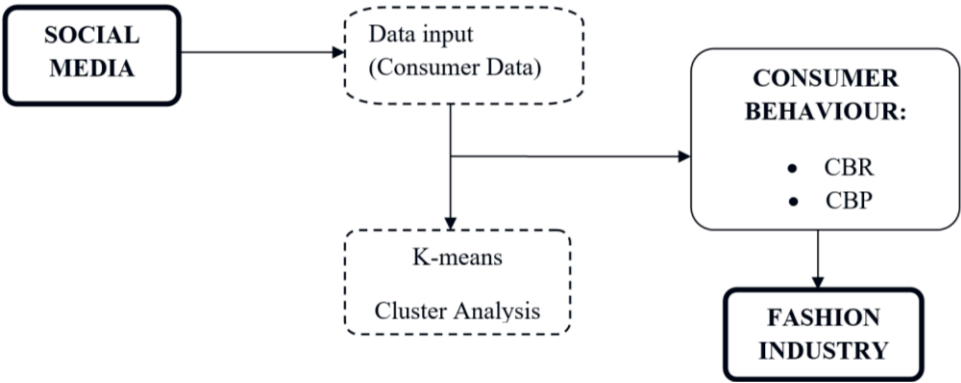


Figure 3. Consumer Segmentation in the Fashion Industry using Social Media

Cluster	Consumer Profile	Social Media Content Strategy
1	Consumers in this cluster score high on personal engagement and consumer involvement	Engagement, which was previously thought to be fairly stable in nature, has been suggested to become more dynamic in the context of social media [26], [27] and as it manifests in user-generated content, which is the totality of how people use social media [7]. Fashion brands can accomplish this by continuously concentrating on their competitive edge and informing these clients of their accomplishments. Along with following their suggestions, it is crucial to constantly solicit feedback from these customers.
2	Consumers in this cluster score high on brand connection. They also score moderate to high aspects of authenticity.	Brands that emphasize their authenticity attribute gain from increased consumer receptivity [28]. Working closely with these consumers and enlisting their participation as co-creators will help to strengthen the brand connection and authenticity. They should be informed of new advances by fashion brands and their comments can help them make improvements.
3	Consumers score high to moderate on intimacy and customer satisfaction. Consumers in this cluster score low on self-concept connection.	Intimacy has both behavioral (like mutual trust, physical familiarity, communication skills or consciousness) and emotional components (such as affective intimacy, cognitive intimacy, presence or commitment) [29]. Tools for consumer promotion may be helpful in winning these customers over to the fashion brands. Promotional campaigns can be created and put into action in order to increase or drive consumer perceptions of value and launch loyalty programmes for retaining customers.

		For these consumers, a strong relationship marketing strategy should be implemented. For fashion brands, customer satisfaction and reviews of their products are crucial.
4	Consumers score high on credibility and brand love.	Brand love expresses favorable thoughts and positive attachment to the fashion brands and helps to define and anticipate crucial post-consumption behaviors among happy customers [30]. The brand will maintain its salience and stay in the consumer's "evoked set" with a steady stream of direct marketing campaigns.

Table 10. Fashion Consumer Brand Relationship using Social Media- Cluster Profiles

5.1.2. Consumer Brand Perception

Based on the state of their perception with the fashion brands, consumers were split into 4 segments. Table 8 presents a complete consumer profile. Additionally, using this profile, appropriate marketing plans were created to target each of the four consumer segments (Table 11).

Cluster	Consumer Profile	Social Media Content Strategy
1	Consumers score extremely high to high on aspects of reasoning, memory and brand awareness of consumer brand perception. A small number of consumers showed uncertainty or disagreement towards buying behavior and brand experience, in forming their perception about the brand.	Quality positioning and benefit positioning can lead to higher cognitive components. Therefore, constant communication regarding the fashion brand's image and activities through mailers and social media posts is required. To enhance the consumer experience, fashion brands should send trial samples of their just launched items. Product evaluation and follow-up with customers regarding their experiences will improve brand perception, creating a strong sense of connection and enhancing the customers favored status.
2	Consumers in this cluster score moderate to high on customer brand resonance, but score moderate to low on belief and authenticity.	Consumer's associate designer labels, slogans and/or brand attributes with their brand knowledge [31]. Campaigns must be developed and carried out in order to increase the cognitive and emotive components of these customers. In order to enhance the customer experience and encourage reviews for peer-group reference, brands should distribute trial samples of their items. To create a sense of a cohort, referral activities should be included. Brands will have to work hard to build a relationship with these

		consumers by offering them a retention/reward plan.
3	Consumers score high on identity and style. Consumers in this cluster score low on society and image.	The brand should encourage customers to adopt a stylish and comfortable lifestyle by providing unique discounts or incentives. By connecting with elite influencers and social achievers in its marketing, the fashion brands should highlight its prestige worth. The fashion brands should use a variety of communication channels to highlight its ability to produce high-quality, fashionable apparel.
4	Consumers score high on customer satisfaction. Consumers in this cluster score extremely low on cultural influences and existing knowledge.	By providing special discounts or incentives for consuming the product, the fashion brands should promote and inspire consumers. The brand will maintain its salience and stay in the consumer's "evoked set" through a steady stream of direct marketing initiatives. The fashion brands should also use its marketing to associate it with elite influencers and social achievers in order to further stress the prestige value of the brand.

Table 11. Fashion Consumer Brand Perception using Social Media- Cluster Profiles

6. Discussion and Managerial Implications

Social media has created new channels for brand communication, as seen by the utilization of online brand interaction on social networking sites. Both CBR and CBP were found to have substantial effects on the importance of social media in the fashion industry in this study. The creation of CBRs involves a variety of potential social networks between vendors and consumers as well as within shared consumer experience. Brand loyalty, brand trust and brand reputation can all support long-term market innovation in the context of e-business.

Similar to marketers in the social media sector, academics are starting to analyze and comprehend the primary structures and processes that support the functioning of social media marketing. Working on various brand engrossment, reliability, conviction and engagement components with fashion customers is crucial for developing a consumer brand relationship. And it is crucial to work on numerous parts of brand impression, brand bonding, brand recognition and brand dependability components with the fashion consumers in order to shape consumer brand perception. Organizations must have a system in place to identify their consumer base, work with the important consumers and persuade them to become brand partners.

6.1. Consumer Brand Relationship

Clusters 2 and 4 are the most important consumer groups since they contain those who are most suited to serve as brand ambassadors. These consumers will be interested in co-creation because they trust the brand and will work with it to ensure its success. The brand should continuously try to inform these consumers about its advancements, successes and competitive advantages. In order to include consumers in the co-creation process, these firms need also maintain a steady flow of consumer feedback and improvise on their end. In terms of size, Clusters 1 and 3 constitute a major cluster. Brands will benefit by investing in this category of consumers. By enticing these consumers with offers of special perks and then rewarding them for their loyalty, they should attempt to establish relationships with them. Consequently, it becomes more appealing and a relationship is established for the future.

6.2. Consumer Brand Perception

Groups of customers in clusters 2 and 4 have the capacity to work together as consumers. By doing this, fashion brands will increase customer base and show connection with the customers that are valued their business. Although customers in clusters 1 and 3 are confused of what to expect from fashion businesses and their capabilities, they nevertheless cherish the positive experience they have with them. Additionally, even though they haven't expressed their attachment to or trust in any particular fashion brands, there is still a chance to convert them by providing information about the products, manufacturing methods, and other factors. By doing so it would give these consumers clarity and inspire trust in the brands.

7. Limitations

With regard to social media, the interaction and perception of fashion consumers in India are helpfully illustrated in this publication. The focus of this work is the user replies from the snowball sampling approach, which were primarily concentrated to the north Indian fashion consumers. This research is broad and does not concentrate on any one brand in particular. In particular, if a vulnerable consumer wishes to make an informed choice, website characteristics will have a big impact on how consumers seek for social media information. Consumers form certain preconceived thoughts in their minds before deciding whether or not to conduct a search, based on the relationship between consumer brands and how those brands are perceived.

8. Future Research Directions

This study is rare in the fashion industry since it provides a strong basis for similar studies to be carried out in other verticals of the industry, such as interior soft goods, footwear, beauty and accessories like bags and luggage. By using the research design of the current study and adapting the items to the applicable industry vertical, the new FCBRI and FCBPI indexes can be put into practice. Focused targeting strategies can be created for each consumer segment after the consumer segments have been

retrieved. This creative study clarifies how fashion consumers perceive social media and the relationship between them. Gaining a deeper comprehension of this relationship can help businesses forge lasting relationships with their customers and help them feel like co-creators of the fashion brand. To make comparisons between other fashion brands, this study can also be carried out for one particular fashion brand or for a large group of fashion brands. This will enable us to better comprehend how fashion consumers interact with fashion businesses and social media.

References

- [1] M. Mijajlović *et al.*, “Determining the Competitiveness of Spa-Centers in Order to Achieve Sustainability Using a Fuzzy Multi-Criteria Decision-Making Model,” *Sustainability*, vol. 12, no. 20, p. 8584, Jan. 2020, doi: <https://doi.org/10.3390/su12208584>.
- [2] V. Singhal, “Segmenting and Targeting Fashion Consumers Using Social Media: A Study of Consumer Behaviour,” *Journal of Creative Communications*, Oct. 2023, doi: <https://doi.org/10.1177/09732586231203848>.
- [3] V. Singhal and V. Ahuja, “Social media marketing and the world of fashion: identification of determinants for building consumer brand relationship and shaping consumer brand perception,” *International Journal of Management Practice*, vol. 16, no. 2, p. 186, 2023, doi: <https://doi.org/10.1504/ijmp.2023.129209>.
- [4] J. H. McAlexander, J. W. Schouten, and H. F. Koenig, “Building Brand Community,” *Journal of Marketing*, vol. 66, no. 1, pp. 38–54, Jan. 2002, doi: <https://doi.org/10.1509/jmkg.66.1.38.18451>.
- [5] ATHANASIOS SBONIAS, “Social Media and Consumer Behaviour,” *Apothesis.eap.gr*, Aug. 22, 2012. <https://apothesis.eap.gr/archive/item/89478> (accessed Nov. 15, 2023).
- [6] J. Bojei, C. C. Julian, C. A. B. C. Wel, and Z. U. Ahmed, “The empirical link between relationship marketing tools and consumer retention in retail marketing,” *Journal of Consumer Behaviour*, vol. 12, no. 3, pp. 171–181, Mar. 2013, doi: <https://doi.org/10.1002/cb.1408>.
- [7] A. M. Kaplan and M. Haenlein, “Users of the world, unite! The challenges and opportunities of Social Media,” *Business Horizons*, vol. 53, no. 1, pp. 59–68, Jan. 2010, doi: <https://doi.org/10.1016/j.bushor.2009.09.003>.
- [8] S. Saghiri, R. Wilding, C. Mena, and M. Bourlakis, “Toward a three-dimensional framework for omni-channel,” *Journal of Business Research*, vol. 77, pp. 53–67, Aug. 2017, doi: <https://doi.org/10.1016/j.jbusres.2017.03.025>.

- [9] U. M. Dholakia, B. E. Kahn, R. Reeves, A. Rindfleisch, D. Stewart, and E. Taylor, "Consumer Behavior in a Multichannel, Multimedia Retailing Environment," *Journal of Interactive Marketing*, vol. 24, no. 2, pp. 86–95, May 2010, doi: <https://doi.org/10.1016/j.intmar.2010.02.005>.
- [10] M. Frassetto, A. Mollá, and E. Ruiz, "Identifying patterns in channel usage across the search, purchase and post-sales stages of shopping," *Electronic Commerce Research and Applications*, vol. 14, no. 6, pp. 654–665, Oct. 2015, doi: <https://doi.org/10.1016/j.elerap.2015.10.002>.
- [11] J. Vithayathil, M. Dadgar, and J. K. Osiri, "Social media use and consumer shopping preferences," *International Journal of Information Management*, vol. 54, p. 102117, Jun. 2020, doi: <https://doi.org/10.1016/j.ijinfomgt.2020.102117>.
- [12] E. A. Elgheit, "Understanding Egypt's emerging social shoppers," *Middle East J. of Management*, vol. 5, no. 3, p. 207, 2018, doi: <https://doi.org/10.1504/mejm.2018.093611>.
- [13] K. Kianpour, R. Anvari, A. Jusoh, and M. Fauzi Othman, "Important motivators for buying green products," *Intangible Capital*, vol. 10, no. 5, Dec. 2014, doi: <https://doi.org/10.3926/ic.470>.
- [14] M. Laroche, M. R. Habibi, M.-O. Richard, and R. Sankaranarayanan, "The effects of social media based brand communities on brand community markers, value creation practices, brand trust and brand loyalty," *Computers in Human Behavior*, vol. 28, no. 5, pp. 1755–1767, Sep. 2012, doi: <https://doi.org/10.1016/j.chb.2012.04.016>.
- [15] P. Salaric, R. Cain, E. Zitkus, and V. Visch, "Stable intimacy: Design of online communication as a tool to enhance wellbeing," *Base Diseño e Innovación*, vol. 7, no. 6, pp. 110–125, Jul. 2022, doi: <https://doi.org/10.52611/bdi.num6.2022.784>.
- [16] V. Singhal, V. Ahuja, and R. Gera, "Using Social Media To Impact Consumer Brand Relationship And Consumer Brand Perception In The Fashion Industry-An Empirical Investigation," vol. 19, no. 3, p. 2022, Available: [https://www.webology.org/data-cms/articles/20220520115944amwebology%2019%20\(3\)%20-%2070%20pdf.pdf](https://www.webology.org/data-cms/articles/20220520115944amwebology%2019%20(3)%20-%2070%20pdf.pdf)
- [17] J. Kumar and V. Kumar, "Drivers of brand community engagement," *Journal of Retailing and Consumer Services*, vol. 54, p. 101949, Nov. 2019, doi: <https://doi.org/10.1016/j.jretconser.2019.101949>.
- [18] R. Ryan, *The Oxford Handbook of Human Motivation*. Oxford University Press, 2019. Accessed: Nov. 15, 2023. [Online]. Available: <https://books.google.co.in/books?hl=en&lr=&id=hNShDwAAQBAJ&oi=fnd&pg=PA47&dq=24.%09Scholer>

- [19] R. Sharma, V. Ahuja, and S. Alavi, "Developing a Research Instrument to Study the Impact of Consumer Brand Perception, Consumer Brand Relationship and Consumer Buying Behaviour on Online Apparel Shopping," *Digital and Social Media Marketing*, pp. 67–81, Nov. 2019, doi: https://doi.org/10.1007/978-3-030-24374-6_5.
- [20] I. Becheur, O. Bayarassou, and H. Ghrib, "Beyond Brand Personality: Building Consumer–Brand Emotional Relationship," *Global Business Review*, vol. 18, no. 3_suppl, pp. S128–S144, Apr. 2017, doi: <https://doi.org/10.1177/0972150917693160>.
- [21] "Investigating the Effect of Brand Satisfaction, Brand Trust and Brand Attachment on Purchase Behavior of Customers," *Research Journal of Applied Sciences, Engineering and Technology*, vol. 4, no. 17, pp. 3182–3187, Sep. 2012, Accessed: Nov. 15, 2023. [Online]. Available: <https://www.airitilibrary.com/Article/Detail/20407467-201209-201512070005-201512070005-3182-3187>
- [22] S. Fournier, "Consumers and Their Brands: Developing Relationship Theory in Consumer Research," *Journal of Consumer Research*, vol. 24, no. 4, pp. 343–353, 1998, Available: <https://www.jstor.org/stable/10.1086/209515>
- [23] F. Rezaee and K. Heidarzadeh, "Investigating the moderating role of consumer diversification, innovation and consumer aptitude on the relationship between satisfaction with customer behavioral loyalty," *Journal of Marketing Management*, vol. 15, no. 49, pp. 1–22, Jan. 2021, Accessed: Nov. 15, 2023. [Online]. Available: https://jomm.srbiau.ac.ir/article_17030.html?lang=en
- [24] R. J. S. Dheer and T. Lenartowicz, "Cognitive flexibility: Impact on entrepreneurial intentions," *Journal of Vocational Behavior*, vol. 115, p. 103339, Dec. 2019, doi: <https://doi.org/10.1016/j.jvb.2019.103339>.
- [25] J. Yadav and M. Sharma, "A Review of K-mean Algorithm," *International Journal of Engineering Trends and Technology*, vol. 4, pp. 2231–5381, 2013, Available: <https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=65f1232434c5eeddd9e658db7ae0dd5c47b6e20d>
- [26] R. J. Brodie, L. D. Hollebeek, B. Jurić, and A. Ilić, "Customer Engagement: Conceptual Domain, Fundamental Propositions, and Implications for Research," *Journal of Service Research*, vol. 14, no. 3, pp. 252–271, Jul. 2011, Available: <https://journals.sagepub.com/doi/10.1177/1094670511411703>
- [27] N. D. Freedman, "Association Between Smoking and Risk of Bladder Cancer Among Men and Women," *JAMA*, vol. 306, no. 7, p. 737, Aug. 2011, doi: <https://doi.org/10.1001/jama.2011.1142>.

- [28] R. Carroll, F. T. Cadet, and L. Kachersky, "Authenticity attracts authenticity: The impact of brand authenticity and self-authenticity on brand loyalty," *Journal of Brand Strategy*, vol. 10, no. 4, pp. 377–388, Jan. 2022, Available:
<https://www.ingentaconnect.com/content/hsp/jbs/2022/00000010/00000004/art00006>
- [29] R. Batra, A. Ahuvia, and R. P. Bagozzi, "Brand Love," *Journal of Marketing*, vol. 76, no. 2, pp. 1–16, Mar. 2012, doi:
<https://doi.org/10.1509/jm.09.0339>.
- [30] B. A. Carroll and A. C. Ahuvia, "Some antecedents and outcomes of brand love," *Marketing Letters*, vol. 17, no. 2, pp. 79–89, Apr. 2006, doi:
<https://doi.org/10.1007/s11002-006-4219-2>.
- [31] J. J. Brakus, B. H. Schmitt, and L. Zarantonello, "Brand Experience: What is It? How is it Measured? Does it Affect Loyalty?," *Journal of Marketing*, vol. 73, no. 3, pp. 52–68, May 2009.

Optimization of the results of a multilingual search engine using a fuzzy recommendation approach

Amine El Hadi

elhadi.amine@gmail.com

*Faculty of Sciences and Technics,
Sultan Moulay Slimane University, Beni Mellal, Morocco*

Youness Madani

younesmadani9@gmail.com

*Faculty of Sciences and Technics,
Sultan Moulay Slimane University, Beni Mellal, Morocco*

Rachid El Ayachi

rachid.elayachi@usms.ma

*Faculty of Sciences and Technics,
Sultan Moulay Slimane University, Beni Mellal, Morocco*

Mohamed Erritali

m.erritali@usms.ma

*Faculty of Sciences and Technics,
Sultan Moulay Slimane University, Beni Mellal, Morocco*

Abstract

Search engines are now the main source for information retrieval due to the huge expansion of data on the internet over the last ten years. Providing users with the most relevant results for their queries poses a significant challenge for search engines. Semantic search engines, which go beyond traditional keyword-based searches, have appeared as advanced information retrieval systems to address this problem. These search engines produce more precise and pertinent search results because they understand the meanings of words and their relationships. They play a pivotal role in managing the vast amount of internet data, with a primary aim of enhancing search precision and user satisfaction. However, improving search precision remains as an important goal for natural language processing researchers. The main objective of our research is to improve the search engine results. We present a novel approach for measuring the similarity between a user's query and a list of documents within a search engine. This approach provides a new fuzzy recommendation system using a syntactic and semantic similarity. Our results indicate that our method outperforms several existing approaches from the literature, achieving a high level of accuracy.

Keywords: Semantic similarity, Fuzzy Logic, Search engine, Query reformulation

1. Introduction

With the growth of the Web, a wide range of services are now available on the internet, but information retrieval [1] remains one of the most popular activities. People may

exchange a wide variety of information online since websites are now simpler to make and utilize. However, finding the precise information you need may not be simple due to the huge amount of information available on the Internet.

In other words, because there is a lot of information available, searching for things on the Internet can be difficult. The more information there is, and the more people are looking for it at the same time, the more complicated it becomes.

Therefore, we may say that without search engines, finding information on the internet would be extremely difficult. Search engines are like practical tools that do the following four tasks: First, they collect information-containing web pages. They organize these web sites together in a second step. They also enable links to be made between web pages. Fourth, they encourage queries from the public and use special methods to find the best websites that provide answers.

Today, search engines [31] have become one of the most helpful tools for obtaining useful information from the Internet. Search engines became the most helpful tool for obtaining useful information from the Internet [30]. However, the search results returned by traditional search engines aren't satisfactory. as an example, when looking for news stories about phd students, with traditional searching technologies, we regularly could only get news entries within which the term "PhD students" appears. Those entries which mention the names of scholars but don't use the term "PhD students" directly are going to be passed over. To overcome this problem the Semantic search engines appears where the meaning of web content is made explicit.

One important goal of the semantic web is to make the meaning of data explicit through semantic mark-up, thus enabling simpler access to knowledge contained in heterogeneous information environments, like the web. Semantic search plays a crucial role in realizing this goal, because it promises to provide precise answers to user's queries by taking advantage of the availability of explicit semantics of information.

The rest of this paper is organized as follows: Section 2 presents literature review, in Section 3 we will describe our Research methodology (the spelling checks and correction method, the language detection and query translation and the calculation of the semantic similarity between documents and finally how we obtain the relevant documents using Fuzzy recommendation system). Section 4 presents the experimental results and finally, in Section 5 the conclusion and the perspectives.

2. Literature Review

In recent years, a lot of approaches have been developed for improving the results of search engines, in regard to returning the most relevant documents for the users. In the literature, we found many studies have been presented on getting the most relevant documents by calculating the similarity between documents.

The authors in [2] proposes a new cluster-based information retrieval approach named ICIR (Intelligent Cluster-based Information Retrieval, the approach combines k-means clustering with frequent closed itemset mining to find the most frequent terms in each cluster. The discussed model obtains clusters of documents and obtains

the most frequent terms in each cluster. The most relevant document clusters are then selected with respect to the patterns discovered in each cluster.

Nguyen et al. [3] propose a tri-partite neural language model that leverages explicit knowledge to jointly constrain word, concept, and document representations. The authors employ the model in two retrieval strategies: document re-ranking and query expansion, and they show the effectiveness of their approach in various IR tasks.

Researchers in [4] presented an approach on ontology-based detection mechanism, they succeed by their approach to reduce memory consumption, decreasing the number of resultant documents, and minimizing the search time. in Their approach They calculate a hash value of each document, then by matching them, they calculate an index, which indicates the similarity or not.

Authors in [5] proposed a novel neuro fuzzy approach for semantic textual similarity that uses neural networks and fuzzy logics. They used the remarkable capabilities of the current neural models that extract and convert features associated with text expressed in natural language with the possibilities that fuzzy logic provides for aggregating numerical information and decoding in a personalized way information of numerical nature.

In this article [6] researchers presented a Fuzzy set similarity measure between Fuzzy Words. They use four different kinds of fuzzy set similarity measures, three that are standard ones for type-1 fuzzy sets and another one based on the distance between defuzzified and normalized COGs for type-2 fuzzy sets and examines both the Pearson and Spearman correlations among these different fuzzy set similarity measures on fuzzy words from four of the six categories established in past sentence similarity research.

Suma V. [7] improves retrieval efficiency and accuracy, addressing issues with conventional information retrieval methods. A novel hybrid deep fuzzy hashing technique was presented by the researcher. The hashing method efficiently retrieves information by mapping similar data into correlated binary codes. Deep neural networks and fuzzy logic are used to train the underlying information, which allows the system to efficiently extract the needed data from distributed cloud sources.

In the work of S.H Farhi et al. [8], the graph-based information retrieval system is well-known and frequently used in a variety of applications. The proposed bibliographic information system has been built to process text-based queries and retrieve information through its interface, building upon this graph-based framework. In addition, Joby et al. [9] discussed the problems with using a natural language model to get information from big data sets. Considering the limitations in probabilistic, space vector, and other conventional retrieval models, the proposed study places a particular focus on a natural language-based retrieval system that retrieves pertinent data from massive datasets.

Ontology-Based Semantic Information Retrieval (NOSIR), a novel method that combines feature selection and classification techniques, was introduced by Selvalakshmi et al. [10]. This technique's main goal is to retrieve data from huge datasets. The authors used fuzzy rough set-based feature selection and Latent Dirichlet Allocation-based semantic information retrieval techniques to further improve feature

selection and classification outcomes. The main advantages of the proposed algorithms are the increase in relevancy, ability to handle big data and fast retrieval.

Esposito et al. [11] developed a hybrid query expansion (HQE) approach based on lexical resources and word embeddings for the question-answering system. The question-answering system was predicted from the information retrieval process, and the questions were received from the MultiWordNet before being provided contexts for the document collection. The Word2Vec model was utilized to generate the results, and performance metrics such as accuracy and Mean Reciprocal Rank (MRR) were employed to achieve optimal results.

The retrieval system can extract information from the vast database with the aid of machine learning-based models because they usually perform efficiently and provide better classification results. The authors of [12] evaluate the most recent studies that have been done in a variety of fields, such as the classification of texts, the analysis of medical diseases the classification of user smartphones and images, etc. In comparison to other methods described in the literature, the decision trees (DT) approach improves classification results, as demonstrated in this study, which presents a detailed approach to the algorithm. Authors in [13] introduced a text classification model for BBC news using machine learning algorithms. They discussed the logistic regression, random forest, and K-nearest neighbor algorithms, providing a thorough analysis of each component of the model as well as the metrics for model evaluation. The results demonstrate that the logistic regression classifier, when combined with the TF-IDF Vectorizer feature, achieves the highest accuracy of 97% for the dataset. This algorithm has proven to be the most reliable classifier, particularly for smaller datasets. Ranjitha and Prasad in [14] presented different machine learning techniques like Hadoop map-reduce and naive Bayes classifiers to classify the data. Their demonstration revealed that Gaussian naive Bayes enhances text classification rates when compared to other machine learning approaches.

Authors in [26] utilizes fuzzy ontology to enhance information retrieval systems through query expansion. It involves creating a concept dictionary from a specific domain and external ontology, assigning fuzzy membership using ConceptNet’s Global Ontology, and defining fuzzy membership for various semantic relationships. The proposed method calculates membership values based on semantic and ConceptNet edge weights, enabling the identification of related concepts within the domain and expanding queries. Evaluation against various parameters showed improved results compared to previous research in literature.

Table 1 show a comparison between multiple approaches cited in the literature review:

Reference	Year	Methodology	Key Findings
[2]	2018	Cluster-based IR	Classification of most relevant document clusters.
[3]	2018	Neural language model	Ranking and query expansion.
[4]	2020	Ontology based detection mechanism	Optimizing search time and improving results

[5]	2021	Neural network and Fuzzy logic	Improved semantic similarity approach.
[6]	2019	Fuzzy set similarity	Improved similarity measures.
[7]	2020	Hybrid deep fuzzy hashing technique	Improved retrieval efficiency and accuracy.
[8]	2018	Graph-based information retrieval	Process text-based queries and retrieve information through its interface.
[9]	2020	Information retrieval from big data sets	Improved retrieval approach from massive datasets.
[10]	2019	Ontology-based semantic IR using Fuzzy	Proposed a new method to increase relevancy, ability to handle big data and fast retrieval.
[11]	2020	Hybrid query expansion	Proposed a new approach based on lexical resources and word embeddings to improve accuracy and Mean Reciprocal Rank (MRR).
[12]	2021	Decision Tree	Improved text classification rate.
[13]	2020	Logistic Regression	Improved classification rate on BBC news dataset.
[14]	2020	Hadoop map-reduce and Naive Bayes classifiers	Improved results on classification rate using Gaussian Naive Bayes.
[26]	2021	Fuzzy ontology	Improved information retrieval systems through query expansion.

Table 1. Comparison table for the literature papers.

3. Fuzzy Logic

In this section, we will present the main concepts of the fuzzy logic: fuzzy sets, fuzzification, fuzzy Rules inference, and Defuzzification.

The concept of fuzzy logic [18], [19] is quite similar to how humans think and reason. Instead of the binary “true or false” (1 or 0) logic that underlies modern computers, it represents a computing approach that is based on “degrees of truth.” Fuzzy logic is generally used to solve issues that don’t have an obvious resolution and instead have several shades of gray [28]. Deterministic logic aligns with crisp sets [29] in the field of set theory, whereas fuzzy logic was first proposed in 1965 by Professor L. A. Zadeh at the University of California, Berkeley [15].

Our daily lives are flawlessly intertwined with fuzzy logic and fuzzy ideas, often without our even noticing it. Think about how, in some surveys, we might respond with vague or ambiguous words like “Not Very Satisfied” or “Quite Satisfied,” which are effectively fuzzy or ambiguous replies. These replies reveal our level of satisfaction or dissatisfaction with a service or good. Only humans, and not machines, are capable of generating and understanding responses with such nuance. Given that computers can only comprehend ‘0’ or ‘1,’ ‘HIGH’ or ‘LOW,’ it is impossible for them to directly respond to survey questions in such a sophisticated way. Crisp or binary data, which form the basis of machine processing, are these forms of data.

3.1. Fuzzy Sets

The concept of a fuzzy set is an extension of the concept of a classic or crisp set. A classical set only takes into account a limited amount of degrees of membership, generally '0' or '1,' where the value of the membership function for an object is either 0 (showing that the object does not belong to the set) or 1 (saying that the object totally belongs to the set).

A fuzzy set, on the other hand, is a generalization of the classical set having a range of 0 to 1. A fuzzy set allows for partial membership from objects, with the degree of membership increasing with the strength of the object's link with the set.

A useful tool for representing objects or members that allows for ambiguity or vagueness is fuzzy sets. For example, in our case we want to get the most relevant documents to the query in an ambiguous way.

3.2. Fuzzification

To apply fuzzy logic to a real-world problem, like document classification in our case, three consecutive steps are required: Fuzzification, fuzzy inference, and defuzzification.

Implementing a fuzzy logic system begins with fuzzification [17]. It involves a transformation from precise to fuzzily defined quantities. Most variables are clear or classic in the real world. These crisp variables must be transformed into fuzzy variables in order to be used in a fuzzy logic system, both as input and output. Fuzzification consists of two essential processes: building membership functions for input and output variables and presenting them using linguistic variables.

Membership functions are crucial for transforming sets of crisp values into fuzzy ones. In practice, there are various types of membership functions, including triangular, trapezoidal, Gaussian, bell-shaped, sigmoidal, and S-curve waveforms.

In order to start the process, a crisp variable needs to be fuzzified. The next step involves applying a specific membership function, such as triangular or trapezoidal function, to this variable. As a result, the variable has a degree of membership that falls between $[0,1]$.

3.3. Fuzzy Rules

The second step of fuzzy logic systems is fuzzy rules [20]. By describing links between input and output variables using linguistic variables and membership functions, they define the logic and decision-making processes in these systems. When there is a lack of precision or uncertainty in the information, fuzzy rules are utilized to make decisions or control actions. A fuzzy rule is a simple IF-THEN rules with a condition and a conclusion. For example, in our work, if semantic similarity is high and syntactic similarity is low then document is relevant. The inputs and the outputs of the rules have fuzzy values.

Fuzzy rules enable fuzzy logic systems to handle complex, real-world problems by incorporating human-like reasoning and decision-making processes that consider

uncertainty and vagueness in data. These rules are commonly used in various applications, such as control systems, expert systems, and decision support systems.

3.4. Defuzzification

Defuzzification [16] is the third stage of a fuzzy logic system (FLS). Most of actions or decisions taken by humans or machines are clear-cut and binary, despite the abundance of fuzzy data we receive on a daily basis. We take binary decisions, and the hardware we use also operates in a binary manner. As a result, as in tasks like classification, we have to transform the fuzzy outputs into crisp values that provide us the solution to our problem.

Defuzzification is the procedure that transforms a fuzzy set into a single valued crisp quantity or a crisp set. The logical union of two or more fuzzy membership functions that are defined inside the context of discourse of the output variable may be the result of a fuzzy process.

There are several defuzzification methods documented in the literature, including the Max-membership principle, the Centroid Method (also known as the center of area or center of gravity), the Weighted Average Method, and the Mean-max membership method (also known as middle-of-maxima).

4. Research Methodology

In this section, we will present the different steps of our work and the methodology of our proposed approach. The aim of our work is to get the most relevant tweets of a query in a search engine using a fuzzy logic system based on semantic and syntactic similarity. To make our proposed approach, we have to implement different steps either in the collection of tweets, the preparation of the tweets for the classification (text preprocessing methods), then classify the tweets according to their class: relevant or not to the query of the user and return the most relevant tweet to the query using the proposed fuzzy approach.

Our system is composed of different steps, we will start by the preparation of the query used by the user (spell check and correction) to get a clean query without any error in the spelling, then and to not treat just the English tweet, we need to translate all the collected tweets to English if this is not the case. To apply our fuzzy logic system we need to calculate the semantic similarity based on n-grams and reinforcement learning and syntactic similarity, the next step is to use these 2 measures as an inputs to our Fuzzy logic system and apply all the different steps of the fuzzy system (Fuzzification, Fuzzy rules and Defuzzification) to find the most relevant tweets, the last stage of our proposed approach is to sort the relevant tweet by the degree of belonging to the relevant class and return these tweets to the user.



Figure 1. Our proposed system

4.1. Spelling Check & correction

In our everyday writing, there exist different types of errors, one of which that frequently occurs is misspelled a character due to the character’s similarity in terms

of sound, shape, and/or meaning. Spelling check is a crucial task to detect and correct human spelling errors in a text. This task is vital for NLP applications such as search engines. Spelling check is a common task in every written language, which is an automatic mechanism to detect and correct human spelling errors. An automatic spelling correction system detects a spelling error and proposes a set of candidates for correction (figure 2) [21]. Researchers divide the whole process into three steps:

1. detection of an error.
2. generation of correction candidates.
3. ranking of candidate corrections

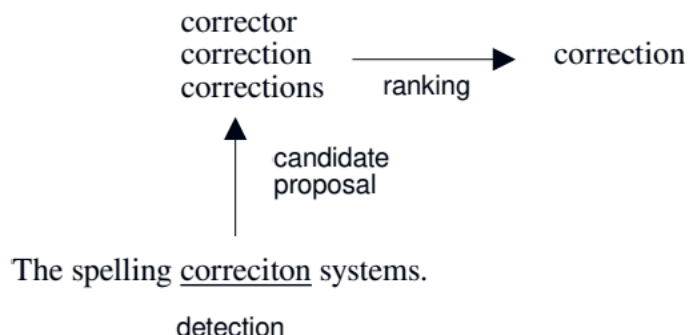


Figure 2. Process of automatic spelling correction

4.2. Translation

Most existing search engines are devoted to query-language entered by the user, while a great share of information is available in other languages. With the growth of the Internet around the world, users can find information in different languages. Searching and getting results in an only single language increases the risks of missing essential information in texts written in other languages.

Our idea is to translate all non-English tweets from the corpus to English, to not have errors in calculating similarity between query and tweets in the corpus, in order to get a good result. For the translation we use a python project library called Translator, this library allows us to translate words or phrases from a language to another one.

To avoid the problems of translation and the errors that can be caused especially, when translating the whole query. We propose to translate it word by word. For that before the translation, we split the tweets into words by removing white spaces, commas, and other symbols, and after all that, we translate it word by word.

4.3. Text pre-processing method

After the step of collecting tweets and translating non-English tweets, we have built our multilingual corpus, however before the use of our methodology, we should make some text pre-processing techniques [22], [23] to prepare the tweets and the query for

the classification and to eliminate the noise existing inside them. in our work we apply some text preprocessing methods such as:

- **Tokenization:** Which is the phase of splitting the tweet into terms or tokens by removing white spaces, commas, and other symbols etc. This step is very important in our work because we focus on individual words.
- **Removing numbers:** that do not express any emotions or attitudes. In general, numbers are no use when measuring sentiment and are removed from tweets to refine the tweet content.
- **Removing Stopword:** There is a kind of word called stopword. They are words of common function in a sentence, such as 'a', 'the', 'to', 'at', etc. These words seem useless for the analysis of the Feeling; therefore, they should be deleted.
- **Removing Punctuations:** We dont need pits as characteristics, this are only symbols for separate sentences and words, so we delete them from our corpus and the query as well.
- **Stemming:** Stemming is another very important process. In our work and because we focus on English language, we use the Porter stemming.
- **URL and @:** The first step is to delete the URL and the word begins with the '@' symbol. We will not follow the content of the Web links, so the URL will be deleted. The '@' symbol has always a username monitoring, which is unnecessary so that the entire word begins with '@' should be deleted.
- **Hashtag #:** The word begins with '#' is a hashtag. A hashtag is different from other words, it gives a label or a subject on the tweet. Usually, the tag speaks of the subject to which people say in this tweet, and not on the attitudes of the people. This word may provide the information but not important. We have therefore decided not to delete the entire word, but simply delete the symbol '#', and treat the tag as a normal word in a tweet.

4.4. Proposed Fuzzy Logic System

In this subsection, we describe our hybrid approach based on n-grams semantic similarity and reinforcement learning approach, syntactic similarity, and the fuzzy logic system (FLS). As presented before the fuzzy logic system begins with a crisp value and after, fuzzify it, using different steps (fuzzification, rules inference). And finally, return a crisp value in the output using the defuzzification methods (centroid, Mean/, Max...). Figure 3 presents the general structure of a fuzzy logic system.

From figure 3, and as a comparison with our proposed approach, the input(crisp value) of the fuzzy logic system is the two measures (semantic similarity and syntactic similarity) calculated with the n-grams semantic similarity based on reinforcement learning approach [27] and other approach of syntactic similarity, and the output(crisp value) is the class of the tweet (relevant, not relevant), finally return to the user all the relevant tweets sorted by the degree of belonging to the relevant class. As presented earlier, the first step is the definition of the input and the output variables of our proposed FLS. In our case and because we want to classify the tweets according to

two classes (relevant, not relevant), we define two input variables: the semantic similarity and syntactic similarity between the query and the tweets; and one output variable which is the class of the tweet (relevant or not).

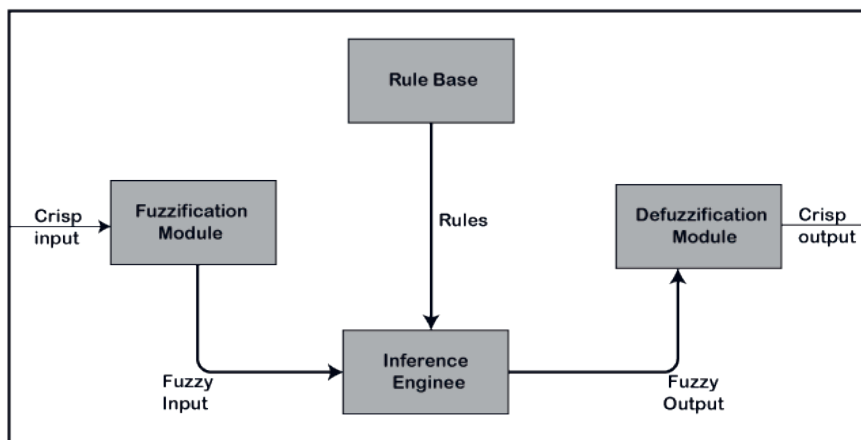


Figure 3. Fuzzy Logic System

In an FLS each variable either in the input or in the output is called linguistic variable, and each linguistic variable has a number of values that can take, these values called linguistic terms or the fuzzy sets. In our case, we have two linguistic variables in the input which are semantic similarity and syntactic similarity, and each one has three linguistic terms which are low, moderate, and high. This means that the semantic similarity score and syntactic similarity score variables can take three possible values, or in other words, can belong to three different fuzzy sets. In the same way, in the output, we have a linguistic variable which is the class of the tweet, and it can also take two different linguistic terms which are relevant, not relevant.

After we have defined the linguistic variables and their linguistic terms in the input and the output the next step of our FLS is the definition of the crisp values of the inputs with which we will begin our approach. For that and as explained in before, we use the n-grams semantic similarity approach based on reinforcement learning to calculate the semantic similarity and syntactic similarity approach of the tweet that will play the role of input's crisp values.

Fuzzification Step: The next step after we calculate the crisp value of each input is the fuzzification step, in which we fuzzify the input variables using the membership function (MF) of each linguistic term. That is, calculating the degree of belonging of the input to each fuzzy set. In this work, we use two different membership functions which are: trapezoidal-shaped MF and the triangular MF [24].

The trapezoidal-shaped MF is a function that depends on four scalar parameters a , b , c , and d , as given by the formula 1 below.

$$f(x) = \begin{cases} 0 & x \leq a \\ \frac{x-a}{b-a} & a \leq x \leq b \\ 1 & b \leq x \leq c \\ \frac{d-x}{d-c} & c \leq x \leq d \\ 0 & d \leq x \end{cases}$$

On the other hand, the triangular MF is a function that depends on three scalar parameters a , b and c , as given by the formula 2 below:

$$f(x) = \begin{cases} 0 & x \leq a \\ \frac{x-a}{b-a} & a \leq x \leq b \\ \frac{c-x}{c-b} & b \leq x \leq c \\ 0 & c \leq x \end{cases}$$

In our case, we need to fuzzify the input variables using one of the MFs presented earlier. For that, we have to define the MF of each linguistic term of the inputs. The linguistic variables “semantic similarity” and “syntactic similarity” have three linguistic terms (three fuzzy sets), so we need to define three MFs, one for the fuzzy set “low”, one for “moderate” and another one for “high”. The next step for calculating the MFs is the definition of the parameters a , b , c and d for each linguistic term. The choice of these parameters depends on the domain of application of the FLS and needs an expert in this domain. For example, in our case, the values a , b , c , and d will be in the range $[0;1]$, because the inputs “semantic similarity” and “syntactic similarity” have values between 0 and 1 as explained in previous section. The optimal values of these parameters are calculated empirically.

As we presented in section 3, if we want to work without the fuzzy logic concepts, we define for each linguistic term (low, moderate and high) a range between 0 and 1. For example, the semantic similarity and the syntactic similarity is low if they are between 0 and 0.4, moderate if they are between 0.4 and 0.6 and high if they are between 0.6 and 1. So using the classical set each value of the semantic similarity and the syntactic similarity is either belongs to a set (low, moderate or high) with a degree of belonging equal to 1, or not belongs to a set with a degree of belonging equal to 0.

After the membership functions are defined for both input and output, the next step is to define the fuzzy control rules.

Rules Inference: The next step after the fuzzification of the inputs is the step of the definition and the application of the different rules of our problem. That is to say, combine membership functions with the control rules to derive the fuzzy output. We have two inputs (semantic similarity and syntactic similarity) and one output (relevant or not) with three linguistic terms, for that we have defined nine fuzzy rules using the IF-THEN model with the AND logic operation between the values of the inputs. The nine rules of our FLS are the following:

- **IF** Semantic similarity is low **AND** Syntactic similarity is low **THEN** Class is not relevant.
- **IF** Semantic similarity is moderate **AND** Syntactic similarity is moderate **THEN** Class is neutral.
- **IF** Semantic similarity is high **AND** Syntactic similarity is high **THEN** Class is relevant.
- **IF** Semantic similarity is low **AND** Syntactic similarity is moderate **THEN** Class is not relevant.
- **IF** Semantic similarity is low **AND** Syntactic similarity is high **THEN** Class is neutral.
- **IF** Semantic similarity is moderate **AND** Syntactic similarity is high **THEN** Class is relevant.
- **IF** Semantic similarity is moderate **AND** Syntactic similarity is low **THEN** Class is not relevant.
- **IF** Semantic similarity is high **AND** Syntactic similarity is moderate **THEN** Class is relevant.
- **IF** Semantic similarity is high **AND** Syntactic similarity is low **THEN** Class neutral.

After the application of the different rules of our system, the next step is the implication of them to generate the value of each output term. In our case and because we use the AND operation between the inputs, the outputs take the minimum value between them. The last step in the rules inference is the aggregation of the results obtained for each output to find one value for each one.

Defuzzification: After the fuzzification of the inputs and the application of the nine rules of our FLS, we find the degree of belonging of our output (class of the tweet) to each output fuzzy set (relevant, not relevant), and to find the final result of our FLS that have to be in the form of a crisp value, we need to apply the defuzzification step.

The defuzzification process is meant to convert the fuzzy output back to the crisp or classical output to the control objective. The fuzzy conclusion or output is still a linguistic variable, and this linguistic variable needs to be converted to the crisp variable via the defuzzification process. In the literature, there is many defuzzification techniques [16], [25], such as:

- **Max-Membership principle:** This method calculates the maximum between the value of belonging of the output to each fuzzy set.
- **Min-Max Method:** This method calculates the minimum between the value of belonging of the output to each fuzzy set.
- **Mean-Max Method:** This method (also called middle-of-maxima) is closely related to the first method, except that the locations of the maximum membership can be non-unique (i.e., the maximum membership can be a plateau rather than a single point).

In this work, we use the max-membership principle method, to get the maximum between the value of belonging of the output to each fuzzy set. After we find the final crisp value of the output (CVO), the final step is to compare the result obtained with

two range : tweet is not relevant if CVO is between 0 and 0.4, and it is relevant if CVO is between 0.4 and 1.

The final step, after getting the relevant tweets from the fuzzification system, is to sort these tweets by the degree of belonging to the relevant class.

Ranking processing: Following the final phase of the fuzzy logic system, we arrange the tweets that have been identified as relevant based on the relevance score (degree of belonging) obtained during the defuzzification step. Subsequently, we present the top ten tweets associated with the user's query. In this study, we have opted for ten as the threshold for displaying the initial ten results, similar to how search engines operate.

4.5. Example of application

In this subsection, we describe with an example how we classify a query and documents (tweets) in corpus according to two classes (relevant or not relevant) using our proposed approach. For that, we assume that we want to classify a tweet T, so the first step after the translation of T if it was written in another language than English, and the spelling check & correction of the query Q, is the application of the text preprocessing methods. Then we calculate the input variables "semantic similarity" and "syntactic similarity" (crisp values) by the method described earlier using the semantic similarity with the semantic hybrid approach and Cosine similarity. Suppose that after all these steps, we find that the crisp values of the inputs are semantic similarity $SM = 0.62$ and syntactic similarity $ST = 0.22$.

After we calculate the crisp values for the inputs, the next step is the fuzzification of these crisp values for that, we use the Trapezoidal-shaped MF presented in formula 3. For all that, we calculate the degree of belonging of the relevant R and the not relevant NR to each fuzzy set (low, high, and moderate) as the following:

- $f(SM, low) = 0$, because $SM = 0.62 \geq d = 0.35$
- $f(SM, moderate) = \frac{d-SM}{d-c} = \frac{0.65-0.62}{0.65-0.55} = 0.3$, because $c = 0.55 \leq SM = 0.62 \leq d = 0.65$
- $f(SM, high) = 1$, because $b = 0.6 \leq SM = 0.62 \leq c = 0.8$
- $f(ST, low) = \frac{d-ST}{d-c} = \frac{0.35-0.22}{0.35-0.2} = 0.86$, because $c = 0.2 \leq ST = 0.22 \leq d = 0.35$
- $f(ST, moderate) = 0$, because $ST = 0.22 \leq a = 0.3$
- $f(ST, high) = 0$, because $ST = 0.22 \leq a = 0.55$

After the fuzzification step, it is the step of the application and the implication of our nine rules as presented below:

- IF (SM is low) = 0 AND (ST is low) = 0.86 THEN (Tweet is Not relevant) = $\min(0, 0.86) = 0$.

- IF (SM is moderate) = 0.3 AND (ST is moderate) = 0 THEN (Tweet is Neutral) = $\min(0.3, 0) = \mathbf{0}$.
- IF (SM is high) = 1 AND (ST is high) = 0 THEN (Tweet is relevant) = $\min(1, 0) = \mathbf{0}$.
- IF (SM is low) = 0 AND (ST is moderate) = 0 THEN (Tweet is not relevant) = $\min(0, 0) = \mathbf{0}$.
- IF (SM is low) = 0 AND (ST is high) = 0 THEN (Tweet is neutral) = $\min(0, 0) = \mathbf{0}$.
- IF (SM is moderate) = 0.3 AND (ST is high) = 0 THEN (Tweet is relevant) = $\min(0.3, 0) = \mathbf{0}$.
- IF (SM is moderate) = 0.3 AND (ST is low) = 0.86 THEN (Tweet is not relevant) = $\min(0.3, 0.86) = \mathbf{0.3}$.
- IF (SM is high) = 1 AND (ST is moderate) = 0 THEN (Tweet is relevant) = $\min(1, 0) = \mathbf{0}$.
- IF (SM is high) = 1 AND (ST is low) = 0.86 THEN (Tweet is neutral) = $\min(1, 0.86) = \mathbf{0.86}$.

The next step is the aggregation of these rules for each output fuzzy set.

- Tweet is neutral $\rightarrow \max(0, 0, 0.86) = 0.86$
- Tweet is not relevant $\rightarrow \max(0, 0, 0.3) = 0.3$
- Tweet is relevant $\rightarrow \max(0, 0, 0) = 0$

So, after all these steps, we find the degree of belonging of the output to each output fuzzy set, and by using the MFs of the output and the method of Max-Membership we defuzzify the output to find the final crisp value of the output (class of the tweet).

After the defuzzification step using the Max-Membership method, the final crisp value obtained by applying our approach is equal to 0.6, and because this value is between 0.6 and 1, the tweet T is relevant to the user's query.

5. Experimental Results

In this section, we will present some experimental results of our work. As shown earlier, the first step is to create a tweet dataset using the Twitter API. For that, our dataset contains the tweets related to covid pandemic. that is, we will classify tweets related to this subject.

As presented above, our Fuzzy Logic System contains two input variables : similarity syntactic and semantic similarity based on n-grams and reinforcement learning and an output variable (class of the tweet : relevant or not), the range of each variable is between 0 and 1 (because all the similarities scores are between 0 and 1), and each has three linguistic terms (linguistic values or fuzzy sets): low, moderate and high for the input variables, and relevant and not relevant for the output variable.

In our FLS we use two membership functions for the fuzzification that are: Trapezoidal MF and Triangular MF, nine IF-THEN rules and four defuzzification

methods (Max-Membership, Min-Max, Mean-Max). From that, to make a choice of the best membership function and the best method of defuzzification for our system, we have six possible combinations for making this choice. The table 2 and the figure 4 show respectively the results obtained for the error rate and the classification rate after the classification of the tweets using six possible combinations: Trapezoidal MF/Min-max, Trapezoidal MF/Mean-max, Trapezoidal MF/Max-Membership, Triangular MF/Min-max, Triangular MF/Mean-max, Triangular MF/Max-Membership.

Fuzzification	Defuzzification	ER	Accuracy
Trapezoidal MF	Min-Max	69%	31%
	Mean-Max	42%	58%
	Max-Membership	7%	93%
Triangular MF	Min-Max	69%	31%
	Mean-Max	68%	32%
	Max-Membership	17%	83%

Table 2. Error rate and Accuracy using Fuzzification/Defuzzification combinations.

From the table 2, the best fuzzification/defuzzification combination is the one which we use the Trapezoidal MF for the fuzzification step and Max-membership method for defuzzification, with an accuracy of 93% and error rate of 7%. From these results we note the use of this combination increase the classification rate in our system compared to other combinations, for that we decide to use in our FLS the Trapezoidal MF for the fuzzification of our two input (semantic and syntactic similarity) and Max-membership method for defuzzification step to find the class of the tweet (relevant or not).

The next experiment is to compare our approach based on fuzzy logic (A) and other approaches from the literature such as: Logistic Regression (B), Gaussian Naive Bayes (C) and Decision Tree (D). For that we compute the accuracy, error rate, recall and F1 score of the classification of the tweets using all the approaches cited above, and compare them with the results obtained with our approach based on semantic/syntactic similarity using fuzzy logic.

The figure 4 shows the results obtained.

According to Figure 4, our approach (A) based on fuzzy logic, syntactic similarity, and semantic similarity using reinforcement learning to classify the tweets in our dataset and return the most relevant tweet outperforms other approaches. Our approach achieved a classification rate of 93%, with an error rate of only 7% when compared to existing literature, such as [12] which employs Decision Tree to enhance classification rates, and Shah et al in [13] who present a text classification model based on the Logistic Regression algorithm to improve classification results. We also compared our approach with the one presented in [14], which relies on Naive Bayes classifiers, and their studies show that Gaussian Naive Bayes improves classification rates. It's worth noting that none of these previously mentioned approaches from the literature used fuzzy logic in their text classification.



Figure 4. Classification Rate

However, based on the data from Figure 4, we conclude that our proposed approach has significantly improved the results in the classification of textual documents. This clearly demonstrates the efficacy of fuzzy logic in enhancing classification quality by increasing the classification rate while simultaneously reducing the error rate.

In the next experiment, we decide to calculate some other metrics to approve that our approach improves the classification rate compared to other approaches from the literature, for that we will calculate the precision, recall and F1-score of our approach, and compare them with the same metrics of the 3 other approaches that are cited in the previous experiment.

	Precision	Recall	F1-Score
Our approach (A)	97%	93%	95%
Logistic Regression (B)	72%	99%	83%
Gaussian NB (C)	94%	89%	91%
Decision Tree (D)	99%	89%	94%

Table 3. Comparison of metrics between different approaches.

From the table 3 and figure 5 we note that our proposed approach A based on fuzzy logic gives the good result either for the accuracy, precision, recall, and F1-score in comparison with the other approaches. It has a good accuracy 93% and it improves the F1-score as 95%. All that demonstrates how our proposed approach outperforms the other approaches.

The idea of this work is coming from this paper [27], for that, the last experiment is to compare the result of our new approach based on fuzzy logic to our last approach of semantic similarity based on reinforcement learning (RL), and the syntactic similarity approach: cosine similarity.

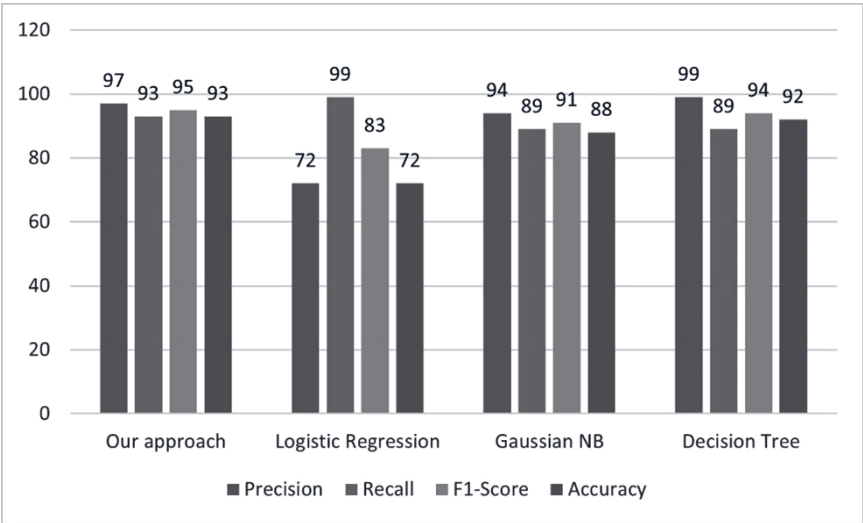


Figure 5. Evaluation of our system

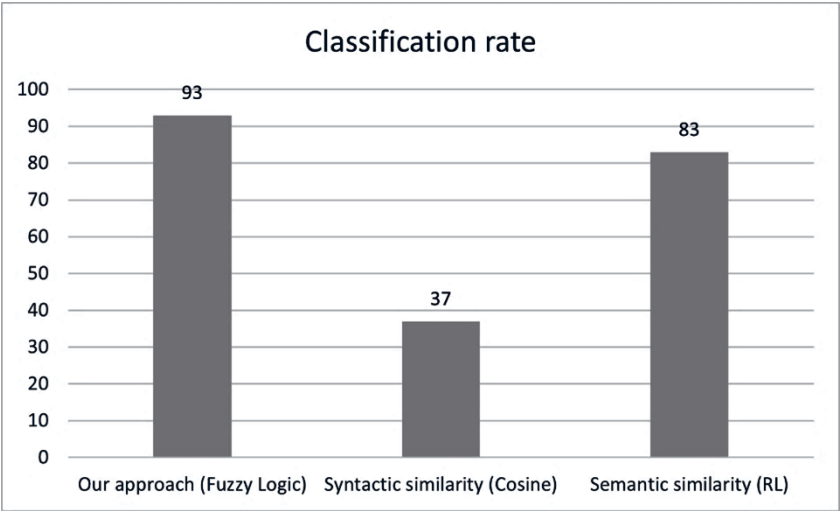


Figure 6. Comparison of our approach with similarity approaches

According to figure 6, we remark that with our new approach based on fuzzy logic, we increase the percentage of the classification rate (from 83% to 93%) and decreases that of the error rate (from 17% to 7%) comparing with our last approach that uses only the semantic similarity without fuzzy logic. We notice from the figure that our approach based on fuzzy logic gives better results compared to the syntactic similarity approach too. Therefore, we can say that by adding the fuzzy logic we can improve the classification rate, then the quality of our results and system.

6. Conclusion

In this article we have presented a new approach that search and return the most relevant result to a query entered by a user of a search engine, our new approach is based on fuzzy logic and use two type of similarity the first one is syntactic similarity which is cosine similarity, and the second one is a semantic similarity based on reinforcement learning and n-grams model. The experimental results show that using fuzzy logic approach gives us better results, and that our proposed approach outperforms some other methods from the literature.

Compliance with ethical standards

Funding declaration: The authors declare that they have no funding for this work.

Authors's contributions: In this article we present a new fuzzy recommendation system based on syntactic and similarity measures and n-grams model, to get the most relevant documents for a user in a search engine. All authors read and approved the final manuscript.

Competing interest: The authors declare that they have no conflict of interest.

References

- [1] R. Kumar and S. C. Sharma, "Information retrieval system: An overview, issues, and challenges," *International Journal of Technology Diffusion (IJTD)*, vol. 9, no. 1, pp. 1-10, 2018.
- [2] Y. Djenouri, A. Belhadi, P. Fournier-Viger, and J. Lin, "Fast and effective cluster-based information retrieval using frequent closed itemsets," *Information Sciences*, vol. 453, pp. 154-167, 2018.
- [3] G. H. Nguyen, L. Tamine, L. Soulier, and N. Souf, "A Tri-Partite Neural Document Language Model for Semantic Information Retrieval," in *Proc. of the 15th European Semantic Web Conference, ESWC 2018*, Springer, pp. 445–461, 2018.
- [4] S. Kumar and K. K. Bhatia, "Semantic similarity and text summarization-based novelty detection," *SN Applied Sciences*, 2020.
- [5] J. Martinez-Gil, R. Mokadem, J. Küng, and A. Hameurlain, "A Novel Neurofuzzy Approach for Semantic Similarity Measurement," in *International Conference on Big Data Analytics and Knowledge Discovery*, Springer, pp. 192-203, 2021.
- [6] V. Cross and V. Mokrenko, "Fuzzy Set Similarity Between Fuzzy Words," in *International Fuzzy Systems Association World Congress*, Springer, pp. 214-223, 2019.
- [7] D. V. Suma, "A novel information retrieval system for distributed cloud using hybrid deep fuzzy hashing algorithm," *Journal of Information Technology and Digital World*, vol. 2, no. 3, pp. 151-160, 2020.

- [8] S. H. Farhi and D. Boughaci, "Graph based model for information retrieval using a stochastic local search," *Pattern Recognition Letters*, vol. 105, pp. 234-239, 2018.
- [9] D. P. Joby, "Expedient information retrieval system for web pages using natural language modeling," *Journal of Artificial Intelligence and Capsule Networks*, vol. 2, no. 2, pp. 100-110, 2020.
- [10] B. Selvalakshmi and M. Subramaniam, "Intelligent ontology based semantic information retrieval using feature selection and classification," *Cluster Computing*, vol. 22, pp. 12871-12881, 2019.
- [11] M. Esposito, E. Damiano, A. Minutolo, G. De Pietro, and H. Fujita, "Hybrid query expansion using lexical resources and word embeddings for sentence retrieval in question answering," *Information Sciences*, vol. 514, pp. 88-105, 2020.
- [12] B. Charbuty and A. Abdulazeez, "Classification based on decision tree algorithm for machine learning," *Journal of Applied Science and Technology Trends*, vol. 2, no. 01, pp. 20-28, 2021.
- [13] K. Shah, H. Patel, D. Sanghvi, and M. Shah, "A comparative analysis of logistic regression, random forest and KNN models for text classification," *Augmented Human Research*, vol. 5, pp. 1-16, 2020.
- [14] V. Venkatesh, K. V. Ranjitha, and B. S. Venkatesh Prasad, "Optimization scheme for text classification using machine learning naïve bayes classifier," in *ICDSMLA 2019: Proceedings of the 1st International Conference on Data Science, Machine Learning and Applications*, Springer Singapore, pp. 576-586, 2020.
- [15] L. A. Zadeh, "Fuzzy sets," *Information and control*, vol. 8, no. 3, pp. 338-353, 1965.
- [16] S. Chakraverty et al., "Defuzzification," in *Concepts of Soft Computing: Fuzzy and ANN with Programming*, pp. 117-127, 2019.
- [17] S. Thaker and V. Nagori, "Analysis of fuzzification process in fuzzy expert system," *Procedia computer science*, vol. 132, pp. 1308-1316, 2018.
- [18] L. A. Zadeh and R. A. Aliev, *Fuzzy logic theory and applications: part I and part II*, World Scientific Publishing, 2018.
- [19] H. T. Nguyen, C. L. Walker, and E. A. Walker, *A first course in fuzzy logic*, CRC press, 2018.
- [20] T. Rattanasawad et al., "A comparative study of rule-based inference engines for the semantic web," *IEICE TRANSACTIONS on Information and Systems*, vol. 101, no. 1, pp. 82-89, 2018.
- [21] D. Hládek, J. Staš, and M. Pleva, "Survey of automatic spelling correction" *Electronics*, vol. 9, no. 10, pp. 1670, 2020.

- [22] A. I. Kadhim, "An evaluation of preprocessing techniques for text classification," *International Journal of Computer Science and Information Security (IJCSIS)*, vol. 16, no. 6, pp. 22-32, 2018.
- [23] L. Hickman et al., "Text preprocessing for text mining in organizational research: Review and recommendations," *Organizational Research Methods*, vol. 25, no. 1, pp. 114-146, 2022.
- [24] A. Jain et al., "Membership function formulation methods for fuzzy logic systems: A comprehensive review," *Journal of Critical Reviews*, vol. 7, no. 19, pp. 8717-8733, 2020.
- [25] K. S. Gilda and S. L. Satarkar, "Analytical overview of defuzzification methods," *International Journal of Advance Research, Ideas and Innovations in Technology*, vol. 6, no. 2, pp. 359-365, 2020.
- [26] S. Jain, K. R. Seeja, and R. Jindal, "A fuzzy ontology framework in information retrieval using semantic query expansion," *International Journal of Information Management Data Insights*, vol. 1, no. 1, p. 100009, 2021.
- [27] A. El Hadi et al., "Finding Relevant Documents in a Search Engine Using N-Grams Model and Reinforcement Learning," *Journal of Information Technology Research (JITR)*, vol. 15, no. 1, pp. 1-17, 2022.
- [28] L. A. Zadeh, "Fuzzy logic—a personal perspective," *Fuzzy sets and systems*, vol. 281, pp. 4-20, 2015.
- [29] H. Liu and M. Cocca, "Fuzzy rule-based systems for interpretable sentiment analysis," in *2017 Ninth International Conference on Advanced Computational Intelligence (ICACI)*, pp. 129-136, IEEE, 2017.
- [30] B. R. Boyce et al., *Text information retrieval systems*, Elsevier, 2017.
- [31] D. Sharma, R. Shukla, A. K. Giri, and S. Kumar, "A brief review on search engine optimization," in *2019 9th international conference on cloud computing, data science & engineering (confluence)*, pp. 687-692, IEEE, 2019.

The Impact of Organizational Support and Employee Attitude to Innovative Work Behavior Mediating Role of Psychologic Empowerment

Nimas Aryany Pratiwi

*Airlangga University
Surabaya, Indonesia*

nimas.aryany.pratiwi-2020@feb.unair.ac.id

Siti Fatimah

*Airlangga University
Surabaya, Indonesia*

siti.fatimah.333510-2020@feb.unair.ac.id

April Kukuh Susilo

*Airlangga University
Surabaya, Indonesia*

april.kukuh.susilo-2020@feb.unair.ac.id

Abstract

Concerning the human aspect of organizational sustainability, this study aims to comprehensively examine organizational support (OS), employee attitude (EA), psychological empowerment (PE), and innovative work behavior (IWB). This study analyzes the relationship between OS, EA, and IWB in flexible manufacturing systems (FMS) and focuses on PE's role as a mediator between OS and EA. By dividing OS into perceived supervisor support (PSS) and procedural justice (PJ) and dividing EA into a sense of belonging (SB) and sense of awe (SA). A questionnaire was used to survey 341 participants from 23 teams employed in 9 large manufacturing enterprises in Indonesia. Eight Hypotheses were examined with Structural Equation Modeling (SEM). Results demonstrated that OS significantly affects EA and IWB, and PE mediates OS and EA through IWB. In this article, we seek to empirically test the entire belonging dimension of the OS as it relates to EA and IWB. These variables were chosen because they have well-documented pragmatic value for organizations. They also have reliable and valid relationships with various organizational support concepts. Future studies should include more variables for determining OS and EA to provide further context for organizational sustainability studies, particularly in FMS-transitioning industries.

Keywords: Organizational Support; Employee Attitude; Perceived Supervisor Support; Procedural Justice; Psychological Empowerment; Innovative Work Behavior

1. Introduction

Indonesia aims to transition from commodity-based sectors to manufacturing-based industries. In 2016, an integrated industrial estate was established as an economic zone

for technology and manufacturing. This initiative aimed to attract investments in the information, communication, and technology sectors to enhance automation and digital manufacturing technologies. Additionally, it sought to promote the adoption of flexible manufacturing systems (FMS). The primary objective of intelligent manufacturing systems is to expedite innovative processes, with FMS catalyzing achieving this goal [1]. The FMS process strategically assigns both human and machine resources [2],[3] to optimize operational efficiency and minimize product costs [4],[5]. The transition to FMS necessitates manufacturing enterprises to update their knowledge by assimilating information through learning [6]. This transition also requires effective communication of information to workers [7]. To successfully navigate the complexities of the FMS transition, IWB is crucial, particularly in significant changes and the organization's commitment to ongoing learning [8]. Therefore, it is important to recognize and embrace the challenging and inspiring nature of the complex task at hand. Furthermore, the concept of Individual Work Behavior (IWB) encompasses the capacity of workers to generate novel ideas, develop innovative processes, establish effective practices, and devise efficient procedures at the individual, group, and organizational levels [9].

Organizational issues, as a precursor to IWB, have attracted substantial attention in the recent two decades [10]. Considering the relevance of IWB, organizational experts focused their attention on elements that determine IWB. Such element includes organizational support (OS) [11], while organizational support is regarded as a critical predictor of employee attitude (EA) [12]. [13] state that OS stimulates employee inventiveness and, in turn, leads to the IWB of the employees. OS positively promotes EA, particularly creativity and IWB [14]. According to [15], EA is the attitude of workers who feel loyal to the organization. [16] characterizes EA as a successful response to the entire organization and the level of attachment or loyalty workers feel to the organization. As a result, the technique of fair organization should be positively associated with the worker's PE. Empirical studies by [17] show that psychological empowerment (PE) influences the association between team autonomy and IWB. [18] observed psychological capital moderating the connection between PE & EA. In addition, PE enhances the possibility of workers influencing outcomes as a prerequisite for innovative achievements [19].

A conceptual framework was established to elucidate the interconnections among operating systems (OS), enterprise architecture (EA), process efficiency (PE), and individual well-being (IWB). The division of organizational support (OS) into perceived supervisor support (PSS) and procedural justice (PJ) has been established [20]. Similarly, the division of employee attitudes (EA) into a sense of belonging (SB) and a sense of awe (SA) has been identified as indicators [21]. Supervisory treatment is bestowed upon workers as a manifestation of organizational support, suggesting a positive relationship between perceived supervisory support and organizational support [22]. The concept of PJ demonstrates a logical correlation with the outcome, emphasizing the methodologies employed [23], and establishing a connection with the SET's techniques, mechanisms, and procedural components inside the organizational framework [24]. Employees not receiving the promised job perks may express disappointment, leading to diminished respect towards the business and a lack

of organizational awe. Based on the scholarly fields of psychology and organizational behavior, the notion of SB holds significant importance in forecasting the favorable conduct exhibited by employees [25].

Nevertheless, the comprehensive utilization of these preceding factors and interactive whiteboards (IWB) in empirical studies has not been extensively explored, resulting in a limited comprehension of how various relational tie ideas encompassed within the same organizational support (OS) dimension affect employee attitudes (EA) and innovative work behavior (IWB). The social exchange theory (SET) posits that there exists a reciprocal interaction between employers and employees [26],[27]. It also offers theoretical support for understanding the connection between organizational support (OS), creativity, and innovative work behavior (IWB) [28]. Likewise, the operating system (OS) empowers employees to initiate innovative work behavior (IWB) by producing and implementing novel ideas, as well as by accomplishing duties in more advanced and improved manners [29]. Previous studies [30],[31],[32],[18],[17] have identified four dimensions (OS, EA, PE, and IWB) as being pertinent to organizational sustainability. However, a lack of comprehensive research examines these four constructs concurrently. Hence, this research undertakes a complete analysis of the OS, EA, PE, and IWB concerning the human aspect of organizational sustainability. It also highlights the increasing significance of IWB in manufacturing-based industries.

Our research primarily emphasizes belonging within the context of IWB, intending to make three noteworthy contributions. Initially, our objective is to differentiate the three concepts encompassed within the empirical aspects of PSS, PJ, SA, and IWB. Although the individual constructs in question have each undergone distinct and thorough methods for developing measures, we offer a comprehensive examination of these variables, which is crucial for empirically evaluating the proposed theoretical model. Furthermore, our objective is to empirically examine the comprehensive belonging component within OS, specifically concerning EA and IWB. These factors were selected based on their practical significance for organizations and their proven and credible associations with SET [26]. Finally, we offer PE as a mediating factor between OS and EA through IWB. The study conducted by [33] demonstrated that the construct of PE mediates the association between empowering leadership and worker creativity. This finding is noteworthy as worker creativity has been identified as a substantial predictor of performance. The study demonstrates empowering leadership through utilizing PSS and fostering workers' creativity, resulting in improved employee performance as measured by the IWB [13]. Consequently, conducting empirical tests to examine the associations involving these variables serves as a crucial means of validating the OS and EA model of the IWB. We further expand upon previous research findings by elucidating the nature of the association between each predictor and outcomes and their relative relevance.

2. Conceptual Framework

2.1. Organizational Support

Social exchange theory (SET) is the predominant framework utilized to analyze interpersonal relationships within the context of the workplace [26]. According to the author [34], the concepts of SET and social structure provide a framework for understanding the dynamic development of the social system. The author argues that these concepts should not be simplified or attributed solely to individual actions. SET has been employed to construct an inclusive framework for elucidating the process of knowledge transfer between individuals and knowledge sources [35], [36], as well as the interaction between an individual and others with the expectation of reciprocation [27]. SET is crucial in comprehending the functioning of an organization's operating system, as it elucidates workers' perception regarding the organization's provision of care, support, and attachment. This perception, in turn, has a significant impact on the performance of workers [37]. To adhere to SET compliance [26] [34] and OS compliance [37], it is imperative for organizations to offer support to their employees, thereby providing them with increased motivation to exert greater effort and achieve enhanced performance. OS within an organization has the potential to elicit a range of positive emotions among workers. These emotions are derived from the support and understanding provided by colleagues and superiors and the recognition of their abilities [38]. The work experience in OS incorporates two indicators, they are perceived supervisory support (PSS) and procedural justice (PJ) [20]. PSS is a construct that encompasses the overall perception of employees regarding the extent to which their supervisors appreciate and acknowledge their contributions, as well as demonstrate care and consideration for their well-being [39].

Organizational justice refers to the subjective opinion of employees regarding the fairness of treatment inside the workplace, which in turn has a favorable impact on their influence, attitudes, and conduct [42]. The study examines four organizational justice models: distributive justice, interpersonal justice, informational justice, and procedural justice (PJ). PJ is utilized as one of the markers of OS in this particular investigation [43]. PJ is used to denote an individual's perspective of the factors inside a social system that govern the distribution of resources in the decision-making processes of organizations [46]. The statement above exhibits a reasonable correlation with the outcome, emphasizing the procedures undertaken [23], and establishing a link with the methodologies, mechanisms, and process components of SET inside organizational system [24].

2.2. Employee Attitude

Workers who trust the organization, value workers' contributions, and care about the welfare of workers have a greater attachment to the organization and will invest more in the performance of workers, subsequently defined as OS [20]. [58] concluded that *supervisory support*, another form of OS, is essential in work environment structure, developing workers in career planning, performance appraisal, and promotion.

Workers view supervisors as competent when they create an attractive work environment, have common goals, and have high worker performance satisfaction [59]. [60] claim that effective supervisor-worker interaction will facilitate EA. According to [15], EA is the attitude of workers who feel devoted to the organization. [16] describes EA as an effective response to the entire organization and the level of attachment or loyalty workers feel to the organization. Workers with low EA will work as an obligation, do not prioritize the vision and mission of the organization, and only care about their success over the success of the organization as a whole. Less committed individuals also tend to see themselves as outsiders and not as long-term members of organizations. Employee performance in a wide range of organizations is positively influenced by a Sense of Belonging (SB) and a Sense of Awe (SA) as EA indicators [21]. SB is a commitment that bonds individuals to groups or communities even when facing challenges [61]. According to the disciplines of psychology and organizational behavior, SB is an important concept that predicts the positive behavior of workers [25].

2.3. Psychological Empowerment

Psychological empowerment (PE) is the increased involvement of individuals in a team that affects work results and is necessary for innovative outcomes [19]. [17] concludes PE results from an individual's perception (cognition) of competence, meaning, self-determination, and the ability to influence organizational outcomes. The PE construct provides a mechanism to illustrate how a team's contribution can innovatively affect project outcomes. Studies previously demonstrated that PE improves organizational performance through motivation, positive attitudes, and worker initiative to respond to changing and competitive work environments [76] or through developing valuable and inimitable human resources [77].

2.4. Innovative Work Behavior

IWB is a systematic introduction to generating and applying new ideas and behaviors required to adopt ideas to improve personal and organizational performance [53]. [72] see IWB as a gradual process in which individuals face difficulties and produce ideas that lead to problem solutions with creativity and support from the work environment. Innovation is the successful execution of innovative ideas. To demonstrate the IWB, workers require a strong perception of management and supervisor support in the form of freedom in the workplace and availability of resources [54]. IWB gathers role behaviors in the workplace to communicate and build support [55] and individual role behaviors that explain personal fulfillment, adaptability, risk-taking, and courage [56]. [57] illustrates the importance of IWB in enhancing performance in a highly competitive environment that benefits the organization. Researchers, therefore, assume that the OS comprises particular psychological qualities that can increase the IWB of workers. In addition, the OS's SET architecture implies that this view promotes a feeling of obligation to modify behaviors that support corporate goals. IWB is one such positive behavior.

3. Hypotheses

3.1. Organizational Justice and Innovative Work Behavior

Workers receive supervisory treatment as an indication of organizational support, meaning that perceived supervisory support leads to OS [22]. When supervisors use techniques that contribute to a supportive climate, organizational performance improves through workers' emotional connection to the organization [40]. Suppose the PSS perceived by workers tends to be damaging through a significant relationship between abusive supervision and poor accountability. Work behavior will be negative, and organizational performance will diminish [41]. [47] conducted an empirical study that related PJ to pleasant sentiments in workers, which can affect IWB. [48] study the major influence of organizational justice through four aspects, one of which is PJ on innovation and IWB, and establish a strong association between PJ and IWB. According to empirical investigations by [49],[50],[51], PJ has a considerable and beneficial direct and indirect effect on the IWB. In other words, when individuals believe that businesses care and provide fair treatment, they will feel more obligation to do their work successfully and engage in idea generation, development, and work-related applications. [52] argue that with such rapid and enormous changes, IWB acts as a durable competitive advantage for organizations, giving companies long-term viability and success. According to the description above, the researcher suggested a hypothesis:

H1 PSS has a positive influence on IWB

H2 PJ has a positive influence on IWB

3.2. Employee Attitude and Innovative Work Behavior

PJ is an additional measure of OS [22], linked to employees' experience of good emotions [62]. Employees who do not receive the promised job perks may experience disappointment, leading to diminished respect towards the organization and a lack of sense of awe (SA). SA can be defined as a multifaceted emotional reaction to stimuli that are visually or perceptually expanding, requiring cognitive adaptation. [64] convey two dimensions of SA: its *vastness* and the need for accommodation. As stated by [63], vastness does not rely on tangible measures, as it can encompass any encounter or sense beyond an individual's boundaries. Accommodation pertains to cognitive processes when individuals encounter external experiences that cannot be readily assimilated into existing mental frameworks. Based on the description above, the authors put out a hypothesis:

H3 PSS has a positive influence on SB.

H4 PJ has a positive influence on SA.

As complex emotional attitudes, SB, SA & IWB encompass a range of antecedents that arise from a comprehensive comprehension of a certain subject [65]. SB is crucial to an individual's holistic psychological well-being. Employees who experience a sense of psychological safety, are more likely to exert significant autonomy and engage in creative and innovative behaviors. Upon acknowledging the

advantages of this form of identification, senior management will exhibit more significant endorsement towards employees who surpass their job description to produce novel ideas and spearhead innovative projects. Consequently, this will result in high worker motivation and satisfaction [66]. Hence, top management has to guarantee experience a sense of pride in their affiliation with the organization and are motivated to contribute towards its achievements actively. Undoubtedly, a prosperous organization can foster strong SB among its team.

Furthermore, besides its favorable impact on job performance, implementing SB benefits emotional and physical well-being in the workplace enhances stress resilience, and fosters a greater willingness to embrace change. On the other hand, SA impacts cognitive functions, as evidenced by experimental studies that demonstrate how induced SA can result in feelings of uncertainty [67]. This uncertainty arises from cues that need individuals to adapt or accommodate their behavior [68]. SA, in this context, represents good emotions [69],[67]. Therefore, the phenomenon of SA has been found to enhance individuals' sense of interpersonal connection and has the potential to contribute to increased levels of job satisfaction [70].

Utilizing IWB facilitates individuals in generating innovative and promising ideas and effectively executing these novel ideas in practical settings [71]. IWB refers to the outcomes, recommendations, and execution of employees' ideas for work-related activities that contribute positively to organizational performance [73]. According to [74], organizations that do not engage in innovation may decrease their capacity to effectively compete with other entities and face the possibility of abandoning the market. According to previous research, organizations that persist in their efforts to innovate have the potential to attain enhanced levels of organizational performance [75]. Based on the analysis mentioned above, the authors put up the subsequent hypothesis:

H5 SB has a positive influence on IWB

H6 SA has a positive influence on IWB

3.3. Psychological Empowerment as Mediating Role

There appears to be no significant correlation between workers' perceptions of PJ and PE. However, prior research findings indicate an association, wherein PJ potentially enhances perceptions of PE, may exist. For instance, the presence of socio-political support, the availability of information and resources, and the establishment of a participative work environment, all of which are believed to be associated with PJ, exhibit a positive correlation with PE [78]. Consequently, there should be a favorable correlation between the process of organizing a fair and the level of employee performance evaluation. Workers who feel empowered perceive themselves as having authority over the work environment, autonomy, and proficiency [79]. Consequently, they are more likely to engage in proactive learning activities that contribute to the overall success of the organization [80]. This will facilitate the development of a more positive SB and SA orientation within the EA.

In general, PJ Implementation in the workplace enables employees to engage in the best practice known as PE, which has been shown to enhance worker productivity

and organizational performance [81]. The study by [82] revealed that empowering leadership directly and indirectly affects PE through self-leadership. This empowerment was positively associated with increased job satisfaction and enhanced creative performance. The study conducted by [83] identified the mediating function of PE in the relationship between empowering leadership and the successful implementation of job responsibilities. The study conducted by [33] shows that the construct of PE mediates the association between empowering leadership and worker creativity.

Furthermore, worker creativity was a substantial predictor of worker performance. The concept of empowering leadership in this study is operationalized through the construct of PSS, which refers to the supervisor's disposition to facilitate and encourage employees to fulfill their duties and obligations. Based on the considerations above, the final hypothesis within the framework of this study can be posited as follows:

- H7 PE mediates the relationship between PSS and SB
- H8 PE mediates the relationship between PJ and SA

4. The Research Method

4.1. The Aim and Importance of the Research

The objective of this study is to ascertain the existence of a correlation between organizational support and innovative work behavior, as well as between employee attitude and innovative work behavior. Additionally, the study aims to explore the potential mediating function of psychological empowerment in this relationship, as illustrated in Figure 1.

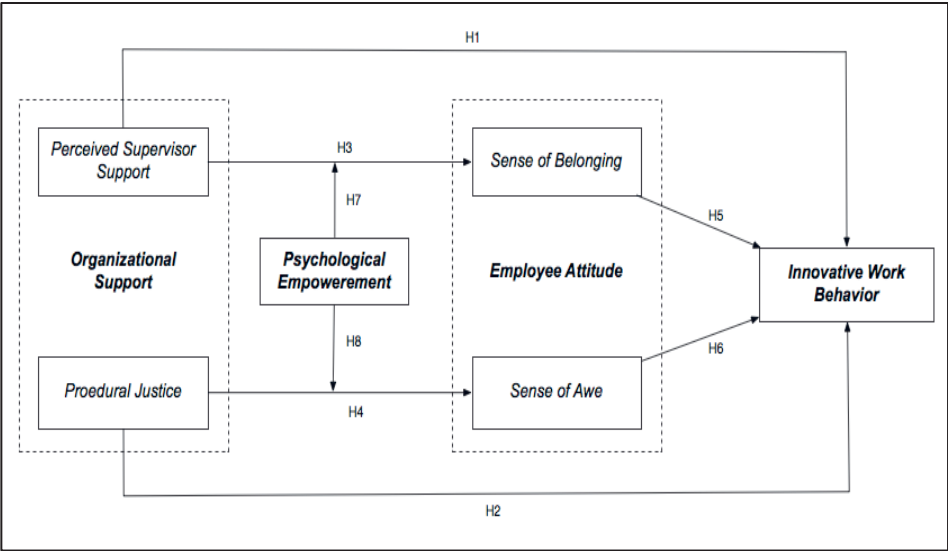


Figure 1. Theoretical Framework

4.2. Universe and Sample

Concentrations and exact measurements are utilized to examine a specific collection of recognized antecedent variables [84][85]. The present study was conducted inside an industrial estate with 15 tenant firms, categorized into five clusters: chemical, energy, metal, electronic, and supporting and logistics. A pilot study was conducted by employees of the major chemical cluster tenant companies, involving the distribution of ten questionnaires to evaluate its efficacy [86]. The pilot study's findings did not demonstrate any significant level of complexity. A survey selected nine tenant companies, including 380 respondents involved in 23 team works. The research team sought authorization from these organizations' management to distribute questionnaires containing information about the study's objectives, which were developed in Indonesian. These firms facilitate researcher access to workers and enable direct communication during the data gathering. Questionnaires are commonly employed in psychology as a general research approach to mitigate bias by effectively segregating predictor factors and criteria [87]. A total of 380 questionnaires were distributed, of which 365 were collected. Additionally, 15 questions were deemed invalid due to incompleteness and excluded from the analysis. Out of the initial sample of 341 questionnaires, 86 percent were successfully validated and included in the data analysis.

The demographic characteristics of the respondents indicate that most participants, comprising 36 percent, fell within the age range of 26-30 years. Additionally, 29 percent of the respondents were aged between 31-35 years, while 19 percent fell within the age range of 36-40 years. A smaller proportion, 9 percent or 30 individuals, were aged between 41-45 years. The remaining 8 percent of respondents were aged between 45-50 years. The distribution of education levels among the participants was as follows: 35 percent had completed education up to senior high school, 39 percent had completed high school education, and 27 percent had attained a college education level. According to the poll, most workers (63 percent) reported an average monthly pay of less than 4,750,000 rupiah. A smaller proportion of workers (20 percent) indicated a salary range between 4,750,000 and 5,500,000 rupiahs, while a minority (17 percent) reported earning above 5,500,000 rupiahs. Most respondents ($n=173$) reported a maximum work length of 3 to 4 years. This was followed by a work term of 5 to 6 years, reported by 116 respondents. Additionally, 53 respondents indicated a work period of 1 to 2 years.

4.3. Data Collection Tools

The variables were assessed via a 5-point Likert scale and demonstrated robust construct validity. [88] employed a set of five questions to assess PSS. These items included statements such as *"the supervisor demonstrates a profound understanding of the challenges faced by employees," "the supervisor displays confidence in managing subordinates,"* and *"the supervisor is dependable in offering valuable guidance to workers."* (Cronbach's $\alpha = .904$). PJ underwent evaluation using a set of four items [89]. For instance, one of the questions stated, *"The continuous execution of salary and wage procedures involves the participation of all employees"*

(Cronbach's $\alpha = .891$). The concept of PE was created by [79] and is characterized by four key elements: meaning, choice, self-efficacy, and impact. An illustrative item of the impact dimension is *"I possess a noteworthy level of influence over the occurrences within my unit"* (Cronbach's $\alpha = .897$). The evaluation of EA was conducted using a scale consisting of six items, which were then divided into two sub-dimensions: SB and SA [90]. The authors developed a set of four measures to assess an individual's SB in the workplace. One of the items inquired about the likelihood of the individual's long-term commitment to a company, with a calculated Cronbach's α coefficient of .872. According to the literature, the concept of SA can be understood through two distinct dimensions: the vastness and the need for accommodation [64]. An illustration of SA items can be observed in the question, *"In what manner does the work system of the company pertain to you?"*, *"How does the organization enforce and regulate the work behavior of its employees?"* (Cronbach's $\alpha = .794$). The assessment of IWB encompassed four dimensions: opportunity, idea production, championing, and application. An illustrative remark from the study indicates that organizations actively encourage employees to generate innovative ideas [91]. (Cronbach's $\alpha = .866$).

5. Findings

5.1. Confirmatory Factor Analyses

We used the AMOS v.23 computer program to assess validity and reliability of our measurement model through confirmatory factor analysis using a combination of statistics, including CMIN, GFI, AGFI, CFI, NFI, TLI and RMSEA. Accepted criteria for relative chi-square (CMIN) < 5 and GFI, AGFI, CFI, NFI, and TLI values $> .9$ [92][93] and RMSEA $< .08$ [93]. Two measurement models were examined to determine the best fit for our data. The first model assumed that all constructs were distinct by allowing measure items for each construct to load on their separate factor. All items loaded on the intended factor, and the model met our criteria for a good fit: CMIN = 269.950, GFI = .937, AGFI = .919, CFI = .989, NFI = .949, TLI = .987, RMSEA = .027. The results of this confirmatory factor analysis are reported in **Error! Reference source not found.**

shows all the items' factor loadings were more than 0.5, and their AVE was more than the recommended value of 0.5 [94]. Therefore, none of the items were deleted. Thus, it can be concluded that all the items have adequate convergent validity [95]. Similarly,

also showed that all the constructs' reliability was higher than 0.7, which meets the cut-off value [95][96].

5.2. Measurement Model

The measurement model (**Error! Reference source not found.**) was used in this study to examine the relationship between the independent, mediator, and dependent

variables. The measurement model is the second level of analysis in structural equation modeling, which is considered part of data preparation. As the analysis of measurement model using AMOS reveals that the model is fit, whereas goodness of model fit is achieved as the following chi-square (CMIN) = 269.950 (df = 215), relative chi-square (CMIN/df) = 1.256, AGFI = .919, GFI = .937, CFI = .989, NFI = .949.

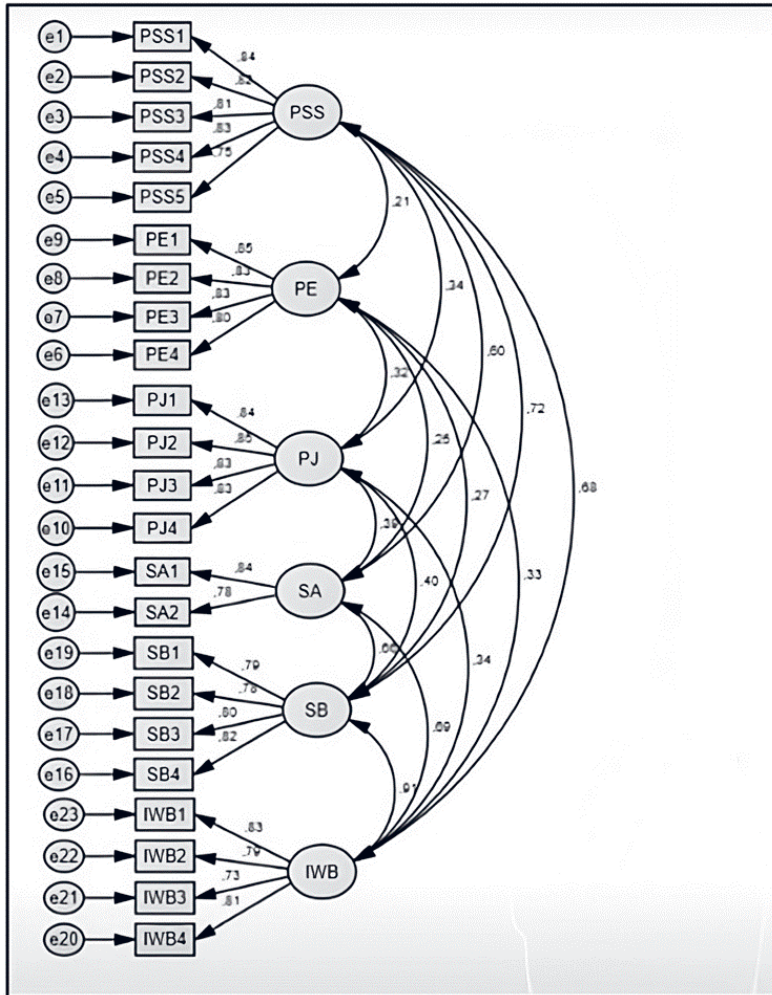


Figure 2. Hypothesized Structural Equation Model with Standardized Factor Loading

5.3. Discriminant Validity

The discriminant validity of the study revealed the extent of the distinction between the constructs in the measurement model. Table 2 below depicts the CFA results summary for discriminant validity. Based on the table, thus, the discriminant validity is achieved when a diagonal value in bold is higher than the values in its row

and column. Therefore, all the constructs in the measurement model exhibit sufficient discriminant validity [93]. In addition, all the correlation (r^2) values between the constructs were less than the recommended correlation value of 0.9 [95].

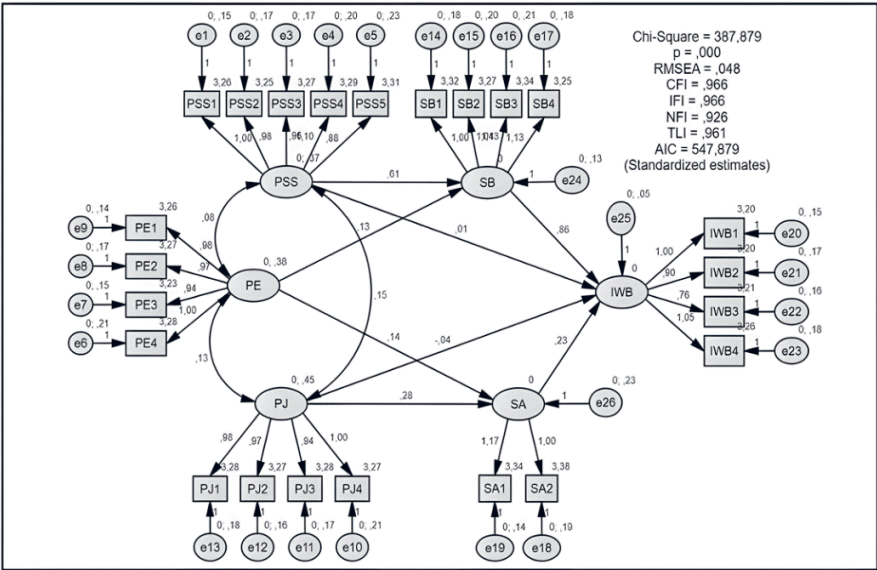


Figure 3. Measurement Model

Construct	Indicator	Factor Loading	Mean	SD	CR	AVE
Perceived Supervisor Support	PSS1	0,842	3,26	0,722	0,818	0,518
	PSS2	0,821	3,25	0,728		
	PSS3	0,812	3,27	0,715		
	PSS4	0,083	3,29	0,816		
	PSS5	0,736	3,31	0,717		
Psychological Empowerment	PE1	0,850	3,26	0,714	0,898	0,687
	PE2	0,831	3,27	0,725		
	PE3	0,836	3,23	0,699		
	PE4	0,797	3,28	0,773		
Procedural Justice	PJ1	0,838	3,28	0,783	0,9047	0,704
	PJ2	0,857	3,27	0,761		
	PJ3	0,835	3,28	0,756		
	PJ4	0,825	3,27	0,815		
Sense of Awe	SA1	0,840	3,34	0,729	0,785	0,647
	SA2	0,767	3,38	0,687		

Construct	Indicator	Factor Loading	Mean	SD	CR	AVE
<i>Sense of Belonging</i>	SB1	0,000	3,32	0,686	0,735	0,480
	SB2	0,780	3,27	0,714		
	SB3	0,800	3,34	0,761		
	SB4	0,820	3,25	0,738		
<i>Innovative Work Behavior</i>	IWB1	0,832	3,2	0,69	0,868	0,623
	IWB2	0,814	3,2	0,658		
	IWB3	0,702	3,21	0,593		
	IWB4	0,803	3,26	0,734		

Table 1. Factors Loading, AVE & Construct Reliability

Constructs	PSS	PE	PJ	SA	SB	IWB
PSS	0,518					
PE	0,046	0,687				
PJ	0,116	0,101	0,704			
SA	0,358	0,062	0,151	0,647		
SB	0,516	0,074	0,161	0,441	0,480	
IWB	0,462	0,108	0,116	0,477	0,349	0,623
<i>The square root of AVE of each construct (on the diagonal) and correlation coefficient (on the off-diagonal)</i>						

Table 2. Discriminant Validity

5.4. Structural Equation Modeling (SEM) Analysis

Structural equation modeling determines the influence of PSS, PJ, SA, and SB on IWB moderated by PE. Maximum likelihood estimation (MLE) is used to estimate the model. This model is estimated using the following criteria: $p = .000$, RMSEA = .048, CFI = .966, and IFI = .966. The hypotheses of the direct relationship between constructs are presented in Table 3. There were eight hypotheses tested; two were hypotheses using moderation variables. Six hypotheses are accepted, they are H1, H2, H3, H4, H5, and H6, with each $CR > 1.98$.

Hypothesis	Path	B	C.R.	P	Decision
H1	PSS $\rightarrow$ IWB	0.28	4.601	0.645	Accepted
H2	PJ $\rightarrow$ IWB	0.43	5.891	0.112	Accepted
H3	PSS $\rightarrow$ SB	0.61	10.998	***	Accepted
H4	PJ $\rightarrow$ SA	0.28	3.021	0.003	Accepted

H5	SB → IWB	0.86	10.548	***	Accepted
H6	SA → IWB	0.23	4.018	***	Accepted

Table 3. Path Co-efficient Result

5.5. Mediation Analysis

This study aims to determine the influence of PE moderation in relationships of PSS, PJ, SB, and SA. The effect of PE moderation on PSS variables on SB was analyzed through the interaction between PSS and PE, as was the impact of PE moderation on PJ variables on SA through PJ and PE interactions. [97] state 4 (four) statistical methods for SEM analysis involving interaction variables, [98][99][100][101]. This study uses [101] method through 4 stages: compiling CFA to the *goodness of fit* by the process of centering variables the effect of multicollinearity, forming moderation variables (formula 1) by multiplying the summation of moderation variable indicators by the summary of exogenous variable indicators to creates interaction effects.

$$Interaction\ Effects = (\sum x_1 + x_2 + \dots + x_3) \times \sum z_1 + z_2 + \dots + z_p)$$

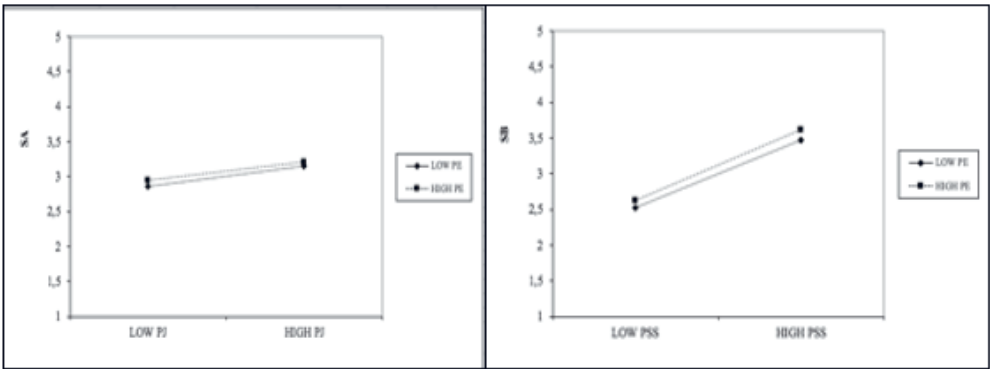


Figure 4. Interaction Effect

For the model to be identified, LF/ variance weighting is carried out for interaction variables, then creating a structural model & evaluating the goodness of fit. The PE moderation test on PSS and SB variables according to predetermined criteria, p-value = .000, RMSEA = .016, CFI = .998, IFI = .966, AGFI = 0.953, with CR>1.96 showing that there is an indirect influence of PSS on SB through PE moderation. While the PE moderation test on PJ and SA variables corresponds to the established criteria, p-value = .003, RMSEA = .000, CFI = .988, IFI = .976, AGFI = .973, with CR>1.96 indicating an indirect influence of PJ on SA through PE moderation. It can be concluded that PE moderation influences the relationship between PSS, PJ, SB, and SA. Thus, hypotheses H7 and H8 are accepted. Visually, shows the role of the PE moderation variable, with PJ and PSS on the X-axis and SA and SB on the Y-axis. The graph of the relationship between PJ and SA with PE as a moderation shows that the higher the

PJ value, the higher the SA value, with PE at high and low. Meanwhile, on the graph of the relationship between PSS and SB, at high and Low PE, the higher the PSS value, the higher the SB value linearly.

6. Discussion

Organizational Support and Innovative Work Behavior

Based on an extensive investigation into frontline employees, authors have identified four essential indicators that must be incorporated into FMS. According to statistical analysis, IWB is influenced by OS through PSS, as shown by hypothesis **H1**. The present findings are consistent with the results reported in prior research [54]. When employees see that their organization provides personal support, they develop a greater sense of organizational connection, enabling them to offer innovative ideas during work execution. The association between PSS and IWB can be elucidated in greater detail by reference to a study conducted by [102]. This study highlights several factors contributing to this link: high power distance, collectivism, and low uncertainty avoidance. High power distance is a phenomenon in which employees perceive their superiors as significant individuals who possess the power to grant or withhold essential resources required for the advancement, safeguarding, and execution of novel concepts within the organizational setting [103][104]. Based on an estimated individualism score of 14, which suggests that Indonesia is primarily a collectivist-oriented society, it is probable that workers in this context would prioritize obtaining approval from all relevant stakeholders, particularly supervisors and employers, before initiating any novel undertakings. Moreover, due to a low level of uncertainty avoidance, the activity of IWB is regarded as a behavior that involves taking risks [105]. The supervisor's assistance is critical as it collectively enables workers to bear the burden of failure or uncertainty.

Another indicator of IWB, OS through PJ, impacts IWB (**H2**). Previous empirical research has investigated correlation between PJ and IWB concerning EA [106][51]. Findings indicate that the organization's sincere endeavors to ensure fairness in decision-making, also known as PJ, favorably impact employee engagement. The individuals engaged in the task are strongly inclined towards disseminating work-related knowledge and demonstrate considerable dedication to IWB. This conduct ultimately has a favorable impact on the firm's long-term viability and environmental stewardship. Organizational justice encompasses the establishment of equitable norms and regulations, the cultivation of fairness within the organizational context, and the consideration of the outcomes gained by employees, all of which are fundamental elements inside a corporation [107]. The statement posits that employees are more likely to perceive their contributions as being fairly acknowledged when they perceive the organization as being mindful of providing equitable treatment, particularly concerning organizational justice, including procedural justice. According to previous research, employees are likely to exhibit higher motivation levels when sharing their ideas with the organization and implementing them [47].

Organizational Support dan Eandoyee Attitude

Based on the findings, it was determined that there is a relationship between PSS and SB (**H3**). According to [108], it may be inferred that OS provides positive or mitigated negative stimuli. Therefore, employees have the potential to experience job happiness. SB is necessary in psychology and organizational behavior, as it predicts several good worker behaviors [25]. When employees have job satisfaction, they are more likely to adapt to the required work demands and develop a sense of organizational identity, also known as SB. This adjustment process can subsequently enhance the employee's motivation.

The study's findings demonstrated a significant correlation between PJ and SA, providing empirical support for **H4**. The significance of PJ in the workplace for facilitating interaction among intelligent systems and influencing worker behavior and EA has been demonstrated in previous study [109]. This research emphasizes the allocation of duties as a means of promoting human-machine-human interactions rather than relying solely on training methods. It can be inferred that a certain degree of resemblance exists in values, standards, and personalities or a profound level of likeness within a psychological contract between supervisors and workers [110]. When a business demonstrates adherence to equitable practices, as facilitated by supervisors, it signifies the organization's concern for its employees and proactive efforts to help them, fostering a sense of support among workers. According to [111], this view will contribute to the cultivation of trust within the organization and enhance the situational awareness of employees.

Sense of Belonging, Sense of Awe and Innovative Work Behavior

The findings of the previous studies on the antecedents of IWB, through EA with SB (**H5**) and SA (**H6**) indicators, demonstrated a solid and favorable impact on IWB. [112] suggest a correlation between servant leadership, strong acceptance, and the development of satisfied workers who voted to contribute towards achieving organizational objectives. Employees with SB are likely to exhibit a favorable demeanor, proactive behavior, commitment, and productivity [113]. Furthermore, it is expected to novel concepts and suggestions to the organization. According to previous research [111], workers are more likely to engage in innovative behavior when they perceive high supervisor support.

Psychological empowerment as moderating variable

The present study showed that PE moderated the relationship between PSS and SB (**H7**) and between PSS and SA (**H8**). The findings indicated that persons who experienced PE reported feeling influenced and having a sense of control over their actions [114]. Scholars have posited that employees who experience a sense of empowerment are likelier to exhibit heightened involvement with their work and demonstrate proactive behavior within the workplace [115]. According to research findings, individuals who encounter PE tend to engage in vocal activities, including identifying issues and providing feedback to enhance the organization's overall functioning [116]. According to empirical research, evidence suggests levels of creativity when they experience psychological empowerment [117]. [118] revealed a

positive relationship between PE and the level of engagement in the creative process, leading to an enhancement in creativity. Additionally, the study consistently found a positive correlation between empowerment and worker performance [119]. PE is negatively related to voluntary turnover of workers, so workers who feel empowered are more likely to stay with the team or organization for a more extended period [120], thus allowing greater possibilities for the group to accumulate performance benefits.

7. Conclusions & Practical Implications

The findings of this research possess numerous theoretical and practical ramifications. This scholarly paper examines the impact of OS and EA on frontline employees who utilize IWB within the framework of FMS. Our study revealed a significant relationship between PSS and SB, indicating that PSS exerted a noteworthy effect on SB. Furthermore, our findings also demonstrated that SB greatly impacted PSS, suggesting a reciprocal relationship between the two variables. In addition to moderating the relationship between PSS and SB, PE was found to have a significant influence on SA through the mediating role of PJ. Subsequently, the implementation of SA yielded a substantial and beneficial impact on integrating IWB and the influence of PE moderating transition from PJ to SA. The findings above contribute to understanding how organizational support impacts EA and offer insights for frontline supervisors and production managers to enhance workers' IWB.

Regarding practical implications, SB impacts IWB, necessitating the provision of support from production managers to foster a sense of attachment among workers. This attachment is expected to serve as a motivational factor, encouraging workers to contribute innovative and creative ideas to the organization. Supervisors and managers must exhibit fairness in their decision-making processes. By doing so, employees are more likely to enhance their perspective of their social exchange relationship and perceive their contributions as valuable to the organization. Consequently, this fosters an environment that promotes increased organizational citizenship behavior. The PE construct is a moderating factor in the relationship between OS and EA.

Consequently, while distributing rewards, such as enhancing procedural assistance, management must prioritize fairness since disregarding may result in adverse consequences. This resource is a practical manual for industrial and other organizations, guiding the importance of prioritizing and enhancing human resources operations. The main focus of this study pertains to the relationship between organizational support and employee attitude in fostering innovative work behavior, with the moderating influence of psychological empowerment. This research aims to enhance organizational support and assess employee attitude as an initial measure in developing innovative work behavior.

8. Limitation and Future Research

This study had several limitations, as with any other research endeavor. This study primarily examined innovative work behavior as one of the factors contributing to the

development of organizational support and employee attitude. Examining the remaining components contributing to the formation of innovative work behavior may have yielded a more comprehensive comprehension of the significance of organizational support, employee attitude, and psychological empowerment in fostering innovative work behavior. Furthermore, the research framework utilized in this study has been implemented in firms working within industrial parks in Indonesia. Indonesia is classified as a developing nation, and the proposed model has the potential to be applicable in various geographical contexts and developing countries that share comparable socio-economic systems and cultural characteristics. The present study does not directly address the function of awe and belongingness as mediators, which can be seen as limitations in the research. Subsequent investigations could potentially explore the significance of the experience of awe and sense of belonging.

It is recommended that future research incorporate this dataset in conjunction with other variables about the establishment of organizational support and employee attitudes. Additionally, it is important to elucidate the role of psychological empowerment as a moderator in applying these variables and their influence on innovative work behavior. In addition, future research can assess innovative work behavior by utilizing appraisal reports and including supervisors' perspectives.

Credit Authorship Contribution Statements

Nimas A. Pratiwi: Writing – Original draft, conceptualization, data curation, formal analysis, methodology, project administration, sophie lythreitis: formal analysis. **April K. Susilo:** Writing – review & editing, writing – original draft, conceptualization, methodology, writing – review & editing. **Siti Fatimah:** Writing – review & editing, writing – original draft, data curation.

References

- [1] A. Florescu and S. A. Barabas, "Modeling and Simulation of a Flexible Manufacturing System-A Basic Component of Industry 4.0," *Appl. Sci.*, vol. 10, no. 22, p. 8300, 2020, doi: 10.3390/app10228300.
- [2] T. Sprock, C. Bock, and L. F. McGinnis, "Survey and classification of operational control problems in discrete event logistics systems (DELS)," *Int. J. Prod. Res.*, vol. 57, no. 15–16, pp. 5215–5238, 2019, doi: 10.1080/00207543.2018.1553314.
- [3] R. El-Khalil and Z. Darwish, "Flexible manufacturing systems performance in U.S. automotive manufacturing plants: a case study," *Prod. Plan. Control*, vol. 30, no. 1, pp. 48–59, Jan. 2019, doi: 10.1080/09537287.2018.1520318.
- [4] L. Lukic, M. Djapic, C. Fragassa, and A. Pavlovic, "Optimization Model for Machining Processes Design in Flexible Manufacturing Systems," *J.*

- Adv. Manuf. Syst.*, vol. 17, no. 2, pp. 137–153, Jun. 2018, doi: 10.1142/S0219686718500099.
- [5] Y. L. Pan, “One computational innovation transition-based recovery policy for flexible manufacturing systems using Petri nets,” *Appl. Sci.*, vol. 10, no. 7, Apr. 2020, doi: 10.3390/APP10072332.
 - [6] EQF, “Recommendation of the European parliament & the council of the European Union on establishing the European qualifications framework for lifelong learning,” *Off. J. Eur. Union*, 2008.
 - [7] D. Mavrikios, N. Papakostas, D. Mourtzis, and G. Chryssolouris, “On industrial learning and training for the factories of the future: A conceptual, cognitive and technology framework,” *J. Intell. Manuf.*, vol. 24, no. 3, pp. 473–485, 2013, doi: 10.1007/s10845-011-0590-9.
 - [8] E. Dóci and J. Hofmans, “Task complexity and transformational leadership: the mediating role of leaders’ state core self-evaluations,” *Leadersh. Q.*, vol. 26, no. 3, pp. 436–447, 2015.
 - [9] A. N. El-Kassar, G. K. Dagher, S. Lythreathis, and M. Azakir, “Antecedents and consequences of knowledge hiding: The roles of HR practices, organizational support for creativity, creativity, innovative work behavior, and task performance,” *J. Bus. Res.*, vol. 140, pp. 1–10, 2022.
 - [10] W. Cai, S. Khapova, B. Bossink, E. Lysova, and J. Yuan, “Optimizing employee creativity in the digital era: Uncovering the interactional effects of abilities, motivations, and opportunities,” *Int. J. Environ. Res. Public Health*, vol. 17, no. 3, p. 1038, 2020.
 - [11] G. Abid, I. Zahra, and A. Ahmed, “Mediated mechanism of thriving at work between perceived organization support, innovative work behavior and turnover intention,” *J. Commer. Soc. Sci.*, vol. 9, no. 3, pp. 982–998, 2015.
 - [12] J. N. Choi, T. A. Anderson, and A. Veillette, “Contextual inhibitors of employee creativity in organizations: The insulating role of creative ability,” *Gr. Organ. Manag.*, vol. 34, no. 3, pp. 330–357, 2009.
 - [13] W. Duan, X. Tang, Y. Li, X. Cheng, and H. Zhang, “Perceived organizational support and employee creativity: The mediation role of calling,” *Creat. Res. J.*, vol. 32, no. 4, pp. 403–411, 2020.
 - [14] Y. Akgunduz, C. Alkan, and Ö. A. Gök, “Perceived organizational support, employee creativity and proactive personality: The mediating effect of meaning of work,” *J. Hosp. Tour. Manag.*, vol. 34, pp. 105–114, 2018.
 - [15] Akintayo D.I., “Work-Family Role Conflict and Organizational Attitude Among Industrial Employees in Nigeria,” *J. Psychol. Couns.*, vol. 2, no. 1, pp. 1–8, 2010.

- [16] G. P. Yadav and A. Uprtou, "Impact of Employee Attitude on The Performance of an Organization," *Allahabad Sch. Manag. Stud.*, 2022.
- [17] M. Malik, S. Sarwar, and S. Orr, "Agile practices and performance: Examining the role of psychological empowerment," *Int. J. Proj. Manag.*, vol. 39, no. 1, pp. 10–20, Jan. 2021, doi: 10.1016/J.IJPROMAN.2020.09.002.
- [18] T. A. Shah, M. N. Khattak, R. Zolin, and S. Z. A. Shah, "Psychological empowerment and employee attitudinal outcomes: The pivotal role of psychological capital," *Manag. Res. Rev.*, vol. 42, no. 7, pp. 797–817, Jul. 2019, doi: 10.1108/MRR-05-2018-0194/FULL/XML.
- [19] A. Mills, P. Berthon, and C. P. Research, "Agile authorship: Evolving innovation models for information-intensive offerings," *J. Bus. Res.*, vol. 110, pp. 577–583, 2020.
- [20] L. Rhoades and R. Eisenberger, "Perceived organizational support: A review of the literature," *J. Appl. Psychol.*, vol. 87, no. 4, pp. 698–714, 2002, doi: 10.1037/0021-9010.87.4.698.
- [21] R. R. Kehoe and P. M. Wright, "The Impact of High-Performance Human Resource Practices on Employees' Attitudes and Behaviors," *J. Manage.*, vol. 39, no. 2, pp. 366–391, 2013, doi: 10.1177/0149206310365901.
- [22] T. S. Suifan, A. B. Abdallah, and M. Al Janini, "The Impact of Transformational Leadership on Employees' Creativity: The Mediating role of Perceived Organizational Support," *Manag. Res. Rev.*, vol. 41, no. 1, pp. 113–132, 2018, doi: 10.1108/MRR-02-2017-0032.
- [23] I. Danaeifar, S. Hasani, S. Kaviani, A. Abed, and A. Abangah, "The relationship between organizational justice and political behavior and employees' job performance of the electricity distribution department of behbahan," *Casp. Sea J.*, vol. 1, no. 4, 2016.
- [24] S. Abdelaziz, Z. Saloua, and H. Mahrane, "The influence of organizational justice on job performance: The mediating effect of affective commitment," *J. Manag. Dev.*, vol. 36, no. 4, pp. 542–559, 2017.
- [25] J. R. Knapp, B. R. Smith, and T. A. Sprinkle, "Clarifying the Relational Ties of Organizational Belonging: Understanding the Roles of Perceived Insider Status, Psychological Ownership, and Organizational Identification," *J. Leadersh. Organ. Stud.*, vol. 21, no. 3, pp. 273–285, 2014.
- [26] R. Cropanzano and M. S. Mitchell, "Social exchange theory: An Interdisciplinary review," *J. Manage.*, vol. 31, no. 6, pp. 874–900, Dec. 2005, doi: 10.1177/0149206305279602.

-
- [27] K. S. Cook, C. Cheshire, E. R. W. Rice, and S. Nakagawa, "Social Exchange Theory," *Handbooks Sociol. Soc. Res.*, pp. 61–88, 2013, doi: 10.1007/978-94-007-6772-0_3.
 - [28] T. Volery and L. Tarabashkina, "The impact of organisational support, employee creativity and work centrality on innovative work behaviour," *J. Bus. Res.*, vol. 129, no. 1, pp. 295–303, 2021.
 - [29] D. J. Hughes, A. Lee, A. W. Tian, A. Newman, and A. Legood, "Leadership, creativity, and innovation: A critical review and practical recommendations," *Leadersh. Q.*, vol. 29, no. 5, pp. 549–569, 2018.
 - [30] S. C. Jwu, Z. Hassan, S. M. Abdullah, and M. E. Kasa, "The Relationship between Employee Attitude Towards Training and Employee Retention in Telecommunication," *J. Cogn. Sci. Hum. Dev.*, vol. 4, no. 1, pp. 1–14, Nov. 2018, doi: 10.33736/JCSHD.1052.2018.
 - [31] M. Chamberlin, D. W. Newton, and J. A. LePine, "A meta-analysis of empowerment and voice as transmitters of high-performance managerial practices to job performance," *J. Organ. Behav.*, vol. 39, no. 10, pp. 1296–1313, Dec. 2018, doi: 10.1002/JOB.2295.
 - [32] J. Wen, S. (Sam) Huang, and P. Hou, "Emotional intelligence, emotional labor, perceived organizational support, and job satisfaction: A moderated mediation model," *Int. J. Hosp. Manag.*, vol. 81, pp. 120–130, Aug. 2019, doi: 10.1016/J.IJHM.2019.01.009.
 - [33] N. Özarallı, "Linking empowering leader to creativity: the moderating role of psychological (felt) empowerment," *Procedia-Social Behav. Sci.*, vol. 181, pp. 366–376, 2015.
 - [34] P. M. Blau, *Exchange and power in social life*. Piscataway: NJ: Transaction Publishers, 1964.
 - [35] B. Yan and L. Jian, "Beyond reciprocity: The bystander effect of knowledge response in online knowledge communities," *Comput. Human Behav.*, vol. 76, pp. 9–18, 2017, doi: 10.1016/j.chb.2017.06.040.
 - [36] K. K. Kapoor, K. Tamilmani, N. P. Rana, P. Patil, Y. K. Dwivedi, and S. Nerur, "Advances in Social Media Research: Past, Present and Future," *Inf. Syst. Front.*, vol. 20, no. 3, pp. 531–558, 2018, doi: 10.1007/s10796-017-9810-y.
 - [37] R. Eisenberger, S. Armeli, B. Rexwinkel, P. D. Lynch, and L. Rhoades, "Reciprocation of perceived organizational support," *J. Appl. Psychol.*, vol. 86, no. 3, pp. 42–51, 2001.
 - [38] T. Chen, S. Hao, K. Ding, X. Feng, G. Li, and X. Liang, "The Impact of Organizational Support on Employee Performance," *Empl. Relations*, vol. 42, no. 1, pp. 166–179, 2020, doi: 10.1108/ER-01-2019-0079.
-

- [39] A. S. Alkhateri, G. S. A. Khalifa, and A. Ameen, "The Impact of perceived supervisor support on employees turnover intention: The Mediating role of job satisfaction and affective organizational commitment.," *Int. Bus. Manag.*, vol. 12, no. 7, pp. 477–492, 2018, doi: 10.3923/ibm.2018.477.492.
- [40] D. Basuil, "Subordinate perceptions of family-supportive supervision: the role of similar family-related demographics and its effect on affective commitment," *Wiley Online Libr.*, vol. 26, no. 4, pp. 523–540, Nov. 2016, doi: 10.1111/1748-8583.12120.
- [41] M. K. Shoss, R. Eisenberger, S. L. D. Restubog, and T. J. Zagenczyk, "Blaming the organization for abusive supervision: The roles of perceived organizational support and supervisor's organizational embodiment," *J. Appl. Psychol.*, vol. 98, no. 1, pp. 158–168, 2013, doi: 10.1037/A0030687.
- [42] J. A. Colquitt *et al.*, "Justice at the millennium, a decade later: A meta-analytic test of social exchange and affect-based perspectives," *J. Appl. Psychol.*, vol. 98, no. 2, pp. 199–236, 2013, doi: 10.1037/A0031757.
- [43] J. A. Colquitt and J. B. Rodell, "Measuring justice and fairness. In R. Cropanzano & M. L. Ambrose (Eds.)," in *Oxford library of psychology. The oxford handbook of justice in the workplace*, New York: Oxford University Press, 2015, pp. 187–202.
- [44] G. S. Leventhal, "The distribution of rewards and resources in groups and organizations. In L. Berkowitz & W. Walster (Eds.)," *Adv. Exp. Soc. Psychol.*, vol. 9, pp. 91–131, 1976.
- [45] R. J. Bies and J. F. Moag, "Interactional justice: Communication criteria of fairness.," *Res. Negot. Organ.*, vol. 1, pp. 43–55, 1986.
- [46] J. A. Colquitt, "On the dimensionality of organizational justice: A construct validation of a measure," *J. Appl. Psychol.*, vol. 86, no. 3, pp. 386–400, 2001, doi: 10.1037/0021-9010.86.3.386.
- [47] T. Akram, M. J. Haider, and Y. X. Feng, "The Effects of Organizational Justice on the Innovative Work Behavior of Employees: An Empirical Study from China," *Innovation*, vol. 2, pp. 114–126, 2016.
- [48] T. Dundar and E. Tabancali, "The relationship between organizational justice perceptions and job satisfaction levels," in *Procedia-Social and Behavioral Sciences*, 2012, pp. 5777–5781, Accessed: Sep. 25, 2022. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S1877042812022495>.
- [49] N. Ramamoorthy, P. C. Flood, T. Slattery, and R. Sardesai, "Determinants of Innovative Work Behaviour: Development and Test of an Integrated Model," *Creat. Innov. Manag.*, vol. 14, no. 2, pp. 142–150, Jun. 2005, doi: 10.1111/J.1467-8691.2005.00334.X.

- [50] M. Momeni, H. Ebrahimpour, and M. . Ajirloo, "The effect of employees' self-efficacy on innovative work behavior at social security organization employees in ardabil province," *Kuwait Chapter Arab. J. Bus. Manag. Rev.*, vol. 3, no. 8, p. 29, 2014.
- [51] U. A. Agarwal, "Linking justice, trust and innovative work behaviour to work engagement," *Pers. Rev.*, vol. 43, no. 1, pp. 41–73, 2014.
- [52] A. Abstein, S. Heidenreich, and P. Spieth, "Innovative Work Behaviour: The Impact of Comprehensive HR System Perceptions and the Role of Work–Life Conflict," vol. 21, no. 2, pp. 91–116, 2014, doi: 10.1080/13662716.2014.896159.
- [53] J. P. J. De Jong and D. N. Den Hartog, "How leaders influence employees' innovative behaviour," *Eur. J. Innov. Manag.*, vol. 10, no. 1, pp. 41–64, 2007, doi: 10.1108/14601060710720546/FULL/HTML.
- [54] B. Afsar and Y. Badir, "Workplace spirituality, perceived organizational support and innovative work behavior: The mediating effects of person-organization fit," *J. Work. Learn.*, vol. 29, no. 2, pp. 95–109, 2017, doi: 10.1108/JWL-11-2015-0086/FULL/XML.
- [55] J. De Jong and D. Den Hartog, "Measuring innovative work behaviour," *Creat. Innov. Manag.*, vol. 19, no. 1, pp. 23–36, 2010, doi: 10.1111/J.1467-8691.2010.00547.X.
- [56] S. Lee, K. J. Lovelace, and C. C. Manz, "Serving with spirit: an integrative model of workplace spirituality within service organizations," *J. Manag. Spiritual. Relig.*, vol. 11, no. 1, pp. 45–64, 2014.
- [57] O. Janssen, "How fairness perceptions make innovative behavior more or less stressful," *J. Organ. Behav.*, vol. 25, no. 2, pp. 201–215, Mar. 2004, doi: 10.1002/JOB.238.
- [58] Y. Lee and J. Y. Lee, "Mediating effects of the meaningfulness of work between organizational support and subjective career success," *Int. J. Educ. Vocat. Guid. 2018 191*, vol. 19, no. 1, pp. 151–172, Aug. 2018, doi: 10.1007/S10775-018-9373-6.
- [59] D. M. Mitterer, "Servant leadership and its effect on employee job satisfaction and turnover intent,," Walden University, 2018.
- [60] U. Khuwaja, K. Ahmed, G. Abid, and A. Adeel, "Leadership and employee attitudes: The mediating role of perception of organizational politics," *Cogent Bus. Manag.*, vol. 7, no. 1, 2020.
- [61] V. Tinto, "Through the eyes of students," *J. Coll. Student Retent. Res. Theory Pract.*, vol. 19, no. 3, pp. 254–269, 2017.

- [62] K. Murphy and T. Tyler, "Procedural justice and compliance behaviour: the mediating role of emotions," *Eur. J. Soc. Psychol.*, vol. 38, no. 4, pp. 652–668, 2008, doi: 10.1002/ejsp.502.
- [63] D. Keltner and J. Haidt, "Approaching awe, a moral, spiritual, and aesthetic emotion," *Cogn. Emot.*, vol. 17, no. 2, pp. 297–314, Mar. 2003, doi: 10.1080/026999303022297.
- [64] J. L. Preston and F. Shin, "Spiritual experiences evoke awe through the small self in both religious and non-religious individuals," *J. Exp. Soc. Psychol.*, vol. 70, pp. 212–221, 2017, doi: 10.1016/j.jesp.2016.11.006.
- [65] M. McBeath, M. T. B. Drysdale, and N. Bohn, "Work-integrated learning and the importance of peer support and sense of belonging," *Educ. Train.*, vol. 60, no. 1, pp. 39–53, Jan. 2018, doi: 10.1108/ET-05-2017-0070.
- [66] F. Slamti, "Linking transformational leadership, sense of belonging and intrapreneurship," in *Economic and Social Development: Book of Proceedings*, 2020, pp. 286–293.
- [67] P. Valdesolo and J. Graham, "Awe, Uncertainty, and Agency Detection," *Psychol. Sci.*, vol. 25, no. 1, pp. 170–178, 2014, doi: 10.1177/0956797613501884.
- [68] P. K. Piff, P. Dietze, M. Feinberg, D. M. Stancato, and D. Keltner, "Awe, the small self, and prosocial behavior," *J. Pers. Soc. Psychol.*, vol. 108, no. 6, pp. 883–899, Jun. 2015, doi: 10.1037/PSP10000018.
- [69] M. Rudd, K. D. Vohs, and J. Aaker, "Awe Expands People's Perception of Time, Alters Decision Making, and Enhances Well-Being," *Psychol. Sci.*, vol. 23, no. 10, pp. 1130–1136, Aug. 2012, doi: 10.1177/0956797612438731.
- [70] N. Krause and R. David Hayward, "Assessing whether practical wisdom and awe of god are associated with life satisfaction," *Psycholog. Relig. Spiritual.*, vol. 7, no. 1, pp. 51–59, Feb. 2015, doi: 10.1037/A0037694.
- [71] K. Birdi, D. Leach, and W. Magadley, "The relationship of individual capabilities and environmental support with different facets of designers' innovative behavior," *J. Prod. Innov. Manag.*, vol. 33, no. 1, pp. 19–35, 2016.
- [72] B. Afsar, Y. F. Badir, B. B. Saeed, and S. Hafeez, "Transformational and transactional leadership and employee's entrepreneurial behavior in knowledge-intensive industries," *Int. J. Hum. Resour. Manag.*, vol. 28, no. 2, pp. 307–332, 2017.
- [73] T. Akram, S. Lei, M. J. Haider, and S. . Hussain, "Exploring the impact of knowledge sharing on the innovative work behavior of employees: a study in China," *Int. Bus. Res.*, vol. 11, no. 3, pp. 186–199, 2018.

- [74] R. Shanker, ... R. B.-J. of vocational, and undefined 2017, "Organizational climate for innovation and organizational performance: The mediating effect of innovative work behavior," *Elsevier*, 2017, doi: 10.1016/j.jvb.2017.02.004.
- [75] C. Ogbonnaya, D. V.-T. I. J. of Human, and undefined 2018, "High performance work practices, employee outcomes and organizational performance: a 2-1-2 multilevel mediation analysis," *Taylor Fr.*, vol. 29, no. 2, pp. 239–259, Jan. 2018, doi: 10.1080/09585192.2016.1146320.
- [76] P. C. Patel and M. S. Cardon, "Adopting HRM practices and their effectiveness in small firms facing product-market competition," *Hum. Resour. Manage.*, vol. 49, no. 2, pp. 265–290, Mar. 2010, doi: 10.1002/HRM.20346.
- [77] K. Jiang, D. P. Lepak, J. Hu, and J. C. Baer, "How Does Human Resource Management Influence Organizational Outcomes? A Meta-analytic Investigation of Mediating Mechanisms," vol. 55, no. 6, pp. 1264–1294, May 2012, doi: 10.5465/AMJ.2011.0088.
- [78] M. T. Maynard, J. E. Mathieu, L. L. Gilson, E. H. J. O'Boyle, and K. P. Cigularov, "Drivers and outcomes of team psychological empowerment: a meta-analytic review and model test," *Organ. Psychol. Rev.*, vol. 3, no. 2, pp. 101–137, 2013.
- [79] G. M. Spreitzer, "Psychological Empowerment in the Workplace: Dimensions, Measurement, and Validation," *Acad. Manag. J.*, vol. 38, no. 5, pp. 1442–1465, Oct. 1995, doi: 10.5465/256865.
- [80] G. M. Spreitzer and C. Porath, "Self-determination as nutriment for thriving: building an integrative model of human growth at work," In Gagne,, New York: Oxford University Press, 2014, pp. 245–258.
- [81] M. T. Maynard, L. L. Gilson, and J. E. Mathieu, "Empowerment—Fad or Fab? A Multilevel Review of the Past Two Decades of Research:," vol. 38, no. 4, pp. 1231–1281, Mar. 2012, doi: 10.1177/0149206312438773.
- [82] H. F. . Abuzid and M. Abbas, "Empowering Leadership and its Role on Job Satisfaction and Employee Creativity: An Empirical Study of Saudi Arabian Banks," *J. Eng. Appl. Sci.*, vol. 12, no. 4, pp. 933–944, 2017.
- [83] K. H. Fong and E. Snape, "Empowering leadership, psychological empowerment and employee outcomes: Testing a multi-level mediating model," *Br. J. Manag.*, vol. 26, no. 1, pp. 126–138, Jan. 2015, doi: 10.1111/1467-8551.12048.
- [84] K. Rudestam and R. Newton, *Surviving Your Dissertation: A Comprehensive Guide to Content and Process*, 2nd editio. CASage, Thousand Oaks, 2001.

- [85] P. D. Leedy and J. E. Ormrod, *Practical Research: Planning and Design*, 8th editio. Upper Saddle River: Prentice Hall, 2005.
- [86] T. Teangsompong and C. Sritong, "The Structural Equation Model of Nascent Entrepreneurial Behavior among Undergraduate Students in Thailand," *Asia-Pacific Soc. Sci. Rev.*, vol. 21, no. 1, 2021.
- [87] P. M. Podsakoff, S. B. MacKenzie, J. Y. Lee, and N. P. Podsakoff, "Common method biases in behavioral research: a critical review of the literature and recommended remedies," *J. Appl. Psychol.*, vol. 88, no. 5, p. 879, 2003.
- [88] M. G. Patterson, M. A. West, V. J. Shackleton, J. F. Dawson, R. Lawthorn, and S. Matilis, "Validating the organizational climate measure: Links to managerial practices, productivity and innovation," *J. Organ. Behav.*, vol. 26, no. 4, pp. 379–408, 2005.
- [89] G. Milkovich, J. Newman, and B. Gerhart, *Compensation*, Eleventh e. McGraw-Hill Irwin, 2013.
- [90] H. N. Chait and L. Summers, "Commitment in the workplace: theory, research and application," *Pers. Psychol.*, vol. 51, no. 1, pp. 245–248, 1998.
- [91] J. P. De Jong and D. N. Den Hartog, "Innovative work behavior: Measurement and validation," *EIM Bus. Policy Res.*, vol. 8, no. 1, pp. 1–27, 2008.
- [92] L. Hu and P. M. Bentler, "Cutoff criteria for fit indexes in covariance structural analysis: Conventional criteria versus new alternatives," *Struct. Equ. Model.*, vol. 6, pp. 1–55, 1999.
- [93] B. M. Byrne, *Structural Equation Modeling with AMOS: Basic Concepts, Applications, and Programming (Multivariate Applications Series)*. New York: Taylor & Francis Group, 2010.
- [94] C. Fornell and D. . Larcker, "Evaluating structural equation models with unobservable variables and measurement error," *J. Mark. Res.*, vol. 18, no. 1, pp. 39–50, 1981.
- [95] J. F. Hair, W. CB, B. JB, and R. EA, *Multivariate Data Analysis*. NJ: Pearson Prentice Hall, 2010.
- [96] A. F. Hayes and M. Scharkow, "The relative trustworthiness of inferential tests of the indirect effect in statistical mediation analysis: does method really matter?," *Psychol. Sci.*, vol. 24, no. 10, p. 191801927, 2013.
- [97] J. M. Cortina, G. Chen, and W. P. Dunlap, "Testing interaction effects in LISREL: Examination and illustration of available procedures," *Organ. Res. Methods*, vol. 4, no. 4, pp. 324–360, 2001.

-
- [98] D. A. Kenny and C. M. Judd, "Estimating the nonlinear and interactive effects of latent variables," *Psychol. Bull.*, vol. 96, no. 1, pp. 201–210, 1984.
- [99] J. Jaccard and C. K. Wan, "Measurement error in the analysis of interaction effects between continuous predictors using multiple regression: Multiple indicator and structural equation approaches," *Psychol. Bull.*, vol. 117, no. 2, p. 348, 1995.
- [100] K. . Jöreskog, F. Yang, G. Marcoulides, and R. Schumacker, "Nonlinear structural equation models: The Kenny-Judd model with interaction effects," *Adv. Struct. Equ. Model. Issues Tech.*, vol. 3, pp. 57–88, 1996.
- [101] P. C. Chih and P. M. Bentler, "Estimates and tests in structural equation modeling," 1995.
- [102] G. Hofstede, G. J. Hofstede, and M. Minkow, *Cultures and Organizations: Software of the Mind*, 3rd editio. USA: McGraw-Hill, 2010.
- [103] M. Sposato, "Understanding paternalistic leadership: a guide for managers considering foreign assignments," *Strateg. Leadersh.*, 2019.
- [104] E. Fournier, "Leadership: Managing Different Perspectives in the Workplace Using Hofstede Dimensions," *Leadership*, vol. 15, no. 4, 2022.
- [105] P. Mishra, J. Bhatnagar, R. Gupta, and S. M. Wadsworth, "How work–family enrichment influence innovative work behavior: Role of psychological capital and supervisory support," *J. Manag. Organ.*, vol. 25, no. 1, pp. 58–80, 2019, doi: 10.1017/jmo.2017.23.
- [106] O. M. Karatepe, "Procedural Justice, Work Engagement, and Job Outcomes: Evidence from Nigeria," *J. Hosp. Mark. Manag.*, vol. 20, no. 8, pp. 855–878, Nov. 2011, doi: 10.1080/19368623.2011.577688.
- [107] Y. Fu and Z. Lihua, "Organizational justice and perceived organizational support: The moderating role of conscientiousness in China," *Nankai Bus. Rev. Int.*, 2012.
- [108] A. H. Anglin, S. W. Reid, J. C. Short, M. A. Zachary, and M. W. Rutherford, "An archival approach to measuring family influence," *Fam. Bus. Rev.*, vol. 30, no. 1, pp. 19–36, 2017.
- [109] S. K. Ötting and G. W. Maier, "The importance of procedural justice in human–machine interactions: Intelligent systems as new decision agents in organizations," *Comput. Human Behav.*, vol. 89, pp. 27–39, 2018.
- [110] I. Cornelis, A. van Hiel, and D. de Cremer, "Birds of a feather: Leader–follower similarity and procedural fairness effects on cooperation," *Eur. J. Work Organ. Psychol.*, vol. 20, pp. 388–415, 2011.
-

- [111] D. Wang, F.-F. Xiu, and H.-B. Yu, "How knowledge employees' perception of organizational justice affects job performance: the mediating role of work attitude," in *International Conference on Management Science & Engineering*, 2014, pp. 931–936.
- [112] K. P. Hung, N. Peng, and A. Chen, "Incorporating on-site activity involvement and sense of belonging into the Mehrabian-Russell model—The experiential value of cultural tourism destinations," *Tour. Manag. Perspect.*, vol. 30, pp. 43–52, 2019.
- [113] K. Kim, L. Kook-Yong, and 김재선, "Trust, sense of belonging and performance expectation: are these related to team collaboration intention," *J. Manage.*, vol. 10, no. 6, pp. 1137–1154, 2014.
- [114] A. E. Randel *et al.*, "Inclusive leadership: Realizing positive outcomes through belongingness and being valued for uniqueness," *Hum. Resour. Manag. Rev.*, vol. 28, no. 2, pp. 190–203, 2018.
- [115] G. Spreitzer, "Taking stock: A review of more than twenty years of research on empowerment at work," in *The SAGE Handbook of Organizational Behavior: Volume I - Micro Approaches*, SAGE Publications Inc., 2008, pp. 54–72.
- [116] S. Raub and C. Robert, "Empowerment, organizational commitment, and voice behavior in the hospitality industry: Evidence from a multinational sample," *Cornell Hosp. Q.*, vol. 54, no. 2, pp. 136–148, 2013, doi: 10.1177/1938965512457240.
- [117] L. Y. Sun, Z. Zhang, J. Qi, and Z. X. Chen, "Empowerment and creativity: A cross-level investigation," *Leadersh. Q.*, vol. 23, no. 1, pp. 55–65, Feb. 2012, doi: 10.1016/J.LEAQUA.2011.11.005.
- [118] X. Zhang and K. M. Bartol, "Linking empowering leadership and employee creativity: the influence of psychological empowerment, intrinsic motivation, and creative process engagement," *Acad. Manag. J.*, vol. 53, no. 1, pp. 107–128, Feb. 2010, doi: 10.5465/AMJ.2010.48037118.
- [119] L. Zhou, M. Wang, G. Chen, and J. Shi, "Supervisors' upward exchange relationships and subordinate outcomes: Testing the multilevel mediation role of empowerment," *J. Appl. Psychol.*, vol. 97, no. 3, pp. 668–680, 2012, doi: 10.1037/A0026305.
- [120] S. E. Seibert, G. Wang, and S. H. Courtright, "Antecedents and Consequences of Psychological and Team Empowerment in Organizations: A Meta-Analytic Review," *J. Appl. Psychol.*, vol. 96, no. 5, pp. 981–1003, Sep. 2011, doi: 10.1037/A0022676.

Towards a Combination of Metrics for Machine Translation

Mawloud Mosbah

mos_nasa@hotmail.fr

LRES Laboratory, Informatics Department

Faculty of Sciences

University 20 Août 1955 of Skikda, Algeria

Abstract

In this scholar, we compare three metrics for machine translation, from English to French and vice versa, and we give some combination formulas based on some schemes, algorithms, and machine learning tools. As an experimental dataset, we consider 10 English and French theses abstracts published in the web with four free in charge machine translation systems. Five combinations, with the same implicit weights, are considered namely: (BLEU+NIST), (BLEU+ (1-WER)), (NIST+(1-WER)), (BLEU+NIST+(1-WER)), and (FR(BLEU)+FR(NIST)+FR(WER)). These combinations are also considered differently through generating weights parameters on the basis of regression. The results of 12 formulas are computed and compared then in total. According to the obtained results, average regression combinations based on machine learning step are the best, especially with the three basic metrics, followed by average WER metric in the case of English to French. For French to English, (FR(BLEU)+FR(NIST)+FR(WER)) combination is the best followed respectively by the average regression combination with both first parameters (Reg(α, β)) and average BLEU basic metric. Another performance criterion is considered here, in the second position, namely: the number of times, over the 10 abstracts, where the formula is the best. Based on the obtained results, combination with regression based on the first and the last parameters (Reg(α, γ)) outperforms the others, in the case of English to French, with 3 times followed by Reg(β, γ), Reg(α, β, γ), NIST+(1-WER), and the basic metrics (BLEU, NIST, and WER) with 2 times for each of them. For French to English, the basic WER metric outperforms the others with three times followed by BLEU, (BLEU+ (1-WER)), (FR(BLEU)+FR(NIST)+FR(WER)), and Reg(α, γ) with 2 times for each of them. To note that there is a room of improvement for the combinations with 1.0914 in the case of English to French and 1.01 in the case of French to English.

Keywords: Machine Translation, Machine Translation Metrics, Combination of Machine Translation Metrics

1. Introduction

Evaluation is an important operation for any scientific field. Indeed, assessment enables us to know in which degree the addressed model is effective, what is its room of optimization and improvement through analyzing and identifying its various weaknesses, and to compare the model in question with other ones proposed in the literature. For machine translation, evaluation is qualified as a difficult task for the

purpose that there are many possible ways to translate a given source sentence. There are two approaches for machine translation evaluation: manual, subjective, and qualitative assessment, done by human experts, and automatic and objective and numerical evaluation implemented by fully automatic metrics [1]. Three aspects are tied to human evaluation of machine translation: fluency, indicating how natural the evaluation segment sounds to a native speaker, adequacy, judging how much of the information from the original translation is expressed in the output, and acceptability, judging how easy to understand the translation is. Unfortunately, human evaluation is subjective and time consuming. Automatic evaluation proceeds to compare the output segment of the translation to the reference one either through associating a score for each translation [2] or to rank the different translations of the same input [3] to each other. In [4], authors have categorized automatic metrics into deterministic metrics, tending to focus on specific aspects of the evaluation, and learned metrics such as BLANC [5], trying to gather and combine all the aspects into a single metric. According to [6], human evaluation metrics are classified based on the criterion of whether human judges which expresses a so-called subjective evaluation judgment, such as 'good' or 'better than', or not. The former methods are based on directly expressed judgment (DEJ) while the latter are called 'non-DEJ-based evaluation. For the DEJ-based evaluation, there are tasks such as fluency and adequacy annotation, ranking and direct assessment (DA) such as Blend [7] whereas for the non-DEJ-based evaluation, there are tasks like error classification and post-editing.

Unfortunately, as reported in [8], there is no automatic metric that practically outperforms the other metrics of the literature or to well reflect human judgment. Combining automatic metrics seems to be then a good idea with two issues to be tackled, namely: (1) what are the metrics to combine and how many numbers of them and (2) which weight to attribute for each one. The scheme of combining metrics have been previously considered in natural language processing applications such as in information retrieval in the image of f-measure [9] which combines both precision and recall.

To the best of our knowledge, there is only one work, in literature, that deals with combination of evaluation metrics for machine translation as we address here. Indeed, in [10], authors have applied a loss function, as an approach from statistical decision theory for weighted cost estimates, to combine three basic metrics namely: correct response, non-response, and incorrect response rates. However, there are few works that address combination differently such as in [11] where authors have combined automatic metrics for predicting human assessment using binary classifiers and in [12] where author has quoted some works that combines evaluation metrics with error classification and analysis. A regression is also taken into consideration here in different ways as considered in [4] where authors have proceeded to combine different criteria and aspects of machine translation.

The methodology adopted in this paper is as follows: as a purpose, we look for the effective formula that combines three basic evaluation metrics for machine translation systems namely: BLEU, NIST, and WER. Four machine translation systems are considered namely: Google Translate, Prompt, Babylon and Bing over 10 theses abstracts in both English and French. Human expert evaluation, through manual

assessment and judgment of the various returned translation outputs, is also taken into consideration to evaluate the performance of BLEU, NIST, and WER as well as the different considered combinations. Based on each machine translation metric and the different combination metrics, the outputs of the adopted four machine translation systems are ranked. These ranks are compared with those given by human experts using an information retrieval evaluation metric which is NDCG. The performance of the three primitive machine translation metrics and especially their different combinations are assessed then using the NDCG metric.

The rest of the paper is organized as follows: section 2 presents the considered four free in charge machine translation systems. In section 3, we show, in details, the different three considered evaluation metrics for machine translation. Section 4 depicts the different considered combinations with and without regression. Datasets and results with their discussions are given in section 5. In Section 6, we establish a conclusion and we draw some perspectives may be implemented later in our future works.

2. The Considered Free in Charge Machine Translation Systems

In this work, we consider the following four machine translation systems available free in the web:

- *Google Translate* [13]: is a multilingual neural machine translation [14] service developed by Google to translate text, documents and websites from one language to another. As of July 2021, Google Translate supports 109 languages at various levels. Moreover, as of April 2016, Google Translate claimed over 500 million total users, with more than 100 billion words daily translated.
- *Prompt* [15]: is a Russian company focused upon the development of machine translation systems. At the moment, Prompt translator exists for more than 25 languages.
- *Babylon* [16]: is a computer dictionary and translation program developed by the company Babylon Software.
- *Bing* [17]: is a service which allows users to translate text and web pages into different languages using the Microsoft statistical machine translation system.

In addition to the free in charge aspect, the four considered machine translation systems adopt different approaches which enables us to obtain theoretically different results.

3. Machine Translation Metrics

We consider here three statistical metrics to evaluate machine translation namely: *BLEU*, *NIST*, and *WER*.

3.1. BLEU

BLEU (Bi-Lingual Evaluation Understudy) is an automatic metric baptized by *IBM* employing several references [18]. In its simple manner, *BLEU* measures how many sequence of words in the block for text under evaluation (the candidate block text) match the sequence of words of some reference blocks of text. It also contains a penalty for translations whose length differs significantly from that of the reference translation. *BLEU* metric is based firstly on computing *n*-grams (or chunks; that are sequence of words) for both the block of text under evaluation and the reference block of text. Secondly, the clipper chunk Counts for the candidate block text is added and divided by the number of candidate chunks in the reference block of text to compute its modified precision score p_n as follows:

$$p_n = \frac{\sum_{C \in (Candidates)} \sum_{ngrams \in C} Count_{clip}(ngram)}{\sum_{C' \in (Candidates)} \sum_{ngram' \in C'} Count(ngram')} \quad (1).$$

Where: $Count_{clip}(ngram)$ is the maximum number of *n*-grams co-occurring in a candidate translation and a reference translation, and $Count(ngram)$ is the number of *n*-grams in the candidate translation.

Let c be the length of the candidate translation and r be the effective reference block of text length, the brevity penalty *BP*, for preventing very short translations that try to maximize their precision scores, is computed as follows:

$$BP = \begin{cases} 1 & \text{if } c > r \\ e^{(1-r/c)} & \text{if } c \leq r \end{cases} \quad (2)$$

Then

$$BLEU = BP * e^{(\sum_{n=1}^N w_n * \log(P_n))} \quad (3)$$

Where: w_n represents the weights given to the number of words constituting the chunks or *n*-grams. According to [18], the ranking behaviour is more immediately apparent in the logarithm domain as follows:

$$\log(BLEU) = \min\left(1 - \frac{r}{c}, 0\right) + \sum_{n=1}^N w_n \log(P_n) \quad (4)$$

Commonly, the following factors are set as follows: $N=4$ (ie. we use uni-gram, bi-grams, three-grams, and four-grams) and $w_n = 1/N$.

3.2. NIST

NIST (US National Institute of Standards and Technology) score weights more heavily on those *n*-grams occurring less frequently according to their information value [19], [20]. That is to say when a correct *n*-gram is found, the rarer that *n*-gram is, the more weight it will be given. The formula of *NIST* score is given as follows:

$$score_{NIST} = \sum_{n=1}^N \left\{ \frac{\sum_{all W_1..W_n cooccur} Info(W_1..W_n)}{\sum_{all W_1..W_n} (1)} \right\} * e^{\left\{ \beta \log_2 \left[\min \left(\frac{L_{sys}}{L_{ref}}, 1 \right) \right] \right\}} \quad (5)$$

Where:

$$Info(W_1..W_n) = \log_2 \left(\frac{\text{the \# of occurrences of } W_1..W_{n-1}}{\text{the \# of occurrences of } W_1..W_n} \right) \quad (6)$$

L_{ref} is the average length of reference.

L_{sys} is the length of target translation.

β is used as a parameter conditioning penalty translation.

To note that both *BLEU* and *NIST* metrics are not cumulative since they are based on the candidate and reference segments at whole rather than to the addition of its sentences. That is to say it is not needed to identify the different sentences.

3.3. WER

WER (Word Error Rate) represents the percentage of words, which are to be inserted, deleted or replaced in the translation for obtaining the sentence of the reference [21]. It can be computed automatically by using the editing distance between the candidate and the reference sentences.

In the aim to encounter the dependency on the sentences of the reference, several references may be considered for each sentence. Indeed, *mWER* (multi reference *WER*) is a version of *WER* metric where for each sentence the editing distance will be computed with regard to the various references and the smallest one is chosen [22]. Nevertheless, adopting *mWER*, considering many references, presents the drawback of requiring a great human effort to generate references although this effort is worthwhile to be used later for hundreds of evaluations [23]. *aWER* is another version of *WER* which calculates the percentage of words to be inserted, detected or replaced in order to obtain a correct translation. Involving automatically synonyms seems to be an essential pre-processing needed in the case of *aWER*.

It is worthy to note that there are other metrics not considered here such as *METEOR*, *ROUGE*, *TER*, *SER*, and *OOV*. For more information about them, authors may ask [8] and [12].

To evaluate the performance of the ranks, for the four considered machine translation systems, given by *BLEU*, *NIST*, *WER*, and their different combinations, we use the *NDCG*.

3.4. Normalized Discounted Cumulative Gain (NDCG)

Normalized Discounted Cumulative Gain (NDCG) [24] is computed according to the following stages:

Given a number of recommendations or ranks where every recommendation has its associated relevance score. Cumulative Gain (CG), as shown in equation (7), is the sum of all the relevance scores in a recommendation set.

$$CG = \sum_{i=1}^n \text{relevance}_i \quad (7)$$

In order to well distinguish the evaluation of two different recommendations, Cumulative Gain is unfortunately not enough. For overcoming this issue, the computation involves to discount the relevance score by dividing it with the log of the corresponding position.

$$DCG = \sum_{i=1}^n \frac{\text{relevance}_i}{\log_2(i+1)} \quad (8)$$

Alternatively, Discounted Cumulative Gain can be computed using the following expression:

$$DCG = \sum_{I+\&}^N \frac{2^{\text{relevance}_i-1}}{\log_2(i+1)} \quad (9)$$

The recommendation should be measured relatively regarding a reference recommendation called ideal order, whose DCG is $iDCG$. Designating its proper upper and lower bounds simplifies comparison with other recommendations of other characteristics and parameters such as the number of considered elements. Normalized Discounted Cumulative Gain is given then in the following equation:

$$NDCG = \frac{DCG}{iDCG} \quad (10)$$

As we consider here four machine translation systems, the best value of $NDCG$ (which is done manually) is then 10.563.

4. The different Considered Combinations

In this section, we present the different combinations, for the basic metrics, considered here.

4.1. BLEU+NIST

As shown in section 3, both *BLEU* and *NIST* metrics have a trade on with machine translation performance. Adding *BLEU* to the *NIST* value seems then to be an intuitive and a logical combination way to think about for introducing a novel metric, that keeps the trade on relationship, and that we hope to be more effective. In addition, there is no need to weight the *BLEU* and *NIST* values because as shown in experimental results, given previously in [8], their values are each other closed and belong commonly to the same scale which is the $[0, 1]$ range. We associate then the same importance for both considered basic metrics which is implicitly 1. The first considered combination formula is simply given then as follows:

$$\text{formula1} = BLEU + NIST \quad (11)$$

4.2. BLEU+(1-WER)

In the same optic of the formula1, *BLEU* is combined now with *WER* metric. The difference is that *WER* has a trade off with machine translation performance that has a trade on with the *BLEU* metric. For this purpose, we need then to consider (*1-WER*) values that have a trade on with machine translation performance. Since *WER* values belong all to the $[0, 1]$ range, as shown previously in [7], (*1-WER*) values belong too to the same range that of $[0, 1]$. As we attribute the same importance for both values: *BLEU* and (*1-WER*), an implicit weight set as 1 is then enough. The second proposed combination formula is given then as follows:

$$formula2 = BLEU + (1 - WER) \quad (12)$$

4.3. NIST+(1-WER)

With the same thinking way, the third formula combining both *NIST* and (*1-WER*) is given as follows:

$$formula3 = NIST + (1 - WER) \quad (13)$$

4.4. BLEU+NIST+(1-WER)

The fourth formula combining *BLEU*, *NIST*, and (*1-WER*) is given as follows:

$$formula4 = BLEU + NIST + (1 - WER) \quad (14)$$

4.5. FR(BLEU)+FR(NIST)+FR(1-WER)

Another combination way is considering an algebraic expression based on a first rank function for the three basic metrics: *BLEU*, *NIST*, and (*1-WER*). The first rank function for a machine translation system (*MTS*) is given as follows:

$$FR(MTS) = \begin{cases} 1 & \text{if } MTS \text{ is ranked first based on } NDCG \\ 0 & \text{else} \end{cases} \quad (15)$$

The fifth formula is given then as follows:

$$formula5 = FR(BLEU) + FR(NIST) + FR(1 - WER) \quad (16)$$

To note that *FR()* means the metric first ranked.

4.6. Combination based on Regression

A regression, as a statistical notion, refers to the prediction of the value of a dependent variable from the values of one or more independent (explanatory) variables [25]. It is able to show whether changes observed in the dependent variable are associated

with changes in one or more of the explanatory variables. To note that we consider here a multiple regression model because we have more than independent variable (*BLEU*, *NIST*, and *WER*) affecting a dependent variable which is the ranking of machine translation systems measured using *NDCG*.

Four combinations may be considered here, namely:

$$\begin{cases} \alpha BLEU + \beta NIST \\ \alpha BLEU + \gamma(1 - WER) \\ \beta NIST + \gamma(1 - WER) \\ \alpha BLEU + \beta NIST + \gamma(1 - WER) \end{cases} \quad (17)$$

Learning consists then to find the adequate or at least the optimal parameters: α , β , and γ that may give more performance in the test step. Table1 presents an illustrative learning example.

Manual Ranking		BLEU	NIST	(1-WER)
3		Google Translate		
		0.540	0.923	0.303
4		Prompt		
		0.478	0.867	0.289
1		Babylon		
		0.534	0.895	0.282
2		Bing		
		0.504	0.902	0.281

Table 1. An Illustrative Learning Example

According to the example, the different non equalities to find parameters α and β considering only *BLEU* and *NIST* are:

$$\begin{cases} 0.534\alpha + 0.895\beta > 0.504\alpha + 902\beta \\ 0.534\alpha + 0.895\beta > 0.54\alpha + 923\beta \\ 0.534\alpha + 0.895\beta > 0.478\alpha + 0.867\beta \\ 0.504\alpha + 902\beta > 0.54\alpha + 923\beta \\ 0.504\alpha + 902\beta > 0.478\alpha + 0.867\beta \\ 0.54\alpha + 923\beta > 0.478\alpha + 0.867\beta \end{cases} \quad (18)$$

The different non equalities to find parameters α and γ considering only *BLEU* and (*1-WER*) are:

$$\begin{cases} 0.534\alpha + 0.282\gamma > 0.504\alpha + 0.281\gamma \\ 0.534\alpha + 0.282\gamma > 0.54\alpha + 0.303\gamma \\ 0.534\alpha + 0.282\gamma > 0.478\alpha + 0.289\gamma \\ 0.504\alpha + 0.281\gamma > 0.54\alpha + 0.303\gamma \\ 0.504\alpha + 0.281\gamma > 0.478\alpha + 0.289\gamma \\ 0.54\alpha + 0.303\gamma > 0.478\alpha + 0.289\gamma \end{cases} \quad (19)$$

The different non equalities to find parameters β and γ considering only *NIST* and (*1-WER*) are:

$$\begin{cases} 0.895\beta + 0.282\gamma > 0.902\beta + 0.281\gamma \\ 0.895\beta + 0.282\gamma > 0.923\beta + 0.303\gamma \\ 0.895\beta + 0.282\gamma > 0.867\beta + 0.289\gamma \\ 0.902\beta + 0.281\gamma > 0.923\beta + 0.303\gamma \\ 0.902\beta + 0.281\gamma > 0.867\beta + 0.289\gamma \\ 0.923\beta + 0.303\gamma > 0.867\beta + 0.289\gamma \end{cases} \quad (20)$$

The different non equalities to find parameters α , β , and γ considering *BLEU*, *NIST*, and (*1-WER*) are:

$$\begin{cases} 0.534\alpha + 0.895\beta + 0.282\gamma > 0.504\alpha + 0.902\beta + 0.281\gamma \\ 0.534\alpha + 0.895\beta + 0.282\gamma > 0.54\alpha + 0.923\beta + 0.303\gamma \\ 0.534\alpha + 0.895\beta + 0.282\gamma > 0.478\alpha + 0.867\beta + 0.289\gamma \\ 0.504\alpha + 0.902\beta + 0.281\gamma > 0.54\alpha + 0.923\beta + 0.303\gamma \\ 0.504\alpha + 0.902\beta + 0.281\gamma > 0.478\alpha + 0.867\beta + 0.289\gamma \\ 0.54\alpha + 0.923\beta + 0.303\gamma > 0.478\alpha + 0.867\beta + 0.289\gamma \end{cases} \quad (21)$$

As we can see, there are six non-equalities for each combination which gives 60 non-equalities in total (over the 10 considered abstracts). These non-equalities are solved using an experimental simple automatic algorithm with 0.01 as a walking step for the different considered parameters (α , β , and γ). The best configuration of the parameters is which satisfies the great number of non-equalities let alone all the 60 non-equalities.

5. Experimental Results

5.1. Dataset and Tools

We consider English and French abstracts for 10 theses published in the web. Four free in charge web machine translation systems, based on various schemes, are used, namely: *Google Translate*, *Prompt*, *Babylon*, and *Bing*. Three basic metrics are adopted namely: *BLEU*, *NIST*, and *WER*. For combination based on regression, we use 10 abstracts for English and French. In total, the machine learning dataset is composed of 100 texts over both languages (20 references + 80 results). For combination based on regression, we consider 60 non equalities for English to French (6 non equalities over 10 learning examples) and the same number for French to English. To solve these non equalities and find parameter weights α , β , and γ , we consider a walking step of 0.01. We consider then two respective sub-sections for presenting results namely: from English to French and from French to English.

Theses Abstractions	Characteristics			
	# of Abstract in Words		# of Abstract in Sentences	
	In English	In French	In English	In French
Thesis #1	264	294	14	13
Thesis #2	295	293	10	09
Thesis #3	289	372	07	07
Thesis #4	317	439	15	15
Thesis #5	250	275	10	08
Thesis #6	578	767	25	27
Thesis #7	170	188	09	07
Thesis #8	275	313	12	12
Thesis #9	287	312	11	11
Thesis #10	301	379	11	10
Total	3026	3632	124	119

Table 2. The characteristics of the considered dataset

5.2. From English to French

Theses Abstractions	Manual Performance	The performance of the primitive metrics		
		BLEU	NIST	WER
#1	10.563	10.463	10.031	9.31
#2		10.12	9.31	10.463
#3		9.654	9.365	9.986
#4		9.365	7.911	10.175
#5		10.563	8.299	9.365
#6		8.544	9.986	8.488
#7		8.011	10.563	9.31
#8		10.375	8.821	9.121
#9		8.011	8.544	9.365
#10		8.011	8.821	8.444

Table 3. The performance of the considered primitive metrics

Theses Abstractions	The performance of the different considered combination formulas				
	BLEU+ NIST	BLEU+ (1-WER)	NIST+ (1-WER)	BLEU+NIST+ (1-WER)	FR(MTS)
#1	10.031	10.175	9.31	10.031	10.563
#2	10.563	9.931	10.375	10.563	9.654
#3	9.654	9.654	9.931	9.654	9.931
#4	8.299	9.986	10.086	7.911	9.365
#5	10.086	10.463	8.299	8.299	10.086
#6	8.544	8.011	8.388	8.388	9.11
#7	10.175	9.11	10.375	9.31	8.388
#8	6.524	9.31	8.821	9.121	9.11
#9	8.544	8.388	8.299	9.11	7.911
#10	8.444	8.544	8.821	8.444	8.544

Table 4. The performance of the different considered combination formulas without regression

Theses Abstractions	The performance of the different metric combinations based on regression			
	$\alpha BLEU + \beta NIST$	$\alpha BLEU + \gamma(1 - WER)$	$\beta NIST + \gamma(1 - WER)$	$\alpha BLEU + \beta NIST + \gamma(1 - WER)$
#1	10.031	9.31	9.31	9.31
#2	10.563	10.375	10.463	10.463
#3	9.654	10.563	10.463	10.563
#4	8.299	10.175	10.175	10.175
#5	10.086	9.365	9.365	9.11
#6	8.544	8.488	8.388	9.11
#7	10.175	9.31	9.31	9.31
#8	6.524	9.121	9.121	9.121
#9	8.544	9.365	9.365	9.11
#10	8.444	8.444	8.444	8.444
Number of verified non equalities	35	34	32	37
Different parameters	$\alpha = 0.01, \beta = 0.01$	$\alpha = 0.04, \gamma = 0.99$	$\beta = 0.05, \gamma = 0.96$	$\alpha = 0.06, \beta = 0.03, \gamma = 0.99$

Table 5. The performance of the different metric combinations based on regressio.

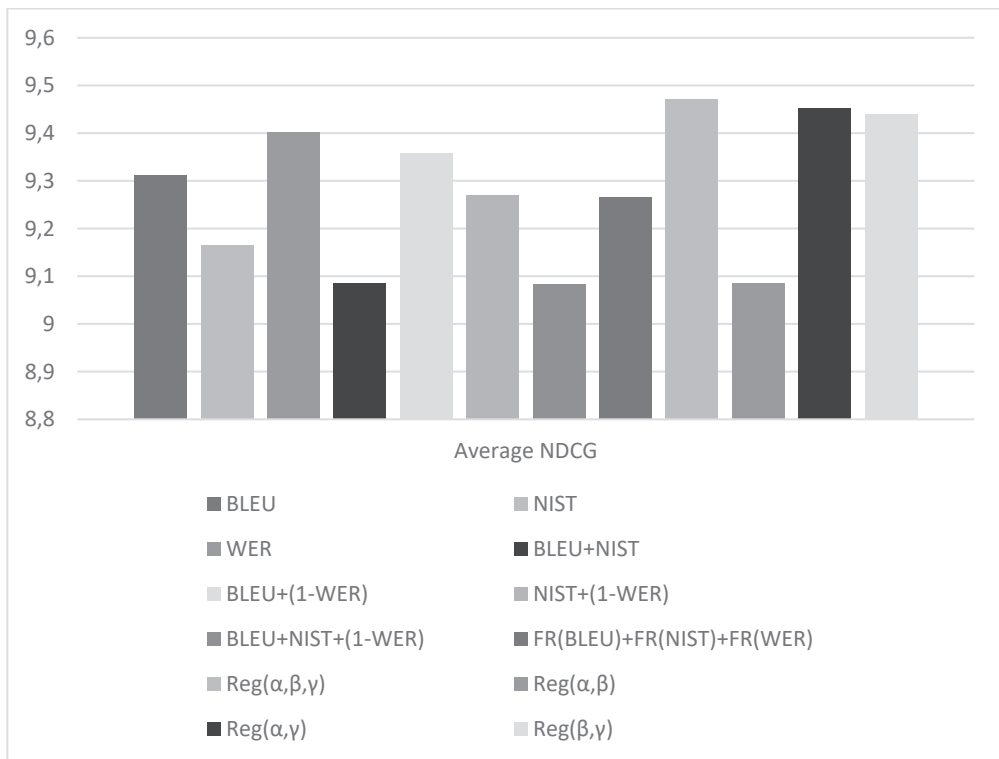


Figure 1. The considered primitive machine translation metrics and their various combinations in the case of 'From English to French'

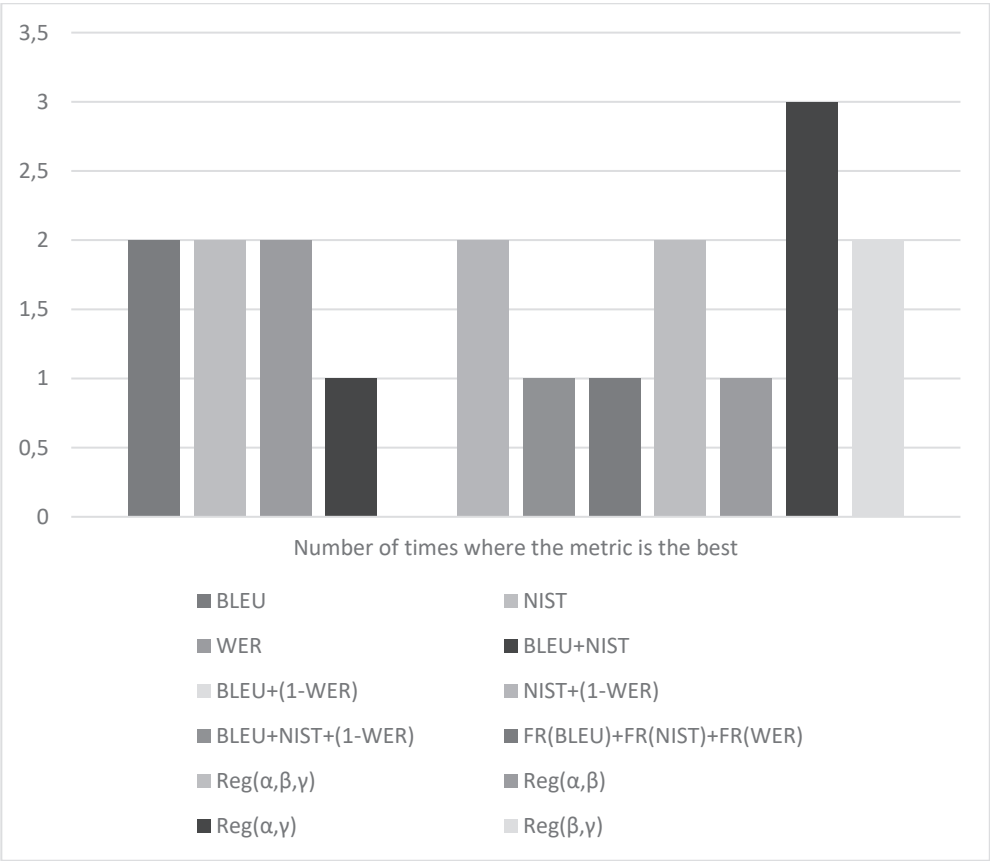


Figure 2. The number of times where the metric, from those considered and their combinations, is the best, in the case of ‘From English to French’

5.3. From French to English

Theses Abstractions	Manual Performance	The performance of the primitive metrics		
		BLEU	NIST	WER
#1	10.563	8.544	8.544	10.031
#2		9.31	9.121	7.911
#3		9.654	8.544	8.488
#4		9.121	9.11	10.463
#5		9.365	8.488	10.563
#6		8.488	9.354	8.011
#7		9.986	10.031	8.388
#8		10.463	9.931	8.821
#9		9.654	10.563	8.299
#10		8.488	9.165	9.664

Table 6. The performance of the considered primitive metrics

Theses Absts	The performance of the different considered combination formulas				
	BLEU+ NIST	BLEU+ (1-WER)	NIST+ (1-WER)	BLEU+NIST+ (1-WER)	BLEU or NIST or WER
#1	8.544	8.544	8.544	8.544	9.31
#2	9.31	10.175	9.31	9.31	8.544
#3	9.31	9.31	9.121	9.31	8.544
#4	9.31	9.121	9.31	9.121	9.509
#5	8.821	10.563	10.031	9.654	10.544
#6	10.175	8.011	7.739	8.388	10.463
#7	10.031	8.388	10.563	10.086	10.463
#8	8.099	8.388	9.354	8.099	9.31
#9	9.654	9.354	9.365	9.654	10.031
#10	8.299	8.444	8.821	8.444	8.821

Table 7. The performance of the different considered combination formulas without regression

Theses Absts	The different metric combinations based on regression			
	$\alpha BLEU + \beta NIST$	$\alpha BLEU + \gamma WER$	$\beta NIST + \gamma WER$	$\alpha BLEU + \beta NIST + \gamma WER$
#1	8.821	10.175	9.986	10.175
#2	9.31	8.299	8.299	8.299
#3	9.31	8.544	8.544	8.544
#4	10.375	8.388	8.011	8.011
#5	10.175	10.563	10.031	10.031
#6	8.444	8.388	8.388	8.011
#7	9.354	8.444	10.175	10.175
#8	10.463	9.121	9.121	9.121
#9	10.031	9.165	9.165	9.165
#10	7.911	9.165	9.165	9.354
Number of verified non equalities	30	35	35	35
Parameters	$\alpha = 0.01, \beta = 0.03$	$\alpha = 0.04, \gamma = 0.97$	$\beta = 0.01, \gamma = 0.97$	$\alpha = 0.01, \beta = 0.03, \gamma = 0.89$

Table 8. The performance of the different considered combination formulas without regression.

5.4. Discussions

- Two performance evaluation criteria have been considered, here, in both cases: from English to French and vice versa. Firstly, the average accuracy computed by the automatic NDCG metric which measures the closeness of the various ranks, for the four adopted translators, given by the different formulas regarding the reference rank generated from the evaluation done by human experts. Secondly, the number of times where the formula is the best over the ten considered abstracts.
- Unfortunately, the solutions given, in the case of regression, do not satisfy all the considered 60 non-equalities. The best solution satisfies only 37 in both senses

‘from English to French’ and vice versa. Considering step value more little than 0.01 may improve the performance.

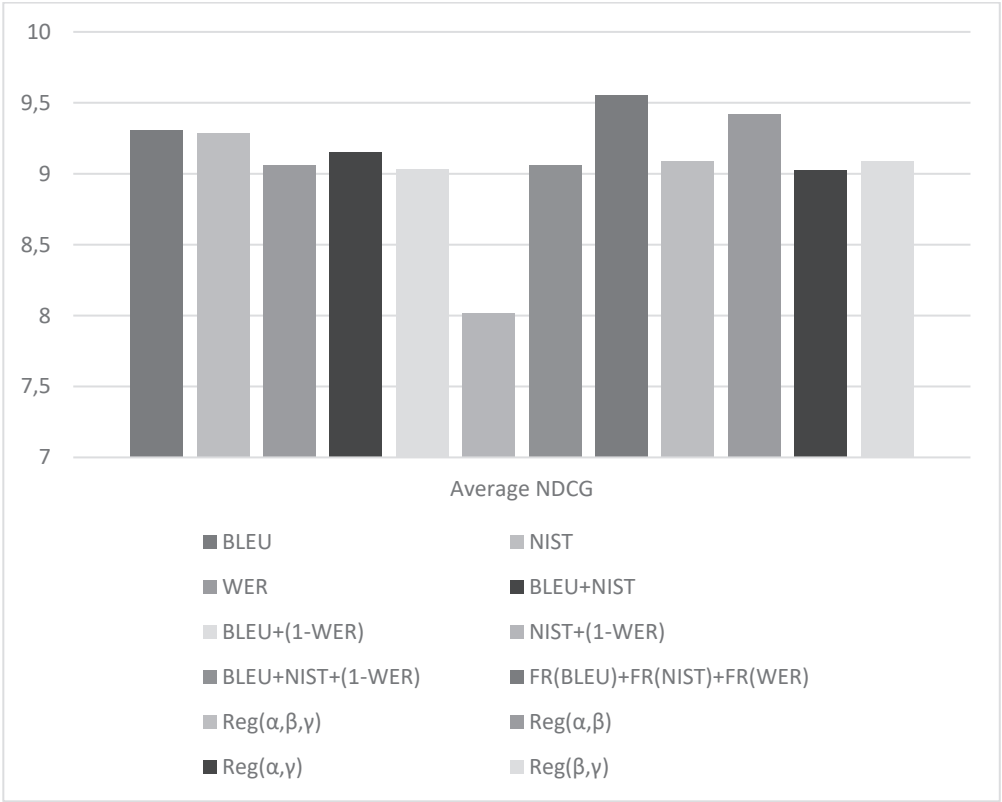


Figure 3. The considered primitive machine translation metrics and their various combinations in the case of ‘From French to English’

5.4.1. From English to French

- In terms of *NDCG*, Regression, with its respective three combinations ($Reg(\alpha,\beta,\gamma)$, $Reg(\alpha,\gamma)$, and $Reg(\beta,\gamma)$), outperforms the others followed by the basic *WER* metric. Unfortunately, regression with the first and the second parameter weights ($Reg(\alpha,\beta)$) downgrades the performances as well as ($BLEU+NIST$) and ($BLEU+NIST+(1-WER)$).
- In terms of number of times where the formula is the best, $Reg(\alpha,\gamma)$ outperforms the others with 3 times followed by ($NIST+(1-WER)$), $Reg(\alpha,\beta,\gamma)$, $Reg(\beta,\gamma)$, and the three basic metrics (*BLEU*, *NIST*, and *WER*) with 2 times for each one. ($BLEU+(1-WER)$) is the only formula where there is no time to be the best.
- Although the scope of this work is to test the possible different combinations of the basic metrics for machine translation systems, it is worthy to note that the rank in terms of performance for the three considered primitive metrics is as follows: *WER*, *BLEU*, and *NIST*.

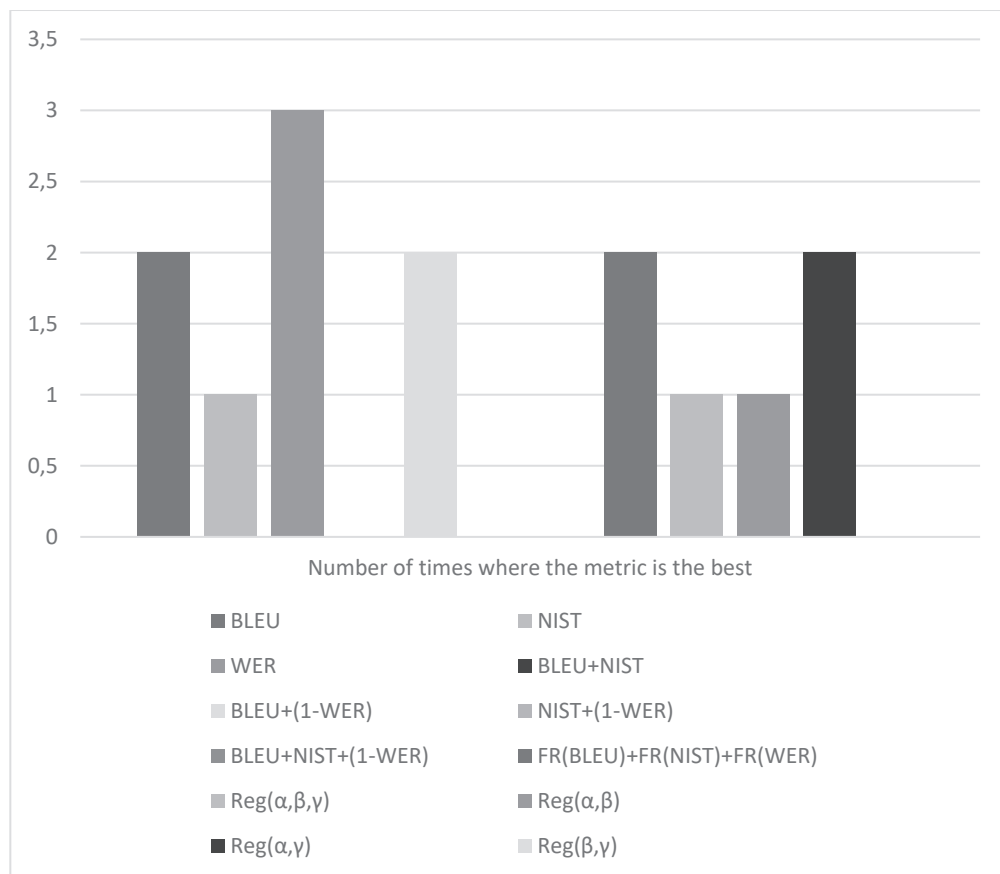


Figure 4. The number of times where the metric, from those considered and their combinations, is the best, in the case of 'From French to English'

5.4.2. From French to English

- (FR(BLEU)+FR(NIST)+FR(WER)) outperforms the others followed respectively by Reg(α, β), BLEU and NIST. Unfortunately, all the other combinations downgrade the performances regarding to the primitive metrics especially BLEU and NIST.
- In terms of number of times where the formula is the best, WER is the best with (three times followed by BLEU, (BLEU+(1-WER)), FR(BLEU)+FR(NIST)+FR(WER)), and Reg(α, γ). Unfortunately, (BLEU+NIST), (NIST+(1-WER)), and (BLEU+NIST+(1-WER)) are the formulas where there is no time to be the best.
- Although the scope of this work is to test the possible different combinations of the basic metrics for machine translation systems, it is worthy to note that the rank in terms of performance for the three considered primitive metrics is as follows: BLEU, NIST, and WER.

6. Conclusion

In this paper, we have tested the effectiveness of the combination for the basic machine translation metrics. Two kinds of combination have been considered: a simple combination with the same implicit parameter weight for each primitive adopted metric, and a combination with regression which designates the parameter weights for each considered basic metric. According to the results obtained, combination may improve performance compared with the basic metrics but it is not always the case. Indeed, some combinations may downgrade basic performance but there are always some ones which upgrade it. There is no specific combination which guarantees performance improvement in both senses 'from English to French' and vice versa. In total, combinations based on regression, which relies on a machine learning collection, are very promising in both senses. Unfortunately, we have considered here only three basic machine translation metrics with only one evaluation metric namely *NDCG*. In the future works, we hope to adopt more primitive machine translation metrics as well as more evaluation metrics and not only *NDCG*.

References

- [1] Chauhan, S., & Daniel, P. (2022). A Comprehensive Survey on Various Fully Automatic Machine Translation Evaluation Metrics. *Neural Processing Letters*, 1-55.
- [2] Przybocki, M., Peterson, K., & Bronsart, S. (2008). Metrics for Machine Translation Challenge (MetricsMATR08). <http://nist.gov/speech/tests/metricsmatr/2008/results>.
- [3] Callison-Burch, C., Koehn, P., Monz, C., Peterson, K., Przybocki, M., & Zaidan, O. (2010). Findings of the 2010 joint workshop on smt and metrics for machine translation. In *Proceedings of the Joint Fifth Workshop on SMT and MetricsMATR*, pages 17-53, Uppsala, Sweden. Association for Computational Linguistics.
- [4] Albrecht, J. S., & Hwa, R. (2008). Regression for machine translation at the sentence level. *Machine Translation*, 22(1), 1-27.
- [5] Lita, L. V., Rogati, M., & Lavie, A. (2005, October). Blanc: Learning evaluation metrics for mt. In *Proceedings of Human Language Technology Conference and Conference on Empirical Methods in Natural Language Processing* (pp. 740-747).
- [6] Chatzikoumi, E. (2020). How to evaluate machine translation: A review of automated and human metrics. *Natural Language Engineering*, 26(2), 137-161.
- [7] Ma, Q., Graham, Y., Wang, S., & Liu, Q. (2017, September). Blend: a novel combined MT metric based on direct assessment--CASICT-DCU

- submission to WMT17 metrics task. In Proceedings of the second conference on machine translation (pp. 598-603).
- [8] Mosbah, M. Web Meta-Machine Translation System based on Voting Algorithm. *International Journal of Web Science* (In Press).
 - [9] Makhoul, J., Kubala, F., Schwartz, R., & Weischedel, R. (1999, February). Performance measures for information extraction. In Proceedings of DARPA broadcast news workshop (Vol. 249, p. 252).
 - [10] Tate, C., & Voss, C. (2006). Combining evaluation metrics via loss functions. In Proceedings of the 7th Conference of the Association for Machine Translation in the Americas: Technical Papers (pp. 242-250).
 - [11] Paul, M., Finch, A., & Sumita, E. (2012). Predicting human assessment of machine translation quality by combining automatic evaluation metrics using binary classifiers. *International Journal of Computer Applications*, 59(10), 9581-406.
 - [12] Rivera-Trigieros, I. (2022). Machine translation systems and quality assessment: a systematic review. *Language Resources and Evaluation*, 56(2), 593-619.
 - [13] <https://www.translate.google.com> visited on September 07th 2021.
 - [14] Dabre, R., Chu, C., & Kunchuttan, A. (2020). A survey of multilingual neural machine translation. *ACM Computing Surveys (CSUR)*, 53(5), 1-38.
 - [15] <https://www.online-translator.com/traduction> visited on September 07th 2021.
 - [16] <https://www.babylon-software.com/?lang=fr> visited on September 07th 2021.
 - [17] <https://www.bing.com/translator> visited on September 07th 2021.
 - [18] Papineni, K., Roukos, S., Ward, T., & Zhu, W. J. (2002, July). Bleu: a method for automatic evaluation of machine translation. In Proceedings of the 40th annual meeting of the Association for Computational Linguistics (pp. 311-318).
 - [19] Doddington, G. (2002, March). Automatic evaluation of machine translation quality using n-gram co-occurrence statistics. In Proceedings of the Second International Conference on Human Language Technology Research (pp. 138-145).
 - [20] Qin, Y., Q., & Wang, J. (2009, September). Automatic evaluation of translation quality using expanded N-gram co-occurrences. In 2009 International Conference on Natural Language Processing and Knowledge Engineering (pp. 1-5).

- [21] Vidal, E. (1997, April). Finite-state speech-to-speech translation. In 1997 IEEE International Conference on Acoustic, Speech and Signal Processing (Vol. 1, pp. 111-114). IEEE.
- [22] Niesen, S., Och, F. J., Leusch, G., & Ney, H. (2000, May). An Evaluation Tool for Machine Translation: Fast Evaluation for MT Research. In LREC.
- [23] Tomas, I., Mas, J. A., Casacuberta, F. (2003, April). A quantitative method for machine translation evaluation. In Proceedings of the EACL 2003 Workshop on Evaluation Initiatives in Natural Language Processing: are evaluation methods, metrics and resources reusable? (pp. 27-34).
- [24] Järvelin, K., Kekäläinen, J. Cumulative Gain-based evaluation of IR techniques. ACM Transactions on Information Systems (TOIS). 2002; 20(4): 422-446.
- [25] Mousavi, S. M. N., & Nagy, J. (2021). Evaluation of plant characteristics related to grain yield of FAO410 and FAO340 hybrids using regression models. Cereal Research.

Publication Ethics; List of Reviewers; Instructions for Authors

1. Publication Ethics

The Journal of Information and Organizational Sciences (JIOS) upholds the highest standards of publication ethics and takes all possible measures against any publication malpractices.

1.1. Duties of the Editor

The editor is responsible for maintaining the integrity of the academic record, for having processes in place to assure the quality of the published material as well as for precluding business needs from compromising intellectual and ethical standards.

The editor selects reviewers for papers, decides on the required revisions and the acceptance of the paper in accordance with the reviewers' recommendation.

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.

1.1.2. Confidentiality

The editor must not disclose any information about a manuscript submitted to anyone other than the corresponding author, reviewers, potential reviewers, other advisory board members, and the publisher, as appropriate.

1.1.3. Disclosure and Conflicts of Interest

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.

1.2. Duties of Reviewers

1.2.1. *Contribution to Editorial Decisions*

Papers will be published in JIOS after a double-blind peer-reviewed process. Reviewers advise the editor. Reviewers do not know the author's identity and their comments to the editor are confidential and will be made anonymous before they are passed on to the author. The names of the reviewers remain strictly confidential, with their identities known only to the editor.

1.2.2. *Promptness*

Any selected reviewer who feels unqualified to review the research reported in a manuscript or knows that its prompt review will be impossible, should notify the editor and withdraw from the review process.

1.2.3. *Confidentiality*

Any manuscripts received for review must be treated as confidential documents. They must not be disclosed to or discussed with others except as authorized by the editor.

1.2.4. *Standards of Objectivity*

Reviews should be conducted objectively. Personal criticism of the author is inappropriate. Reviewers should express their views clearly with supporting arguments, if necessary with explanation.

1.2.5. *Acknowledgement of Sources*

Reviewers should identify relevant published work that has not been cited by the authors. They should point out whether observations or arguments derived from other publications are accompanied by the respective source. Reviewers will notify track directors or the editor of any substantial similarity or overlap between the manuscript under consideration and any other published paper of which they have personal knowledge.

1.2.6. *Disclosure and Conflict of Interest*

Privileged information or ideas obtained through the review process must be kept confidential and not used for personal advantage. Reviewers should not consider manuscripts in which they have conflicts of interest resulting from competitive, collaborative, or other relationships or connections with any of the authors, companies, or institutions associated with the papers.

1.3. Duties of Authors

1.3.1. Reporting Standards

Authors of manuscripts should present an accurate account of the work performed as well as an objective discussion of its significance. Underlying data should be represented accurately in the manuscript. A manuscript should contain sufficient detail and references to permit others to replicate the work. Fraudulent or knowingly inaccurate statements constitute unethical behaviour and are unacceptable.

1.3.2. Data Access and Retention

Authors may be asked to provide the raw data in connection with a manuscript for review and should be prepared to provide public access to such data, if practicable, and should in any event be prepared to retain such data for a reasonable time after publication.

1.3.3. Originality and Plagiarism

The authors should ensure that they have written entirely original works, and if the authors have used the work and/or words of others, that this has been appropriately cited or quoted. Plagiarism takes many forms, including the touting of material contained in another paper (of the same authors or some other author) with cosmetic changes as a new paper, copying or paraphrasing substantial parts of another's paper (without attribution), and claiming results from research conducted by others. In all its forms plagiarism constitutes unethical publishing behaviour and is unacceptable.

1.3.4. Acknowledgement of Sources

Proper acknowledgment of the work of others must always be given. Authors should cite publications that have been influential in determining the nature of the reported work.

1.3.5. Multiple, Redundant or Concurrent Publication

An author should not in general publish manuscripts describing essentially the same research in more than one journal or primary publication. Submitting the same manuscript to more than one journal or conference concurrently constitutes unethical publishing behavior and is unacceptable.

1.3.6. Authorship of the Paper

Authorship should be limited to those who have made a significant contribution to the conception, design, execution, or interpretation of the reported study. All those who have made significant contributions should be listed as co-authors. Where there are

others who have participated in certain substantive aspects of the manuscript, they should be acknowledged or listed as contributors.

The corresponding author should ensure that all appropriate co-authors and no inappropriate co-authors are included on the manuscript, and that all co-authors have seen and approved the final version of the manuscript and have agreed to its submission for publication.

1.3.7. Fundamental Errors in Published Work

When an author discovers a significant error or inaccuracy in his/her own published work, it is the author's obligation to promptly notify the editor or publisher and cooperate with the editor to retract or correct the paper.

If the editor or the publisher learn from a third party that a published work contains a significant error, it is the obligation of the author to promptly retract or correct the paper or provide evidence to the editor of the correctness of the original paper.

1.3.8. Disclosure and Conflicts of Interest

All authors should disclose in their manuscript any financial or other substantive conflict of interest that might be construed to influence the results or interpretation of their manuscript. All sources of financial support for the paper should be disclosed.

1.3.9. Publisher's Confirmation

In cases of alleged or proven scientific misconduct, fraudulent publication or plagiarism the publisher, in close collaboration with the editors, will take all appropriate measures to clarify the situation and to amend the paper in question. This includes the prompt publication of an erratum or, in the most severe cases, the complete retraction of the affected work.

2. List of Reviewers

Gokhan Kerse, Kafkas University, Turkey
Lukasz Zakonnik, Lodz University, Poland
Alen Lovrenčić, Sveučilište u Zagrebu, Croatia
Bojan Žugec, Sveučilište u Zagrebu, Croatia
Jan Paralič, Technical University of Košice, Slovakia
Jasminka Dobša, Sveučilište u Zagrebu, Croatia
Goran Hajdin, Sveučilište u Zagrebu, Croatia
Kornelije Rabuzin, Sveučilište u Zagrebu, Croatia
Mohamed Shaheim Patel, Institute of Commerce and Management at Regent, Southern Africa
Riad Sahara, University of Siber Asia, Indonesia
Olga Kanishcheva, Friedrich Schiller University Jena, Germany
Ivana Čavar, Sveučilište u Zagrebu, Croatia
Mike Joy, University of Warwick, United Kingdom
Deepak Kumar Raj, NIT Durgapur, Indonesia
Violeta Vidaček Hainš, Sveučilište u Zagrebu, Croatia
Mihalj Bakator, University of Novy Sad, Serbia
Sandra Lovrenčić, Sveučilište u Zagrebu, Croatia
Igor Balaban, Sveučilište u Zagrebu, Croatia
Ruben Picek, Sveučilište u Zagrebu, Croatia
Andrei Yermolenko, Universty of Nevada, USA
Mario Konecki, Sveučilište u Zagrebu, Croatia
Tayfun Arar, Kırıkkale University, Turkey
Attila Pethoe, Universty of Debrecan, Hungary
Radoslava Stankova Krалеva, South-West University "Neofit Rilski, Bulgaria
Neven Vrčec, Sveučilište u Zagrebu, Croatia
Dušan Barać, University of Belgrade, Serbia
Iva Gregurec, Sveučilište u Zagrebu, Croatia
Sahab Kareem, Erbil Polytechnic University, Iraq
Kristina Detelj, Sveučilište u Zagrebu, Croatia

William Steingartner, Technical University of Košice, Slovakia

Emily Maria K. Jose, Velore Institute of Technology, India

Joana Kosho, Xhuvani University, Albania

Marko Hell, University of Split, Croatia

Lana Žaja, Croatian State Archives, Croatia

3. Instructions for Formatting JIOS Articles

Alen Lovrenčić

alen.lovrencic@foi.hr

University of Zagreb, Faculty of

Organization and Informatics, Varaždin, Croatia

Goran Hajdin

goran.hajdin@foi.hr

University of Zagreb, Faculty of

Organization and Informatics, Varaždin, Croatia

First Name Middle Name Last Name

email.address@domain

Full Institution/Organization/Company Name

City/Town, Country

Abstract

This document describes the required formatting of JIOS papers, including margins, fonts, citation styles, and figure placement. While the format requirements are only compulsory for final submissions, we strongly encourage authors to adopt this template, as well as its recommendations throughout the submission process. Abstract must not exceed 150 words. The abstract appears at the beginning of the paper, indented 0,5 cm from the left and right margins. The title "Abstract" should appear in bold face 11 pt, centered above the body of the abstract. The abstract body should be in 10 pt. Spacing between Abstract and author(s) affiliations is 36 pt, and spacing between "Abstract" title and abstract text is 6pt.

Keywords: formatting instructions, Microsoft word template, JIOS

3. Introduction

To ensure that all articles published in the journal have a uniform appearance, authors must produce a PDF document that meets the formatting specifications outlined in this document. The same document will be used for digital and hard copy version of the journal. Paper submission must be made in one ZIP archive which must include source document (ie. MS Word file) and PDF. When crating PDF make sure all fonts are embedded.

This document briefly describes and illustrates format used by JIOS journal. Your article should look as similar as possible to this document. This template can be obtained form journal web site at the address <http://www.jios.foi.hr>. Below the basic specifications, including font sizes, margins, etc. will be outlined. We encourage you to use this sample in case of any dilemma. For any questions you cannot decide, feel free to contact JIOS.

JIOS is published twice a year. 1st volume is published 30th of June, and 2nd volume 31st of December. All papers that enter copyediting process at least one month 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.

4. Format and Margins

Papers must be in the single column format as shown in the enclosed sample. The page format should be set to B5. Left, right and top margin should be set to 2,2 cm while bottom margin should be set to 2,5 cm. Headers should be 1,27 cm from top and footer should be 2,18 cm from bottom of page. Title should be 36 pt below the header.

4.1. Fonts

You should use Times Roman style fonts. Please, do not use any non-standard fonts in your paper. They could make problems in formatting of the paper, as well as in printing.

4.2. Authors

Authors' names should appear in designated areas below the title of the paper in 12 pt bold type. Authors' affiliations and complete addresses should be in italics 11 pt, and their email addresses in 10 pt italic. If author is part of institution, organization or company, information should include full author name, full institution/organization/company name, town/city and country. If author is publishing as a private person, information should include full author name, full address (street address and number), town/city and country. Authors' affiliations and email address must be aligned according to the left and right paper margin.

4.3. Title, Headings and Sections

The title of the paper should be in 14 pt bold. When necessary, headings should be used to separate major sections of your paper. First headings should be in 12 pt bold and second headings should be in 11 pt bold. The text and body of the paper should be in 11 pt. Third-level headings should also be in 11 pt italic. Each heading should have 18 pt spacing above and 6 pt spacing below it. Do not skip a line between paragraphs. After a heading, the first sentence should not be indented.

Paper title and all headings should be capitalized. Please refer to Rules for Capitalization in Titles regarding capitalization of paper title and section headings.

References to sections (as well as figures, tables, theorems and so on), should be capitalized, as in "In Section 4, we show that...".

4.4. Figures and Tables

Figures and tables should be inserted in proper places throughout the text. Do not group them together at the beginning of a page, nor at the bottom of the paper. Number figures sequentially, e.g., Figure 1, and so on.

The figure or table number and the caption should appear under the illustration. Spacing around caption should be 6 pt above and 11 pt below. Captions, labels, and other text in illustrations must be at least 9 pt.

	CPU Speed	Wage
A		
B		
C		

Table 1. Note well that JIOS expects table captions below the table. $\geq$ 9pt font.

We strongly suggest not to use color figures and pictures. Authors are responsible for providing grayscale figures and pictures without any loss of information.

When placing figures and tables in the paper please keep in mind possible blank spaces which might appear at the bottom of some pages. Please relocate paper elements (tables, figures and text) to fill existing blanks. While doing so pay attention not to create new ones.

4.5. Headers and Footers

Headers and Footers should be in 9 pt. All information in headers should be in small caps, respecting capital first letters. The first page of your article should include the short journal name, volume, number and year in the upper left corner, and the submission date and acceptance date in the upper right corner. The editor will let you know the volume, number, year, submission date and acceptance date.

On the even numbered pages, the header of the page should be the authors' names in the upper left corner and short title of the paper in the upper right corner. If paper title is too long to fit in the header (maximum 40 characters), please shorten the title and add three dots (...) at the end. Please do not abbreviate any title words. On the odd pages, starting with page 3, the header should be the full name of the journal, aligned right.

4.5.1. Page Numbering

Please do not add any page numbers in the article. They will be assigned by the publishing board at the bottom of the page in the center, as well as added in the footer of the article.

4.5.2. *Footnotes*

We encourage authors to use footnotes sparingly, especially since they may be difficult to read online. Footnotes should be numbered sequentially and should appear at the bottom of the page, as shown below.¹

4.6. **References**

The reference section should be labeled "References" and should appear at the end of the paper. References must be ordered according to their appearance in the paper. Please prepare complete and accurate citations. References should be formatted according to the IEEE Citation reference. Do not include references that are not cited in the text of the paper.

Citations within the text should include the number of the reference in the reference section in the brackets, for example [1]. Multiple citations should be separated by a colon, as in [1], [2].

Acknowledgements

The acknowledgments section, if included, appears after the main body of the text and is headed "Acknowledgments." The section should not be numbered. This section includes acknowledgments of help from associates and colleagues, financial support, and permission to publish..

Appendix A: Title of the Appendix

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].
- [2] References should be indented on the left side by 0,63 cm and hanging must be set to 0,83 cm.
- [3] Hyperlinks should be formatted as plain text and without underline formatting.
- [4] All references should be aligned left.

¹ A footnote should appear like this. Please ensure that your footnotes are complete, fully punctuated sentences.

Contact

Alen Lovrenčić
University of Zagreb
Faculty of Organization and Informatics
Pavilinska 2, HR-42000 Varaždin, Croatia
Tel.: +385 42 390 866
Fax: +385 42 213 413
E-mail: alen.lovrencic@foi.unizg.hr
E-mail: jios@foi.hr (Correspondence Mail)
jios-pub@foi.hr (Publishing Board)
URL: www.jios.foi.hr

JIOS is indexed in the following repositories and portals

Academic Journals Database
Academic Resource Index
Advanced Science Index
BASE
Central and Eastern European Online Library (CEEOL)
CORE
Crossref
CWTJ Journal Indicators
Dimensions
Directory of Open Access Scholarly Resources (ROAD)
Directory of Open Access Journals (DOAJ)
Directory of Research Journals Indexing (DRJI)
Elektronische Zeitschriftenbibliothek
ERIH PLUS
EuroPub – Directory of Academic and Scientific Journals
Genamics JournalSeek
Google Scholar
Hrčak - Central portal of Croatian scientific journals
Index Copernicus
Internet Archive
Information Matrix for the Analysis of Journals (MIAR)
International Journal Impact Factor (IJIFACTOR)
J-Gate
JournalTOCs
LENS.ORG
Microsoft Academic
OALster
Open AIRE
Open Academic Journals Index (OAJI.net)
PRADEC
Scientific Indexing Services (SIS)
Scilit
Sherpa Romeo
Ulrich's Periodicals Directory
VINITI RAN
WorldCat
World Journal Clout Index Report (WJCI)

www.jios.foi.hr

Proofreading

Authors

Copyeditor and Computer Type Set

Goran Hajdin
Mladen Konecki

Cover and Layout Design

ri mo dizajn

Printing

Printera Grupa d.o.o., Sveta Nedelja, Croatia

JIOS is indexed in the following databases

SCOPUS
Emerging Sources Citation Index (ESCI) - WoS
Academic Search Complete (EBSCO)
Academic Search Elite (EBSCO)
Academic Search Premier (EBSCO)
Academic Search Ultimate (EBSCO)
Aerospace Database - ProQuest
Civil Engineering Abstracts - ProQuest
Central & Eastern European Academic Source (CEEAS) - EBSCO
Communication Abstracts - ProQuest
EBSCO Essentials
INSPEC
Library and Information Science Abstracts (LISA) - ProQuest
Library & Information Science Source - EBSCO
Library, Information Science & Technology Abstracts (LISTA) - EBSCO
Library Literature & Information Science - EBSCO
Metadex - ProQuest

Frequency

JIOS is published twice per year.

Printed in 100 copies.

Access to JIOS is free of charge through following sources:

Journal of Information and Organizational Sciences
Hrčak - central portal of Croatian scientific journals
Directory of Open Access Journals (DOAJ)
OALster



Creative Commons Licence

Journal of Information and Organizational Sciences by Faculty of Organization and Informatics is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License.
<http://creativecommons.org/licenses/by-nc-nd/4.0/>



CONTENTS

<i>From the Editor</i>	III
Lambodara Parabhoi, Rebecca Susan Dewey, Prem Chand, Ajit Kumar Kainchi, Manoj Kumar Verma: Bibliometric Mapping of Gender Disparity in Research Publications in India during 1999-2018: A Case Study of Shimla District, Himachal Pradesh Original Scientific Paper	255-269
Xhelil Bekteshi, Sevdie Alshiqi: Marketing Strategy as Driving Force of Export Performance Small and Medium Enterprises - Case of Kosova Original Scientific Paper	271-281
Maria Ali Yari, Mahmoud Modiri, Kaveh Khalili Damghani, Kiamars Fathi Hafshjani: Measuring Customer Satisfaction Using Multi-Criteria Analysis Model of Customer Satisfaction to Evaluate Product Lines (Case Study: Kaveh Glass Industrial Group) Original Scientific Paper	283-304
Tamara Šmaguc, Ksenija Vuković: Forms and conversions of the economic capital of Croatian entrepreneurs in the computer programming industry with insights into variations of the company's development stages Original Scientific Paper	305-331
Mohammed Abbas Fadhil Al-Husainy, Hamza A. A. Al-Sewadi, Ahmed M. Sayed: Using the 3D Protein Structure as Key to Encrypt Images Original Scientific Paper	333-354
Norzaidi Mohd Daud: The Impact of Transformation in Higher Education: Introductory of New Technology, Is It Good or Bad? Original Scientific Paper	355-372
Riad Sahara, Syahid Abdullah, Muhammad Ikhwan Saputra: Integration Model of Academic Information Systems and Learning Management Systems with REST Web Services Using External Databases Preliminary Report	373-384
Tomáš Červinka: Digital transformation of strategic management of SMEs in the Czech Republic Original Scientific Paper	385-398
Virtika Singhal, Anurupa B. Singh, Vandana Ahuja, Rajat Gera: Consumer Segmentation in the Fashion Industry Using Social Media: An Empirical Analysis Original Scientific Paper	399-419
Amine El Hadi, Youness Madani, Rachid El Ayachi, Mohamed Erritali: Optimization of the results of a multilingual search engine using a fuzzy recommendation approach Original Scientific Paper	421-441
Nimas Aryany Pratiwi, Siti Fatimah, April Kukuh Susilo: The Impact of Organizational Support and Employee Attitude to Innovative Work Behavior Mediating Role of Psychologic Empowerment Original Scientific Paper	443-470
Mawloud Mosbah: Towards a Combination of Metrics for Machine Translation Original Scientific Paper	471-488
Publication Ethics; List of Reviewers; Instructions for Authors	489-498