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From the Editor

Dear readers,

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

We are trying to keep and improve the high quality of the review process, resulting in the high quality of the papers on different topics of information and communication sciences, making the Journal interesting for a wide range of scientists from the field.

I hope that you will find the papers published in this issue interesting and inspiring for your own research.

Alen Lovrenčić

Editor

Towards Detecting Influential Members and Critical Topics from Dark Web Forums: A Data Mining Approach

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Abstract

Conventionally, the Internet consists of three parts: Surface, Deep, and Dark Webs. In the last two decades, a massive increase in illicit activities took place on the different platforms of the Dark Web. Moreover, social networks on Dark Web implicate extremism dissemination on a wide scale. In this paper, we propose an approach to generate textual patterns from discussions on Dark Web terrorist forums employing Data Mining techniques. The discovered patterns help identify the influential members and extract critical topics. We describe our system modules that perform data preprocessing, text preprocessing with TF-IDF weighting, outlier detection, clustering evaluation, clustering, and clustering validation, implemented with the RapidMiner tool. We apply K-Means as the Clustering method with different distance metrics, evaluate the clustering process using Elbow and Silhouette methods, and validate it using Davies-Bouldin Index. Furthermore, we investigate the effects of altering the distance metrics for outlier detection on the Clustering results.

Keywords: Dark Web, Forum, Elbow Method, Silhouette Method, Davies-Bouldin Index, Data Mining, Clustering, Text pre-processing, Terrorism.

1. Introduction

Notably, researchers use the terms Deep Web and Dark Web interchangeably, though they do not refer to the same thing. Deep Web refers to websites that standard search engines, such as Google, cannot index. The Deep Web content includes platforms restricted by a paywall or require sign-in credentials. In addition, some administrators

set constraints on their websites that block web crawlers, thus making such websites inaccessible by search engines. On the other hand, the Dark Web is a part of the Deep Web that uses specific encryption software and requires particular browsers, such as TOR¹, to be accessed [1].

Websites on the Dark Web look roughly like any other website, though with some essential differences. Of the naming structure, instead of the common extensions, such as .com or .net, websites hosted on the TOR network by TOR Hidden Services have the unique one of .onion. These websites are only accessible via the TOR browser [2] [1]. Websites on Dark Web also use a scrambled naming structure in their URLs to make them impossible to remember. For example, a Dark Web market called Dream Market goes by the incomprehensible address of `eajwlv3z2lcca76.onion`.

Many internet users are not thoroughly aware of the criminal activities taking place on the dark side of the web. On the other hand, numerous websites disseminating terrorism and extremism contents use languages other than English, thus making it laborious for investigators to understand the website content [3] [2].

Initially, terrorist groups used open social networks, such as Facebook and Twitter, for thoughts dissemination and recruitment purposes. However, as social media websites employ ever-improved techniques to detect such suspicious behaviors, they immediately disclose and suspend such accounts. Thus, terrorist communities have moved their activities to Dark Web forums [4].

Data Mining and Machine Learning techniques play a vital role in forming the proper intelligence needed to detect and analyze malicious and illicit activities over the Dark Web platforms. In particular, DM and ML help discover new advantageous information about terrorism discussion forums, members, and posts [4].

In this paper, we introduce a methodology based on unsupervised methods, specifically Clustering, to analyze terrorist discussions on the Dark Web, providing a better understanding of the trending and most common topics they discuss and finding influential members. We discuss the importance of evaluating the clustering process to gain accurate results. We start with a brief description of Data Mining, data pre-processing, outlier detection methods, cluster evaluation methods (specifically Elbow and Silhouette methods), and clustering algorithm with several metrics (Cosine Similarity, Euclidean Distance, and Manhattan Distance), and validation metric (the Davies-Bouldin Index). We discuss our results, demonstrating how the outlier detection and clustering validation processes improve the clustering results. Finally, we discuss the utilization of text pre-processing in detecting the relationships between forum members and their posts, and extracting the most critical terms characterizing the terrorism domain, such as "تفجير = explosion", "قتل = kill", and "ارهاب = terrorism". Our approach helps law enforcement and security agencies to investigate terrorist forums and detect influential members and trending topics.

The remainder of this paper is organized as follows: Section 2 discusses related work and the contributions of this paper, Section 3 demonstrates the theoretical and

¹ TOR Project, <https://www.torproject.org>

mathematical background, Section 4 describes the research methodology and experimental results, and Section 5 is for the conclusion and future work.

2. Related Work

Numerous researches introduced approaches to analyze the Dark Web contents in general and terrorism dissemination in particular, utilizing a variety of Data Mining and Machine Learning techniques. Such studies comprise various approaches of Clustering, Classification, Topic Modeling, and statistical analysis.

The study of Baghel and Yogesh [5] analyzes the increased rate of terrorist incidents from 1970 to 2016 worldwide, intending to detect and curb such incidents in a particular country (India). The study follows a prediction methodology to predict the new areas prone to become the following targets of terrorist activities by determining the pattern of increasing probability of the least significant areas in terms of density and region. The researchers retrieved the global data from online sources to study the specific situation of the selected country and modeled the data using the K-means algorithm. The study suggests that the data contains many broad variables over periods, so assuming values as a whole can lead to erroneous insights. Thus, the number of clusters was verified using the Davies-Bouldin Index to select the best value of k and therefore ensure better efficiency and validate the results.

Similarly, Alkhatib and Basheer [3] introduced an approach that utilizes Data Mining techniques to infer valuable patterns from a Dark Web marketplace content. They demonstrated the system modules that perform several tasks, including crawling, extracting the whole market data, data preprocessing, and Data Mining. They employed K-means algorithm and validated the results using Davies-Bouldin Index. The study discussed the common characteristics among clustered objects, identified Top Vendors, and analyzed products promoted by the latter, in addition to identifying the most viewed and sold items on the market using the RapidMiner tool.

Goel, Sharma, and Gurve [6] proposed a classification approach conducted on the Global Terrorism Dataset (GTD), which comprises statistics on domestic and international terrorist attacks since the 1970s. They developed a model using the Orange Data Mining tool and applied different Machine Learning algorithms, such as Support Vector Machine (SVM), Naïve Bayes, Neural Networks, and K-Nearest Neighbor (KNN). The model employs statistical analysis by classifying five decades of real-time global terrorism datasets to predict future attacks.

Atsa'am, Wario, and Okpo [7] employed the Agglomerative Hierarchical Clustering technique on the Global Terrorism Database (GTD) to classify terrorism into four newly suggested groups based on losses and consequences. The proposed system comprises several processes, including data preprocessing, attribute selection, missing values handling, and data normalization. The approach utilized internal validation methods to estimate the compactness, connectedness, and separation of the generated clusters. Furthermore, it evaluated the optimal number of clusters using the Elbow Method.

Similarly, Kumar et al. [8] proposed an approach that employs classification techniques to observe trends in terrorist attacks worldwide in terms of casualties,

attacks frequencies, and most vulnerable locations in the world. The dataset created for experimental purposes was collected from various public and open sources during 1970-2015, consisting of reported attacks, which caused massive losses of life and property. The research focuses on the importance of data preprocessing in increasing the accuracy of the results and analyzes the performance of several classifiers. The classification criteria are based on attacks responsibility by taking the party responsible for the attack as a classification category to predict the organizations involved in the reported attacks.

Alguliyev, Aliguliyev, and Niftaliyeva [9] proposed a method for detecting terrorism-related activities in the e-government environment based on the similarity between user opinions and a vocabulary database. They generated the vocabulary database from terrorism-related words for automatic analysis and identification of potentially dangerous statements using Naive Bayes classification to prevent terrorist threats, identify suspects, and monitor their activities. The approach identifies the positive, negative, and neutral comments, selects only the negative ones for analysis, and calculates the proximity between the comments' words and the terrorism-related dictionary database. If the proximity exceeds the specified limit, the system enters the related statement in the list of suspicious comments. The approach includes several processes, including data preprocessing, determination of comments polarity, and selection of terrorism-related comments.

Onyekachi, Norbert, and Uzoamaka [10] discussed the importance of employing Deep Learning to analyze terrorist events. The research introduced improvements to a previous work by including extra features in the dataset and proposing a Deep Neural Network (DNN) model to predict the success of terrorist attacks. They used a dataset retrieved from the Global Terrorism Database (GTD). The employed methodology comprised several steps, including data preprocessing and handling the missing values.

Mashechkin et al. [11] proposed a methodology to predict potential risks from online communities by detecting potentially dangerous users without having full access to the content they distribute, such as on private channels and chat rooms. The study aims to identify and monitor users, communities, and web resources that spread terrorist or extremist content on the Internet by classifying users as "dangerous" or "non-dangerous". The approach employed Orthonormal Non-negative Matrix Factorization and words representation as n-grams to handle language variations, misspellings, and typos. Furthermore, it relies on noise filtration and weighing the generated n-grams to fit relevant individual text parts and remove the less important parts of the document; thus, the retained text parts describe all the essential thematic topics of the source text. The study paid particular attention to issues related to text quality, such as addressing the presence of links and hashtags, multiple languages, slang, or intentionally disguised words, in addition to typos and grammatical errors.

Soliman and Abou-El-Enien [12] proposed a hybrid prediction algorithm integrating different Operations Research (OR) and Decision support tools with Data Mining techniques (prediction and classification). The research purpose is to predict terrorist groups responsible for terrorist attacks on Egypt from 1996 to 2017 and thus use the predictions as a warning tool that identifies the networks of terrorist groups

and reduce or curb terrorist attacks. The system employed K-Nearest Neighbors (KNN) and Random Forest (RF) algorithms controlled by metaheuristics optimization methods to determine the minimum number of the selected features to achieve a high classification accuracy. The proposed methodology included data preprocessing and utilized evaluation and validation measures.

Tavabi et al. [13] analyzed a large corpus from 80 forums on Deep and Dark Webs during 2016 and 2017. They identified topics using Latent Dirichlet Allocation (LDA) and employed a non-parametric Hidden Markov Model (HMM) to model the evolution of the topics across different forums. The proposed system examines the dynamic patterns of discussions according to their similarities. Eventually, they demonstrated anomalous events identification process in rich, heterogeneous data.

Saini and Bansal [4] proposed an automatic model to detect terrorist recruitment over online social media to generate actionable intelligence. The approach is based on classification techniques applied to messages from five Dark Web forums under the Dark Web Portal Project of University of Arizona. Two experts manually labeled the messages into two classes: "recruitment" and "non-recruitment". They employed five classifiers: Support Vector Machine, Logic Boosting, Random Forest, Generalized Linear Model, and Maximum Entropy-based model.

Our work contributes to the same purposes focusing on the substantial role of Data Mining in countering terrorism. The main contributions of this paper are as follows:

- We Propose a Data Mining approach on Dark Web terrorist forums in the Arabic language. It includes Clustering using K-means, Outlier Detection, Cluster evaluation using Elbow and Silhouette Methods, Cluster validation using Davies-Bouldin Index, and text preprocessing.
- We discuss the outlier detection effects on the Clustering process using K-means, comparing different distance metrics. Consequently, we choose the best distance metric after a validation process using Davies-Bouldin Index.
- We demonstrate the implementation of text preprocessing on the selected datasets in discovering influential members and trending topics around critical terms such as “قتل = kill” and “ارهاب = terrorism”.

3. Theoretical and Mathematical Background

Data Mining is a business process that extracts meaningful patterns and rules from a massive volume of data. Data mining techniques help discover hidden relationships among raw data elements, leading to inferring information and insights about the data for decision-making purposes [14]. Data Mining can be defined as a knowledge retrieval process that discovers useful and comprehensive information from massive volumes of raw data to support decision-making and problem-solving objectives in a specific domain [15].

3.1. Clustering

The main goal of clustering is to group the elements that share certain similarities; thus, the elements within the same cluster are similar to each other and different from those in the other clusters [7] [16]. Clustering, or grouping, is an essential unsupervised Machine Learning method and is widely used in various domains due to its ability to find and group objects of specific characteristics [15] [17]. Clustering algorithms vary into multiple types based on partitioning criteria, density, and model. Partition-based clustering creates clusters of a predetermined number k . One of the most commonly used Partition-based clustering algorithms is K-means [17].

K-means involves two main steps: selecting k objects as clusters' centers, called centroids, and assigning the other objects to their closest centroid [14]. K-Means is more sensitive to outliers than other clustering methods such as K-Medoids. Thus, the accuracy of the K-Means algorithm improves when the outliers are removed [18].

3.2. Outlier Detection

Outlier detection is the process of detecting and subsequently excluding outliers from a given set of data [19]. The traditional outlier detection techniques have six types: clustering-based, deviation-based, density-based, subspace-based, statistical-based, and distance-based [20]. We choose a distance-based approach, which calculates the distances between a data point and its neighbors. Outliers are objects that have long distances from their set [21] [22].

3.3. Optimal Number of Clusters

The number of clusters k is the most fundamental hyperparameter in K-Means clustering. Therefore, external and internal clustering validations are crucial for results validity [23]. The main goal of cluster validation is to ensure that clustering results are meaningful and not just artificial effects of the clustering algorithm [7]. In this work, we utilize two validation methods: the Elbow and Silhouette methods.

3.3.1. Elbow Method

The Elbow Method is one of the most popular methods for determining the optimal number of clusters. It starts with calculating the Within-Cluster-Sum of Squared Errors (defined in Equation 1) for different values of k and selects the k value for which the change in Sum of Squared Errors (SSE) first starts to decline. In other words, the point after which the distortion starts decreasing, forming a bend as an angle, or elbow, will indicate the best value of k to be selected [14].

$$SSE = \sum_{k=1}^k \sum_{x_i \in S_k} \|x_i - c_k\|_2^2$$

Equation 1: Sum of Squared Errors (SSE)

3.3.2. Silhouette Method

The Silhouette Coefficient integrates separation and cohesion [17]. In this method, a value close to (-1) indicates that the clustering of the data points is not optimal. Conversely, a value close to (1) refers to an optimal clustering [17]. Equation 2 defines the Silhouette Coefficient.

$$S(i) = \frac{b(i) - a(i)}{\max\{a(i), b(i)\}}$$

Equation 2: Silhouette Coefficient

Where $b(i)$ is the smallest average distance of the point (i) to all points in any other cluster and $a(i)$ is the average distance of (i) from all other points in its cluster.

3.3.3. Davies-Bouldin Index

The Davies Bouldin Index computes the quality of clustering. Similarities between points in the same cluster increase if the distance of points to the cluster centroid is minimum, while similarities between clusters decrease if the distance is maximum [24]. The longest distance among clusters and the shortest distance within the cluster produce the lowest Davies-Bouldin score, indicating optimal results [25]. Equation 3 defines the Davies Bouldin Index.

$$DB = \frac{1}{k} \sum_{i=1}^k \max_{i \neq j} R_{ij}$$

Equation 3: Davies-Bouldin Index

3.4. Distance Metrics

The second fundamental factor in a clustering process is determining the distance metrics. A distance metric defines the distance between two objects. In Clustering, we can divide similarity metrics into two categories: Similarity-Based Metrics and Distance-Based Metrics.

From the Similarity-based Metrics, we choose Cosine Similarity. The Cosine Similarity calculates the cosine of the angle between two objects' vectors, defined by Equation 4.

$$S(x, y) = \frac{x \cdot y}{\|x\| \|y\|} = \frac{\sum_{i=0}^{n-1} x_i y_i}{\sqrt{\sum_{i=0}^{n-1} (x_i)^2} \times \sqrt{\sum_{i=0}^{n-1} (y_i)^2}}$$

Equation 4: Cosine Similarity Measure

As Distance-Based Metrics, we choose the Euclidean Distance and Manhattan Distance. The distance between two points as a straight line is the Euclidean distance [26]. It is suitable for continuous numerical variables and is defined by Equation 5.

$$EUC(x, y) = \sqrt{\sum_{i=1}^n (x_i - y_i)^2}$$

Equation 5: Euclidean Distance

The Manhattan Distance, also known as city block distance, is the sum of absolute differences between points across all the dimensions, and computed as in Equation 6.

$$Manhattan\ Distance = \sum_{i=1}^n |x_i - y_i|$$

Equation 6: Manhattan Distance

3.5. Text Preprocessing

Data preprocessing is a substantial task in Data Mining in general and Text Mining in particular. It is a strategy for extracting meaningful and significant data elements from raw data by converting the latter into formats suitable for the intended research and experimental purposes [8].

In Text Mining, There are three weighting approaches applied when converting documents to vectors of terms: Term Frequency (TF), Document Frequency (DF), and Term Frequency-Inverse Document Frequency (TF-IDF). In TF-IDF, if a term is significant, it is assigned a heavier weight. Conversely, an insignificant term will have a trivial weight [27]. TF-IDF is defined as follows:

$$TF = \frac{\text{Number of times the word } t \text{ occurs in the text}}{\text{Total number of words in the text}}$$

$$IDF = \frac{\text{Total number of documents}}{\text{Number of documents that contain the word } t}$$

$$TFIDF = TF \cdot IDF$$

4. Research Methodology

In this paper, we have two main objectives:

- We investigate the effects of outlier detection by comparing distance metrics in Clustering experiments using the K-Means method. Consequently, we choose the best distance metric by applying the cluster validation method Davies-Bouldin Index.
- We demonstrate the implementation of text preprocessing on the selected datasets to detect members and messages around critical words such as “قتل = kill” and “ارهاب = terrorism”.

After filtering the data, we saved it in an Excel file. We implemented the proposed processes using RapidMiner 9.6. In the following subsections, we describe the

datasets we used in experimenting with the designed processes. We demonstrate in detail the modeling steps, processes architecture, and results.

4.1. Dataset

We used three datasets in the Arabic language, namely *AlFaloja*, *Alqimmah*, and *AsAnsar*, retrieved from *Azsecure-data.org*². The datasets include posts of worldwide Jihadi social media from 2005 to 2012. Since the datasets contain missing and null values in addition to duplicates, we removed records with such entries from the dataset to clean the data for further analysis. To experiment the proposed system, we considered approximately 9000 records for analysis.

4.2. Modeling Steps

Our proposed approach consists of four main steps described in the following subsections. Figure 1 illustrates the process design.

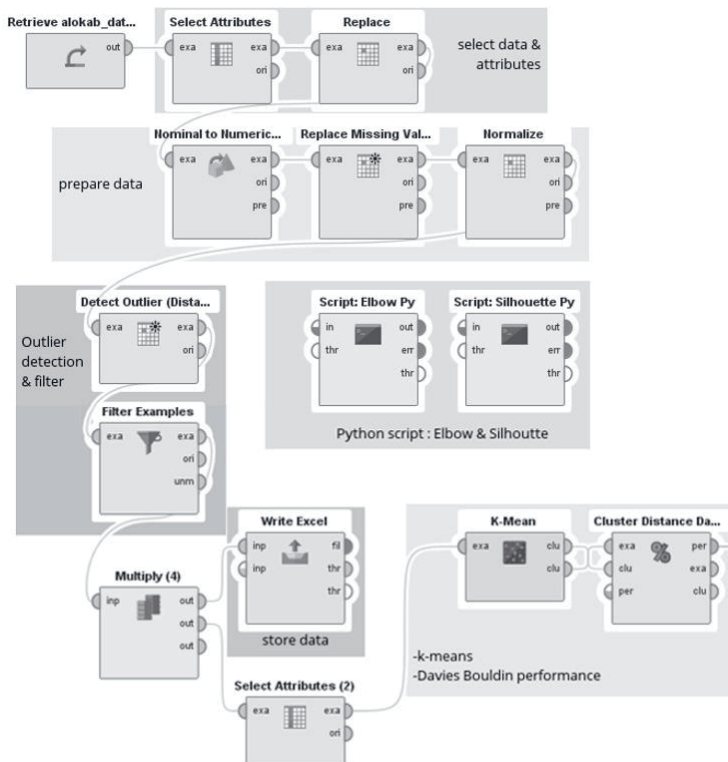


Figure 1. The Process of the Proposed Modeling Method

² <https://www.azsecure-data.org/dark-web-forums.html>

4.2.1. Step 1: Retrieve and Prepare Data

We saved the downloaded datasets in Excel files. On RapidMiner, we retrieve the dataset and select the attributes: *ThreadName*, *MemberName*, *Message*, *P_Year*, *P_Month*, and *P_Day*. Subsequently, we replace special characters - such as “@#&...” - with spaces. We convert the results to numerical values, replace the missing values, and normalize them by Z-transformation formula.

4.2.2. Step 2: Outlier Detection

We utilize a distance-based outlier detection tool to discover the outliers from the retrieved data and filter them out. Then, we save the produced dataset in a new Excel file.

4.2.3. Step 3: Validate Clustering

We apply cluster validation on the Excel file data achieved from the previous step with Python code. We employ the Elbow and Silhouette methods, as illustrated in Figures 2 and 3, respectively. As shown in Figure 2, there is a plain bend at three. Thus, the optimal number of clusters with the Elbow method is $k=3$ for *AlQimmah* dataset.

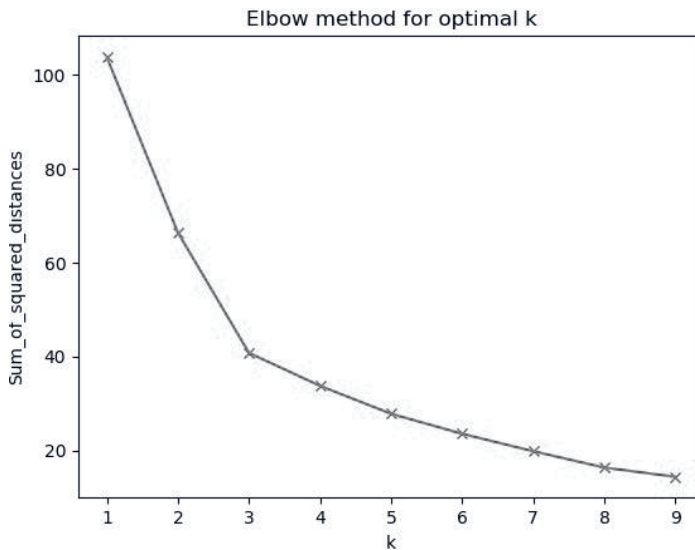


Figure 2. The Elbow Method Results for *AlQimmah* Dataset, Showing $k=3$ as the Optimal Value

Similarly, the result of the Silhouette method, as shown in Figure 3, is three for *AlQimmah* dataset, having the highest score in the illustrated chart.

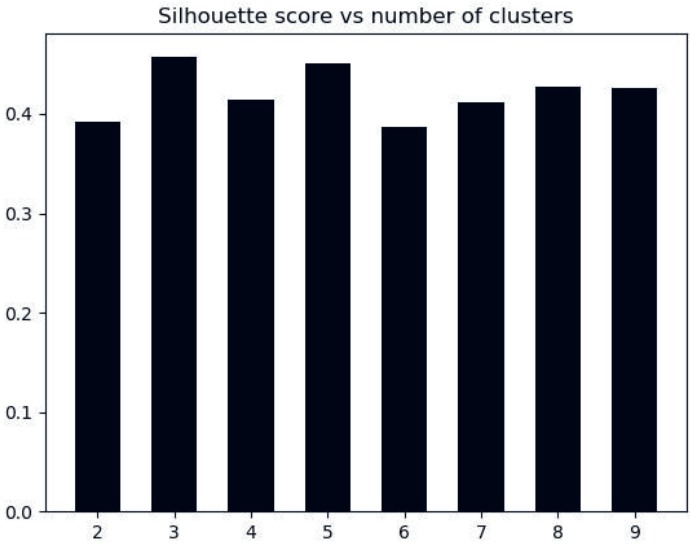


Figure 3. The Silhouette Method Results for *AlQimmah* Dataset, Showing $k=3$ as the Optimal Value

4.2.4. Step 4: Applying K-Means and Validation Performance

K-Means clustering algorithm groups the data objects according to their proximity to each other. To compute the closeness of the data points, we test Euclidean Distance, Cosine Similarity, and Manhattan Distance measures, illustrated in the sub-process in Figure 4.

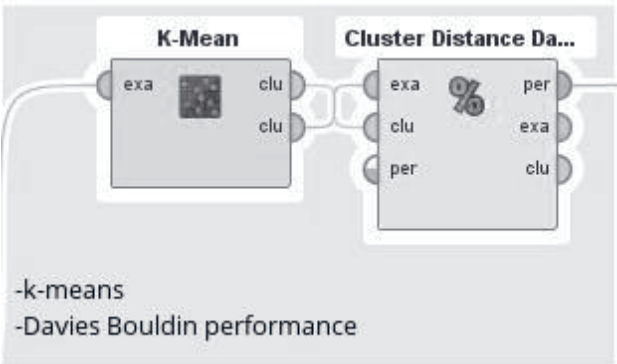


Figure 4. K-Means Algorithm and Davies Bouldin Index Performance Measuring

4.2.5. Results

Table 1 illustrates the results of the described process applied to the three datasets (*AlFaloja*, *AlQimmah*, *AsAnsar*).

Dataset	Elbow & Silhouette (<i>k</i>)	K-Means		
		Metrics / Distance		
		Euclidean Distance	Cosine Similarity	Manhattan Distance
		Davies-Bouldin Index		
AlFaloja	4	0.220	0.226	0.227
AlQimmah	3	0.143	0.143	0.141
AsAnsar	4	0.177	0.195	0.178

Table 1. The Value of *k* Based on Elbow, Silhouette, and Davies Bouldin with Different Metrics (Euclidean, Cosine, Manhattan)

As the table shows, the minimum values of the Davies-Bouldin Index for *AlFaloja* and *AsAnsar* datasets are achieved when using the Euclidean Distance (0.220 and 0.177, respectively), as the best number of clusters is where the average value of Davies-Bouldin Index is minimized [24].

For *AlQimmah* dataset, the scores of the Davies-Bouldin Index with Euclidean Distance and Cosine Similarity are the same, achieving the minimum value (0.141) when using the Manhattan Distance.

4.3. Text Preprocessing

We use a specialized component, Process Document from Data, to perform data preprocessing. This function transforms the textual data into word vectors by calculating the TF-IDF weights of the word set. Before implementing the TF-IDF function, we retrieve the dataset and convert the entries from Nominal to Text, as shown in Figure 5. After retrieving and converting the data (Nominal to Text), we select two attributes (one for *ThreadName*, refers to the subject or title, and one for *Message*, refers to the full topic) as we will discuss in the following sections. The “Replace” component is used to replace outliers or missing values, and the “Process Document from Data” component is used to perform data preprocessing, as illustrated in Figure 6.

In this section, we discuss the text preprocessing steps, illustrated in Figure 6, which include the following:

- Stop words removal
- Tokenization
- Filter tokens by length
- Filter tokens by content

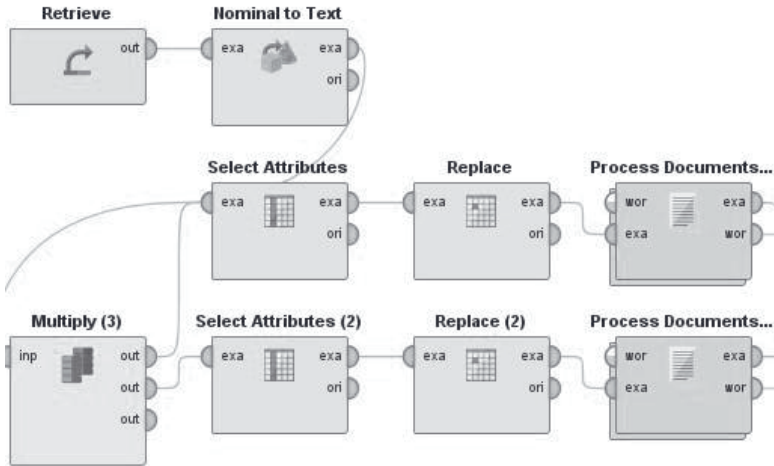


Figure 5. Implementation of Process Documents from Data, Selecting the ThreadName and Message Attributes

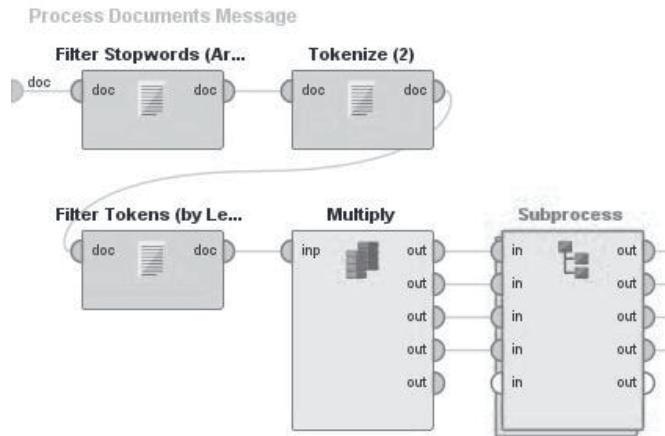


Figure 6. Process Documents for the *Message* Attribute

4.3.1. Stop Words Removal

This process (called *Filter Stopwords (Arabic)* in Figure 6) removes the common words or the words that have no significance in producing intelligence patterns or valuable information. Moreover, such terms may negatively affect the accuracy of the results. For example, the Arabic words "كل", "أما", "كم" are stop words. On RapidMiner, we can apply various functions, such as Filter Stopwords, based on the used language dictionary. We employ the Filter Stopwords process for the Arabic language.

4.3.2. Tokenization

This process (called *Tokenize* in Figure 6) splits the sequence of strings into words [28]. It removes all the punctuations from the textual data and extracts words of the text, called tokens. RapidMiner tool provides three splitting methods; the default and commonly used one is the Non-Letter Character, which splits words based on the non-letters such as spaces, commas, full stops, and others³.

4.3.3. Filter Tokens by Length

Through this function, we filter tokens of specific lengths. RapidMiner provides two parameters to restrict the lengths of the tokens, the maximum number of characters max chars and the minimum number of characters min chars [27]. Subsequently, the *Multiply* operator is used to make one input available for several outputs after processing. The *Subprocess* in Figure 6 executes multiple filters, which has the same behavior in one package that is divided into five functions (Filter Tokens by Length).

4.3.4. Filter Tokens by Content

This operator (Filter Tokens by Content) filters tokens based on their contents; in other words, it keeps a token according to defined criteria, such as equals, contains, or does not contain a given value. In our approach, we define a regular expression (condition =contains match) to match critical words such as "قتل = kill", "ارهاب = terrorism", or "تفجير = explosion". Figure 7 illustrates this process and its parameters.

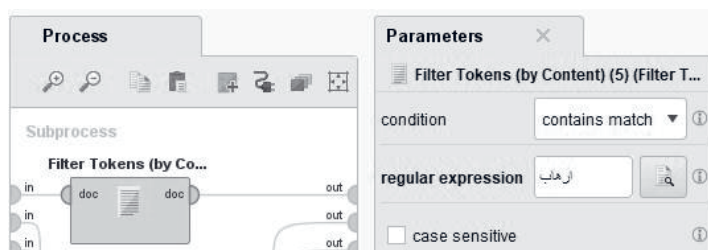


Figure 7. Filter Tokens by Content and its Parameters

4.3.5. Results

Figure 8 shows the counts of the critical words "الاسلحة = weapons", "التفجيرات = explosions" and "الارهاب = terrorism", represented by the *ThreadName* attribute,

³ In our research, we noticed that Stemming might change the form of the word and make it ambiguous or meaningless, and it is critical in Dark Web analysis to understand the specific meaning of the word; thus, we preferred to keep the forms of the words as they are without Stemming, knowing that RapidMiner does not perform Lemmatization:

<https://community.rapidminer.com/discussion/11285/lemmatization>.

against members' usernames (from the *MemberName* attribute) in *AsAnsar* forum. The member "عبد الله الوزير" shared the highest number of these words.

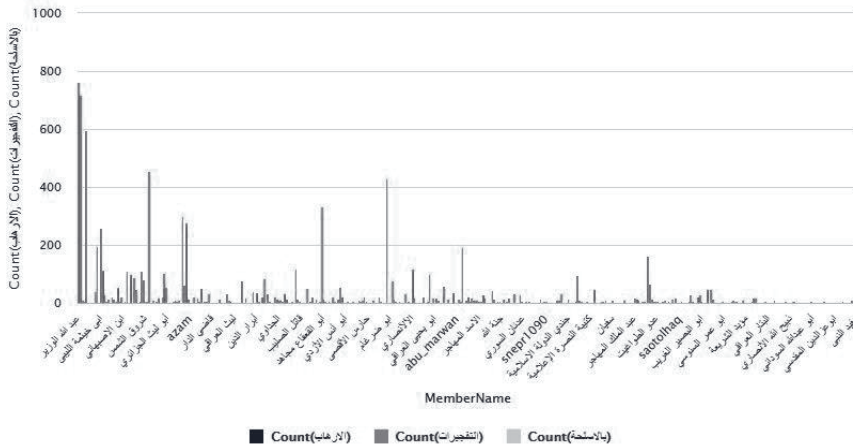


Figure 8. The Frequency of Occurrences of the Critical Words in *AsAnsar* Dataset after Selecting the *ThreadName* Attribute according to the Member Username (*MemberName*)

We sort the example set (selecting *ThreadName* attribute) by the month attribute (*P_Month*). Figure 9 shows that *May* witnessed the highest occurrences of the aforementioned critical words.

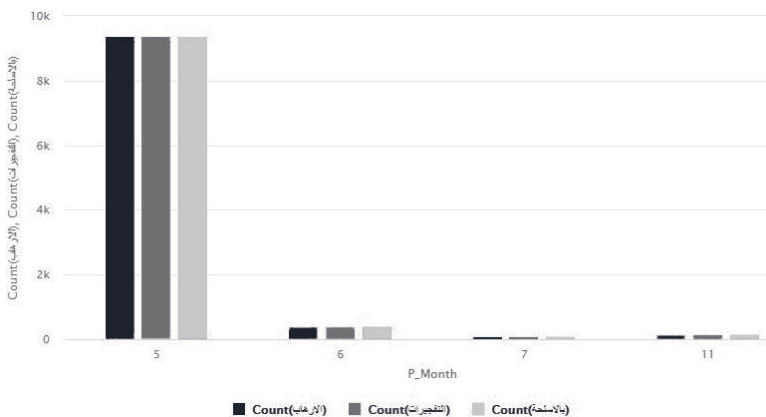


Figure 9. The Frequency of Occurrences of the Critical Words in *AsAnsar* Dataset after Selecting the *ThreadName* Attribute according to the Month of the Year (*P_Month*)

Similarly, Figure 10 also shows that the member "عبد الله الوزير" was the member who shared the highest number of the aforementioned critical words according to the Message attribute.

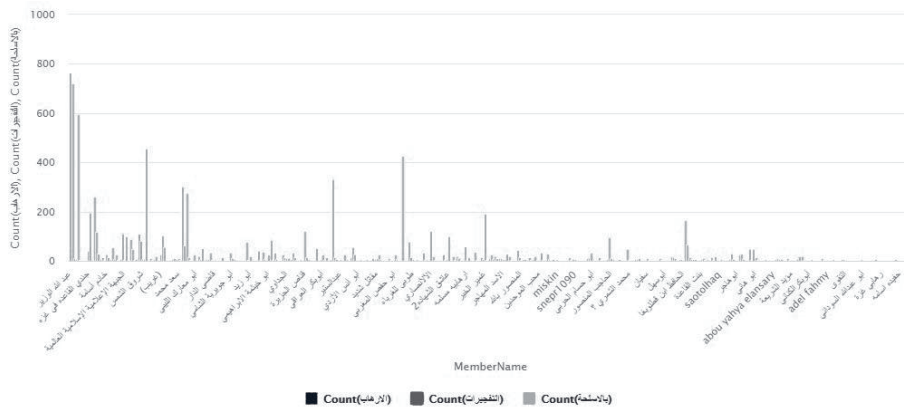


Figure 10. The Frequency of Occurrences of the Critical Words in *AsAnsar* Dataset after Selecting the *Message* Attribute according to the Member Username (*MemberName*)

In Figure 11, we sorted the example set by the year attribute (*P_Year*); thus, it shows that the aforementioned critical words converged in 2012 with excessive usage.

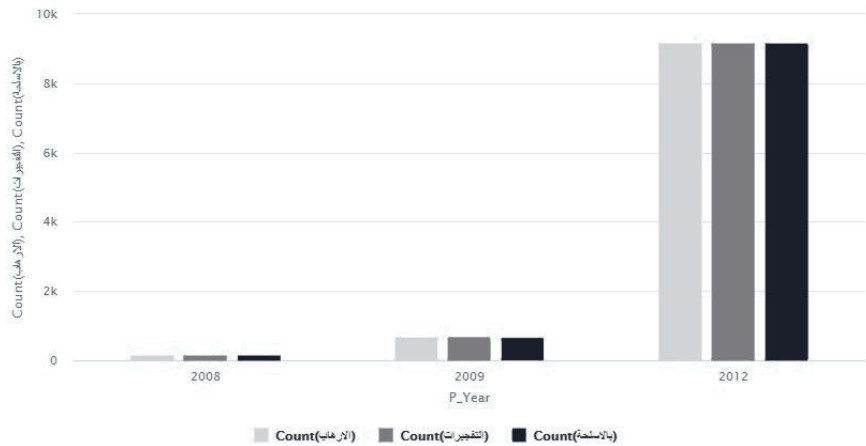


Figure 11. The Frequency of Occurrences of the Critical Words in *AsAnsar* Dataset after Selecting the *Message* Attribute according to the Year (*P_Year*)

5. Conclusion and Future Work

In this paper, we presented a Data Mining approach to analyze the contents of Dark Web terrorism forums, providing valuable insights that help investigators and law enforcement agencies to understand the nature of terrorist discussions and detect influential members.

Using the RapidMiner tool, we applied the K-means clustering method with different distance and similarity metrics (Euclidean Distance, Cosine Similarity, and Manhattan Distance). Our approach comprises several processes, including Outlier Detection (distance-based), Evaluation using Elbow and Silhouette methods to find

the optimal number of clusters, and Validation using the Davies-Bouldin Index, as shown in Table 1.

Furthermore, we discussed the importance of text preprocessing and weighting, using TF-IDF, to extract meaningful information from the raw data. We analyzed forums posts according to two main attributes: the thread name (*ThreadName*) and the corresponding message (*Message*), and computed the frequency of occurrences of critical words related to terrorism according to The posting members (*MemberName*), month (*P_Month*), and year (*P_Year*), as shown in Figures 8-11.

Our approach helps investigators detect the most influential members and popular topics from terrorist forums on the Dark Web. In its future directions, we aim to develop our model to analyze larger volumes of data and compare other outlier detection methods. Furthermore, we consider extending the list of critical words and employing Association Rules to extract patterns and relationships among these words.

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Identification and Evaluation of the Design Risks in Iran's Oil, Gas and Petrochemical Industry

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Abstract

Proper risk assessment and management are considered important issues in design improvement. This tendency has been due to the continuing uncertainty of the global economy and the advancement of information technology. Despite the most important and valuable benefits, developed design topics are more vulnerable and can expose the organization to higher levels of risk. Achieving sustainability is recognized as a growing and effective strategy to meet today's global design challenges. Design in the oil, gas and petrochemical industry is important due to its characteristics and high risk in different countries, especially Iran, due to its different effects on the environmental dimension. The issue of identifying and evaluating design risks has also been neglected in recent research. Therefore, the purpose of this study is to identify and evaluate design risks in Iran's oil, gas and petrochemical industry. The present research is descriptive-survey and is qualitative and quantitative in terms of technique and data used. Based on the literature review, 13 risk factors affecting the design were identified, in two stages, in-depth interviews were conducted with the opinions of experts, and by collecting opinions through a questionnaire, and 10 key risk factors were finally confirmed. In the first stage, the validity of the questionnaire was finally confirmed based on the opinions of 5 experts and in the second stage, using the opinions of 8 experts in this industry. Cronbach's alpha coefficient of the risk questionnaire is higher than 0.7, which indicates the reliability of the research tool. According to the research findings, two factors such as weak technology / knowledge sustainability and environmental pollution, compared to other risk factors, have a higher priority in design projects in Iran's oil, gas and petrochemical industry. It is suggested that industry owners take serious and continuous measures in the field of "improving the level of process knowledge".

Keywords: Risk, Design, Oil, Gas and Petrochemical of Iran

1. Introduction

In the last decade, industry pioneers have recognized that the key to achieving greater market share depends on meeting customer needs. Today, addressing consumer needs is even more important. And organizations try to provide high-quality goods and services according to their needs (Charmchi, 2001). Facilitating the relationship between customer needs, distribution networks, and the organization's internal operations requires a scientific approach in itself. Design can provide this for companies, and also has a significant impact on organizational performance, sustainability, and stakeholder satisfaction. The goal of each designer is to maximize the total production value and customer satisfaction. The profitability of the design process should be divided among all design steps. Accordingly, the success of a design is defined in terms of its profitability and satisfaction, thus, today, sustainable development is considered as one of the key elements of design (Nikabadi, 2013). Sustainable development was first addressed in 1987 in the Environment Committee and United Nations Development Report, and since then, this issue has been recognized as one of the biggest challenges facing the world. Over the past two decades, as globalization has expanded, sustainability and sustainable development have shifted from a technical concept to the political mainstream and then commercial concept (Sheikh, 2011). The most important factors disrupting sustainable development are the destruction of water resources and their excessive pollution, air pollution, noise pollution and waste in cities, and how nuclear waste is disposed of. In this report, for the first time, the terms "sustainable development" and "sustainability" entered the environmental literature and then entered the field of economic literature (Bagheri et al, 2015). Naturally, every activity is associated with risk, and human beings have always sought to identify its causes and resources. Another issue that arises in today's organizational and decision-making environments is the complexity of the situation and the composition of the information, which has made it extremely difficult to make the right decisions, therefore, the rules of thumb and speculation will be ineffective (Boroujerdi, 2015).

Arefi (2016) noted that understanding and risk management in engineering and design projects is a challenging task in the early stages. The failure of engineering and design projects increasingly emphasizes the importance of risk management, especially in the defense industry, the construction industry, and the oil industry due to the significant damage that may occur (Hajiabadi, 2012). Numerous studies have examined active modeling and project management methodologies to develop a systematic approach and an integrated project risk management methodology (Hajiabadi, 2012). Also in recent years, many researchers have focused on identifying, analyzing, prioritizing, and managing risk (Hosseini et al, 2012). Research has identified many reasons for project overpayments, including inaccuracies, project complexity, poor risk assessment, and management (Safaei et al, 2013). Research has provided many reasons for risk control and risk management, which include: Extending safety risk assessments to prevent or reduce their occurrence (Arefi, 2016). Due to dealing with numerous errors and accidents in process industries (oil and gas, etc.), and in order to analyze the risk and prevent events and reduce them, various risk

assessment methods have been developed and used (Hadizadeh, 2014). Risk management and understanding in large engineering projects, especially in the initial phase is very challenging (Agi, 2016). This is usually very difficult, even due to the lack of sufficient information, and it is almost impossible to extract the potential amount of risks (Zhang, 2011). Examining the relevant literature for project risk assessment, we found that there are many advanced methods, such as fuzzy logic, analytic hierarchy process ¹³, analytical network process ¹⁴, failure mode and effects analysis ¹⁵, fault tree analysis, event tree analysis, fishbone diagram, Monte Carlo ¹⁶ construction and structural equation modeling ¹⁷ (Bastas, 2018). The Bayesian belief Network ¹⁸ performs better than other methods because it can address the potential causal relationships of the risks posed by expert judgment and update previous beliefs and probabilities learned from new information. Oil and gas projects have a complex system and there are numerous dependencies among the risk factors in the fuzzy concept. Therefore, the aim of this study is to develop a Fuzzy-Bayesian model for risk assessment, identification, and prioritization of risks in oil, gas, and petrochemical projects. To create this model, a review of the printed works has been done and the shortcomings of the previous models have been revealed, observations indicate that Bayesian belief network systems have been less studied in risk analysis. And since large oil and gas projects pose numerous risks to the national capital, list the risks of engineering services in the various parts of an oil and gas consulting firm (industrial plumbing, architecture, Process, etc.) and their effects on the environment (leakage of hazardous fluids, etc.), as well as their control strategies, are examined in this study. Since most decision-makers and managers rate risk factors with linguistic values (for example, very high, high, medium, low, very low, etc.), thus, fuzzy theories provide a useful tool for examining ambiguities in the data evaluation process. In this research, using the fuzzy approach, a new method for identifying, measuring, and ranking the risks (technical and environmental) on oil, gas, and petrochemical projects (detailed phase) in consulting engineering companies will be presented. In this research, we intend to change the current system (current situation) and achieve the desired situation (optimal situation) in consulting companies, to evaluate the design risks of oil, gas, and petrochemical projects, and present the relevant model.

2. Literature Review

According to ISO 31000 standard, risk management is a set of coordinated activities in the organization, in order to guide and control the organization according to the type of risk (ISO 31000 standard). This set of activities can include a plan for risk response, follow-up, or risk control. In relation to risk management, it is necessary for the organization to define its attitude towards risk; Attitude to risk in the organization includes the organization's overall view of risk, pursuing, eliminating risk, or ultimately avoiding risk (Cetin et al, 2011). In fact, the systematic process of risk management, based on Deming's cycle: Plan-Do-Check-Act (PDCA), according to which, the process does not have a one-step algorithm, but the process cycle is repeated many times and in each cycle, an improvement is achieved and the risk management program is updated (Christopher et al, 2011). Risk management involves

contingency planning for the design of upstream and downstream processes and supply chains (Chiu et al, 2006). Risk and risk management are among the factors that are indirectly discussed in the topic of design. In design studies, in addition to the short-term profitability of organizations, risk management has been considered, which includes factors such as work-related injuries due to production, loss of environmental resources, public safety, and employee health (Corbett, 2007). Based on the results of studies, it can be concluded that in the sustainable development of design, the concept of security should be considered, which includes security against severe environmental threats, protection against the extinction of generations, climate change, famines, food shortages, and population growth. In this way, organizations can manage the risks associated with these factors in the long run (Dakov and Novkov, 2008). In general, risk can be defined as the probability of deviation from a predicted output. In the field of design, risk and risk management are relatively new concepts and several definitions have been provided about them. Dorli et al. have defined design risk as the potential for an internal process occurrence in a way that affects the needs of industry customers (Corbett, 2007). Design risks can occur under the following headings: natural disasters (Atkinson ²¹, 2006), legal requirements (Qureshi, 2015), inadequate demand forecasting, and failure to coordinate demand requirements across organizational processes (Christopher and Lee²³, 2004), changes in the prices of raw materials including energy (Zailani, 2012), poor quality of suppliers and insufficient accuracy in the number of deliveries, poor performance of the organization and its suppliers in environmental and social contexts that lead to costly legal measures; (Xu et al, 2013). One dimension of risk will be related to the organization's sense of social responsibility and can disrupt the reputation of the design output, which, through its activities, provokes emotions and dissatisfaction in society, and even worse, can lead to delinquent behaviors, which severely affect the reputation of design outputs (Hou et al, 2019). In sustainable design, the organization's ability to understand and manage the economic, environmental, and social risks of design (Zhao et al, 2018). HP, for example, has conducted a preliminary risk assessment in the design process of its products and, accordingly, has set its own risk management priorities. Significant and critical HP risks include geographical location, chemical processes or hazardous work, length of time with HP, commitment to citizens, and globalization (Qureshi and Ansari, 2015). These researchers address the risks associated with sustainable design in Table 1 through a combination of different categories found in the thematic literature (Sajjad et al, 2015; Tseng et al, 2018; Xu et al, 2013) and provided interviews with selected design managers.

Factors	Internal	External
Environmental	1-Environmental accidents (such as fire and explosion), 2- Pollution (air, water and soil), 3- Non-compliance with sustainability laws, 4- Emission of greenhouse gases, depletion of the ozone layer, 5- Energy consumption (incorrect energy consumption), 6-	1-Natural disasters (such as storms, floods and earthquakes), 2- Water shortage, 3- Heat wave, drought

	Unnecessary and double packaging, 7- Waste of products.	
Social (society)	1-Extraordinary working hours, imbalance between life and work, 2- Inadequate wages, 3- Child labor / forced labor, 4- Discrimination (race, gender, religion, disability, age, political views), 5- Environment Safety, 6- Exploitative employment policies, 7- Immoral treatment of animals	1-pervasive (universal), 2- social instability, 3- demographic challenges / elderly population
Financial (economic)	1-Bribery, 2- False claims / dishonesty, 3- Price fixing charges, 4- Unreliable claims, 5- Patent infringement (copyright), 6- Tax evasion	1-Sanctions, 2- Lawsuits, 3- Fluctuations in energy prices, 4- Financial crises

Table 1. Effective risks in sustainable design

Table 2 shows the differences between (design-related risk management) and (common risk management) activities from different aspects:

	Common design risks	Design-related risks
Risk identification	Design disorders (delays, forecast errors, intellectual property, inventories, capacity, etc.)	Ecosystem degradation, impact on social values and accountability
Risk Assessment	Based on financial or operational criteria / methods	Inferential studies (deductive)
Risk-taking behaviors	Share and understand it throughout the organization through testing and adapting risks	A portfolio of strategies for managing all three dimensions of sustainability
Proposed methods for dealing with risk	Based on risk management and evaluation and proper business planning	Scenario-based planning and simulation, Automatic tracking of faults, Auto repair and recovery
Opportunities for risk management	Opportunities to improve and enhance (internal) business and overcome competitors	Competitive Advantages and Chances for Business Excellence

Table 2. Risk management for common and design-related risks

The results of Tseng et al (2018) showed that the top 8 risk factors associated with sustainable design are: natural disasters, greenhouse gas emissions, forced labor/child labor, financial crisis, bribery charges, pollution, Non-compliance with the rules of sustainability, and energy consumption; Of course, considering that the relevant study was conducted in the southern region of Europe, it can be stated that the priorities obtained are due to the climatic, socio-economic conditions and regulations governing this region. Hou et al. (2019) have developed a framework for assessing and

measuring sustainable design risk by measuring various risks to create a comprehensive standard. Sustainable design risks are expressed in three dimensions and components as described in Table 3.

Operational risks	
Supply, process, demand and organization risks of the organization	
Environmental risks	Individual health, ecosystem quality, resource deficiencies
Social risks	Social indicators (global), governance indicators (global)

Table 3. Sustainable Design Risks

These researchers have used the risk assessment gap analysis technique to analyze the risk of sustainable design. They also used two distinct design case studies to evaluate the proposed framework. The results show that the differences in the design structure and size of companies are the two main factors of sustainable design.

Major research in the field of risk management and sustainable design is presented in Tables 4 and 5.

Factors										Year (AD/Solar)	Researcher / researchers	
Basic model	The human factor	control-ability	Error	Insurability	Control cost	Probability of discovery	Extent of pollution	Rate of exposure	Impact intensity			Probability of occurrence
FTA ¹ / HAZOP ²			*								2017	Hou et al
BBN ³									*	*	2009	Cetin et al
FMEA ⁴						*	*		*	*	2017	Tseng et al
William Fine					*			*	*	*	2016	Dorli et al
FMEA				*		*			*	*	2018	Corbett
BBN		*							*	*	2017	Xu et al
FBN ⁵									*	*	2016	Zailani et al
FBN										*	2009	Sajjad et al
Monte Carlo	*		*								2016	Qureshi
		*				*			*	*	2012	Zhang

Table 4. Major research related to sustainable design and analysis methods and risk management

¹ Fault Tree Analysis

² Hazard & Operability study

³ Bayesian Belief Network

⁴ Failure Modes and Effects Analysis

⁵ Fuzzy Bayesian Network

Researcher/ Research ers	Year	Risks										
		Safety and Occupational environmental	Political	Legislation	Economical	Research and exploration	Technical	Budgeting (people, hours, etc.)	Import of materials and Technical knowledge	Work partners	investment	Management(Internal)
Hou et al	2019						*					
Cetin et al	2013				*		*				*	
Tseng et al	2018	*	*									
Dorli et al	2012	*	*									
Corbett	2007											*
Xu et al	2013				*					*		*
Zailani et al	2012	*	*									*
Sajjad et al	2015		*									
Qureshi	2015		*	*	*	*		*		*	*	*

Table 5. Major research conducted in the areas of sustainable design and risk management

Critical risks in design

According to the review of the thematic literature and the identification of various risk factors presented in previous research, this study has extracted the most important risk factors affecting the design (13 risk factors) as described in Table 6.

Risk factors	Description
Inflexibility of security sources	Supplier inflexibility to environmental changes (including Inflexible capacity)
Complexity of the coordination process	Extraordinary coordination responsibilities due to information distortion, different goals of design members, conflicts among partners.
IT Risks	Lack of necessary IT infrastructure and mechanisms in order to receive and disseminate information among design members in a timely manner.
Weakness of technology / knowledge sustainability	Weakness and lack of knowledge and correct understanding of technology, operations and sustainable methods among partners.
Undermining brand / reputation	The credibility and reputation of the organization becomes vulnerable when customers do

	not look at the organization as a possible source to meet their needs.
Errors	Human error / machine / method.
Inefficient use of resources	Inefficient resources (e.g., energy, reversible waste) are used to produce and deliver goods and services.
Environmental pollution	Air, water, soil, or other contaminants caused by operations, equipment, or products.
Production of hazardous waste	Unused and unwanted materials or goods produced during or as a result of a process such as production or distribution.
Violation/ breach of Human Rights	Behavior that violates the dignity of a person or humiliates the person. Such as forced labor and child labor, discrimination, long working hours beyond legal needs.
Weakness in fulfilling social obligations	Lack of involvement in local technological, cultural, educational and social development, job creation, health care, social investment.
Violation of Business Ethics	Behavior that violates business ethics such as corruption, unfair trade, and invasion of privacy and so on.
Regulations	Laws / Regulations /Internal and External Codes.

Table 6. Primary risk factors affecting the design of the research literature review

3. Research Methods

The present study is a descriptive-survey research, and in terms of techniques and data used, it is qualitative and quantitative. In two quantitative and qualitative phases, in order to identify and evaluate the risks of sustainable design in the oil, gas and petrochemical industry, the opinions of experts were used. The qualitative phase includes two-part sampling. In the first part of the qualitative phase, to hold in-depth interview sessions (Delphi method), 5 experts in a non-random and judgmental manner appropriate to the type of activity of related companies, among senior managers of the organization (CEOs and strategists) with related fields of study (Management) and at least 10 years of work experience are selected. In the second part of the qualitative phase, 8 experts (including 5 experts participating in in-depth interviews) again participated non-randomly and according to the type and scope of activities of companies, often among senior and middle -level managers of the organization and related to design, management Risk and decision-making. It should be noted that in this part of the study, using data collected through a questionnaire (opinions of 8 academic and industrial experts), 13 risk factors identified through review of thematic literature and structured interviews were examined.

This study used the depth study method to review the literature for extracting initial critical risk factors. The field study (interview and questionnaire) method was then employed for final confirming the risk factors and assessing their validity and

reliability, as well as collecting and structurally testing the data required for analyzing critical risks. The questionnaires were scored based on a 5-point Likert scale. A questionnaire on the “risk factors” was used for the final verification of risk factors, construct validity assessment, and structural testing. Another questionnaire was employed to elicit experts’ views on various topics such as the impact of risk factors, the impact of risk, risk probability, and risk detectability. The third questionnaire was used to evaluate the interaction of risk factors. The second and third questionnaires were filled out during specialized interviews with eight experts. Risk factors were confirmed after two round-Delphi method according to figure 1. The construct validity for sustainable design risks is confirmed in Table 7.

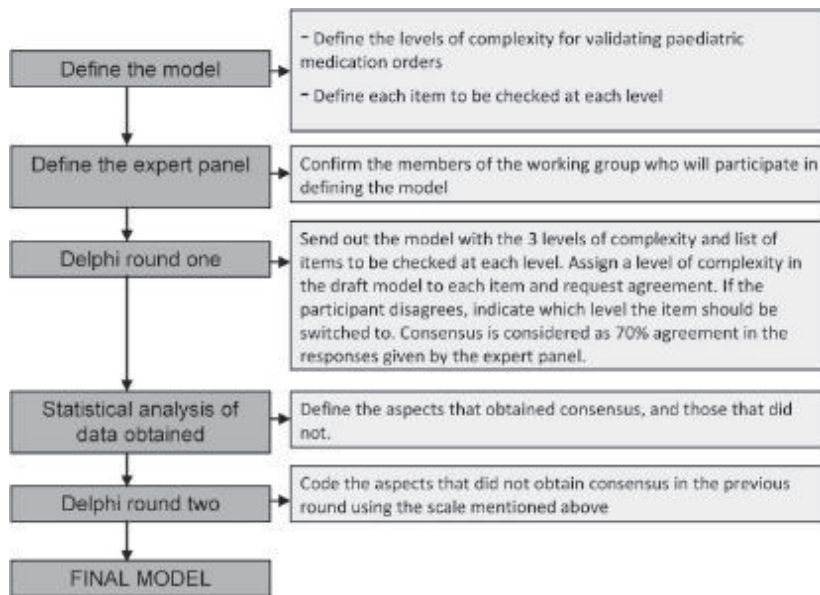


Figure 1. Two round-Delphi method for selecting risk factors

In round one of the Delphi process, the questionnaire contained 13 items for evaluation and it was sent out to the 8 panel members. A total of 8 questionnaires were answered and returned in the first round and consensus was reached in 13 items. In the interim results’ report, details were given on the items that did not obtain consensus, how responses were distributed and a proposal was made for new features arising from the non-consensual items. In round two of the Delphi process, the questionnaire contained 10 items for evaluation and it was sent out to the 8 panel members. A total of 8 questionnaires were answered and returned in the second round and consensus was reached in 10 items. Finally, 10 risk factors were confirmed after two round-Delphi method.

Indicator	Average of answers *	Approval / disapproval
Inflexibility of supply sources	6.9	Approval
Complexity of the coordination process	6.9	Approval
IT Risks	7.1	Approval
Weakness of technology / knowledge sustainability	6.2	Approval
Undermining brand / reputation	4.7	Disapproval
Errors	6.3	Approval
Inefficient use of resources	6.4	Approval
Environmental pollution	6.6	Approval
Production of hazardous waste	6.3	Approval
Unsafe / dangerous workplace	6.8	Approval
Violation/breach of human rights	4.5	Disapproval
Weakness in fulfilling social obligations	6.1	Approval
Regulations	4.6	Disapproval

Table 7. Validity results of the questionnaire

In this research, library studies have been used to thematic literature review of research and the initial extraction of risk factors, also, the field method (interview and questionnaire) has been used for final confirmation of effective risk factors, validity and reliability, structural testing and data collection required for risk analysis. In questionnaires, a five-point Likert scale was used. In the section of final confirmation of risks, and in order to assess the reliability of the structure and structural test, the questionnaire "Risk factors affecting the design of sustainability" has been used.

The content validity of the questionnaires was assessed in two stages. In the first stage, the opinions of 5 experts who were familiar with the concepts of design and risk management as well as the industry were used. For this purpose, meetings were held with these people and the content validity of the questionnaires was examined. As a result of these discussions, changes were made in order to modify and validate the questionnaires. In the second stage, in order to validate the structure of the questionnaires, 8 experts in this industry were surveyed, and based on the announced opinions, the validity of the structure was confirmed. The opinions of the same experts (five people) were used to determine the face validity of the questionnaire, and the questions were modified to formulate exactly the same concept as the researcher. The reliability of the questionnaires was analyzed using information obtained from 181 return questionnaires in SPSS software. Considering the total number of statistical population (340 participants in field of design and risk management in Iran's oil, gas and petrochemical industry), and according to Krejcie & Morgan (1970) table, 181 people were determined as the minimum statistical sample, which were selected by simple random sampling method. Period of data collecting from survey, responses of the two round-Delphi method are collected during period of 3 weeks, and for questioners are collected during period of 3 months, also questionnaire used combined type for answering based on the online and in paper form. Also, the range for probability of occurrence and impact of a risk (sometimes called its consequence) are

defined in terms of a discrete scale, such as 1=very low, 2=low, 3=medium, 4=high, and 5=very high.

Table 8 shows Cronbach's alpha related to risk factors.

Indicator	Number of data	Cronbach's alpha
Inflexibility of supply sources	181	0.738
Complexity of the coordination process	181	0.712
IT Risks	181	0.775
Weakness of technology / knowledge sustainability	181	0.789
Errors	181	0.795
Inefficient use of resources	181	0.722
Environmental pollution	181	0.739
Production of hazardous waste	181	0.741
Unsafe / dangerous workplace	181	0.786
Weakness in fulfilling social obligations	181	0.752

Table 8. Results of the reliability of the questionnaire

Based on the results in the table above, it can be seen that the Cronbach's alpha value for all indicators is greater than 0.7, which means the reliability of the survey tool. The results of the AVE (Average Variance Extracted) index are presented in Table 9.

Indicator	Convergent Validity	Variable Status
Inflexibility of supply sources	0.558	Acceptable
Complexity of the coordination process	0.462	Relatively acceptable
IT Risks	0.576	Acceptable
Weakness of technology / knowledge sustainability	0.522	Acceptable
Errors	0.538	Acceptable
Inefficient use of resources	0.552	Relatively acceptable
Environmental pollution	0.517	Acceptable
Production of hazardous waste	0.541	Acceptable
Unsafe / dangerous workplace	0.547	Acceptable
Weakness in fulfilling social obligations	0.498	Relatively acceptable

Table 9. Convergent validity of research variables

The table above shows the convergence validity of the research variables. Given that the majority of values are close to 0.5, so convergent validity is acceptable for all research variables. To analyze different risk factors, quantitative calculation methods, risk priority, and risk matrices have been used in Excel and fuzzy DAMETEL software. SPSS software is used to analyze descriptive statistics of data.

4. Results

The results of descriptive statistics showed that in the qualitative phase, men constituted 100% of the statistical sample of this study. 17.65% of the statistical sample were under 35 years old, 47.06% were between 35 and 45 years old and 35.29% were over 40 years old. Also in terms of education level, 29.42% of members had a Ph.D. degree, 58.82% had a master's degree and 11.76% had a bachelor's degree. As can be seen from the statistics, the highest percentage of participants have a master's degree and in the next rank are people with a Ph.D. degree. In terms of work experience, 35.29% of people with less than 10 years of experience, 29.42% between 10 and 20 years, and similarly 35.29% of people over 20 years of experience. Also, 35.29% of the people were in the highest executive position of the organization (CEO or board of directors) and 64.71% were the middle-level managers of the organization in the field of oil, gas, and petrochemical industry. It should be noted that among the participants in this part of the study, all people have organizational management positions and 41.18% of people in addition to organizational positions have been working as university lecturers in the field of oil, gas, and petrochemical industry management.

Sustainable design risks: In summary, the conditions of each of the risk factors will be as described in Table 10.

Risk factor description	Probability of occurrence	Impact Intensity	Risk Status
Inflexibility of supply sources	3.35	2.59	Medium
Complexity of the coordination process	2.32	2.99	Medium
IT Risks	2.81	2.40	Medium
Weakness of technology / knowledge sustainability	3.34	2.26	Medium
Errors	3.33	2.43	Medium
Inefficient use of resources	2.56	2.15	Medium
Environmental pollution	3.01	2.14	Medium
Production of hazardous waste	4.02	3.03	High
Unsafe / dangerous workplace	4.23	3.10	High
Weakness in fulfilling social obligations	2.35	49.2	Medium

Table 10. Risk matrix analysis (impact intensity)

The results show that in terms of the probability of occurrence and impact intensity in the design of the industry, 10% of risk factors have a low-risk status, 70% have medium risk factors and 20% have a high-risk status.

RPN-based critical risk rating:

At this stage, to determine the amount of risk of each of the risk factors affecting sustainable design, the risk priority number (RPN) has been used. For this purpose, based on the data collected through a questionnaire, risk numbers of probability, detectability, and impact intensity were calculated, and then the product of these three values was used as risk priority numbers (RPN). According to the risk priority

numbers obtained in this step, the ranking of risk factors will be done and appropriate behavioral strategies will be provided. Based on the risk priority numbers obtained as described in the table above, the prioritization of risk factors affecting sustainable design will be as shown in Table 11.

Priority	Risk factor description	RPN
1	Environmental pollution	58.29
2	Weakness of technology / knowledge sustainability	41.99
3	Production of hazardous waste	36.89
4	Unsafe / dangerous workplace	33.76
5	Inefficient use of resources	32.74
6	Complexity of the coordination process	27.58
7	Errors	24.21
8	Inflexibility of supply sources	23.95
9	IT Risks	21.88
10	Weakness in fulfilling social obligations	16.21

Table 11. Prioritization of risk factors based on risk priority numbers (RPN)

According to the table above and the values obtained for risk priority numbers, it can be seen that risk factors such as environmental pollution, Weakness of technology / knowledge sustainability, and production of hazardous waste with RPN values of 58.29, 41.99, and 36.89, respectively, are of higher priority than others, and have been identified as key risks.

Risk response strategy:

Conducting specialized interviews with 3 industry experts and obtaining their opinions on risk response strategies (avoidance, exploitation, transfer/sharing, decrease/increase, acceptance) is presented in Table 12. It should be noted that in exclusive interviews with experts, each interviewee was asked to provide at least one suggested solution for each of the two key initial risks.

Risk description	Response strategy	Response solutions
Environmental pollution	avoid Decrease	- Upgrading the level of process knowledge - Development of recycling activities - Planning to hold training courses in the field of environment
Weakness of technology / knowledge sustainability	avoid Decrease	- Transfer of knowledge from other countries - Development of activities in the field of R & D - Planning to hold in-service training courses

Table 12. Key risk response strategies

5. Discussion

In this study, the identified risk factors in the sustainable design of the oil, gas, and petrochemical industries have been investigated. In this regard, first, by completing a questionnaire by 8 industry experts, the data required for analysis were collected and then in two phases, descriptive and quantitative data analysis was performed. In the statistical description of the data, after describing the demographic composition of the respondents, some information such as mean values, maximum and minimum impact intensity indicators (time, cost, and performance), probability of occurrence, and delectability were calculated and presented. Then, in the quantitative analysis section, the matrix of risk priority values was calculated. In the statistical analysis sections of the research data, according to the obtained results, risk priority factors were identified and appropriate behavioral strategies were determined. Obviously, by identifying the effective risk factors and determining and defining appropriate behavioral strategies and solutions, it will be possible to maintain efficiency inefficient units (time periods) and improve efficiency in inefficient units (time periods) in terms of design stability. By analyzing the risk factors affecting sustainable design, it was found that the two risk factors, weak technology/knowledge sustainability, and environmental pollution, have a higher priority than other risk factors. The table is below.

Risk factor	
	Thematic literature
Weakness of technology / knowledge sustainability	Tang and Tomlin, 2008
Environmental pollution	Blackburn, 2007

Table 13. Comparative Results of Risk Factors Analysis with Thematic Literature

6. Conclusion

The purpose of this study is to determine and identify the most important risk factors affecting design in the oil and gas and petrochemical industries was done using the opinions of experts and getting help from in-depth interviews with 5 industry experts and university professors, as well as completing a questionnaire by 8 experts (including 5 experts participating in in-depth interviews). According to the research findings, one of the key risks in sustainable design has been "environmental pollution", regarding the key risk of "environmental pollution", it is suggested that industry owners take serious and continuous measures in the field of "upgrading the level of process knowledge" and "planning training courses in the field of the environment". Other measures, such as the "establishment and maintenance of integrated management systems (IMS)", can have functionally good results in design. Finally, difficult access to senior managers due to their high workload for conducting interviews and completing questionnaires is one of the key limitations of the research. For future studies, it is suggested that sustainable design risk assessment in the Iran's oil, gas and petrochemical industry be done using machine learning and deep learning. In the present study, the evaluation of sustainability and identification of risk factors

in the Oil, Gas and Petrochemical Industry is considered, which can be developed for other industries, especially the electricity and energy industries.

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The Role of Internal Human Resource Orchestration on Firm Performance

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Abstract

The purpose of this research is to measure the mediating role of teamwork and participation (T&P) on the relationship between two human resource (HR) practices – “training and development” (T&D) and “performance appraisal” (PA) – and operational performance (OP). Employing the contingency approach, this study develops a research model that validates the assumption that appropriate internal orchestration of HR practices improves firm performance. Using AMOS, data from 157 manufacturing firms are analyzed through structural equation modeling (SEM). The results show that T&P fully mediates the relationship between T&D and OP, and partially mediates the relationship between PA and OP. This study, which provides empirical support for the importance of OP to firm effectiveness, finds that OP is positively related to financial performance (FP). The study develops a theoretical logic and empirically demonstrates that T&P is an appropriate practice for mediating the impact of T&D and PA on OP. The inclusion of T&P contributes to the theory and shows that appropriate internal orchestration of HR practices can realize effective OP and consequently greater FP of the firm.

Keywords: Training and Development, Performance Appraisal, Teamwork and Participation, Operational Performance, Financial Performance

1. Introduction

Firms are looking for ways to gain competitive advantage and improve their performance against rivals [1]. In this regard, various HR practices have received significant attention in the management literature, focusing on their impact on organizational [2], [3] and individual outcomes [4], [5], [6]. Although the direct impact of HR practices on firm performance has been widely studied [7], findings are inconsistent [8].

Most studies show a positive impact on performance [9], [3], [10], while other studies show a negative effect [11] or failed to find significant associations [12]. This

leaves several research questions unanswered or misinterpreted. Therefore, the question of how and which methods to use to improve performance remains a topic for further investigation [13]. As there is little consistency in the impact of HR practices on firm performance and little is known about whether HR practices influence each other and enable better OP, the need to integrate developmental HR practices is an important contribution to the literature. However, to date, little research has examined the impact of the mediating means of HR practices through which T&D and PA influence firm performance. This research gap is addressed in this study.

This research focus is on T&D – the level of formal training provided to a firm's workers [14]. And on PA – an effective system used by firms to develop their employees' appraisal and motivation [10] - as potential enablers of OP through the mediating means of T&P. In this vein, the aim of the present study is to explore the causal relationship between T&D, PA, T&P and OP, as well as the mediating role of T&P between T&D and PA practices and OP. By achieving the aim of the study, it contributes to the current state of the literature in several ways. First, the study contributes to broadening our understanding of the role of T&D and PA in realizing better firm performance (i.e., OP). HR researches believe that are quite limited studies that examine the implication of T&D [15], [16] and PA [17], [13]. In this respect, this paper is crucial as it provides empirical evidence on the impact of T&D and PA on achieving better business performance, especially OP.

Second, the debate on the instrument that transfers the impact of T&D and PA to performance concepts is relatively limited. In particular, little is known about the mediating role of T&P in relation to other developmental HR practices. Exploring the role of T&P as a mediator between T&D and PA practices and OP is another unique contribution of this study. “Individuals who are engaged in their work have high levels of energy, are enthusiastic about their work, and are completely immersed in their work activities” [18] (p. 4). Teamwork engagement is the focus of interest for HR practices [19], as it has been found to be positively related to team performance [20] and organizational performance [18]. T&P is critical to firm outcomes as it builds mutual trust and respect within a firm [10] and increases employee engagement. However, Bhuiyan [21] suggests empirically investigating whether the positive effect of participation on FP exceeds the cost of its implementation.

To recapitulate, in this research we identify the significant gap that can be bridged by examining the mediating effect of T&P on the link between T&D and OP or PA and OP, respectively. We also investigate the effect of OP in FP. To achieve the objective of this paper, it is necessary to answer the following research questions in particular: What is the nature of the relationship between T&D and PA practices with OP? What is the nature of the relationship between T&P and OP? How T&P mediates the relationship between T&D and PA practices with OP? And, what is the nature of the link among OP and FP? Hence, the outcomes of this research may have useful contributions for both researchers and practitioners to recognize the role of T&D, PA and T&P in providing better firm performance. Based on HR theory [17], the following section discusses the hypothesized relationships between T&D, PA, T&P and firm performance (OP and FP).

2. Theoretical background

2.1. Human resource practices

It is widely agreed that HR development can produce comparative advantage to the firm [22], if internal practices are well orchestrated. This study specifies additional values and develops new dimensions of HR management through the synthesis of three practices: training and development, performance appraisal, and teamwork and participation.

Training and development refer to the amount of informal education given to firm employees [14]. Training is defined as “[...] the most important factor in the business world because training increases the efficiency and the effectiveness of both employees and the organization” [23] (p. 63). It aims to bridge the gap between the extant capability of employees and job requirements [24]. Whereas, development is “[...] an unfolding process that enables people to progress from a present state of understanding and capability to a future state in which higher-level skills, knowledge and competencies are required” [25] (p. 570). Therefore, the integration of T&D practice is a boundless process to keep improving employees all the times [22]. Training targets the skill development [26], which may influence the employee performance in two ways, (a) improves and updates relevant abilities and skills of employees, and (b) increase employees’ happiness with their actual job and workplace [27]. Kadiresan et al. [22] highlight that T&D is essential to ensure workers with needed skills and competencies in order to improve, organization competitiveness, productivity and performance.

Although firms by T&D opportunities aim to increase employee knowledge, motivation and skills, training in itself may not generate the intended employee outcomes [28]. Indeed, the huge capital spending on T&D are not always translated into improved firm performance [30], it may have negative consequences, notably in the short term [31]. That said, empirical evidence about the contribution of HR development to organizational performance is inconsistent [32]. It is not clear if T&D is applied and brings benefit to all firms’ size [16], hence several “barriers” are identified to organizing formal T&D in smaller companies [33]. Therefore, Sung and Choi [28] highlight that given the prevailing skepticism on the benefits of T&D, a closer investigation of the connection between HR development and firm performance is necessary.

Performance appraisal has been broadly known by academics and practitioners as a HR practice [29], which aims to evaluate the effectiveness and efficiency of employees [5]. Its purpose “is to improve goal setting and feedback processes in order that employees can direct, correct and improve their performance” [14] (p. 1354). According to Fletcher [34], PA consists to “a variety of activities through which organizations seek to assess employees and develop their competence, enhance performance and distribute rewards” (p. 473). PA presents the most effectual method for workers’ evaluation, motivation and development, in modern time [5]. According to, Shaout and Yousif [35] PA aims to recognize the existing skills’ status of firm’s employees.

Even though PA is costly firms still adopt it, considering as an essential HR practice, the evaluation of employees “may either shape a satisfied frame of behavior after being appreciated or a frame of dissatisfaction after not being appreciated” [22] (p. 163). Thus, PA is an integral and undividable part of the organization [27]. Besides its importance and positive effect, still, employees may dislike PA, so it can serve also as a deregulator in the motivation process and organizational productivity [10]. According to Noe et al. [36], the words that come to workers’ minds when they make performance appraisals are: “time-consuming”, “dread”, “burden”, “frustrating” and “pain”, arguing that PA systems are ineffective to the point that they are manipulative, counterproductive, abusive and autocratic. Armstrong [25] shows several ways of realizing PA, such as, monolithic system, use of ratings, focus on quantified objectives, bureaucratic – complex paperwork, annual appraisal meeting, top-down assessment, and often linked to pay.

Teamwork and participation are a vital HR practices for firm success [10]. Teamwork refers “[...] to a group of employees created on purpose to carry out a particular job or to solve problems” [14] (p. 1353). The main purpose of the teamwork is to make employees to share knowledge, judgment and ideas among one another in order to achieve better organizational performance. Whereas, participation is described by Gulzar [37] as “[...] a process which allows employees to exert some influence over their work and the conditions under which they work” (p. 59). Employee participation plays a key “role in increasing employee commitment and determines the degree of job satisfaction” [10] (p. 22). Thus, T&P is an important HR practice for a high productivity and good communication among employees in the firm [38].

Social theorists consider the firm’s ability to develop teamwork as one of the growth and success elements for a high level of efficiency [39]. Therefore, adoption of teamwork and the application of collective skills improve employees’ productivity [19]. Employees working together to perform a job, to think and argue about it, generate a rich and comprehensive work plan, which make their productivity and progress more visible [40]. However, Bhuiyan [21] highlights that the positive impact of employee T&P on performance of the firm cannot be considered a postulate, it is essential to make further measurements in order to find its real effect. According to him, there are several factors that hinder employees to participate or work in a team, such as, lack of workforce diversity, unwillingness of the management, absence of labor union activities, illiteracy of workers and political grouping among workers.

2.2. Firm performance

According to Islami [10], performance refers to “[...] the difference between the cost of capital used by an organization to operate and its achieved results” (p. 74). In literature, the performance of an organization mainly is measured using operational indicators – measuring firm achievement in non-monetary terms or competitive advantage items – (e.g., [31], [14]), financial indicators – focusing on items that directly reflect the financial value – (e.g., [41], [42], [43]), or integrating both OP and

FP indicators (e.g., [44], [45], [1], [46]). In this study, the items to measure OP and FP will be adopted in line with above literature.

3. Research model and Hypotheses

The conceptual model in Figure 1 describes that the correlation between T&D and PA with OP would be mediated by a suitable HR practice. Precisely then, T&P would mediate the relationship between T&D and OP; and secondly, T&P would also mediate the relationship between PA and OP. In addition, the direct relationship between OP and FP is described. The rationale for the research hypotheses is described below. The summary for the relationship between H_{1A} , H_{1B} , H_{2A} , H_{2B} , H_3 , H_4 , H_5 and H_6 is shown in Figure 1.

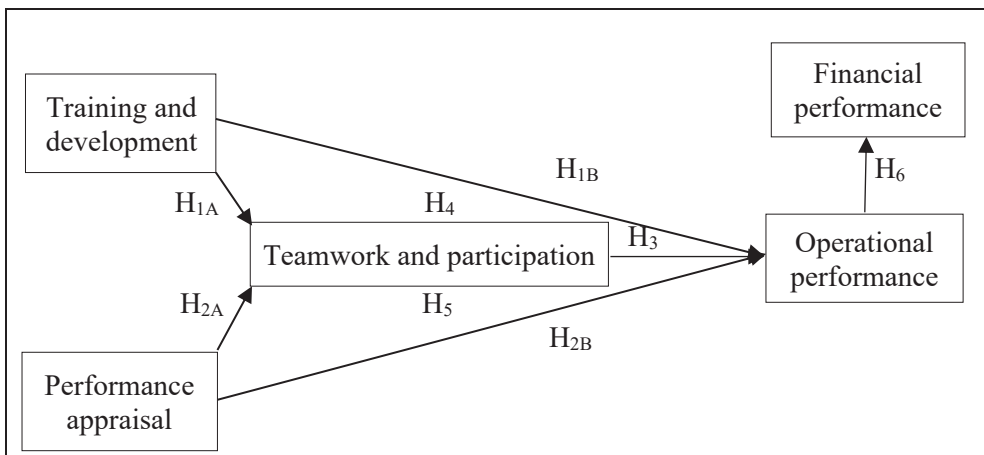


Figure 1. Research model and hypotheses

3.1. Training and development, performance appraisal, teamwork and participation, and operational performance

T&D affects employees' capabilities and is a tool to improve their productivity and thus the overall performance of the company [47]. Furthermore, Susomrith et al. [16] emphasize that employee engagement is related to T&D. PA, a management method for improving employee outcomes [48], is also an essential dimension of organizational performance. It can be considered as a trust mechanism between employees and their organization, which is crucial for improving employee engagement and commitment in the firm [17]. Following this argument, first hypotheses of this research (H_{1A} , H_{1B} , H_{2A} and H_{2B}) postulate the main relationships between T&D and PA with T&P and OP.

A link between T&D and affective organizational commitment is analyzed by Susomrith et al. [16], where T&D is examined as the antecedents of employee participation and engagement. Affective organizational commitment refers to an employee's emotional attachment and engagement with the work organization [49].

In such a participative employee environment, it is important to provide employees with access to T&D opportunities [50]. This is because employees view T&D as a mechanism to improve their career prospects and work performance [51]. It can encourage employees to respond through positive organizational behavior and show more loyalty to the organization [52]. In addition, T&D practice contributes to the growth of positive sentiment towards organizational progress and change as it is affirmed by individuals, groups and teams [53]. This positive feeling to contribute will increase their ambitions for T&P in the firm. Thus, based on the findings of previous research, it is fair to say that this relationship is still quite unexplored in the management literature. Therefore, the effect of T&D on T&P is an empirical question. Accordingly, it is proposed that:

H_{1A}: An employee's T&D has a positive influence on its T&P.

T&D is a key factor in human resource management because it improves the individual, group and organizational efficiency and effectiveness [23], [54] and provides various benefits for society [51]. Therefore, Chatterjee [55] classifies T&D practice as a human capital investment that has a positive influence on the strategic benefits and returns of the organization. Therefore, developing employees through training is an important practice for organizational success as employees have clear communication and feel valued [15]. Previous studies have shown that there is a positive relationship between training and organizational performance [56], [57]. For instance, Lyons [58] highlight that T&D improves employee performance by developing appropriate skills. Kadiresan et al. [22] also points out how important it is for companies to use T&D to increase the competence and performance of their employees. If there are unexpected problems in the implementation of OP in the company, relational T&D programs would help the company to improve its product quality, responsiveness to customer queries and customer service, which in turn can increase customer loyalty towards the firm. Therefore, we propose the following hypothesis:

H_{1B}: An employee's T&D has a positive influence on firm's OP.

Workers' awareness that their individual performance is valued increases their productivity because they work harder to perform better [5]. But "working in a team hinders the identification of individual performance because of the presence of interdependencies" [29] (p. 9). Accordingly, teamwork is identified as a dimension that presents difficulties in measuring employee performance. This may discourage employees from working as a team, as their individual contributions may not be fairly evaluated due to interdependencies. To address this problem, we seek to measure whether PA affects employees' T&P. In other words, the aim is to measure whether employees work more as a team and participate more in solving problems when they are aware of their performance evaluation.

Several studies have found that employee engagement is closely related to their perception of fairness of PA [59], [60]. Employees' perception that the performance appraisal process is fair increases their efforts to contribute to the achievement of organizational goals [22]. Therefore, Akhtar and Khattak [61] point out that

performance appraisal is important because it determines the level of participation in the organization. Firms “capable of building performance appraisal systems which employees consider to be satisfying harvest many vital employee outcomes at the workplace” [62] (p. 111). It is therefore predictable that the experience of fair treatment by employers can increase employee participation in improving organizational performance. It is expected that a positive perception of the PA system by employees will encourage them to participate and be highly engaged [17]. PA is thus an upstream factor in employee engagement [63]. Therefore, we propose the following hypothesis:

H_{2A}: An employee’s PA has a positive influence on its T&P.

PA should be designed to produce positive effects for the organization. Bayo-Moriones et al. [29] show that performance appraisal is multidimensional and that the manager must design it in such a way that the organization receives positive results. Several previous studies have indicated that there is a significant relationship between PA and organizational performance [56], [64], [57], [13]. Harmonizing HR practices, such as incentive compensation and formal training, increases PA, leading to a greater effect on productivity [65]. PA is indeed a means of providing incentives for talented employees to be satisfied with the organization [66]. On the other hand, ineffective PA can lead to various undesirable problems, such as low enthusiasm for organizational support, lower employee productivity and morale, and thus lower organizational performance [67]. Thus, fair and proper implementation of the employee appraisal process enables higher employee productivity and, consequently, higher organizational performance. In line with the foregoing, the following hypothesis can be made:

H_{2B}: An employee’s PA has a positive influence on firms’ OP.

3.2. The mediating role of teamwork and participation

One of the main elements that realize a good OP is the nature of the links between HR practices, reflected in the cohesion between them. For this reason, to explore the contribution of staff T&D and their evaluation by PA on the participation and cohesion among staff (teamwork), which in turn can improve the working climate and OP, and then FP. We proposed to measure the mediating role of T&P.

The literature indicates that employee participation improves firm performance [67], [57]. Employee participation plays an important role in the decision-making process, which leads to the efficiency of the firm [68]. According to Abdulkadir et al. [69], T&P is an arrangement that ensures that workers have the opportunity to influence supervisory decisions and contribute to the improvement of organizational performance. In this context, Mohammad [70] highlights that participation is the mechanism of work discussion among employees that enables them to share ideas and information. Worker involvement and participation at different levels is therefore considered an important indicator of firm competitiveness, capacity for continuous innovation and excellence in production [68]. We assume that T&P can play a crucial role in promoting OP.

H₃: An employee's T&P has a positive influence on firms' OP.

Although much of the management literature has demonstrated that T&D and PA are positively related to firm performance, both empirical evidence and theory provide a logical argument for why T&D and PA can predict firm performance, the mechanisms that enable this relationship remain vague. They were left to explore that the role of T&P practices could be a significant factor in making the link between T&D and PA practices to OP more effective. Thus, if the company does not adopt T&P practices, it cannot reap the full benefits of T&D and PA. Thus, T&D and PA influence workers' commitment and dedication to organizational improvement and make them feel more involved in fulfilling organizational tasks [22]. In this way, employees are perceived as part of the team. This can improve their commitment to the organization [71], which in turn can improve overall organizational performance. T&P can therefore transform the effects of T&D and PA achieved in the human resource management process into a contribution to overcoming the organization's difficulties.

This study focuses on the potential mediating role of T&P in the relationship between T&D and PA practices and OP for the following reasons. First, T&P is one of the most widely studied PA practices and has been found to be significantly associated with a variety of outcomes, including firm performance, in recent empirical research [10], [45], [14], [67], [57]. Second, organizing appropriate T&D programs and fair compensation systems will increase employees' willingness to be more involved in the organization, to work in teams to solve organizational problems, and to implement company procedures and policies. Third, previous studies have also found that T&P is significantly associated with T&D [50], [53], and PA [61], [17], [63]. Fourth, previous research has substantiated a substantial relationship between T&P and firm performance through various research positions (e.g., [69], [13]). Finally, T&P is believed to facilitate the link between other HR practices and firm performance. For example, Islami [10] notes that companies that provide a suitable internal environment view workers as an important part of the team and are able to contribute their ideas, which in turn can improve firm performance.

Based on these arguments, it can be concluded that T&P practices have a mediating effect in the link between T&D and PA practices and the OP, in the following way: the company's leaders have a clear vision of what the company wants to be and what it wants to achieve in the future. T&P activities play an important role in realizing the manager's plan to achieve a viable competitive position. By organizing T&D and PA systems, the manager's plan will not be effectively translated into the better OP without the collaboration of internal HR practices such as T&P. In order for the plan to become a reality, T&D and PA practices must be based on T&P activities to help the company become competitive in the market. In summary, assuming that T&D and PA practices predict T&P and T&P predict OP, it is possible that T&P mediates the link between T&D and PA practices and OP. Therefore, in light of the theoretical and empirical research discussed earlier, we expect that T&P mediates the relationship between T&D and PA practices and OP, in such a way that T&D and PA

are positively related to T&P, which in turn positively increases OP. Therefore, based on the above discussion and arguments, this study hypothesizes the following:

H₄: An employee's T&P mediates the link between employee's T&D and firms' OP.

H₅: An employee's T&P mediates the link between employee's PA and firms' OP.

3.3. Operational and financial performance

Li et al. [46] highlight that “having a competitive advantage generally suggests that an organization can have one or more of the following capabilities when compared to its competitors: lower prices, higher quality, higher dependability, and shorter delivery time” (p. 111). These indicators will in turn increase the overall performance of the firm [72]. Improving firm OP to a level that “a competitive advantage can lead to high levels of customer satisfaction and loyalty, relationship effectiveness” and economic performance [46] (p. 111). Accordingly, a firm that offers high quality products can charge higher prices and thus increase its return on investment and profit margin on sales. An organization that responds to customer requests in a short time, provides a high level of service and delivers its products quickly and reliably can increase customer loyalty and achieve a higher sales volume. Therefore, a positive relationship between OP and FP can be proposed.

H₆: The higher the OP level, the higher the FP level.

4. Methods

4.1. Sampling and data collection

A mail survey was used to collect the required data. The element of analysis was the manufacturing firm. Key respondents were selected from senior and middle managers who responded authoritatively to questions on human resource practices and OP [10]. Then, two months later, financial managers were asked in a separate questionnaire about the financial aspect of their firm [10]. Following Gölgeci and Kuivalainen [42] and based on the Podsakoff et al. [73] requirements to mitigate the “common method variance” (CMV), this study used dual respondents of each firm for the survey. In order to make the examination more in-depth, which allows for more reliable and realistic results, the research variables measure the use of HR practices and the benefits derived from their relationships from March (2017 - 2020), while the company's performance was observed for the period of March (2019 - 2020). It was considered that the full effect of the use of the independent variables (training and development, and/or, performance appraisal) and the mediator (teamwork and participation) as HR practices on operational and financial performance will be revealed after 2 years.

The sampling frame used the “Kosovo Agency of Statistics” (KAS), where 600 firms meeting our selection criteria were selected from the 10,190 firms listed by KAS

[10]. Only 447 manufacturing firms had up-to-date contact information. The questionnaires were accompanied by a cover letter specifying the objectives of the study, the confidentiality of the use of their data, potential contributions and ethical issues. In line with Frohlich [74] and Islami [10] suggestions to improve the response rate, emails were followed up with phone messages and calls. Finally, with an effective response rate of 35% of the contacted sample, 157 firm were used in our further analyses. The main characteristics of the firms in the sample are presented in Appendix A. The results show that about 43 per cent of the responding firms had more than 20 years of work experience and more than half of them had less than 49 employees.

4.2. Measurement

In this study, we used existing validated scales to measure “training and development” [10], [45], [14], [75], “performance appraisal” [64], [45], “teamwork and participation” [10], [14], [76], “operational performance” [44], [10], and “financial performance” [42], [44], [10], [1], [77]. Respondents answered on a Likert-type scale ranging from 1 to 7. The scores of the scale items are provided in Appendix B.

5. Analysis and results

5.1. Reliability and validity

To validate the dimensionality and reliability of the research constructs a rigorous process is used. Following the requests of Podsakoff et al. [73] and based on previous practices used by Huo et al. [44] and Islami and Topuzovska Latkovikj [1] prior to data collection, “content validity was established through a domain search of the literature, an iterative construct review by domain experts, careful synthesis and critical evaluation of existing constructs executive interviews, pre-pilot study and pilot study” [10] (p. 122). After data collection, “several purification processes and analyses to test the reliability and validity of the constructs were conducted, including factor analysis, means, standard deviations, internal consistency analysis (Cronbach’s alpha)” [10] (p. 122) and correlation analysis (see Table 1). In addition, the study addressed potential non-response bias during the data collection process using Harman’s single-factor test where no single factor is found to explain more than fifty percent (>50%) of the variance. Consequently, there was no serious common-method bias in this research.

CFA measurement model was run to estimate construct validity. The results of the measurement model indicate a moderate model fit: ($\chi^2_{(157)} = 374.28$; $df=218$; $p<.001$; $NFI=.85$; $IFI=.93$; $TLI=.92$; $CFI=.93$; $RMSEA=.06$). For all measures, the estimates of “composite reliability” (CR) and “average variance extracted” (AVE) were above the recommended thresholds of 0.7 and 0.5, respectively, demonstrating convergent validity.

Definition	# Items	α^1	Mean	S.D.	1	2	3	4	5
1. Training and development	4	0.87	3.94	0.97	.				
2. Performance appraisal	5	0.90	5.39	0.96	0.62**	.			
3. Teamwork & participation	3	0.87	4.33	0.96	0.65**	0.67**	.		
4. Operational performance	4	0.88	5.94	0.65	0.44*	0.62**	0.59**	.	
5. Financial performance	7	0.88	5.13	0.74	0.24**	0.41**	0.21**	0.31**	.

Table 1. Descriptive statistics, cronbach's alpha, and inter-correlations.²

Indeed, according to Hair et al. [79] CR values ($>.7$) confirm reliability, AVE values ($>.5$) confirm convergent validity, and maximum shared variance ($MSV < AVE$) and the square root of AVE greater than inter-construct correlations confirm discriminant validity. In addition, to address potential multicollinearity issues, the “variance inflation factor” (VIF) is measured. The results show that none of the constructs pose a multicollinearity problem, as the values are well below the threshold of 4 recommended by Pan and Jackson [78]. All these results are presented in Table 2. Finally, the “exploratory factor analysis” (EFA) shows that all item loadings are above the recommended threshold value of .50 [79], and none of them are cross-loaded with other constructs.

Construct	CR	AVE	MSV ³	T&D	PA	T&P	OP	FP	VIF ⁴
Training and development (T&D)	0.87	0.69	0.43	0.83					1.86
Performance appraisal (PA)	0.90	0.64	0.45	0.62	0.80				2.28
Teamwork and participation (T&P)	0.88	0.71	0.45	0.65	0.67	0.84			2.49
Operational performance (OP)	0.80	0.51	0.39	0.44	0.62	0.59	0.71		1.00
Financial performance (FP)	0.87	0.50	0.17	0.25	0.41	0.21	0.31	0.70	

Table 2. Convergent and discriminant validity of the measurement model.⁵¹ Cronbach's alpha³ Maximum Shared Variance⁴ Variance Inflation Factor⁵ Note: N = 157. “Correlation is significant at the 0.01 level (2-tailed)”. (** p < 0.01; * p < 0.05). Bold values on the diagonal are the square root of the AVE values.

5.2. Hypotheses testing

Figure 1 illustrates the theoretical model on which this research is based. This study by estimating a SEM in AMOS 26 has tested the hypothesized relationships. SEM is a comprehensive technique that enables to analyses relationships of latent variables, and test non-normal and time-series data [42]. Therefore, for this study, the SEM method is considered appropriate, as the majority of constructs in the conceptual model are latent and it tests for mediation effects in the whole model.

In the whole model, both direct and mediating T&P paths are tested. Where the interaction terms in the model are applied, using the single indicator estimation method to calculate them [42]. The fit statistics for the structural model are well within generally accepted limits ($\chi^2_{(157)}=385.25$, $df=221$, $p<.001$; NFI=.84; IFI=.93; TLI=.92; CFI=0.93; RMSEA=.06). The standardized parameter estimates and directional significance levels for the structural paths examined are presented in Table 3. The full set of relationships in the proposed model is presented in Appendix B and C.

(Hypotheses) Path		Coefficient (t-value)		Results	
<i>Direct effects</i>					
(H _{1A})	T&D → T&P	0.38 (4.00)***		Supported	
(H _{1B})	T&D → OP	-0.03 (-0.26)		Not supported	
(H _{2A})	PA → T&P	0.44 (4.45)***		Supported	
(H _{2B})	PA → OP	0.44 (3.36)***		Supported	
(H ₃)	T&P → OP	0.31 (2.44)*		Supported	
(H ₆)	OP → FP	0.33 (3.20)**		Supported	
<i>Mediating effects</i>		Total Effects	Direct Effects	Indirect Effects	
(H ₄)	T&D x T&P → OP	0.09 (<1.65)	-0.03(<1.65)	0.12 (>2.58)**	Supported
(H ₅)	PA x T&P → OP	0.58(>3.30)***	0.44 (>1.65)*	0.14 (>1.96)*	Supported

Table 3. Structural model estimation results.⁶

5.2.1. Direct effects and mediation

In H_{1A} is argued that T&D is connected positively to T&P, while in H_{1B}, a positive relationship between T&D and OP is not found. The results support the first hypothesis (H_{1A}) with ($\beta=.38$; $t=4.00$; $p<.001$), but do not support hypothesis H_{1B} with ($\beta=-.03$; $t=-0.26$; $p>.10$).

In H_{2A} and H_{2B}, is argued that PA is connected positively with T&P and OP. The results support these hypotheses ($\beta=.44$; $t=4.45$; $p<.001$, and $\beta=.44$; $t=3.36$; $p<.001$,

⁶ Notes: “Critical values of the t distribution for $\alpha=0.10$, $\alpha=0.05$, $\alpha=0.01$, and $\alpha=0.001$ (two-tailed test) are $^+=1.65$, $^*=1.96$, $^{**}=2.58$, and $^{***}=3.30$, respectively”. The coefficients are standardized regression coefficients.

respectively). In H_6 , is expected that OP is positively linked with FP. In support of this hypothesis, the path between OP and FP is significant ($\beta=.33$; $t=3.20$; $p<.01$).

To test mediation, initially was tested the direct links between T&P and OP. Where in H_3 , was expected that T&P is positively linked with OP. In support of this hypothesis, the path between T&P and OP is significantly positive ($\beta=.31$; $t=2.44$; $p<.05$). Then was analyzed indirect effect by setting the number of sampling iterations (N) to 5000, using the bootstrapping method suggested by Hayes [80]. When testing the mediating effect of T&P, the direct effects between T&D and OP were found to be still non-significant at $p<.05$ with the mediation. Moreover, the bootstrapping method revealed that the indirect effect of T&D on OP through T&P was significant at $p<.01$ ($p=.007$). This result argument the full mediation and supports H_4 . In addition, when testing the mediating effect of T&P, the direct effects between PA and OP were found to be significant at $p<.05$ with the mediation, whereas $p<.001$ without the mediation. The bootstrapping method, also revealed that the indirect effect of PA on OP through T&P was significant at $p<.05$ ($p=.014$), which argument the partial mediation and supports H_5 .

6. Discussion and conclusions

Firms operate in an increasingly unfriendly and turbulent environment [42]. Therefore, the firm's T&D and PA practices, resulting from its network connections with other HR practices, could provide exclusive income that could influence its OP. Yet, little is known how and when the interactions among the HR practices lead to OP. This study place of interest the scarce attention paid to inspecting the in-depth image of the relationship between R&D and PA practices and OP. It also takes out the dominant premise that T&P can play an influential role in clarifying how companies can utilize T&D and PA and improve their OP, consequently, their FP. The findings of this study suggest that T&P can function as a linking pin between T&D and PA practices and OP and clarify how T&D and PA can be used to increase the firm performance. For the reason, that T&D and PA are vital resources, link intra-boundary capability of T&P are necessary to channel its potential toward planned ends so as to realize its influence on the competitive market and OP. This result advances the existing researches that examine the linkages between T&D and firm performance [23], [28] and between PA and performance of the firm [29], [13], but have overlooked mediating internal mechanisms that serve as a channel on the relationship between these constructs. The outcomes also expose that the role of OP has positive and significant influence on FP, which is in line with Li et al. [46] who found that competitive advantage can have a direct and positive influence on performance of the organization.

The findings of this study rich the extant body of HR and strategic management literature in several directions. First, it contributes to inquiries on how the dimension of T&D is put into use through T&P to concretize its potential impact on OP. Therefore, these outcomes on the effect of T&D practice as a relational basis of OP complement existing study, which has measured mainly the impact of HR practices on performance of the firm using behavioral but not contingency perspectives (e.g.,

see [10], [45], [14], [81]). Second, it suggests that the utilization of PA competences should not be separated from T&P of employees. The addition of T&P into the equation develops an indirect view of the effect that PA shows in OP. Hence, these findings indicate that T&P is an important condition for firm performance and organizational existence, since firms may face a greater chance to failure if they do not integrate their HR practices (e.g., T&D, PA and T&P) strategically. This contribution can explain why some firms might have bad OP although they may possess a high level of T&D and conversely help decompose paradoxical findings in research on T&D, PA, T&P and OP. Third, previous studies have mainly assumed T&D and PA as essential practices in volatile and disruptive settings [10], [45], [16], but paid little attention to the internal orchestration of HR practices using empirical tests. This study moves beyond a mere supposition that T&D and PA are crucial for firm performance and empirically tests whether T&P channels the potential impact of T&D and PA on increasing firm performance.

To conclude, this study orchestrates HR practices as a set of tactics to integrate T&D, PA and T&P, which practices work interdependently and complement one another in a manner to be able to ensure both individual and operational performance. Following the Sabiu et al. [13] approach, in this paper HR practices are treated as activities that ensure that resources are integrated in the manner to fulfill organizational goals. The study results acquired through SEM depicted in Figure 1 and solved in Appendix B indicate that T&D and PA practices have a positive indirect effect (through T&P) on OP. The results for mediating role of the T&P practice are in harmony with modern HR management requests and undoubtedly have theoretical and practical implications where managers think about how to link internally HR in the employment of T&D and PA.

6.1. Managerial implications

The results of the current study show that employee satisfaction with the PA system is an important element that affects their participation and thus leads to an improvement in the climate of teamwork in the company. This suggests that companies should priorities employee satisfaction with the PA system in order to achieve the desired results. In particular, top managers should use effective evaluation systems that are reliable and neutral. In addition, before implementing T&D programs and PA systems, management should define employee satisfaction or acceptance and inform them how they will be implemented. In addition, practitioners should note that satisfaction with T&D and employee appraisal can be achieved through relational fairness - the degree to which the employees involved are treated with respect by managers. This strategy emphasizes the importance of T&P for employees at every stage of the task implementation process to perform their tasks well and contribute positively to the organization as a whole.

It also recommends that T&D programs and PA systems should be organized more frequently and that managers should know their employees well in order to provide appropriate development programs and fair appraisal. These activities should be organized to increase staff motivation, make them feel valued and improve their

contribution to the company in terms of participation and teamwork in solving problems to improve the company OP. In order for employees to be more committed to participation and teamwork, they should be able to see how their performance is valued and their skills improved.

Finally, most companies have valuable resources and effective policies embedded in their organization. However, some of these essential resources cannot have their impact if they are not linked to the company's internal practices. Therefore, companies should encourage and stimulate employees' T&P and use their T&D in the pursuit of better OP. Although heavy investment in T&D is required to develop, sustain and operate it. It is a valuable endeavor as it could play a significant role in organizational performance in the long run [31]. In addition, we highlight that T&P also facilitates the realization of PA's potential for OP, thus we believe that T&P is a valuable practice for companies. Therefore, maintaining organizational cohesion through resources embedded in internal HR practice relationships is beneficial to achieving better OP. Companies that seek greater internal integration of HR practices are likely to be better able to manage their T&D, PA and T&P to improve OP and FP.

6.2. Limitations and future research

This research offered a relational view of HR practices. It suggests that the orchestration of HR practices can be a critical source of organizational performance. Nevertheless, a deeper approach is needed to analyze the internal linkages of HR practices in order to specify how such practices can be used to help companies be leaders in their industry. As there might be a difference between the perception and reality of T&D and PA as HR practices, it is not clear how such a difference might affect T&P and business performance. Future research may measure the role of other HR practices in OP or FP. For example, the practices analyzed in this study do not represent all HR practices. Therefore, future research can investigate the integration of additional practices, such as: recruitment and selection, compensation incentives, job analysis and description, and employment security [10], which have been overlooked in this study. Moreover, this model can be implemented in different industries and in different contexts.

In addition, since the majority of existing studies focus on HR practices that have a positive impact on performance, it is important to examine which practices may hinder or affect employee or organizational performance. For example, the negative factors that may hinder effective implementation of T&D, PA or T&P should be identified and investigated.

Furthermore, Tóth et al. [82] emphasize that qualitative analysis provides a better understanding of how different combinations of conditions/structures lead to a particular outcome. From a procedural position, human resource management studies can therefore “benefit from methodologies beyond commonly adopted methods of case studies and survey-based research” [42] (p. 73). In turbulent and dynamic markets, qualitative analysis can be used to discover different pathways or patterns in the implementation of human resource management strategies, as it allows researchers

to interpret the collaborative nature of the underlying forces behind human resource practices.

Finally, this research only measured the upright relationship between T&D, PA, T&P, OP and FP. Future research could focus on investigating reverse causality, e.g., the influence of FP on OP or whether better OP has an influence on the use of T&D, OP or T&P practices, which would provide more information about the cause-effect relationship uncovered in this research.

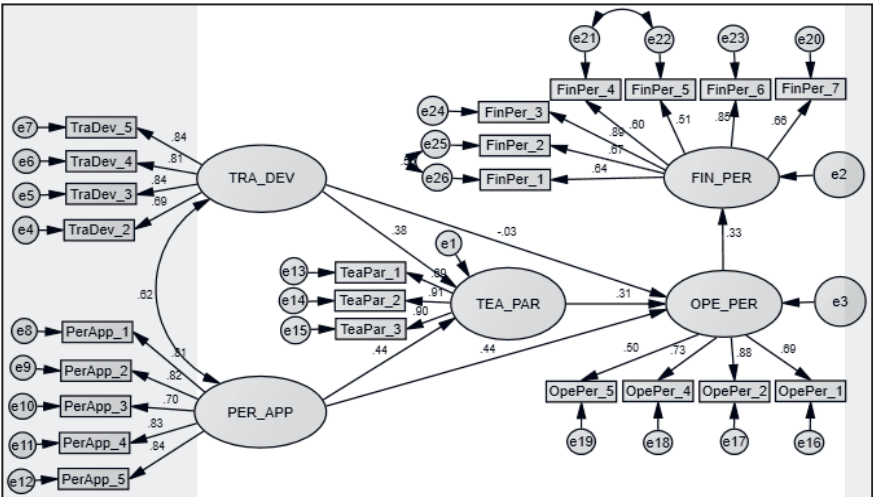
Acknowledgment

This paper analyses data collected by the first author for his PhD thesis. The dissertation is published by the Faculty of Economics of the "Ss. Cyril and Methodius" University, Skopje, Republic of North Macedonia. Based on the same data, we tested the model we propose in this paper, which is completely different from the model tested in my PhD thesis and other related research.

Appendix A. Characteristics of sample firms.

Industry sector	Food	Textile	Construction	Wood	Metal	Plastic	Chemical	Other
Number	31	7	63	15	11	6	5	19
Percent (%)	19.7	4.6	40.2	9.8	7.1	3.9	2.6	12.1
Number of employees	10–49	50-249	≥250	Firm age		≤10	11–20	>20
Number	96	57	4	Number		49	41	67
Percent (%)		61.2	36.3	Percent (%)		31.2	26.1	42.7
Annual revenue (2019 value)			≤€1 million	€1 –10 million		> €10 million		
Number			71	80		5		
Percent (%)			45.5	51.3		3.2		

Appendix B. Measurement items and proposed model.



Note: Standardized loadings - all items' loadings are significant at p < .001 (***).

Appendix C. Constructs and items abbreviations

“To what extent did your organization use the following practices in last three years 2017 March – 2020 March”, (evaluate from 1 – “not at all” to 7 – “to an extreme extent”).

Training and development (TRA_DEV)			
“TraDev_1*”	“Providing extensive training programs for individuals in their jobs.”		
“TraDev_2”	“Activities of the training program provided meet the needs of the employees.”		
“TraDev_3”	“Formal training programs are offered to employees in order to increase their promotability.”		
“TraDev_4”	“Identifying realistic and useful training needs based on the competitive strategy of the organization.”		
“TraDev_5”	“Providing formal training programs to teach new hires the skills they need to perform their jobs.”		
Performance appraisal (PER_APP)			
“PerApp_1”	“Appraisal system is growth and development oriented.”		
“PerApp_2”	“Employees have faith in the performance appraisal system.”		
“PerApp_3”	“Appraisal system has influence on individual and team behavior.”		
“PerApp_4”	“The appraisal data is used for making decisions like job rotation, training, and compensation.”		
“PerApp_5”	“The objectives of the appraisal system are clear to all employees.”		
Teamwork and participation (TEA_PAR)			
“TeaPar_1”	“During problem solving sessions, an effort to get all team members’ opinions and ideas is given before making a decision.”		
“TeaPar_2”	“Forming teams to solve problems and in the past 3 years many problems have been solved through small group sessions.”		
“TeaPar_3”	“Problem solving teams have helped improve manufacturing processes.”		
“TeaPar_4*”	“Employee teams are encouraged to try to solve their problems as much as possible.”		
“TeaPar_5*”	“Allowing employees to make decisions related to cost and quality matters.”		
Market/operational performance (OPE_PER)		Financial performance (FIN_PER)	
“OpePer_1”	“Overall product quality.”	“FinPer_1”	“Return on investment (ROI).”
“OpePer_2”	“Responsiveness to customers.”	“FinPer_2”	“Growth in return on investment.”
“OpePer_3*”	“Customer service level.”	“FinPer_3”	“Growth in sales.”
“OpePer_4”	“Delivery speed.”	“FinPer_4”	“Return on sales (ROS).”
“OpePer_5”	“Delivery dependability.”	“FinPer_5”	“Growth in return on sales.”
		“FinPer_6”	“Growth in market share.”
		“FinPer_7”	“Growth in profit.”

Note: “Items marked by an asterisk (*) were removed in the final instruments”.

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A Modified Boosted Ensemble Classifier on Location Based Social Networking

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Abstract

One of the research issues that researchers are interested in is unbalanced data classification techniques. Boosting approaches like Wang's Boosting and Modified Boosted SVM (MBSVM) have been demonstrated to be more effective for unbalanced data. Our proposal The Modified Boosted Random Forest (MBRF) classifier is a Random Forest classifier that uses the Boosting approach. The main motivation of the study is to analyze sentiment of geotagged tweets understanding the state of mind of people at FIFA and Olympics datasets. Tree based model Random Forest algorithm using boosting approach classifies the tweets to build a recommendation system with an idea of providing commercial suggestions to participants, recommending local places to visit or perform activities. MBRF employs various strategies: i) a distance-based weight-update method based on K-Medoids ii) a sign-based classifier elimination technique. We have equally partitioned the datasets as 70% of data allocated for training and the remaining 30% data as test data. Our imbalanced data ratio measured 3.1666 and 4.6 for FIFA and Olympics datasets. We looked at accuracy, precision, recall and ROC curves for each event. The average AUC achieved by MBRF on FIFA dataset is 0.96 and Olympics is 0.97. A comparison of MBRF and Decision tree model using 'Entropy' proved MBRF better.

Keywords: Social Network Services (SNS), Location Based Social Media (LBSM), Random Forest, Imbalanced data learning

1. Introduction

Users quickly adopted the global popularity of Social Network Services (SNS) such as Foursquare and Yelp, and they have become an integral part of people's daily lives [1][2][3]. Users can search for people who share their interests, share check-in and check-out locations, and upload photos of places they've visited. Location Based Social Networks (LBSN) encourage users to discover destinations and guide them to familiar or unfamiliar locations. An event is a scheduled occurrence that contains

spatial information. People from various countries who attend the event share their reactions to the events [4] as well as location information, resulting in location-based social media (LBSM). When compared to a social media post without geotagging, the location parameter is estimated to be twice as valuable. These reactions convey sentiment classified as positive or negative.

The objective of this work is to examine the sentiment of people who tweet from the venue. Sentiment-based marketing is possible due to this type of analysis, which extracts geolocation as well as views and interests. Marketers get access to extensive information from the posts, such as check-in statistics, activities, patterns, and transactions, all of which can be used to provide commercial recommendations. Marketers can use these tweets from events to become proactive organizers to generate or involve customers in business. Recommendations such as top-rated locations (in vicinity to event locations), activities to participate in (such as sight-seeing, dining, and shopping), and friends to collaborate can be posted to Tweeter. We use Random Forest classification to implement the Adaptive Boosting approach. Freund and Schapire presented Adaboost as one of the boosting ensemble strategies in 1996. An ensemble system, also known as a multiple classifier system, is a supervised learning model.

Data can either be balanced with an equal number of instances in both classes and imbalanced data with an unequal number of occurrences [6]. For example, fraud detection and disease detection are both examples of imbalanced data. Classification algorithms classify the majority class more accurately in comparison to minority class. In real life situations for enhancing marketing minority class prediction plays an important role. One way for reporting with an imbalance class is to 'boost' the dataset using classification methods [7][8][9]. We propose AdaBoost Ensemble Approach using Random Forest classification to address Imbalanced data.

The remainder of the paper is organized as follows: Section 2 goes over the associated work. Section 3 elaborates on the proposed Modified Boosted Random Forest (MBRF) method using an architecture model with heuristics and data sources. Section 4 depicts the studies carried out, which include i) a performance comparison of the MBRF and decision tree using performance measures also at different folds. ii) comparison of MBRF using ROC curves. Finally, in section 5 we'll make a few remarks with the conclusion.

2. Related work

LBSM has been used by researchers to analyze event usage and traveler mobility patterns. Natural disasters such as hurricanes, earthquakes, and other natural disasters are also exploited through social network systems. People actively utilize social media to share disasters by tweeting about them, sending out alerts, and marking them as safe [10][11]. We discuss how researchers have used Adaboost and Random Forest (RF) classification to classify species, traffic signs, cancer cells, crops, and many other things in the second section of related work. Random Forest is utilized in medical sector predictions, such as neuroimaging data in alzheimer's disease [12], optimal drug therapy [13], prediction of early kidney transplant [14][15], COVID-19

prediction using patient's symptoms [16]. Ensemble method-based architecture using random forest predicts employee's turn over [17], for classifying urban land cover [18], in soil data [19][20], in twitter sentiment analysis with the polarity detection task in [21][22][23].

Related work has examined imbalanced class problems and techniques which are applied is discussed in table 1.

Reference Number	Technique	Methods and Description
[24]	One-class classification techniques	using local outlier factor, one-class support vector machine and isolation forest methods. Better performances when the datasets have very high-class imbalance ratios.
[25]	SMOTE Oversampling and Random Oversampling techniques	ML algorithms such as KNN and Naïve Bayes. Increases the number of minority class data.
[26]	Im.ADABOost combining weighted -SVM	Initializes error weights and calculates confidence weights.
[27]	Tomek link under sampling algorithm.	Balancing approach - oversampling the minority class data or undersampling the majority class data.
[6]	Modified Boosted SVM (MBSVM)	distance-based weight-update rule and sign based classifier removal technique.
[28]	Wang's Boosted SVM	Cost-sensitive boosting algorithm.
[29]	Two-stage clustering-based surrogate model	Undersampling approaches.
[30]	Boosting and crossover methods real-world medical datasets	Optimizing the ratio of the two classes with different imbalance ratios.
[31]	Boosted support vector machine (B-SVM)	Classification techniques for predicting the credit ratings of banks.

Table 1. Research work on Imbalanced data and its techniques.

3. Working of MBRF

With the use of smart devices growing, social media's popularity is at an all-time high. Individuals can share their location and interests through photographs or tweets on location-based social media (LBSM). The location parameter serves higher information content when compared to social media post without geotagging. By analyzing reactions posted by attendees at global events, business and the economy can be elevated. Each reaction indicates a state of mind, emotion, or interest, along with a sentiment, all of which can be used to provide commercial recommendations. Such as travel locations, activities to participate in (such as sight-seeing, dining, and shopping), and friends to collaborate with based on similarity are some of such suggestions.

Geotagged tweets from event locations are collected and sentiment is analyzed to create a commercial recommendation system. The proposed MBRF approach has two significant changes to the MBSVM: (1) a distance-based weights updating strategy based on K Medoids and (2) RF classification based on the ensemble adaboosting approach rather than Boosted SVM.

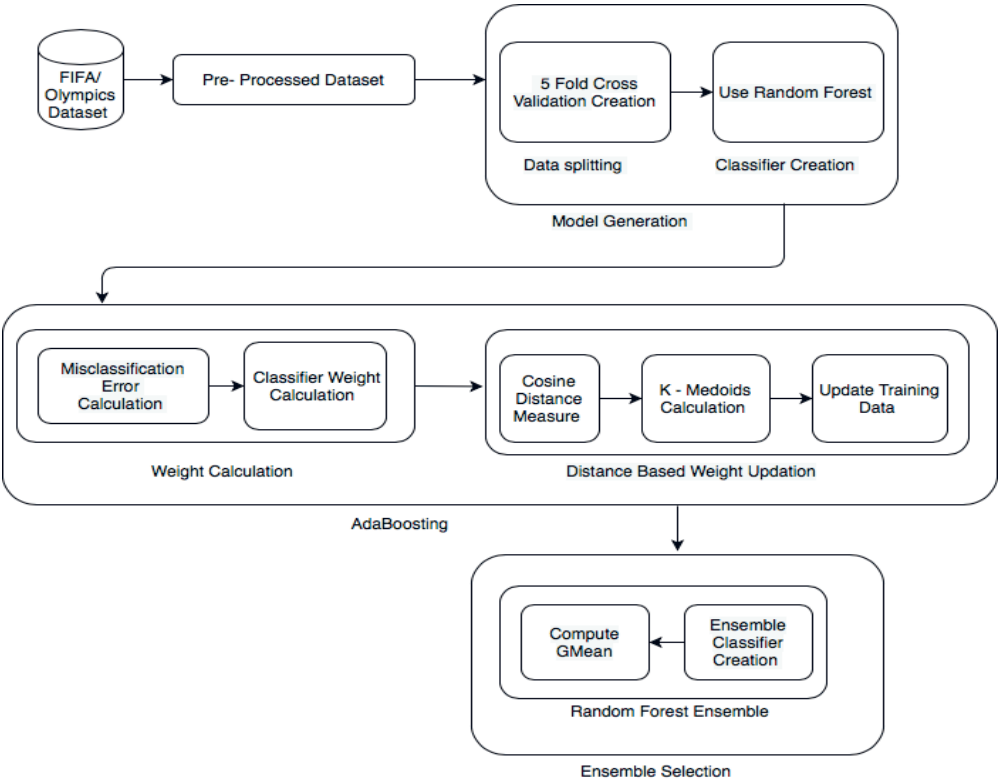


Figure 1. Data Model for MBRF

Figure 1 depicts the MBRF algorithm which has three phases: model generation, adaboosting, and ensemble selection of an MBRF data model. Adaboosting is implemented by MBRF in an iterative method in which weak learners are fitted and aggregated to the ensemble model.

3.1. Data Collection

The geotagged tweets are retrieved from Twitter using the Twitter API and annotated with hashtags listed in table 2 in English language and a sample screenshot of the tweets in figure 2.

Event Name	Hashtags
FIFA	#worldcup, #worldcupfinal, #FIFASTadium, #Russia2018, #worldcup2018, #FIFA, #WorldCupRussia
Olympics	#pyeongchang2018, #winterOlympics, #Olympics

Table 2. Hashtags used to extract tweets

Lowercase conversion, stop words, and special character removal are all performed on all retrieved tweets. The most prevalent terms in a language are referred to be stop words. Such tokens, for example, 'and', 'the', do not have a semantic meaning or sentiment attached with them. Twitter allows the use of hashtags (#) to indicate a trending topic, however special characters such as @,!,\$, and so on are eliminated because they are meaningless.



Figure 2. Screenshot of the tweets after extraction process

We refer to tweets as either positive or negative observations throughout this paper. Initially, all observations are given the same weights. As a result of the learning process, the identified misclassified observations will be given higher weights [32] [33]. This step is repeated n times to create a strong classification model. A model like this can classify any new observation by predicting its classification using its weights [34]. As previously stated, MBRF employs Random Forest Classification with discrete class labels (for instance cloudy or sunny).

3.2. Location Data

Twitter API's supports tweeter to post tweet and include approximate location if they decide to enable geolocation setting with "Tweet with location". Each tweet contains the place attribute comprising of latitude and longitude or the exact location from where tweeter has posted the tweet. FIFA 2018 games were held in 11 locations and Olympics 2018 games across 10 locations as shown in table 3.

FIFA 2018	Olympics 2018
Kaliningrad	Pyeongchang-gun
Kazan	Korea
Moscow	Seoul
Nizhny Novgorod	Gangneung-si
Rostov-on-Don	Ongjin
Saint Petersburg	Wonju
Samara	Jeongseo
Saransk	Jongno
Sochi	Yangyeong
Volgograd	Jung-gu
Yekaterinburg	-

Table 3. Locations of FIFA and Olympics Events

3.3. Description of datasets

The data set is separated into two sets named as training sets, which is used to form the learned hypothesis, and a separate validation set, which is used to evaluate the accuracy. The description of both datasets is given in Table 4.

Characteristics	FIFA	Olympics
Number of Observations	25,000	28,000
Number of variables	5	5
Positive Class	19,000	23,000
Negative Class	3000	5000
Imbalanced Ratio	3.1666	4.6

Table 4. Imbalanced dataset and their characteristics

3.4. Phases of MBRF

MBRF algorithm has four phases:

Phase 1: Model Generation

- (i) **Data splitting:** The algorithm starts by splitting the data using 5-fold cross validation $f = 1, 2, \dots, 5$. For each fold we have one part serving as validation data (X_{val_f}) and the rest as training data (X_{train_f}). The validation and training parts are switched until all five components have been validated at least once.
- (ii) **Classifier Creation:**
Initial weights $W_i = \frac{1}{N}$ where $i = 1, 2, \dots, N$ Equation (1)
N is the number of tweets or also called as observations.

We have classifier RF_{mf} created for all the folds i.e number of classifiers created is $RF_{m1}, RF_{m2}, \dots, RF_{m5}$. Random Forest (RF) is modelled by setting the hyperparameters.

$RF_{mf} = RFTrain(X_{train_f}, 'method')$
 $RF_{mf} = [w_1, w_2, \dots w_n]$

Where m is the current iteration, $m = 1, 2, \dots, M$, M is the Maximum number of iterations.

Phase 2: Adaboosting

- (i) Misclassification Error (e_{mf}): Misclassification is computed by classifying X_{train_f} using RF_{mf}

$$e_{mf} = \frac{\sum W_{if} * Prediction_error_rate_{if}}{\sum W_{if}} \dots \text{Equation (2)}$$

The $Prediction_error_rate_{if}$ is calculated for each training observation 'i' across all folds (f). If an observation is misclassified 'i' = 0, otherwise it is assigned a value of 1. Hence, we have misclassification error for each fold $e_{m1}, e_{m2} \dots e_{m5}$.

- (ii) The component classifier (α_{mf}) the classifier weight is derived from the misclassification error as shown in Equations 3. In this case,

$$\alpha_{mf} = \log \frac{1 - e_{mf}}{e_{mf}} \quad \text{if } e_{mf} < 0.5 \dots \text{Equation (3a)}$$

$$\alpha_{mf} = 0 \quad \text{if } e_{mf} > 0.5 \dots \text{Equation (3b)}$$

$$\alpha_{mf} = \alpha_{mf} + \varepsilon \quad \text{if } e_{mf} = 0 \dots \text{Equation (3c)}$$

When the error e_{mf} becomes 0 we assume to add a small value ε , a constant value used to adjust the magnitude of the component classifier α_{mf} (where $\varepsilon = 0.001$)

Observation weight update (w_{if}): we change the weights of all misclassified observations identified in the phase 2 and transform the data to classify them correctly.

Phase 3: Ensemble Selection

In this phase, for every iteration 'm', we create component classifier (G_{mf})

$$G_{mf} = \alpha_{mf} * S_{mf} \quad \dots \text{Equation (4)}$$

Where S_{mf} is the base classifier.

Next, we compute the various evaluation metrics for each fold's ensemble classifier using the respective fold's $X_{val,f}$.

Elaborating MBRF algorithm in different phases:

Phase 1

We create a data Matrix X with N observations which includes $X_{train,f}$ and $X_{val,f}$. to generate Y a class label of data Matrix X . Tweet, Location, Sentiment, Number of Followers, and Hashtags are used as attributes of the X . Breiman invented the Random Forest (RF) learning method, which is an ensemble of Classification and Regression Trees (CART) procedures used to build a forest.

The RF uses random variation to build a forest, many individual decision trees are generated using the $X_{train,f}$. This tree construction considers all the attributes the data Matrix X , tree is grown and aggregated as base learners for prediction. In general, higher number of trees implies more resilient forest. The prediction of the model emphasizes on aggregating the results generated from different decision trees. RF can be trained on a dataset that consists of a collection of tree predictors, each of which is based on a randomly sampled vector.

The best prediction of accuracy results of the MBRF model can derived by the tuning process of hyperparameters. MBRF hyperparameters are set using Random Forest classifier built with Scikit-learn (Sklearn) a useful and robust library for machine learning in Python. We elaborate the Random Forest hyperparameters settings in table 5 set prior to the learning process.

Hyperparameter	Description
Estimators	The number of trees in the MBRF model. We've set n estimators to 120 and 90 estimators for the FIFA and Olympics events, respectively.
Criteria	splitter object whose function is to discover the best internal node split. Assesses the goodness of a split and to rank the importance of the qualities.
Maximum Features	Influences tree diversity. $max_features = 1$ creates forests with diverse and complicated trees; $max_features$ is close to the number of features, it creates forests with simpler trees.
Maximum Depth	$max_depth = \text{None}$ by default, which means that each tree will extend until every leaf is pure. Otherwise, splitting occurs until all the leaves are pure, indicating that all the leaves belong to the same.

Table 5. Hyperparameters settings in MBRF Model

The number of trees to construct the Random Forest was assessed using the out-of-bag (OOB) error rate. OOB samples are defined as a set of bootstraps (produced by random resampling from the training dataset) that are not part of the dataset but are used as a test dataset. OOB error also known as out-of-bag estimate, is used to estimate the random forest prediction error. The critical part in the feature selection process is selection of the optimal number of features determined based on the minimum OOB error rate. OOB prediction computes classification error for each 'n' observations by taking the majority vote for the i^{th} observation. For the classification, max features set to 'sqrt' to examine the OOB error rate versus n estimators. Figure 3 depicts the out-of-bag error rate with n estimators for event datasets after the MBRF is applied. The results clearly show that FIFA and the Olympics have the lowest OOB error rates at n estimators, at 120 and 90, respectively.

Once the model is fitted computation of error (e_{mf}) for misclassified data is estimated by weighted average method. Here misclassified observations are weighed focusing on weak learners of $X_{\text{train},f}$. The weighted average method detects and boosts the misclassified observations.

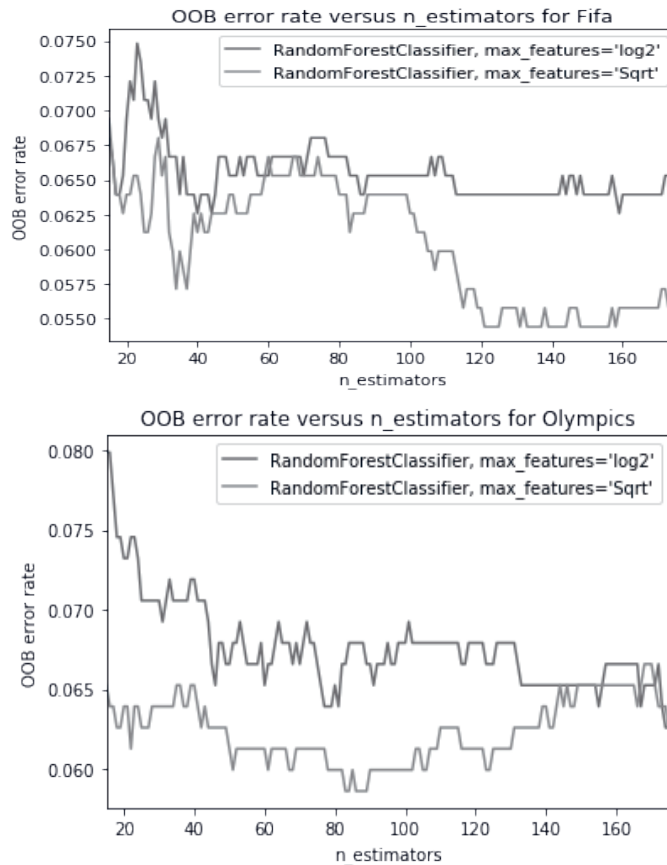


Figure 3. Demonstration of Out of the bag error rate with n_estimators for events datasets

Phase 2

The weights of misclassified observations are updated using the distance ratio and classifier weight (mf). Weight update procedure prioritizes the distance of each misclassified observation from its own group's centroid and handles them separately. The weight of these observations is updated at each iteration through clustering to correctly classify them using distance measurement.

The weight update procedure use K medoids to select one of the points in the cluster as centroid [35][36] to similar observations are grouped together in a cluster, while dissimilar observations are grouped together in other clusters [37][38]. Accordingly, we have calculated the centroid of both groups namely group1 and group2 (since $k=2$). Each misclassified observation in group1 is compared with distance from centroid 1 and 2. If the data instance's distance is far away from centroid 1.

The below expression is used for weight update using the below equation 5.

$$w_{if} = w_{if} * \exp \left(\alpha_{mf} * \frac{d_{i2f}}{d_{i1f}} * \text{prediction_error_rate}_i \right) \text{ if } d_{i1f} > d_{i2f} \text{ for group 1} \quad \dots \text{Equation (5a)}$$

$$w_{if} = w_{if} * \exp \left(-\alpha_{mf} * \frac{d_{i1f}}{d_{i2f}} * \text{prediction_error_rate}_i \right) \text{ if } d_{i2f} > d_{i1f} \text{ for group II} \quad \dots \text{Equation (5b)}$$

We use equation 5a to make the data instance closer to group1 centroid such that observation shall be classified correctly. The same implies to each misclassified observation in group 2, the distance from group 2 centroid is compared. If the data instance's distance is far away from centroid 2. Equation 5b is applied to make data instances closer to group 2 centroid such that observation shall be classified correctly.

As previously stated, our research focuses on the events dataset, which is primarily a social interaction of user tweets in the form of text [39][40]. The cosine of the angle between observations is measured by cosine similarity, which is a measure of similarity between two non-zero vectors of an inner product space [41]. As shown in equation 6, cosine similarity is used to calculate the distance between the misclassified observations A and B.

$$A \cdot B = \|A\| \|B\| \cos \theta \quad \dots \text{Equation (6)}$$

Based on the clustering we have shown the locations plotted as positive and negative in figure 4. These results are identified with K medoids process with group1 and group2 to select one of the points in the cluster as centroid.

Phase 3: Ensemble Selection

The Random Forest Ensemble stage of MBRF is where the Ensemble selection processing takes place. Ensemble pruning, also known as post-selection, is used in this process. During this process, a subset of the original ensemble's base

classifiers/learners is removed with no loss of predictive performance. This pruning allows an ensemble to grow freely before pruning it, resulting in an effective ensemble [42][43][44]. Finally, we compute the ensemble performance of each fold using various evaluation metrics such as precision, recall, accuracy widely used for recommendation algorithms in equations 7-10 [45][46].

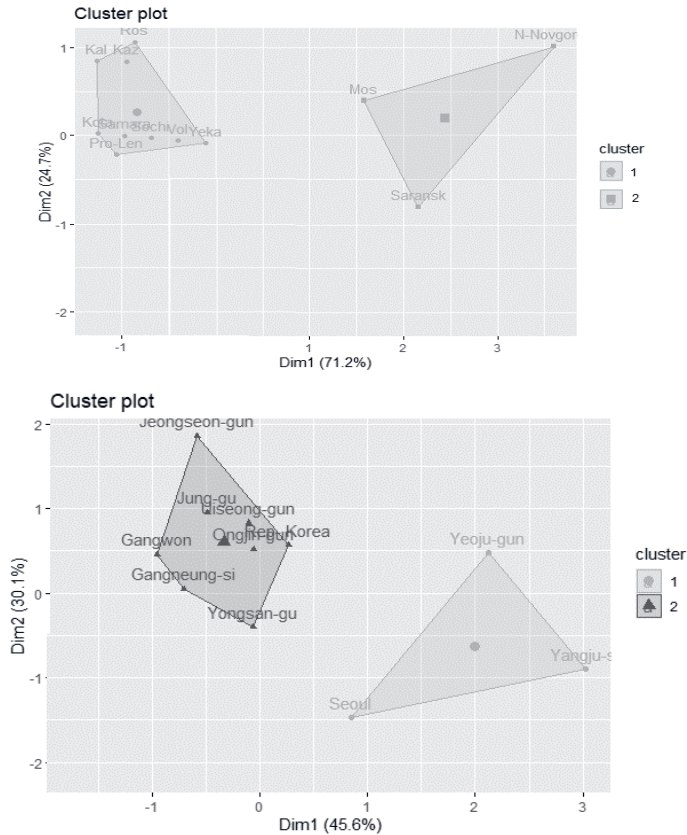


Figure 4. Location Based Clustering with K=2 at FIFA and Olympics events

We define the recommendation metrics which were applied to evaluate the MBRF model and DTC.

- a. Precision (P) the fraction of recommended items that is relevant to the user.

$$P = \frac{N_{rs}}{N_s} \quad \dots \text{Equation (7)}$$

- b. Recall (R) the fraction of relevant items that are also part of the set of recommended items.

$$R = \frac{N_{rs}}{N_r} \quad \dots \text{Equation (8)}$$

Where

N_{rs} – Correctly recommended locations

N_s – Total recommended locations

N_r – Total relevant locations

- c. Accuracy (A) is the fraction of correct recommendations out of total possible recommendations.

$$A = \frac{N_{rc}}{N_{rp}} \quad \dots \text{Equation (9)}$$

N_{rc} -Number of correct recommendations

N_{rp} – Total possible recommendations

- d. F1 – Score the harmonic mean of precision and recall is considered as in equation 10.

$$F1 - Score = 2 \frac{P \cdot R}{P + R} \quad \dots \text{Equation (10)}$$

4. Results

4.1. Performance Comparison using performance metrics.

Various metrics – precision, recall, F1- score, accuracy and Support is measured using Random Forest Classifier by setting the splitter criterion as ‘Gini’ and ‘Entropy’. Entropy is a measurement of impurity or randomness in observations. The degree of impurity is 0 -1 order. Gini Index calculates the amount of probability of a specific feature that is classified incorrectly when selected randomly. We compare the performance of MBRF with DTC using splitter criterion set as ‘Gini’ and ‘Entropy’. Table 6 has the comparison results tabulated and it is evident that MBRF performs better than DTC. These findings also show that MBRF outperforms DTC using the ‘Gini’ and ‘Entropy’ criteria. In table 6 we attempt to bring out the accuracy of each fold using MBRF and DTC to prove MBRF to be better than DTC across all the folds.

Classifier Name	Event	Precision	Recall	F1-score	Support	Accuracy
MBRF (criterion= ‘Gini’)	FIFA	0.92	0.93	0.93	303	93.36
	Olympics	0.90	0.92	0.91	206	91.291
MBRF (criterion= ‘Entropy’)	FIFA	0.92	0.94	0.93	303	93.99
	Olympics	0.91	0.90	0.90	206	94.747
DTC (criterion= ‘Gini’)	FIFA	0.91	0.91	0.91	303	91.419
	Olympics	0.90	0.90	0.90	206	90.29
DTC (criterion = ‘Entropy’)	FIFA	0.90	0.92	0.92	303	91.749
	Olympics	0.90	0.90	0.90	206	90.56

Table 6. Performance Metrics for the Events

Classifier Name	Accuracy	Fold 1	Fold 2	Fold 3	Fold 4	Fold 5
MBRF(criterion='Entropy')	FIFA	93.01	93.44	92.76	93.79	93.24
	Olympics	94.46	94	94.12	94.55	94
DTC (criterion='Entropy')	FIFA	91.58	91.16	91.49	91	91.65
	Olympics	91.23	90.11	90.4	90.56	91.36

Table 7. Performance Metrics for the Events across the folds

4.2. Comparison of classification performance through ROC curve

One of the most common methods for comparing binary classification models is Receiver Operating Characteristic curve (ROC). The ROC analysis is demonstrated using the ROC curve, which is a tool for evaluating, comparing, and selecting the best classifier based on classification performance. The False Positive Rate (FPR) and True Positive Rate (TPR) for both events are plotted using a ROC curve. The terms FPR and TPR are derived from the confusion matrix, as shown in equations 11 and 12, respectively. Where TP rate refers to the percentage of correctly identified positives. The TPR rate is also known as the sensitivity or recall rate.

$$TPR = \frac{TP}{TP+FN} \quad \dots \text{Equation (11)}$$

The proportion of correctly identified negatives is measured by the TN rate. TNR rate is also known as specificity number of true positives - TP, number of true negatives - TN, number of false positives - FP, and number of false negatives – FN, where the total number of observations is equal to the sum of TP + TN + FP + FN = n.

$$TNR = \frac{TN}{TN+FP} \quad \dots \text{Equation (12)}$$

The geometric mean (Gmean) metric, formulated in equation 13, is an ensemble classification for measuring sensitivity and specificity.

$$Gmean = \sqrt{TPR * TNR} \quad \dots \text{Equation (13)}$$

We created the ROC curves for both datasets using the framework described above. Figure 5 shows the ROC curve for FIFA and Olympics events to demonstrate MBRF. On both datasets, we calculated AUC using MBRF values. On the FIFA dataset, the average AUC value is 0.96. On both datasets, we calculated AUC using MBRF values. The average AUC value on the FIFA dataset is 0.96, and the Olympics is 0.97, indicating that our proposal will be performed well.

5. Conclusion

Ensemble methods are highly effective at boosting performance of simple learners. They have earlier been used in many applications; in this work we apply on analysis

of location based social networks for events. Random Forest (RF) is a stable ensemble of trees with a self -testing feature that is robust to overfitting. From the results, MBRF proves to be a good classifier to predict reactions of people's events and recommend them suitably based on current need. We have provided empirical evidence with classical measurement metrics yielding good results (accuracy, precision and recall) for classification results. Limitation/future enhancement - We have focused only on two global events we can extract tweets of other events such as awards and recognition, musical concerts. Further we can consider other social media such as Instagram and Facebook rather than using only tweets.

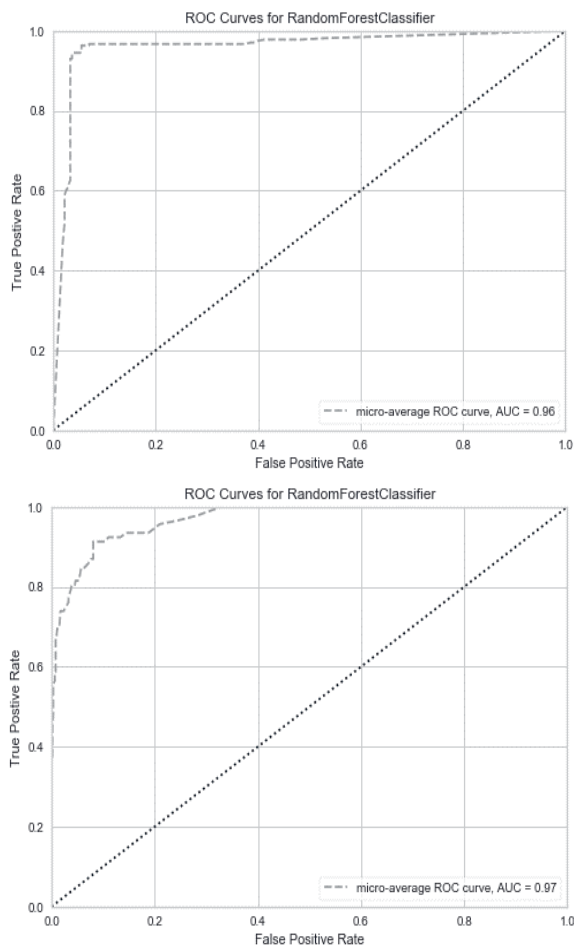


Figure 5. Demonstration of ROC curves for FIFA and Olympics Events

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Exploring Work from Home: Scale Construction and Its Use in Determining Croatian Engineers' Job Satisfaction

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Abstract

Working from home and work flexibility have been highly researched academic topics over the past forty years, and their importance was further amplified during the COVID-19 pandemic. Numerous qualitative and quantitative studies were aimed at better understanding this work arrangement, but they often encountered the challenges of limited scope and the inability to generalize their results. The goal of this study was to test the consistency of the instrument used in measuring the experiences of working from home for Croatian engineers, check the presence of its latent dimensions, and finally determine whether these dimensions could predict engineers' job satisfaction. Three factors were extracted by exploratory factor analysis (productivity and work quality, work-life balance, and organizations' distrust and control), while the multiple linear regression analysis ran on those factors as predictors proved that, although work-life balance does not influence job satisfaction, productivity and work quality positively predict it, while organizations' distrust and control do so negatively.

Keywords: work from home, exploratory factor analysis, multiple linear analysis, job satisfaction, Croatian engineers

1. Introduction

Over the past forty years, working from home has emerged primarily as a significant topic in academic research on work flexibility. However, the main driving force behind the growth in interest in working from home was certainly based on the rapid development of information technologies, and especially the Internet. As early as the early 1980s, futurologically oriented academics put forward the idea of an "electronic cottage" that symbolized the spatio-temporal autonomy of experts whose remote work was based on the use of computers [1]. The idea, as it seemed, fit into the broader

process of restructuring the existing division of labor in developed industrial countries and the need to find new and more flexible patterns to resolve the stalemate in the process of capitalist accumulation and reproduction caused by the decline of the Fordist model of division of labor dominant at that time [2], [3].

In a series of studies and theoretical explanations since the mid-1980s, work from home has found its place in the field of spatial flexibility of work [4]. To date, it has been considered in a matrix that included: changes brought on by the growing technological possibilities for its realization [5]; challenges of effective work organization, i.e. issues of autonomy and control [6]; skills and qualifications necessary for its implementation, that is, an analysis of occupations and professions for which it would be appropriate [7]; challenges in reorganizing previously divided aspects of paid work and private life [8]; changes in employment types and career issues [4]; possibilities of its incorporation into legislation [9]; and, finally, its actualization – the actual share in the contingent of the labor force affected by it [10].

The initial optimism of futurists and technology enthusiasts has been continuously questioned by research findings that have shown how, despite decades of rapid growth in technological capabilities, working from home has different outcomes not only within individual professional categories, but also among them [11]. Also, the work-life dichotomy has proven to be an important issue, especially when accompanied by the growing needs of work efficiency and its organization [8]. Finally, perhaps the most important question about the possibilities of organizing work from home, up until the COVID-19 pandemic in 2020, stemmed from the fact that the share of employees working from home, even in the most developed economies, rarely exceeded 20% [12]. In other words, despite its great potential in terms of flexible work organization, this phenomenon has remained largely neglected in practice.

One of the issues, which is of central importance for this article, was related to the approaches in researching work from home. On the one hand, numerous qualitative research provided a better understanding of work from home and enabled the development of theoretical constructs [13], [14], [15], [16]. For example, one of the most widely used theoretical approaches when examining work from home, border theory, was a product of qualitative research [13]. Nevertheless, numerous and relevant qualitative studies have continuously faced objections towards their relatively limited scope in terms of generalization. On the other hand, quantitative research, despite copious amounts of available data, often encountered challenges in harmonizing instruments and metrics as well as the problems of representativeness of the samples they used [17].

With regards to the latter, the mentioned issues form the crucial basis for this article. Starting from the assumption that generating appropriate scales for measuring work from home among specific segments of the workforce would contribute to the discussion on open issues of research standardization [18], the basic idea of the paper was to reconsider the compatibility of the instrument it used in studying work from home among Croatian engineers with theoretical concepts that were used in its development. In doing so, the focus on Croatian engineers was seen as justified in many ways. Engineers, as a professional category, are a part of the segment of the workforce that fits into most of the dimensions in the aforementioned matrix for the

study of work from home. They are key actors in the growth of technology and related knowledge and skills, and are, by the very nature of their jobs, preoccupied with issues of work organization efficiency. They are also subject to unpredictable changes in the labor market, resulting from the growing flexibility of work, which are reflected in their predominantly precarious careers [19]. Since the instrument for researching various aspects of work from home among Croatian engineers was developed by independently creating individual items, while also relying on some already existing research recommendations [20], the suitability test of the developed scale, as well as testing the existence of its latent dimensions, was carried out by exploratory factor analysis. This led to a meaningful reduction of the instrument which, in its final version, may be useful in future research on work from home. In addition, multiple linear regression has been conducted to determine whether, and to what degree, can the retained latent dimensions explain job satisfaction among engineers, since most of the research to date has shown that the experience of working from home, or at least some of its aspects, influences job performance, training opportunities, relationships with colleagues, and consequently overall job satisfaction.

2. Theoretical background

Working from home is, like all dimensions of the post-industrial division of labor, affected by the knowledge economy [21], flexible firm [22] and new forms of work and employment [4]. In public discourse, this arrangement is promoted mainly as a win-win situation in which employers benefit from various types of savings related to the workspace while maintaining labor productivity and which presents employees with greater opportunities to reconcile their private and work life with increased job satisfaction and commitment [11]. At the same time, the issue of trust, perceived by employers in terms of labor productivity and by employees in terms of job security, was mainly viewed as self-evident. However, research on the experience of working from home has shown that the perception of it being a win-win arrangement is based on a naïve understanding of the nature of modern work and that the incidence of working from home varies greatly depending on a number of mediating factors such as employment type, suitability of tasks, organizational culture, position in organizational hierarchies, interaction patterns at work, technological skills, family environment, etc.

In designing the instrument for researching work from home among Croatian engineers, the mentioned mediating factors were observed through theoretical approaches and research findings that focus on the quality of working from home, the possibilities of work-life balance, and the issue of organization and control of work from home. All three aspects are intertwined in the daily experience of remote work and will be presented in broad strokes below, in order to clarify the basic categories used for the development of the research instrument.

From a predominantly managerial and employer perspective, the *quality of work* from home is often reduced to the issue of *productivity* [16], [17]. According to Donnelly and Proctor-Thompson [16], such an approach is predictable and is based largely on cost-benefit analyses that indicate how positive outcomes are embedded in

the expectations of both employers and employees. On the one hand, higher productivity has indeed been confirmed in some studies [23], [24], but the issue of productivity measurement is questioned, given that the findings are mostly based on self-statements [17]. Bailey and Kurland [17, p. 389] warn that these results should not be taken at face value, since employees who decide to work from home on their own, as well as those who are forced to do so, find themselves in a position to defend that kind of work and present it as successful and productive. In addition, Bailey and Kurland refer to research findings showing that employees working from home often equate the issue of productivity with the amount of work-hours, reporting they work too much. This coincides with the findings of a Eurofound and ILO [9] survey about how long working hours (more than 48 per week) are a significant feature of work arrangements of different types of teleworkers, including those working from home. Although the abundance of self-reports of increased productivity from home cannot be ignored, in order to fully understand the quality of work, additional dimensions should be included.

One of them is the issue of autonomy in terms of work organization and ways of solving work tasks. Research shows that spatial flexibility allows employees to intervene autonomously in regular work schedules, which often results in “porous” patterns of working hours that deviate from the usual eight-hour workday in an office [25]. A similar situation involves task discretion as an informal understanding between employees and their managers, often covered in research based on social exchange theory which states that employees would be willing to work harder or longer hours in exchange for the option of altering their work arrangements, both spatially and temporally [11], [15].

The second dimension of work quality relates to the connection with other employees and includes not only the issue of isolation and technical aspects of communication, but also opportunities for non-formal learning and mentoring, and is usually reflected in general job satisfaction. Summarizing the results of previous research, Brunnelle and Fortin [26] view the issue of isolation and the absence of frequent face-to-face interactions with co-workers as the biggest challenge teleworkers are facing. This means that working from home involves making a conscious effort to create additional opportunities to establish formal and informal interactions. In practice, however, such efforts are addressed mainly by holding online meetings which is a weak substitute for negative consequences affecting workers’ performance, satisfaction and working relationships [27], [28]. This is confirmed in the research by Bailey et al. [29] on the challenges of workplace socialization for remote workers which shows how teleworking not only often remains outside the scope of traditional socialization goals, but also opens new or different patterns of organizational identification and career issues.

The general assumptions of border theorists on how work from home reflects on the *work-life balance* coincide with the mixed results of research conducted to date [9], [11], [12], [13], [30]. This is not surprising since the workplace in industrialized countries throughout the 20th century was a distinctive location outside one's own home. With technological growth and efforts towards spatial flexibility, this constellation has changed primarily among middle-class professionals. However, the

relocation of paid work to the nominally private sphere has led to a change in the social meaning of space and time. This manifested in the need to redefine private space, which has a strong emotional dimension for people, as well as in the need to redefine the length of working hours – i.e. in a more or less clear distinction between paid and unpaid work and non-work. Clark [13] summarized these challenges in terms of border theory, pointing out that the basic features of borders are contained in their permeability and flexibility. In that sense, permeability refers to psychological and behavioral aspects of the process of intertwining work with family life, while flexibility indicates the extent to which one domain can shrink or expand to meet the requirements of another domain [8]. However, as Karassvidou and Glaveli [30] note, this theory somewhat failed to explain the factors (spatial, temporal, personal, organizational, gender, cultural, etc.) that contribute to the permeability and flexibility of borders, which manifested itself in inconsistent methodologies and research results around the world [12].

Finally, the third theoretical aspect of working from home used for developing the instrument for this study relates to the issues of *management and control* in this kind of work, as a permanent and dominant preoccupation of managerial structures in organizations that has, according to some authors [31], [32], become a central element of modern organizations. In a review of studies on organizational control, de Vaujany et al. [33, p. 678] point out that this is a basic principle in achieving organizational goals – control is the formal or informal ability of managers to act with the aim “to direct or influence their employees’ conduct, in a ‘balanced’ manner entailing both motivating incentives and effective sanctions, so that they result in behavior consistent with organizational aspirations, rules and objectives”. Over the past century, organizational control has taken its dominant pattern in the form of Taylorist scientific management, which insists on a strict division of labor between managers and their subordinates as a key prerequisite for establishing a functional organizational structure. Contrary to the initial belief that this management style would lead to higher levels of productivity, it primarily resulted in underqualification of work, its monotony, and distrust of managers towards workers. This distrust is well captured by McGregor’s theory of X management [34] which is based on the assumption that workers avoid work at every opportunity and should therefore be forced to work under strict supervision and threats of punishment in order to make the efforts necessary to achieve organizational goals.

As one of the factors in the decline of the Fordist model of division of labor [35], the Taylorist pattern of control survived to this day and even imposed itself as an integral part in the development of new, flexible forms of work which were believed to open a new space for the expansion of work autonomy and job discretion in post-industrial knowledge economies. This survival of Tayloristic organizational principles in employee motivation [4] in a form of digital Taylorism represents a new and technologically supported form of employee control, which, along with an organization’s or employer’s trust, becomes one of the most important challenges in organizing work, especially the remote kind.

As an unforeseen consequence of new forms of work, organizational control of work from home was confirmed in a series of studies that showed that: managers do

not support this type of working arrangement and reluctantly allow it; the temporal flexibility of this kind of work is absent, since it tends to follow the traditional work schedule; employees working from home must continuously prove the effectiveness of their work, often by showing constant presence and availability, etc. [6], [17], [29], [33], [36], [37], [38]. Employees experience growing career uncertainty, and their anxiousness is only deepened by the belief that physical presence at work (“face-time”) is “necessary to signal work devotion to colleagues and managers” [38, p. 4]. With all the suspicion expressed by managers and employers, it seems as though flexible work policies are at an impasse.

As already mentioned, the three presented aspects of the organization of work from home formed the basis for developing the instrument used in researching work from home among Croatian engineers.

3. Methodology

3.1. Research goals and methods

Apart from the fact that the developed questionnaire has never been used, it is also, as it will later be demonstrated, quite comprehensive, so the main intent of this preliminary survey was to test its consistency and see if the presence of the predicted domains of homeworking can be confirmed. Apart from that, another goal of this paper was to follow this up with shortening and simplifying the questionnaire to ensure its potential for broader use. Finally, the last goal of this study was to determine whether attitudes and experiences of working from home influence job satisfaction in respondents.

The research questions in this study can hence be summarized into two:

1. What are the latent dimensions present in the questionnaire used to measure Croatian engineers’ experiences and attitudes towards homeworking?
2. Are there any significant correlations and causations between the obtained dimensions and job satisfaction?

To give an answer to the first research question, and to achieve the first two research goals, this study used an exploratory factor analysis (EFA), while the multiple linear regression analysis was applied in order to answer the second question and to accomplish the third goal.

3.2. Questionnaire

The questionnaire was divided into four parts, totaling 63 questions. Two of its parts, not examined in this paper, dealt with the respondents’ sociodemographic characteristics, their place of work and its suitability for homeworking, and finally the circumstances and conditions of their working from home experience. The remaining two parts consisted of 34 items measuring engineers’ attitudes and experiences of home working and their job satisfaction on a 5-point scale, ranging from “1 – Don’t agree at all” to “5 – Completely agree”.

As it was already mentioned, the specific variables intended to measure homeworking attitudes and experiences were compiled and included in the questionnaire according to three predicted domains: management and control (MC) of workspace and working hours, work-life balance (WLB), and productivity and work quality (PWQ). The total number of variables in this part of the questionnaire was 29 and their initial content and arrangement can be seen in Table 1.

Domain	Item	$\bar{x}$	SD
Management and control	MC1 The prevailing view in the organization is that employees are more productive when working in the office than from home	3.26	1.248
	MC2 I feel that I constantly have to prove that I'm actually working	2.51	1.344
	MC3 My superiors tend to put more emphasis on controlling our work than its effectiveness/quality	2.35	1.410
	MC4 There's a prevailing distrust in my organization about the quality of work from home	2.63	1.46
	MC5 I tend not to use sick days or paid leave because I think my superiors wouldn't believe me	1.88	1.180
	MC6 I have a hard time justifying overtime	2.18	1.377
	MC7 I'm worried that I'll get fired in the event of company restructuring or lower profits	1.78	1.104
	MC8 I'm less likely to be promoted compared to my colleagues	2.24	1.304
	MC9 I feel that my colleagues will forget about me while planning major projects	2.38	1.149
Work-life balance	WLB1 I often feel overwhelmed with work responsibilities	3.04	1.108
	WLB2 I often find myself working overtime or on weekends	2.71	1.342
	WLB3 I don't have enough time for my family, friends and hobbies because of work	2.80	1.380
	WLB4 In my organization, employees are expected to be available in their free time	2.51	1.390
	WLB5 Work responsibilities negatively affect my private life	2.53	1.320
	WLB6 I feel my home has turned into an office	2.84	1.385
Productivity and work quality	PWQ1 In general, the quality of my work from home is better than that in the office	2.97	1.186
	PWQ2 When I work from home, I tend to finish tasks faster	3.06	1.255
	PWQ3 Working from home allows me to better organize my time and work tasks	3.48	1.250
	PWQ4 At home I have less distractions and it's easier for me to concentrate on more complex tasks than in the office	2.92	1.387
	PWQ5 I can provide information, ideas and instructions to others via online platforms with ease	3.21	1.267
	PWQ6 If I worked from the office, I would be able to get help from colleagues easier and faster	3.93	1.041
	PWQ7 Since working from home, it is harder for me to do tasks that require teamwork	3.39	1.145
	PWQ8 When I work from home, my working hours are longer than usual	3.22	1.275
	PWQ9 I always know what is expected of me and what my responsibilities are	4.00	0.896
	PWQ10 The quality of online meetings is worse than the meetings in real life	3.27	1.324

	PWQ11 Work from home requires more meetings and coordination than work in the office	3.37	1.085
	PWQ12 Online meetings are mostly a waste of time	2.76	1.142
	PWQ13 Teamwork quality declines when some members work from home	3.04	1.202
	PWQ14 Working from home has negatively affected my professional development and new skills acquisition	2.56	1.289

Table 1. Initial questionnaire measuring Croatian engineers' homeworking experiences with means and standard deviations (N=158)

A significantly shorter instrument was used to measure the engineers' job satisfaction (JS) in this study, consisting of only five variables presented in Table 2 below.

Domain	Item	$\bar{x}$	SD
Job satisfaction	JS1 Generally speaking, I'm happy with my job	3.93	0.860
	JS2 I often think about quitting	2.30	1.181
	JS3 I regularly search for new job ads	2.25	1.231
	JS4 I wouldn't mind spending the rest of my career in the organization where I currently work	3.20	1.122
	JS5 I get along well with my colleagues	4.35	0.715

Table 2. Initial questionnaire measuring Croatian engineers' job satisfaction with means and standard deviations (N=158)

3.3. Sample and data collection

The preliminary survey was conducted on a non-probabilistic convenience sample of mechanical, civil, and electrical engineers in Croatia between July 1st 2021 and October 30th 2021 using an online questionnaire via LimeSurvey service. The research used snowball sampling in a way that the online survey link was first sent to the alumni associations of Croatia's biggest engineering faculties¹ that were asked to disseminate the link to their graduates, who were then asked to forward it to any colleagues they thought would be interested in participating. A total of 158 respondents was surveyed, predominantly located in Croatia's two largest cities, with slightly more than 60% of them being from Zagreb and 20% from Split.

4. Results

4.1. Factor analysis

As already mentioned, in order to identify the underlying factors and provide a structural representation of homeworking experiences, an exploratory factor analysis (also known as common factor analysis) was conducted on the measured variables

¹ Faculty of Mechanical Engineering and Naval Architecture and Faculty of Electrical Engineering and Computing of the University of Zagreb, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture of the University of Split, and to Zagreb University of Applied Sciences.

previously shown in Table 1. As the goal of this paper was to explore latent constructs that explain homeworking experiences, EFA will be used instead of the, perhaps more common, principal component analysis (PCA), as most methodologists recommend [39, p. 228]. The EFA of this paper was conducted via JASP, an open-source statistics program, using the *principal axis* factoring method to extract a common factor model, as, according to Watkins [39, p. 229], it outperforms the other most common method of *maximum likelihood*, especially when variables and factors are weakly correlated (which is true for most of the factors in the initial solution, as will be demonstrated) and sample sizes are smaller than 300, which also fits the analyzed data. Finally, as it is frequently the case in social sciences, the theorized factors are expected to be correlated so oblique rotations (oblimin) was applied.

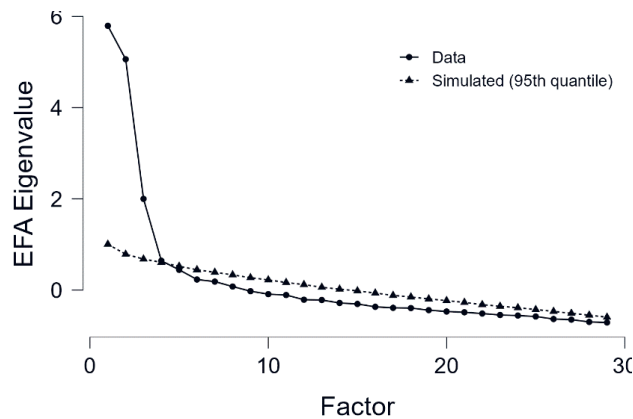


Figure 1. Scree plot of EFA eigenvalues

In order to estimate how many factors should be retained, parallel analysis was applied to the EFA. According to the scree plot (Figure 1), it can be seen that the eigenvalues reach their inflection point at the fourth retained component, while only three factors are above the line of the parallel analysis' simulated data, which indicates that those three factors should be retained. Since the theory underlying the questionnaire design also expected three latent constructs, namely *management and control*, *work-life balance*, and *productivity and work quality*, after testing the appropriateness of the correlation matrix for factor analysis with Bartlett's test of sphericity and Kaiser-Meyer-Olkin's test (KMO), three factors will be examined in order to attain *simple structure* as defined by Thurstone [39]. Factor loadings for the initial solution of the structure matrix are presented in Table 3.

	Factor 1	Factor 2	Factor 3
MC1	0.000	0.522	0.116
MC2	-0.085	0.740	0.227
MC3	-0.202	0.837	0.227
MC4	-0.209	0.895	0.268
MC5	0.034	0.671	0.447
MC6	0.078	0.594	0.518

	Factor 1	Factor 2	Factor 3
MC7	0.027	0.468	0.369
MC8	0.042	0.597	0.254
MC9	0.091	0.565	0.283
WLB1	-0.181	0.373	0.780
WLB2	-0.079	0.185	0.792
WLB3	-0.144	0.209	0.844
WLB4	0.002	0.354	0.640
WLB5	-0.065	0.365	0.761
WLB6	0.145	0.179	0.543
PWQ1	-0.810	0.192	0.185
PWQ2	-0.787	0.262	0.235
PWQ3	-0.729	0.170	0.104
PWQ4	-0.739	0.237	0.215
PWQ5	-0.640	0.037	0.004
PWQ6	0.577	-0.111	-0.061
PWQ7	0.702	-0.045	0.028
PWQ8	0.235	-0.020	0.359
PWQ10	0.634	0.013	0.117
PWQ11	0.492	-0.015	0.103
PWQ13	0.716	0.058	-0.016
PWQ14	0.624	0.178	0.061
PWQ9	-0.286	-0.353	-0.132
PWQ12	0.340	0.180	0.108

Table 3. Initial EFA solution (Structure Matrix)

The results of Bartlett's test showed that the correlation matrix was not random ($p < .001$), while the KMO statistic was satisfactory (.83), or as Kaiser [40] put it, meritorious, which means EFA can be applied.

The initial solution, where three factors were manually retained, accounted for 47.30% of the total variance, with the first factor accounting for 20.90%, the second one for 18.60%, and the third for 7.80%. The inter-factor correlations were relatively low, as shown in Table 4.

	Factor 1	Factor 2	Factor 3
Factor 1	1.000	-0.102	-0.069
Factor 2	-0.102	1.000	0.340
Factor 3	-0.069	0.340	1.000

Table 4. Inter-factor correlations of the initial EFA solution

Retained factors of a methodologically and theoretically acceptable "simple structure", according to Watkins [39, p. 235], must meet several criteria: (1) each factor should be saliently loaded by at least three variables, (2) each variable should load saliently on only one factor, (3) each factor should demonstrate internal consistency reliability $\geq .70$, and (4) all factors should be theoretically meaningful [39, p. 234-235].

Having these prerequisites in mind, in the first iteration of EFA, the items MC5, MC6, MC7, WLB1, WLB4 and WLB5 were removed due to their double loading, i.e. due to the presence of loadings above .300 on more than one factor. After their removal, item PWQ2 showed double loadings, so that was the only variable removed in the second step of analysis. After its removal, item PWQ9 demonstrated double loadings, so this variable was removed in the third iteration of EFA. No more items showed double loadings after this iteration.

Apart from not having any double loadings, as can be seen in Table 5, this iteration also meets three other simple solution criteria: all three factors are loaded with at least three variables (specifically, the first factor with 11, the second with six, and the third with four items); each factor has an internal consistency reliability greater than $\geq .70$ (Factor 1=.873, Factor 2=.852, and Factor 3=.734); and all factors are generally theoretically meaningful. Although item PWQ8 theoretically belongs to the Productivity and work quality domain, considering its content being related to longer working hours, its grouping with the variables in the Work-life balance domain is neither surprising nor theoretically inexplicable.

	Factor 1	Factor 2	Factor 3
MC1	0.023	0.558	0.071
MC2	-0.050	0.747	0.173
MC3	-0.177	0.854	0.169
MC4	-0.174	0.927	0.189
MC8	0.063	0.553	0.172
MC9	0.106	0.534	0.219
WLB2	-0.067	0.156	0.761
WLB3	-0.119	0.191	0.828
WLB6	0.165	0.128	0.539
PWQ1	-0.773	0.234	0.208
PWQ3	-0.684	0.231	0.113
PWQ4	-0.698	0.282	0.178
PWQ5	-0.630	0.094	0.015
PWQ6	0.582	-0.100	-0.014
PWQ7	0.726	-0.085	0.035
PWQ8	0.250	-0.030	0.397
PWQ10	0.658	-0.017	0.123
PWQ11	0.521	-0.039	0.109
PWQ13	0.742	0.037	-0.048
PWQ14	0.648	0.118	0.029
PWQ12	0.369	0.176	0.059

Table 5. "Simple" EFA solution (Structure Matrix)

As shown in Table 6, this iteration's inter-factor correlations are still relatively low, and even lower than those of the initial solution.

	Factor 1	Factor 2	Factor 3
Factor 1	1.000	-0.120	-0.046
Factor 2	-0.120	1.000	0.217
Factor 3	-0.046	0.217	1.000

Table 6. Inter-factor correlations of the “simple” EFA solution

Although a simple solution has been achieved, as can be seen in Table 7, the same cannot be said for its goodness of fit, with the Tucker-Lewis Index (TLI) lower than .90 and the Root Mean Square Error of Approximation (RMSEA) higher than .08. Apart from that, some of the variables kept in this solution, specifically PWQ8 and PWQ12, have weak loadings (below .04), so in order to achieve better fitness of the instrument, those variables were removed in the next EFA solution.

RMSEA	RMSEA 90% confidence	TLI	BIC
0.093	0.081 - 0.106	0.790	-404.166

Table 7. Fit indices of final EFA solution

Finally, in the last few EFA iterations, a total of six items from the original questionnaire were removed, so the entire instrument could be theoretically and conceptually sounder. This was done by going through the content of the kept variables in each factor separately, starting with the second factor, since this factor gathered the variables of the first theorized domain, Management and control. After the fifth EFA solution, this factor is loaded with six variables, now mainly related to the control and supervision aspect of homeworking, with the exception of items MC8 and MC9 that are more related to the employees’ fear of being left out. Apart from that, these variables also saturate Factor 2 the least, with loadings of .551 and .536 respectively, which is the reason why they were removed in the sixth EFA solution.

Since the third factor, which gathered variables from the Work-balance domain, consists of only three variables after the fifth EFA solution (the minimum for maintaining a simple solution), its content wasn’t further modified.

However, with the removal of items MC8 and MC9, one item (PWQ4) from the first factor, the one gathering the variables from the Productivity and work quality domain, shows double loading, also saturating the second factor. Besides, since it is fairly similar to item PWQ3, but with a somewhat greater standard deviation, it is the first item removed from this domain in the seventh iteration of EFA. Alongside item PWQ4, items PWQ5, PWQ7 and PWQ11 were also removed in this iteration, the first one because of its similarity to item PWQ6 which had an opposite orientation, simpler wording and smaller standard deviation, and the latter two because item PWQ13 represents a general and comprehensive representation of them both, all in order to achieve a more parsimonious instrument.

This final solution, as shown in the Table 8, consists of 13 variables in total, spread across three factors. The first one, with a Cronbach α value of .827, gathered six variables from the theorized domain *Productivity and work quality* (PWQ) that can, considering it kept all of its initial variable diversity, also keep the same name.

The same can be said for the third factor ($\alpha=.734$) that loaded three variables of the theorized domain named *Work-life balance* (WLB). The only factor whose content changed significantly is the second one ($\alpha=.896$) consisting of four variables from the original domain Management and control, which can now, considering the content of the variables that remain, be renamed *Organizations' distrust and control* (ODC) towards homeworking.

	Factor 1	Factor 2	Factor 3
ODC1	0.064	0.579	0.068
ODC2	-0.045	0.789	0.170
ODC3	-0.156	0.893	0.195
ODC4	-0.141	0.901	0.201
WLB2	-0.071	0.189	0.780
WLB3	-0.135	0.169	0.892
WLB6	0.126	0.080	0.454
PWQ1	-0.810	0.246	0.208
PWQ3	-0.668	0.235	0.120
PWQ6	0.544	-0.102	-0.037
PWQ13	0.772	0.020	-0.093
PWQ14	0.617	0.074	0.012
PWQ10	0.622	-0.010	0.079

Table 8. Final EFA solution – Factor Loadings (Structure Matrix)

The final EFA solution accounts for 54.80% of the total variance, with the first factor accounting for 24.20%, the second one for 19.20%, and the third for 11.40%. According to Bartlett's test, the matrix is still not random ($p<.001$), the KMO statistic is also still satisfactory (.75), while the inter-factor correlations are now, although slightly higher than those of a "simple solution", lower than those in the initial solution, as can be seen in Table 9.

	Factor 1	Factor 2	Factor 3
Factor 1 (PWQ)	1.000	-0.119	-0.110
Factor 2 (ODC)	-0.119	1.000	0.212
Factor 3 (WLB)	-0.110	0.212	1.000

Table 9. Inter-factor correlations of the final EFA solution

Finally, as shown in Table 10, this solution has a TLI of .955 and an RMSEA of .053, which attests to the good fit of this model.

RMSEA	RMSEA 90% confidence	TLI	BIC
0.053	0.018 - 0.082	0.955	-151.417

Table 10. Fit indices of final EFA solution

4.2. Multiple linear regression analysis

Although the variables intended to measure job satisfaction showed reasonable internal consistency ($\alpha=.794$) and correlation coefficients, in order to provide an answer to the second research question in the simplest manner, linear regression was conducted only on the first, most general, satisfaction variable. Given that the correlation matrix shows moderate to large correlations of the rest of the variables with the first one, with their Pearson's r ranging from .386 to .606, using it as a proxy for overall job satisfaction seems justifiable.

Since the regression model has one dependent and multiple independent variables, namely three factors obtained from the previous exploratory factor analysis, the multiple linear regression model was used to explore the existence of significant correlations and causations between them. In order to do so, and not risk the collinearity problem that would've been present if using the variables that make up the factors, the regression will be analyzed by using the factor scores saved after the final EFA iteration.

Before examining the linear regression results, it is necessary to check if the use of multiple linear regression (MLR) is even justified, specifically if the assumptions of the independence of observations, linearity, homoscedasticity, additivity, and normality are satisfied.

As can be seen in Table 11, the Durbin-Watson statistic for this regression model is 1.765 and, since its value is close to 2, it can be concluded that there is no correlation between residuals, i.e. that the residuals are independent and that the first assumption is satisfied.

Model	R	R ²	Adjusted R ²	RMSE	Durbin-Watson		
					Autocorrelation	Statistic	p
H ₁	0.472	0.223	0.208	0.766	0.106	1.765	0.130

Table 11. Initial MLR model summary

As Figure 2 shows, the linearity assumption is also satisfied, meaning that there is a linear relationship of independent variables with the dependent one, both collectively and individually, together with the one related to homoscedasticity, according to which the spread of the variance is equal both for the residuals and the predicted values.

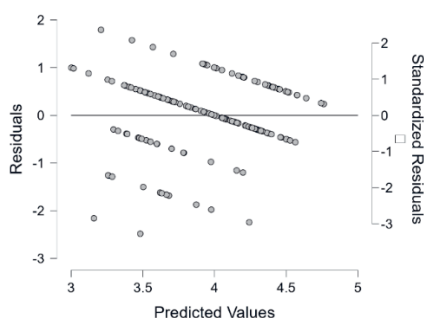


Figure 2. Residuals vs. predicted values

As the correlation matrix of the independent variables (Table 12) indicates, there are no high correlations between the kept factors, which means that there is no multicollinearity problem in this model and that the additivity assumption is satisfied as well. The Tolerance (ranging from .949 to .994) and Variance Inflation Factor (VIF) values (ranging from 1.006 to 1.048) of this model confirm that.

Variable	Factor 1	Factor 2	Factor 3
1. Factor 1 (PWQ)	—		
2. Factor 2 (ODC)	0.075	—	
3. Factor 3 (WLB)	0.003	0.214	—

Table 12. Correlation matrix of the factors (independent variables in MRL)

Finally, as Figure 3 shows, the standardized residuals of this model are somewhat normally distributed, meaning that the last assumption justifying the conduct of the MLR is also satisfied.

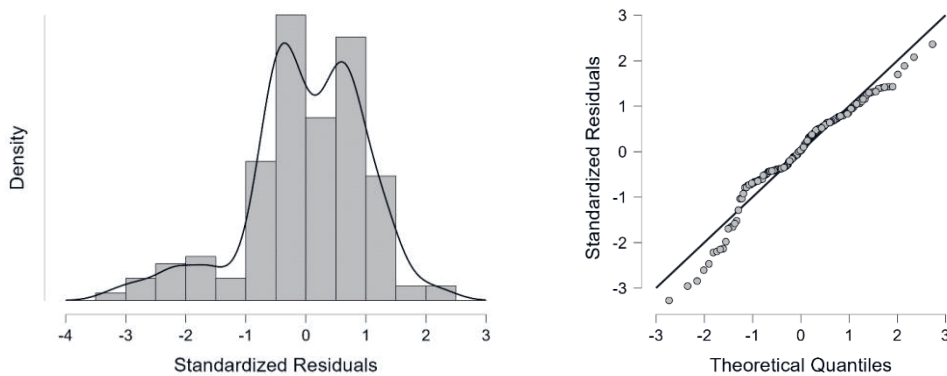


Figure 3. Standardized Residual Histogram and Q-Q Plot Standardized Residuals

Looking back at the model summary, shown in Table 10, the multiple correlation coefficient (R) is .472, which indicates moderate to strong linear association between this model's independent variables (factors) and the dependent one (job satisfaction), while the squared multiple correlation coefficient (R^2) equals to .223, meaning that the three factors together explain a significant 22.30% portion of the variability of the job satisfaction variable. Even when considering the value of adjusted R^2 (.208), the experience of homeworking still explains slightly more than 20% of the variance in the engineers' satisfaction with their jobs.

Model		Sum of Squares	df	Mean Square	F	p
H ₁	Regression	25.909	3	8.636	14.724	< .001
	Residual	90.325	154	0.587		
	Total	116.234	157			

Table 13. ANOVA of the initial MLR model

Since the p value of this regression model is less than .05, as can be seen in Table 13, it can be concluded that it is statistically significant. However, by observing the p values for each independent variable in the Coefficients table of this MLR model (Table 14), it becomes clear that Factor 3 (WLB) isn't statistically significant ($p=.693$) and that there is no association between the changes in that independent variable and the shifts in the model's dependent variable. To put it more simply, work-life balance does not influence job satisfaction and, for the purpose of ensuring the model's precision, it will be removed from the MLR.

		Collinearity Statistics						
Model		Unstandardized	Standard Error	Standardized	t	p	Tolerance	VIF
H ₁	(Intercept)	3.930	0.061		64.509	< .001		
	Fac1 (PWQ)	0.132	0.066	0.143	2.003	0.047	0.994	1.006
	Fac2 (ODC)	-0.409	0.066	-0.454	-6.220	< .001	0.949	1.054
	Fac3 (WLB)	-0.027	0.068	-0.029	-0.396	0.693	0.954	1.048

Table 14. Coefficients of the initial MLR model

As can be seen in Table 15 and Table 16, after removing the third factor from the MRL model, not much has changed – the model is still statistically significant, now with R and R^2 values being only slightly lower (.471 and .222 respectively), and the adjusted R^2 value being slightly higher (.212), meaning that in this model experience of homeworking altogether explains slightly more than 21% of the variance in the engineers' satisfaction with their jobs.

Model	R	R ²	Adjusted R ²	RMSE	Durbin-Watson		
					Autocorrelation	Statistic	p
H ₁	0.471	0.222	0.212	0.764	0.112	1.753	0.115

Table 15. Final MLR model summary

Model		Sum of Squares	df	Mean Square	F	p
H ₁	Regression	25.817	2	12.908	22.129	< .001
	Residual	90.417	155	0.583		
	Total	116.234	157			

Table 16. ANOVA of the final MLR model

The p values of both kept independent variables (Table 17) are statistically significant. However, from both their unstandardized and standardized coefficients it can be concluded that the second factor (ODC) is the better and much stronger predictor of job satisfaction. Those values also indicate that the independent variables negatively affect the dependent one, and while the increase in Factor 1 (PWQ) is associated with the increase of the independent variable, the increase in Factor 2 (ODC) results in its decrease. In more concrete terms, the organization distrust towards homeworking Croatian engineers experience predicts their job satisfaction to a greater extent than the productivity and quality of homeworking they report. Unsurprisingly, the greater

the organizations' distrust and control, and the lower the engineers' productivity and quality of work done from home, the lower their job satisfaction.

Model		Unstandardized	Standard Error	Standardized	t	p	Collinearity Statistics	
							Tolerance	VIF
H ₁	(Intercept)	3.930	0.061		64.685	< .001		
	Fac1 (PWQ)	0.132	0.066	0.143	2.014	0.046	0.994	1.006
	Fac2 (ODC)	-0.414	0.064	-0.460	-6.473	< .001	0.994	1.006

Table 17. Coefficients of the final MLR model

To build on an earlier conclusion, the two-factor MLR model of this study explains 21.20% of the total variance in the Croatian engineers' satisfaction with their jobs, and a great majority of that percentage is accounted for by the organization's distrust towards homeworking arrangements.

Finally, to exactly establish the effect sizes of the above-described coefficients, i.e. to see how much variance of the dependent variable does each independent variable account for while controlling the effect of the other, the part and partial correlations of the independent variables of the final MRL model were calculated and are shown in the Table 18.

Model		Partial	Part
H ₁	Fac1 (PWQ)	0.160	0.143
	Fac2 (ODC)	-0.461	-0.459

Table 18. Part and partial correlations of the independent variables in final MRL model

From these partial coefficients it is again easy to infer that the second factor (ODC), with an R value of $-.461$, is more strongly connected to the dependent variable than the first one (PWQ), whose R value is much smaller and amounts to $.160$. However, the squares of these values are more interesting, since they indicate the variances of the dependent variable explained by solely one factor, without the influence of the other one and their overlap. That way, the first Factor 1 ($R^2=.026$) accounts for only 2.60% of the independent variable's variance, while Factor 2 ($R^2=.213$) accounts for 21.30% of it. This means that productivity and work quality which Croatian engineers report, while controlling the influence of their organizations' distrust towards homeworking, account for less than 3% of the job satisfaction variability, while, on the other hand, organization distrust and control, with the control of the productivity influence, account for more than 21%, the same as the overall model itself.

5. Discussion

The twofold goal of this paper was to first explore the latent constructs that explain the homeworking experiences of Croatian engineers in order to develop a more

concise and simpler instrument, and later to check the influence of those constructs on the engineers' jobs satisfaction.

The predicted latent constructs were tested with an exploratory factor analysis, beginning with the parallel analysis which confirmed the existence of three theorized factors. Furthermore, the first goal of the EFA was to obtain the simple structure, which was achieved after the third factor iteration (Table 5) meeting all the simple solution criteria: all of the factors were theoretically meaningful, loaded with at least three variables (Factor 1 with 11, Factor 2 with 6, Factor 3 with 4 items), had no double loadings, and an internal consistency reliability greater than $\geq .70$ (Factor 1=.873, Factor 2=.852, and Factor 3=.734). Although *simple*, this solution had some problems, such as poor goodness of fit ($TLI < .90$ and $RMSEA > .08$) and weak loadings ($< .04$) of some variables, that required further iterations and item removal. Apart from achieving a statistically better fitting model, some of the items were removed in order to achieve a better theoretically and conceptually fitting instrument, i.e. the one that fits the predicted dimensions the most.

After a total of seven iterations, the initial instrument measuring the attitudes and experiences of working from home with 29 items was shortened to 13 items in total spread across three factors (Table 8). The domains kept explain almost 55% of the total variance, with the first one accounting for most and almost half of that amount (24.20%), and the second and third accounting for 19.20% and 11.40% respectively. Although renamed to better represent their items, the retained factors of *Productivity and work quality*, *Work-life balance* and *Organizations' distrust and control*, show a high level of consistency with the theorized domains, and correspond to their initial diversity, with the exception of the second factor (*Organizations' distrust and control*) whose content has been narrowed compared to the domain *Management and control* from which it originated.

To predict engineers' job satisfaction from the retained three factors, a multiple linear regression was analyzed and, although the model was statistically significant (Table 14) with a moderate to strong linear association ($R = .472$, $p < .001$) and more than 20% of variance explained, the *Work-life balance* factor ($b = -.03$, $t = -.40$, $p = .693$) did not prove to be a statistically significant predictor of job satisfaction. On the other hand, the remaining two factors were found to be both statistically significantly influencing job satisfaction, and while *Productivity and work quality* ($b = .13$, $t = 2.00$, $p = .047$) predicted it positively, *Organizations' distrust and control* ($b = -.41$, $t = -6.22$, $p < .001$) did it negatively and to a greater extent. This means that engineer's job satisfaction increases with rising homeworking quality and productivity, and especially with the experience of less employer's control and distrust towards the effectiveness of that kind of work, while it decreases otherwise.

Although somewhat surprising, the finding that work-life balance isn't a good predictor of job satisfaction could be explained with the mentioned social redefinition of private and working life and space and their mutual permeation and spillovers. That could be the reason why employees don't perceive working overtime and its interference with their private obligations and leisure as problematic nor as something that could cause their overall dissatisfaction. On the other hand, the decreasing effectiveness and productivity, hindered teamwork and professional development,

together with the constant pressure of proving otherwise, evidently affects employees more and leads to increased stress and dissatisfaction levels.

In order to reaffirm these results, especially that of the second factor being the better predictor of job satisfaction, partial correlations (Table 18) of the final MRL model factors (without the WLB one) were calculated. These correlations indicate that *Organizations' distrust and control* ($R=-.461$, $R^2=.213$) is indeed better at predicting job satisfaction than *Productivity and work quality* ($R=.160$, $R^2=.026$). More importantly, correlations indicate that the productivity and work quality of engineers alone (when controlling the influence of organizations' distrust and control) account for less than 3% of the job satisfaction variability, while organization distrust and control (when controlling the influence of productivity and work quality) account for more than 21%. In other words, the second factor (ODC) is a much better predictor of job satisfaction that on its own explains the same amount of its variance as the entire two- or three-factor model.

6. Study limitations

As mentioned earlier in the text, the sample size ($N=158$), its non-probabilistic convenience sampling and recruiting via snowball method pose some challenges in the generalization of results as they could be seen as leading to overrepresentation or underrepresentation of certain subsample groups, affecting both EFA and MLR.

Although it was not possible to infer which groups were under- or overrepresented, some subgroups stood out as obvious, most notably based on their geographic location (over 80% of respondents were from Croatia's two largest cities – Zagreb and Split), their age (less than 5% were over 50 years old), their education level (with 18% having a PhD), and their sector of employment (8% of them working in the education sector).

Without information on the population size and given the general lack of definite minimum sample size for conducting factor and linear analysis it is difficult to assess with certainty whether this study's sample is adequate for the methods of analysis it used.

According to Mundfrom and Shaw [41], defining an adequate sample for factor analysis includes observing the number of factors, the number of variables per factor (p/f ratio), and the level of communality. Considering this study retained three factors, with a 4.3 p/f ratio and a wide level of communalities (ranging between .2 and .8), an excellent-level criterion would need a sample of 260 respondents, while a good-level criterion would need 120 respondents [41] which leads to the conclusion that a sample of 158 respondents is acceptable. In the case of multiple linear regression, sample size can be defined using the precision efficacy analysis for regression (PEAR), which limits the amount of expected shrinkage² in R^2 and enhances the cross-validity potential of regression model, combining it with the effects of multicollinearity [42].

² As Brooks and Barcikowski put it: "PEAR method can be viewed as cross-validation in reverse. That is, instead of determining by how much the sample will shrink due to the sample size, the PEAR method determines how large a sample is required to keep from shrinking too much" [42, p. 3]

For a successful cross-validation of the R^2 (.222) of this study, with a precision efficacy of .80, while meeting the trivial multicollinearity condition (predictor correlations lower than .30), according to Brooks and Barcikowski [42], the minimum sample size should be 113. Although a larger sample would surely provide a better predictive power of the study's models, a sample of 158 respondents is considered acceptable.

Finally, with regards to the percentage of variance explained by the retained factors in EFA, it should be noted that, although relatively low by some standards [43], three factors explaining 54.5% of variance can be considered acceptable as such percentage is common in social sciences [43].

One last note regarding potential limitations sees the practice of alternating positively and negatively charged items in the constructed scales (see for example items JS1 and JS2 in Table 2.). As Sauro and Lewis [44] and Salazar [45] have shown, alternating positively and negatively oriented questions can often lead to their misinterpretation by respondents or result in coding errors done by researchers. Such complications are seen as outweighing the positive sides brought by an alternation of positive and negative wording, specifically minimizing acquiescence and extreme response biases. Having that in mind, future versions of the scales used in this research will have their wording revised.

7. Conclusion

The initial design of the instrument for researching homeworking experiences of Croatian engineers was made by combining three intertwined categories derived from a review of previous theoretical approaches and research findings on remote work. The first category referred to the *quality of work* from home as a broad concept encompassing the productivity and effectiveness of that kind of work, but also the autonomy of work, in terms of spatial and time organization given to the employees, and the accessibility of colleagues, as well as learning and training opportunities. The second category included in questionnaire design covered issues of relocation of paid work to the private sphere, and possibilities and successfulness in *balancing personal and work life* while working from home. Issues related to *management and control* of homeworking made up the third category, as well as the entailing problems of employers' trust and employees' motivation, and consequentially job satisfaction.

Exploratory factor analysis was used to test the consistency of the instrument and to check and confirm the presence of the predicted categories, i.e. latent constructs. It extracted three factors named *Productivity and work quality*, *Work-life balance* and *Organizations' distrust and control* explaining almost 55% of the total variance. Thus, the initial instrument measuring the attitudes and experiences of working from home with 29 items was shortened to 13 items in total. The multiple linear regression applied in order to predict job satisfaction from the retained three factors as predictors showed that, although work-life balance does not influence job satisfaction, productivity and work quality predict it positively, and organizations' distrust and control negatively and in a greater extent.

Although it is surprising that job satisfaction is not predicted by engineers' work-life balance, especially considering they reported higher amounts of working hours per week, this finding could be considered in line with Falstead and Gesenke's [11], as well as Ojala's [15] results pertaining to research on social exchange theory, which states that employees are indeed willing to work longer hours in exchange for the "flexibility" offered by working from home. On the other hand, the low correlation between work-life balance and job satisfaction could indicate that engineers have higher "tolerance" levels pertaining to permeability and flexibility in terms of border theory [13], being less affected by porous patterns of work, or perhaps more accustomed to it, especially if that kind of arrangements are not novel to them.

The fact that engineers who experience better work quality and productivity while working from home will also report higher levels of job satisfaction is in line with Cascio's [23] and Harker's and MacDonnell's [24] findings of higher productivity in working from home arrangements, and it could very well indicate that engineers find that these kinds of arrangements allow them to better manage their time, while less face-to-face interactions enable them to be more productive, which results in higher satisfaction not only with one's employment, but also with one's work.

Finally, the fact that engineers who experience lower levels of organization's control and distrust towards that kind of working arrangement will be the most satisfied with their jobs is a result that is not only expected, considering research done by de Vaujany [33], but also an important piece of information that should be adopted by employers still subscribing to a (digital) Tayloristic management style.

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The Influence of Digital Maturity, Competitive Priorities and Decision-making Styles on the Acceptance of Digital Technologies in Micro and Small Organizations

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Abstract

The subject of this research is to determine the level of digital technology acceptance in micro and small organizations. There is a lack of research in the existing literature that would move away from existing models and theories and explain the reasons for digital technology acceptance by micro and small organizations. It was noticed that research on the intention to accept digital technologies in micro and small organizations needs to focus on moderating factors, the influence of which has been neglected in existing research.

For this reason, a model for digital technology acceptance by micro and small organizations was created, which explored the effect of moderating factors and encompassed the key characteristics of micro and small organizations. The effect of perceived financial risk, perceived security risk, perceived loss of time, perceived government pressure, and the level of knowledge of decision-makers on the intention to accept digital technologies are examined. As well the relationship between external pressure (market participants' pressure and crisis circumstances) and the level of knowledge of decision-makers in organizations was explored.

The focus of the research is to explore the moderating effect of the organization's digital maturity and competitive priorities on the relationship of factors (perceived security risk, perceived loss of time, perceived government pressure) and intent to accept digital technologies. The moderating effect of the decision-makers decision-making style on the relationship between external pressure (market participants' pressure and crisis circumstances) and the level of knowledge of decision-makers are explored as well.

Keywords: micro and small organizations, digital technologies, intention to accept, moderating effect, digital maturity, competitive priorities, decision-making style

1. Introduction

A review of previous research has identified a lack of research that would move away from existing models and theories and explain the reasons for the digital technology's

acceptance by micro and small organizations. As part of this research, micro and small organizations are all entities involved in economic activity, regardless of legal form, which meet two of the three criteria, namely: income up to HRK 60,000,000, total assets up to HRK 30,000,000, and the number of employees up to 50 [1], [2].

The number of micro and small organizations is growing rapidly and they are becoming the foundation of the global economy by creating a large number of workplaces and contributing to its further development [3]. In the Republic of Croatia alone, micro and small organizations make up to 98% of total organizations [2]. In order for digital technologies to improve the business of micro and small organizations and ensure their survival in the market and as well to achieve a competitive advantage, they need to be accepted and perceived as useful and necessary. Digital technology adoption is crucial for organizations to ensure resilience and achieve sustainability in the market.

Today there is a new paradigm in the world known as the Global Resilience Project (GRP) that tries to shift the focus of businesses to invest in upfront measures that reduce disaster risk, rather than post-disaster relief and recovery efforts [4]. Observing the covid crisis and the disturbances it has created, the application of digital technologies has gained great importance. Digitally mature organizations have found it easier to cope with the restrictions imposed during the covid crisis. It is digital technologies that can help organizations prepare in advance for potential crises and market disruptions.

Regarding sustainability, as a starting point for the organization can serve the "2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015. The main focus of agenda is to provide a shared blueprint for peace and prosperity for people and the planet, now and into the future" [5]. In order to achieve this the 17 Sustainable Development Goals (SDGs) are set, which are an urgent call for action by all countries - developed and developing - in a global partnership. Some of the set goals are to foster innovation and promote sustained, inclusive, and sustainable economic growth, that will ensure productive employment and decent work for all [5]. The Agenda itself highlights the need for innovation and economic growth, which can be achieved primarily through the application and adoption of digital technologies, which are one of the beginnings towards digitalization and ultimately the digital transformation of organizations. The above indicates the necessity for micro and small organizations to accept digital technologies in order to survive the unstable market environment.

The number of models explaining the intention to accept technologies in the literature is extensive, but due to the accelerating development of technologies and the number of their characteristics, it is difficult to develop a single general model suitable for research into the acceptance of all innovations [4], [5], [6].

The existing literature review showed that the research on new technology acceptance focused mainly on large organizations, while only a small number of them dealt with micro and small organizations. Research involving micro and small organizations generally looks at acceptance at the level of SMEs (small and medium organizations). The analysis of the definitions of small and medium-sized organizations shows that there are very pronounced differences between them,

primarily in the context of their size, which means that they need special consideration in examining the intention to accept new technologies [1].

A review of secondary data also revealed that research on the intention to accept digital technologies in micro and small organizations needs to focus on moderating factors, the influence of which has been neglected in existing research. There is a gap in research that would investigate the effect of moderating factors when exploring the correlation between factors and the acceptance of new technologies. Generally, only the direct or indirect influence of factors on the acceptance of new technologies was observed. In order to fulfil the observed gap in the literature, it is necessary to focus more research on determining the effect of moderating factors and as well to broaden the explored types of moderating factors [7].

This research was created as part of the author's doctoral dissertation. The work is a continuation of the previously published work of the author [8]. A detailed description of the construct, as well as an extensive presentation of the topic, is presented as part of the author's doctoral dissertation, which will be published afterward.

The remainder of this paper is organized as follows: Section 2 presents a review of the literature on technology adoption models. Sections 3 and 4 discuss the research model and research methodology, respectively. Sections 5 and 6 detail the data analysis. Section 7 concludes the paper with a discussion of the findings and the conclusions drawn from them.

2. Literature review

Agarwal and Prasad, criticizing existing models for technology acceptance, emphasize the need to direct research toward moderating factors [9]. Thus, the TAM 3 model (Technology Acceptance Model 3) explores as moderating factors: experience, willingness to use, and quality of output, while the UTAUT model (The Unified Theory of Acceptance and Use of Technology) adds experience, willingness to use, age and sex. Sun and Zhang, exploring the moderating factors in individuals' models of technology acceptance, group them into organizational factors (willingness to use and routine and non-routine tasks), technological factors (individual / group technology, purpose, complexity), and individual (personal) factors (intellectual ability, cultural background, gender, age, and experience) [7]. Research on technology acceptance by organizations involving moderating factors is far less. Existing research focused on organizations explores the moderating effect of organizational culture [10], the ability to use computers [11], and size and experience.

An extensive literature review showed a gap in research that would fully cover the key characteristics of micro and small organizations, primarily the problem of lack of resources (financial and human) and decision-making that is entirely in the hands of directors, i.e. owners [12]. Micro and small organizations lag behind in the acceptance of new technologies precisely because of their characteristics that act as barriers to acceptance and lead to fear of the unknown and thus perceiving technology as risky and unnecessary [13], [14], [3], [15], [16], [17], [18]. In this sense, this

research is adjusted to cover the needs and characteristics of micro and small organizations.

By focusing research on micro and small organizations, it is also necessary not to neglect the key characteristics of these organizations when considering moderating factors. Bearing this in mind one of the key features of a micro and small organization is centralized decision-making, which is usually in the hands of an individual who is often the owner of the organization. Given that the main function of decision-makers is decision-making, the question arises whether there is a difference based on different decision-making styles. Therefore, the decision-making style is observed as one of the moderating factors in this research. It is explored how the different decision-making style of the decision-maker as a key person in micro and small organizations affects his knowledge of the digital technology he accepts. Therefore, the research question is:

RQ1: How does the different decision-making style of the decision-maker moderates the relationship between market participants and crisis circumstances and the level of knowledge of the decision-maker?

Observing previous research, it was also noted that there is no research that would include some kind of the motive for acceptance and observed its moderating effect on the intention to accept. Every acceptance of new technology, including digital technologies, is motivated by achieving a certain goal. Observing the business of organizations, the key goals are competitive priorities, so the next moderating factor is competitive priorities (quality, speed, reliability, flexibility, and cost) [19]. It is explored how competitive priorities influence the decision to accept digital technologies and whether there is a difference in acceptance depending on the competitive priority that digital technology seeks to achieve. Therefore the research question is:

RQ2 How do competitive priorities moderates the relationship between factors and intent to accept digital technologies?

Digital technology acceptance in organizations aims to achieve the digitalization of the business and ultimately to achieve digital transformation of business. Digital transformation is a frequent research topic, but there is a lack of research that would unite digital transformation and the very acceptance of digital technologies. Progress in achieving digital transformation is "measured" by the maturity of the organization. Therefore, there is a need to examine the dependence of the level of digital maturity of the organization and its digital technology acceptance. Incorporating the digital maturity of the organization into the digital technology acceptance model will help to get a broader picture of the "state" of the organization and its overall thinking about the digitalization of business, or digital transformation. In doing so, it is investigated whether there are differences in the acceptance of digital technologies between organizations at different levels of digital maturity. Accordingly, the research question is:

RQ3 How does the organization's level of digital maturity moderate the relationship between factors and intent to accept digital technologies?

Following the above, a digital technology acceptance model for micro and small organizations is proposed to will fill the gap in existing research by covering the key

characteristics of micro and small organizations and exploring the effect of moderating factors.

The relationship between perceived financial risk, perceived security risk, perceived loss of time, perceived government pressure, market participants pressure, perceived crisis circumstances, and the level of knowledge of decision-makers with the intention to accept digital technologies in micro and small organizations is explored. It is also explored whether there are differences in the acceptance of digital technologies between organizations at different levels of digital maturity, as well as whether there is a difference in acceptance depending on the competitive priority that the organizations seek to achieve by accepting digital technology. As well it is explored how different styles of directors' decision-making affect the relationship between market participants' pressures and crisis circumstances on the level of directors' knowledge of digital technology that is being accepted.

3. Conceptual model

Figure 1 shows the digital technology acceptance model for micro and small organizations. The model is derived from an analysis of the literature, following Rogers' recommendations, which suggests that the necessary direction of research is the development of new models, not the validation of existing ones [5].

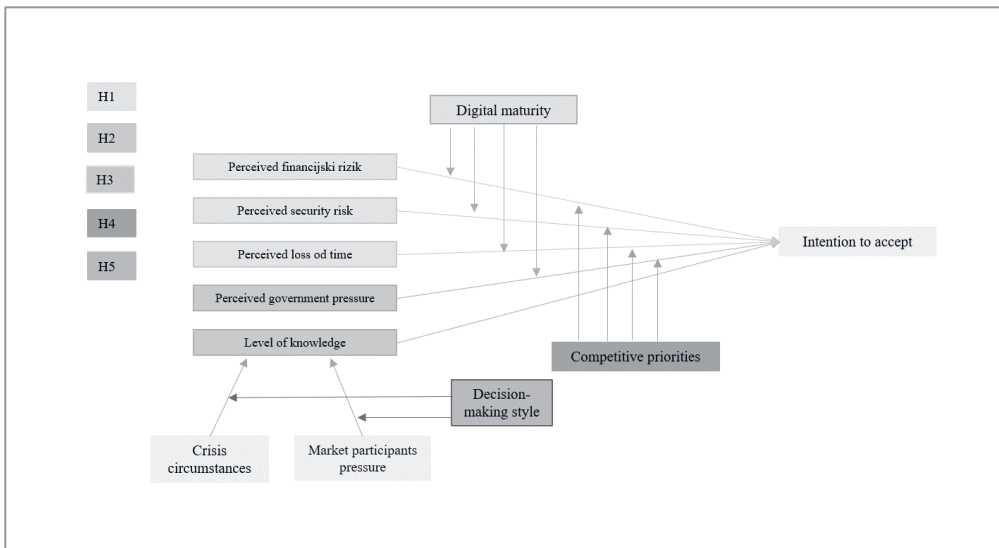


Figure 1. Digital technology acceptance model for micro and small organizations

All constructs of the model are explained in detail in the paper [8] except the one described below.

3.1. Competitive priorities

Competitive priorities include five priorities defined by Slack and others that enable the acquisition of competitive advantage, and thus the achievement of more efficient operations. Competitive priorities include *quality, speed, reliability, flexibility, and cost*. Quality implies an increase in quality in meeting the needs of the market based on the acceptance of digital technologies. Speed refers to the acceleration of business processes within the organization due to the acceptance of digital technologies, as well as faster recognition and meeting market demands. Reliability refers to the fulfilment of expectations related to meeting the deadlines for the delivery of services and products and the perception of business partners, which has a direct implication on gaining customer loyalty. Flexibility refers to variability in meeting expectations regarding adaptation to market requirements, the acceptance of digital technologies will enable organizations to be more agile. Finally, the cost refers to the expected reduction in operating costs that may result in a reduction in the price of products and services and/or enable the allocation of funds for other purposes [19], [20].

Based on existing theories, the following hypotheses are formulated:

H1 Perceived risks (financial, security, loss of time) have negative effects on the intention to accept digital technologies in micro and small organizations.

H2 Perceived government pressure and the level of knowledge of directors have positive effects on the intention to accept digital technologies in micro and small organizations.

H3 The level of digital maturity of the organization moderates the relationship between factors (perceived financial and security risk, perceived loss of time, and perceived government pressure) and intention to accept digital technologies.

H4 Competitive priority moderates the relationship between factors (perceived financial and security risk, perceived loss of time, and perceived government pressure) and intention to accept digital technologies.

H5 Decision-making style moderates the relationship between external pressures (crisis circumstances and market participants' pressure) and the level of knowledge of the decision-maker.

4. Methodology

The model is tested on the acceptance of cloud computing in micro and small organizations. Cloud computing in the context of this research includes "technological and infrastructural digital platforms, which enable efficient and secure use of almost unlimited digital (hardware, data, and software) capacities for data management, storage, and use" [21].

A review of the literature showed that a questionnaire as a research instrument is most often used in research on technology acceptance, and in this study for the purpose of testing the proposed model a measuring instrument (survey questionnaire) was developed [4].

The reliability and validity of the measuring instrument are tested. Reliability is tested with the Cronbach's alpha reliability coefficient, which for acceptable reliability

needs to be greater than 0.7 [22]. Validity testing includes convergence and discriminatory validation testing. Convergent validity is measured using the average extracted variance (AVE) [23]. The AVE value for an individual construct must be 0.5 or more [6]. Discriminatory validity is tested to confirm that variables within a certain factor do not correlate strongly with variables in another factor. In order to confirm this, it is necessary that the square of the AVE value of each construct is greater than the correlation between that construct and any other construct, also the correlation between each pair of the latent exogenous constructs should be less than 0.85 [6], [23].

Structural Equation Modeling (SEM) is used to test the conceptual model and evaluate the hypotheses.

The moderating effect is tested using multigroup analysis. All three variables used in this research: digital maturity, decision-making style, and competitive priorities are categorical, with digital maturity having three groups, decision-making style two groups, and competitive priorities five groups. The categorical variable serves as a grouping variable and divides the sample into subgroups, i.e. subsamples. Once divided into subsamples the same theoretical model is estimated for each group. The aim is to determine whether there are statistically significant differences between groups, which is achieved through the use of multigroup analysis. Multigroup analysis compares the same model across different groups in the sample [24].

The digital maturity model is adopted and adjusted from the research of Kruljac [25]. It contains five dimensions (resources to implement digital transformation, advanced technologies use, technology management efficiency, openness and communication, and risk acceptance) The calculation of the digital maturity of the organization is taken from the research of Blatz and others who in their research propose a model of digital maturity for small and medium enterprises [26].

5. Results

The results of the statistical analysis are presented below. Data were collected through the online questionnaire, that was sent to a total of 1.670 email addresses. The return rate is 28% as shown [27]:

$$\% \text{ return rate} = \frac{\text{total number of returned questionnaires}}{\text{total number of questionnaires sent-inappropriate}} = \frac{457}{1670-25} = 28$$

A total of 457 questionnaires were returned, 25 of them were excluded from the further analysis because they belong to the organisations from the IT industry that were excluded from this research.

Characteristics of respondents and organizations from the sample as well as descriptive statistics were processed using Microsoft Excel and IBM SPSS. Multivariate analysis is performed via PLS SEM made in SmartPLS3. The sample consisted of 432 organizations.

Variable	Category	Number of Organizations	Structure %
<i>Size of organization</i>	Micro	215	49,8
	Small	217	50,2
Total		432	100
<i>Type of organization</i>	Crafts	80	18,5
	Company	352	81,5
Total		432	100

Table 1. Size and type of organization from the sample

The calculation of the digital maturity of the organizations in the sample showed that the largest number of organizations (41.20%) is at the first level. At the second level is 37.3% while only 21.5% of organizations are at the third level of digital maturity.

Level of digital maturity	Number of organizations	Structure %
1 level	178	41,2
2 level	161	37,3
3 level	93	21,5
Total	432	100

Table 2. Digital maturity of the organization from the sample

Determining the decision-making style of the respondents is done using the mean value. The respondent was assigned a decision-making style depending on whether the mean was higher on the intuitive or rational style scale. The analysis found that 56 respondents have an intuitive decision-making style (13%) while 376 (87%) have a rational decision-making style.

Decision-making style	Number of organizations	Structure %
Intuitive	56	13
Rational	376	87
Total	432	100

Table 3. The decision-making style of the respondents

Table 4 shows the competitive priorities that organizations want to achieve by embracing cloud computing. It is a tie between increasing flexibility and cutting costs.

Competitive priorities	Number of organizations	Structure %
Speed	85	19,7
Flexibility	84	19,4
Quality	107	24,8
Reliability	52	12
Cost	104	24,1
Total	432	100

Table 4. Competitive priorities

After presenting the characteristics of the respondents, the results of testing the research model are presented in the next section.

5.1. Measurement Model Assessment

The Cronbach's alpha coefficient and the composite reliability coefficient (CR) are applied to verify the internal consistency and reliability of the construct. Table 5 shows that the values for both coefficients are above 0.7, which indicates good reliability and internal consistency of the construct [28].

Convergent validity is assessed by the Average Variance Extracted (AVE). The obtained values for each individual construct are above 0.5, which indicates good convergent validity [28] (Tabel 5).

The relationship between perceived financial risk, perceived security risk, perceived loss of time, perceived government pressure, and the level of knowledge of decision-makers with the intention to accept digital technologies is examined. The connection between the market participants' pressure and crisis circumstances with the level of knowledge of decision-makers in organizations is also explored.

Items	Loading	Cronbach's alfa	Composite Reliability CR	Average Variance Extracted AVE
Perceived financial risk (PFR)				
C_PFR1	0,828	0,805	0,872	0,632
C_PFR2	0,668			
C_PFR3	0,840			
C_PFR4	0,831			
Perceived security risk (PSR)				
C_PSR2rev	0,907	0,903	0,939	0,837
C_PSR3rev	0,930			
C_PSR4rev	0,908			
Perceived loss of time (PGV)				
C_PGV1	0,798	0,929	0,948	0,822
C_PGV2	0,958			

Items	Loading	Cronbach's alfa	Composite Reliability CR	Average Variance Extracted AVE
C_PGV3	0,961			
C_PGV4	0,901			
Perceived government pressure (PPD)				
C_PPD1	0,854	0,883	0,918	0,738
C_PPD2	0,897			
C_PPD3	0,869			
C_PPD4	0,813			
Level of knowledge of decision-makers (RZ)				
C_RZ2	0,846	0,702	0,834	0,629
C_RZ3	0,682			
C_RZ4	0,841			
Crisis circumstances (KO)				
C_KO1	0,713	0,885	0,909	0,668
C_KO2	0,743			
C_KO3	0,886			
C_KO4	0,885			
C_KO5	0,845			
Market participant's pressure (PST)				
C_PST1	0,827	0,854	0,889	0,669
C_PST2	0,847			
C_PST3	0,712			
C_PST4	0,875			
Intention to accept (NP)				
C_NP1	0,980	0,961	0,981	0,963
C_NP2	0,982			

Note: Crisis circumstances (C_KO), Intention to accept (C_NP), Perceived financial risk (C_PFR), Perceived loss of time (C_PGV), Perceived government pressure (C_PPD), Perceived security risk (C_PSR), Market participant pressure (C_PST), Level of knowledge (C_RZ)

Table 5. Measurement model

Discriminant validity is assessed by the Fornell Larcker criterion and by calculating cross-loadings [28]. Hair et al. suggest that the value of the factor load should be 0.7 or more [28] (Table 6).

	C_KO	C_NP	C_PFR	C_PG V	C_PPD	C_PSR	C_PST	C_RZ
C_KO1	0,713	0,229	0,101	0,120	0,082	-0,093	0,414	0,232
C_KO2	0,743	0,180	0,081	0,118	0,119	-0,153	0,338	0,252
C_KO3	0,886	0,071	0,309	0,367	0,156	-0,056	0,224	0,577
C_KO4	0,885	0,048	0,302	0,393	0,215	-0,066	0,282	0,474
C_KO5	0,845	0,264	0,104	0,214	0,170	-0,180	0,372	0,364

	C_KO	C_NP	C_PFR	C_PG V	C_PPD	C_PSR	C_PST	C_RZ
C_NP1	0,175	0,980	-0,211	-0,171	0,360	-0,378	0,331	0,055
C_NP2	0,145	0,982	-0,217	-0,164	0,382	-0,396	0,284	0,091
C_PFR1	0,230	-0,221	0,828	0,585	0,028	0,178	0,253	0,415
C_PFR2	0,130	-0,150	0,668	0,474	0,115	0,018	0,127	0,324
C_PFR3	0,150	-0,144	0,840	0,703	0,089	0,078	0,171	0,421
C_PFR4	0,277	-0,157	0,831	0,728	0,129	0,129	0,208	0,441
C_PGV1	0,352	-0,100	0,581	0,798	0,109	0,150	0,255	0,514
C_PGV2	0,300	-0,202	0,764	0,958	0,177	0,156	0,203	0,564
C_PGV3	0,293	-0,173	0,740	0,961	0,199	0,155	0,221	0,569
C_PGV4	0,312	-0,087	0,720	0,901	0,280	0,156	0,161	0,573
C_PPD1	0,230	0,256	0,168	0,278	0,854	-0,165	0,118	0,285
C_PPD2	0,228	0,261	0,126	0,185	0,897	-0,230	0,082	0,233
C_PPD3	0,114	0,420	0,053	0,125	0,869	-0,243	0,046	0,231
C_PPD4	0,120	0,307	0,048	0,148	0,813	-0,184	-0,011	0,201
C_PSR2re v	-0,091	-0,410	0,124	0,171	-0,229	0,907	-0,108	0,089
C_PSR3re v	-0,128	-0,328	0,100	0,096	-0,221	0,930	-0,081	0,005
C_PSR4re v	-0,112	-0,332	0,152	0,189	-0,219	0,908	-0,015	0,049
C_PST1	0,346	0,346	0,112	0,110	0,189	-0,080	0,827	0,093
C_PST2	0,293	0,260	0,210	0,114	0,102	-0,112	0,847	0,112
C_PST3	0,298	0,383	0,083	0,054	0,032	-0,202	0,712	0,018
C_PST4	0,301	0,213	0,275	0,307	-0,049	-0,015	0,875	0,172
C_RZ2	0,402	-0,069	0,522	0,563	0,109	0,128	0,112	0,846
C_RZ3	0,308	0,317	0,194	0,277	0,487	-0,126	0,108	0,682
C_RZ4	0,478	-0,026	0,459	0,568	0,108	0,102	0,140	0,841

Note: Crisis circumstances (C_KO), Intention to accept (C_NP), Perceived financial risk (C_PFR), Perceived loss of time (C_PGV), Perceived government pressure (C_PPD), Perceived security risk (C_PSR), Market participant pressure (C_PST), Level of knowledge (C_RZ)

Table 6. Cross-loadings

Fornell Larcker represents the second root of the AVE indicator and points to the discriminant validity of a construct when the second root of the AVE indicator of an individual construct is greater than the correlation between that construct and other constructs in the external reflective model [28]. Table 7 shows how this condition is met.

	C_KO	C_NP	C_PFR	C_PGV	C_PPD	C_PSR	C_PST	C_RZ
C_KO	0,817							
C_NP	0,162	0,981						
C_PFR	0,253	-0,218	0,795					
C_PGV	0,335	-0,170	0,778	0,907				
C_PPD	0,190	0,379	0,106	0,203	0,859			
C_PSR	-0,119	-0,394	0,137	0,168	-0,244	0,915		
C_PST	0,364	0,312	0,247	0,229	0,063	-0,078	0,818	
C_RZ	0,508	0,075	0,506	0,606	0,274	0,056	0,153	0,793

Note: Crisis circumstances (C_KO), Intention to accept (C_NP), Perceived financial risk (C_PFR), Perceived loss of time (C_PGV), Perceived government pressure (C_PPD), Perceived security risk (C_PSR), Market participant pressure (C_PST), Level of knowledge (C_RZ)

Table 7. Fornell-Larcker Crirerion

5.2. Structural Model Assessment

The collinearity check is performed using the variance inflation factor (VIF). Table 8 shows that all values are within the recommended range of 0.2 to 5, which leads to the conclusion that there is no multicollinearity between independent and dependent variables in the structural model [28].

	C_NP	C_RZ
Crisis circumstances (C_KO)		1,153
Intention to accept (C_NP)		
Perceived financial risk (C_PFR)	2,574	
Perceived loss of time (C_PGV)	3,095	
Perceived government pressure (C_PPD)	1,190	
Perceived security risk (C_PSR)	1,123	
Market participant pressure (C_PST)		1,153
Level of knowledge (C_RZ)	1,653	

Table 8. Collinearity statistics (Inner VIF values)

The coefficient of determination (R^2) indicates the quality of the adjusted model. Cohen stated that values of 0.26, 0.13, and 0.02 indicate strong, moderate, and weak predictive power [29] (Table 9).

	R^2	Predictive power (Results interpretation)
Intention to accept (C_NP)	0,310	Moderate
Level of knowledge (C_RZ)	0,259	Weak

Table 9. The R^2 of endogenous latent variables

Table 10 shows the values of the Cohen f^2 coefficient, which represents the strength of the influence of each path coefficient of the structural model. A value of 0.02 represents a small impact, a value of 0.15 represents a medium impact, and a value of 0.35 represents a large impact [29]. As it can be seen from the Tabel 10 the crisis circumstances (C_KO) have a medium impact on the level of knowledge (C_RZ) while market participant pressure (C_PST) has a small impact on the level of knowledge (C_RZ). The perceived financial risk (C_PFR), perceived loss of time (C_PGV), perceived government pressure (C_PPD), perceived security risk (C_PSR), and level of knowledge (C_RZ) have a small impact on the intention to accept (C_NP).

	C_NP	C_RZ
Crisis circumstances (C_KO)		0,318
Intention to accept (C_NP)		
Perceived financial risk (C_PFR)	0,020	
Perceived loss of time (C_PGV)	0,012	
Perceived government pressure (C_PPD)	0,116	
Perceived security risk (C_PSR)	0,099	
Market participant pressure (C_PST)		0,002
Level of knowledge (C_RZ)	0,034	

Table 10. The f^2 effect sizes

To assess the predictive relevance, the calculation of Stone-Geisser indicators (Q^2) is performed. A Q^2 value greater than 0 indicates low predictive relevance, a value greater than 0.25 indicates medium predictive relevance, and a value greater than 0.50 indicates high predictive relevance of the PLS model [30] (Table 11).

	Q^2	Results interpretation
Intention to accept (C_NP)	0,291	Medium
Level of knowledge (C_RZ)	0,157	Small

Table 11. Predictive relevance Q^2

5.3. Path analysis

The path coefficient analysis examines the impact on the endogenous variable. Values range from -1.00 to +1.00, with values closer to +1.00 indicating a statistically strong positive relationship between variables.

With a degree of significance of 5%, the p-value must be lower than 0.05 in order to conclude that the relationship between the constructs is significant. A t-value greater than 1.96 with a degree of significance $\alpha = 5\%$, indicates the significance of the path coefficient. Table 12 shows the values of the path coefficient, t-value, and p-

value for individual connections and the interpretation of the results, i.e. the set hypotheses.

Hypotheses	Path	Path Coefficients β	t - Values	p- Values	Interpretation	Supported
H1	C_PFR $\rightarrow$ NP	-0,188	2,996	0,003	Significant	Yes
	C_PSR $\rightarrow$ NP	-0,277	6,610	0,000	Significant	
	C_PGV $\rightarrow$ NP	-0,160	2,442	0,015	Significant	
H2	C_PPD $\rightarrow$ NP	0,309	7,548	0,000	Significant	Yes
	C_RZ $\rightarrow$ NP	0,198	3,208	0,001	Significant	

Note: Crisis circumstances (C_KO), Intention to accept (C_NP), Perceived financial risk (C_PFR), Perceived loss of time (C_PGV), Perceived government pressure (C_PPD), Perceived security risk (C_PSR), Market participant pressure (C_PST), Level of knowledge (C_RZ)

Table 12. Summary of the structural model

Table 12 shows that H1 and H2 are accepted. There is a statistically significant negative effect of perceived risks (financial, security, loss of time) on the intention to accept digital technologies in micro and small organizations. As well there is a statistically significant positive effect of perceived government pressure and the level of knowledge of directors on the intention to accept digital technologies in micro and small organizations.

6. Moderating effect

To examine the moderating effect of digital maturity and competitive priorities on the relationship between factors (perceived financial and security risk, perceived loss of time, and perceived government pressure) and intention to accept digital technology, and the effect of decision-making style on the relationship between external pressures (crisis circumstances and market participants pressure) and level of knowledge, an analysis of the moderating effect is performed.

6.1. Moderating effect of digital maturity

Prior to the analysis, it was checked whether there are differences between the observed groups, which was done by univariate analysis of variance (ANOVA) [22].

		Sum of Squares	df	Mean Square	F	Sig.
C_PFR	Between Groups	15,942	2	7,971	12,817	0,000
	Within Groups	266,804	429	0,622		
	Total	282,746	431			

		Sum of Squares	df	Mean Square	F	Sig.
C_PSR	Between Groups	15,044	2	7,522	9,437	0,000
	Within Groups	341,937	429	0,797		
	Total	356,981	431			
C_PGV	Between Groups	19,706	2	9,853	13,350	0,000
	Within Groups	316,613	429	0,738		
	Total	336,319	431			
C_PPD	Between Groups	0,157	2	0,079	0,092	0,912
	Within Groups	367,158	429	0,856		
	Total	367,316	431			
C_NP	Between Groups	12,244	2	6,122	8,489	0,000
	Within Groups	309,394	429	0,721		
	Total	321,638	431			

Note: Crisis circumstances (C_KO), Intention to accept (C_NP), Perceived financial risk (C_PFR), Perceived loss of time (C_PGV), Perceived government pressure (C_PPD), Perceived security risk (C_PSR), Market participant pressure (C_PST), Level of knowledge (C_RZ)

Table 13. ANOVA – level of digital maturity

When the p-value of the F-ratio is less than 0.05, it can be stated that the differences between the arithmetic means of the groups (groups) are statistically significant ($p < 0.05$). The results indicate that there are statistically significant differences in the arithmetic means between the groups for all variables except for the variable perceived government pressure (C_PPD). After checking that the groups differed from each other, a multigroup analysis is performed.

Path	Path Coefficients (1 level)	Path Coefficients (2 level)	Path Coefficients (3 level)	t-Values (1 level)	t-Values (2 level)	t-Values (3 level)	p-Values (1 level)	p-Values (2 level)	p-Values (3 level)
C_PFR → C_NP	-0,093	-0,358	-0,277	0,846	3,556	1,471	0,398	0,000	0,141
C_PSR → C_NP	-0,178	-0,280	-0,324	3,073	4,416	2,658	0,002	0,000	0,008
C_PGV → C_NP	-0,070	-0,315	0,065	0,587	3,194	0,245	0,557	0,001	0,806
C_PPD → C_NP	0,471	0,074	0,310	5,368	1,045	1,947	0,000	0,296	0,052

Note: Crisis circumstances (C_KO), Intention to accept (C_NP), Perceived financial risk (C_PFR), Perceived loss of time (C_PGV), Perceived government pressure (C_PPD), Perceived security risk (C_PSR), Market participant pressure (C_PST), Level of knowledge (C_RZ)

Table 14. Multigroup analysis - level of digital maturity

The results of the multigroup analysis indicate that for the first level of digital maturity, there is a statistically significant negative effect of a perceived security risk (C_PSR) and a statistically significant positive effect of perceived government

pressure (C_PPD) and the intention to accept. For the second level of digital maturity, there is a statistically significant negative effect between perceived financial risk (C_PFR), perceived security risk (C_PSR), and perceived loss of time (C_PGV) and the intention to accept. For the third level of digital maturity, there is a statistically significant negative effect between perceived security risk (C_PSR) and intention to accept.

Previously, results of ANOVA showed that there are no differences in arithmetic means within the groups for the variable perceived government pressure (C_PPD), so a parametric test was performed to confirm that there are differences between the groups (Table 15). A parametric test assuming equal variance in groups indicates whether there are differences between the observed groups.

Table 15 shows that there is a statistically significant difference between the first and second levels of digital maturity in the relationship between perceived government pressure (C_PPD) and intention to accept (C_NP), and as Table 14 shows, this link is stronger at the first level.

Path	Comparison	Path Coefficients difference	t- Values	p- Values
C_PPD -> C_NP	1 level vs 2 level	0,397	3,494	0,001
	1 level vs 3 level	0,161	0,964	0,336
	2 level vs 3 level	-0,237	1,554	0,121

Note: Crisis circumstances (C_KO), Intention to accept (C_NP), Perceived financial risk (C_PFR), Perceived loss of time (C_PGV), Perceived government pressure (C_PPD), Perceived security risk (C_PSR), Market participant pressure (C_PST), Level of knowledge (C_RZ)

Table 15. Parametric test – level of digital maturity

According to the results of multigroup analysis and parametric test, it can be confirmed that digital maturity moderates the relationship between factors (perceived financial and security risk, perceived loss of time, and perceived government pressure) and intention to accept cloud computing in micro and small organizations, thus accepting H3.

Observing the relationship between perceived security risk and intention to accept, it is clear that the strongest influence is with organizations on a 3. level. On a 2. level, there is the strongest influence as well between perceived loss of time (C_PGV) and intention to accept cloud computing. Regarding the connection between perceived financial risk and intent to accept it is clear that the strongest influence is with organizations on the 2. level. On level 1 there is the strongest influence between perceived government pressure (C_PPD) and intent to accept.

6.2. Moderating effect of competitive priorities

In order to check the moderating effect of competitive priorities (speed, flexibility, quality, reliability, costs) on the relationship between factors (perceived financial and

security risk, perceived loss of time, and perceived government pressure) and the intention to accept cloud computing, a multigroup analysis is performed.

ANOVA was used to test the differences in the arithmetic means of the groups.

		Sum of Squares	df	Mean Square	F	Sig.
C_PFR	Between Groups	10,228	4	2,557	4,006	0,003
	Within Groups	272,518	427	0,638		
	Total	282,746	431			
C_PSR	Between Groups	16,177	4	1,044	5,067	0,001
	Within Groups	340,804	427	0,798		
	Total	356,981	431			
C_PGV	Between Groups	11,068	4	2,767	3,633	0,006
	Within Groups	325,251	427	0,762		
	Total	336,319	431			
C_PPD	Between Groups	16,429	4	4,107	4,998	0,001
	Within Groups	350,887	427	0,822		
	Total	367,316	431			
C_NP	Between Groups	28,399	4	7,100	10,338	0,000
	Within Groups	293,239	427	0,687		
	Total	321,638	431			

Note: Crisis circumstances (C_KO), Intention to accept (C_NP), Perceived financial risk (C_PFR), Perceived loss of time (C_PGV), Perceived government pressure (C_PPD), Perceived security risk (C_PSR), Market participant pressure (C_PST), Level of knowledge (C_RZ)

Table 16. ANOVA – competitive priorities

ANOVA results shown in Table 16 indicate that there are statistically significant differences in arithmetic means between the observed groups for all variables ($p < 0.05$). After checking that the groups differed from each other, a multigroup analysis is performed. Table 18 shows the results of a multigroup analysis.

	C_PFR -> C_NP	C_PSR -> C_NP	C_PGV -> C_NP	C_PPD -> C_NP
Path Coefficients (S)	-0,561	-0,02	0,254	0,307
Path Coefficients (F)	-0,128	-0,378	-0,264	-0,115
Path Coefficients (Q)	0,204	-0,316	-0,483	0,151

	C_PFR -> C_NP	C_PSR -> C_NP	C_PGV -> C_NP	C_PPD -> C_NP
Path Coefficients (R)	-0,475	-0,593	0,296	0,218
Path Coefficients(C)	-0,073	-0,465	-0,232	0,378
t- Values (S)	3,443	0,2	1,67	2,209
t- Values (F)	0,714	4,019	1,202	0,641
t- Values (Q)	0,627	3,07	2,196	1,619
t- Values (P)	1,925	4,074	1,212	1,25
t- Values (C)	0,412	6,062	1,27	3,839
p- Values (S)	0,0010	0,8410	0,0950	0,0270
p- Values (F)	0,4750	0,0000	0,2290	0,5220
p- Values (Q)	0,5310	0,0020	0,0280	0,1060
p- Values (R)	0,0540	0,0000	0,2260	0,2110
p- Values (C)	0,6800	0,0000	0,2040	0,0000

Note: Crisis circumstances (C_KO), Intention to accept (C_NP), Perceived financial risk (C_PFR), Perceived loss of time (C_PGV), Perceived government pressure (C_PPD), Perceived security risk (C_PSR), Market participant pressure (C_PST), Level of knowledge (C_RZ), speed (S), flexibility (F), quality (Q), reliability (R), costs (C)

Table 17. Multigroup analysis – competitive priorities

It is evident that for the competitive priority *speed* there is a statistically significant negative effect of perceived financial risk (C_PFR) and a statistically significant positive effect of perceived government pressure (C_PPD) on the intention to accept (C_NP). For *flexibility and reliability*, there is a statistically significant negative effect of a perceived security risk (C_PSR) on the acceptance intent.

For *quality*, there is a statistically significant negative effect of a perceived security risk (C_PSR) and perceived loss of time (C_PGV) on the acceptance intent (C_NP) while for *cost* there is a statistically significant negative effect of a perceived security risk (C_PSR) and statistically significant positive effect of perceived government pressure (C_PPD) on the acceptance intent (C_NP). Observing the relationship between perceived security risk and intent to accept, it is clear that the strongest influence is with organizations that want to increase *reliability* by accepting cloud computing.

It can be concluded that competitive priorities moderate the relationship between factors (perceived financial and security risk, perceived loss of time, and perceived government pressure) and the intention to accept cloud computing, thus accepting H4.

6.3. Moderating effect of decision-making style

The T test is used to check whether there are differences in the arithmetic means of the observed groups and it was confirmed that the groups differed from each other (p-value <0.05) [22].

	T-test		
	t	df	P- Values
C_KO	5,478	430	0,000
C_PST	3,788	430	0,000
C_RZ	2,668	430	0,008

Note: Crisis circumstances (C_KO), Intention to accept (C_NP), Perceived financial risk (C_PFR), Perceived loss of time (C_PGV), Perceived government pressure (C_PPD), Perceived security risk (C_PSR), Market participant pressure (C_PST), Level of knowledge (C_RZ)

Table 18. T-test (decision-making style)

After checking that the groups differed from each other, a multigroup analysis is performed. Table 19 presents the results of a multigroup analysis of the impact of decision-making style on the relationship between market participants' pressure (C_PST) and crisis circumstances (C_KO) on the level of knowledge of decision-makers (C_RZ).

It is evident that for both styles a statistically significant positive effect was observed between the crisis circumstances and the level of knowledge. The relationship between market participant pressure and level of knowledge is not statistically significant. It is also evident that the effect of crisis circumstances on the level of knowledge is stronger among decision-makers with intuitive style (rational $\beta = 0.481$, intuitive $\beta = 0.911$).

Path	Path Coefficients (Intuitive)	Path Coefficients (rational)	t- Values (Intuitive)	t- Values (rational)	p- Values (Intuitive)	p- Values (rational)
C_KO -> C_RZ	0,911	0,481	9,784	12,222	0,000	0,000
C_PST -> C_KO	-0,193	-0,000	1,562	0,001	0,118	0,999

Note: Crisis circumstances (C_KO), Intention to accept (C_NP), Perceived financial risk (C_PFR), Perceived loss of time (C_PGV), Perceived government pressure (C_PPD), Perceived security risk (C_PSR), Market participant pressure (C_PST), Level of knowledge (C_RZ).

Table 19. Multigroup analysis – decision-making style

It can be concluded that the decision-making style moderates the connection between crisis circumstances and the level of knowledge, thus partially accepting H5.

7. Discussion and conclusion

In accordance with the conducted analysis, a summary of the research results is presented in Table 20.

Hypotheses	Results
H1 Perceived risks ... have negative effects on the intention to accept cloud computing in micro and small organizations.	
financial risk	Accepted
security risk	Accepted
loss of time	Accepted
H2 Perceived ... of directors have positive effects on the intention to accept cloud computing in micro and small organizations.	
government pressure	Accepted
level of knowledge	Accepted
H3 The level of digital maturity of the organization moderates the relationship between factors.	
perceived financial risk and intention to accept cloud computing	Accepted
perceived security risk and intention to accept cloud computing	Accepted
perceived loss of time and intention to accept cloud computing	Accepted
H4 Competitive priority moderates the relationship between...	
perceived financial risk and intention to accept cloud computing	Accepted
perceived security risk and intention to accept cloud computing	Accepted
perceived loss of time and intention to accept cloud computing	Accepted
H5 Decision-making style moderates the relationship between ...	
crisis circumstances and the level of knowledge of decision-makers	Accepted
market participants' pressure and the level of knowledge of decision-makers	Rejected

Table 20. Summary of results

A total of five hypotheses are presented in this paper of which four of them are fully accepted while hypothesis H5 is partially accepted due to the absence of moderating effect of decision-making style on the relationship between the market participant pressure and the level of knowledge of director on the cloud computing.

The level of digital maturity is found to moderate the relationship between factors (perceived financial and security risk, perceived loss of time, and perceived government pressure) and the intention to accept cloud computing. Observing the relationship between perceived financial risk and perceived loss of time, the effect is strongest at the second level of digital maturity, while in the relationship between security risk and intention to accept, the effect is strongest at the third level of maturity.

Observing the moderating effect of competitive priorities on the acceptance of cloud computing, the results indicate that there is a moderating effect on the relationship between factors (perceived financial and security risk, perceived loss of time, and perceived government pressure) and intention to accept cloud computing. The relationship between perceived financial risk and intention to accept is strongest by the competitive priority *speed*, while the relationship between perceived security risk and intent to accept is strongest by *reliability*. *Quality* has the strongest effect on

the relationship between perceived loss of time, while *cost* has the strongest impact on the relationship between perceived government pressure and the intention to accept cloud computing.

The last moderating factor observed was the decision-making style and its effect on the relationship of external pressures (crisis circumstances and market participants' pressure) to the intention to accept. The moderating effect of decision-making style on the relationship between crisis circumstances and intention to accept was confirmed. It is found that this influence is stronger among decision-makers who have an intuitive decision-making style. The moderating impact of decision-making style on the relationship between market participants' pressure and acceptance intentions is not been confirmed.

As mentioned in the introduction, this research is created as part of the author's doctoral dissertation, in which the proposed model is described in more detail. As part of the dissertation, the model was tested on two digital technologies: cloud computing and smart contracts. As well in the dissertation, the development of the measurement instrument is presented, the sample is explained, and the remaining tests that are not presented in this paper are presented together with an extended results discussion, conclusion and limitation, and recommendation for further research.

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Query Refinement into Information Retrieval Systems: An Overview

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Abstract

Query, expressing the user need and requirement, has an important role, in an information retrieval system, for reaching a high accuracy search. In this paper, we present an overview of the different refinement operations that the query may undergo, in the sake to enhance performance of an information retrieval system, such as: automatic query formulation through words prevision, query reformulation, query expansion, and query optimization.

Keywords: Information Retrieval, Query Processing, Automatic Query Formulation, Query Reformulation, Query Expansion, Query Optimization.

1. Introduction

Information retrieval consists to retrieve, from a large collection or corpus, a subset of documents relevant to the user requirement submitted as a textual query composed of some key-words. Information retrieval task is ensured commonly by automatic systems known as information retrieval systems in the case of a limited corpora and information retrieval engines, such as Google, where asking unlimited and extensible corpus in the image of the web.

An information retrieval system architecture is composed of three components: (i) indexing module, responsible to encode and represent the documents of the database to be asked in a compact and a significant form based on some discriminative features, (ii) interrogation module, designing the protocol and the language to be adopted to formulate the query reflecting the user information need and requirement, and (iii) the matching process, able to compare semantically between both pre-cited representations.

Unfortunately, the users are not well satisfied for the results returned by an information retrieval system which leads to think about improving these results and in consequence enhancing the global quality of the system. In retrospect of what happens in the past scientific researches, it is clear to observe that many efforts have been put for improving the quality of information retrieval systems through introducing new effective indexing signatures with high level semantics such as using of ontology and proposing new smart and intelligent reasoning modes for comparing

between the documents and the submitted queries such as adopting of expert systems based on ‘making the mind’ approach and using neural networks relying on ‘modelling the brain’ paradigm. Moreover, the quality of information retrieval system may be improved also over the interrogation protocol either through the high interactivity with the user, relevance feedback mechanism as a post-processing step, or query refinement.

In this paper, we give an overview of query refinement, with its different aspects, in information retrieval system. Review of literature reveals that there exists some similar works, with different handling, that have addressed the chasm issue, in terms of vocabulary, between the queries submitted by the user and the existed documents. In [1], for instance, authors have presented an overview of the vocabulary gap in information retrieval between the queries and the documents through query rewriting scheme. They have categorized the existent works, in this direction, into two categories: works using shallow learning such as substitution-based and translation-based methods and works with deep learning like using of word embedding and deep reinforcement learning. In [2], authors have surveyed query expansion, query suggestion, and query refinement techniques with a detailed comparison between these three considered schemes. In terms of terminology, the authors have named query reformulation as a query refinement.

2. Query Expression and Interrogation Protocol

One of the major problems of information retrieval is the formulation of queries by the user. Indeed, two users formulate two different queries with different terms for referring to the same concepts of the same information requirement. Commonly, it is not easy, especially for a simple user, to formulate the appropriate query well reflecting the user information need and requirement. Unfortunately, in major of time, users do not know really what they are looking for. User requirement may be then tied to the information available in the asked collection, especially when the corpus is very large and rich such as in the case of the web, and the user requirement is progressively constructed over the contact with the initial results. According to [3], there are three categories of a query for web searching: (i) informational queries, covering a broad topic, (ii) navigational queries, looking for specific websites or URLs, and transactional queries, demonstrating the user’s intent to execute a specific activity such as downloading papers or buying books. So, among the issues of information retrieval systems, from interrogation point of view, is the gap may exist between the user requirement and the user query. Owing to the position of query formulation, as a first step into information retrieval pipeline, it has, unfortunately, drastic effects on the quality of the information retrieval results. The richness of the interrogation language, considered frequently as a natural language with its ambiguity issue, as well as the gap between the vocabularies of the query and the collection, to be asked, may also be accused.

Unlike indexing step, performed offline, query expression and formulation, is established online, in ad hoc or in fly manner, which makes efficiency an important aspect to be taken into account although the littleness of the query compared to the

documents corpus. Many works of the scientific literature has considered the interrogation process and query refinement as a module to be improved for enhancing the results of the information retrieval system. In the rest of this paper, we give an overview of the scientific works focusing on query refinement with its different aspects: formulation, auto-completion, reformulation, expansion, optimization and terms reweighting, and recommendation or suggestion.

3. Query Refinement into Information Retrieval Systems

In the hope to increase the accuracy and the effectiveness of information retrieval systems, including search engines, a lot of schemes have been adopted such as query refinement and relevance feedback. Both mechanisms, addressing respectively the system inputs and outputs, are going from outside the system in the purpose to inject obvious and more information helping the system to well understand the user information need and requirements. It is well recognized that formulating the query which represents really the user need and requirement is a difficult task especially from user view point. Accordingly, there is always a gap between the user requirement and the user query which has to be filled. Query refinement constitutes then an important scheme may help to fill this gap especially when the user is not satisfied for the returned results. This satisfaction comes from three situations: (i) the results are out of the scope of user requirement, (ii) the results are very vague where there is a lot of results, with general purpose, difficult to be explored, and (iii) the results are not enough required to be enriched and re-enforced. As shown in Figure 1, the query refinement, the scope of this paper, is implemented by three different manners regarding the involvement degree of the user: the manual way where there is a fully user intervention relying only on his/her experience and his/her own heuristics with no machine contribution, the interactive manner where the decision of terms selection is taken by the user with the assistance of the machine through suggesting some eventual terms to add, and the automatic alternative where the task is performed completely by the machine.

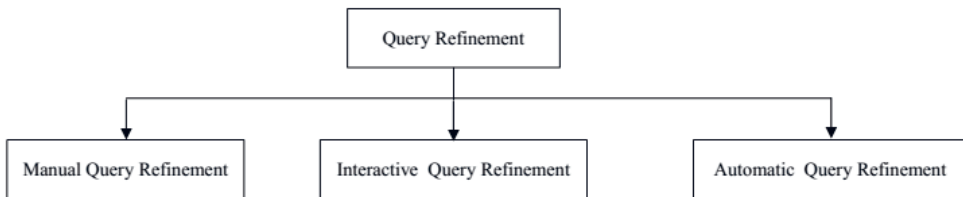


Figure 1. Query Refinement Types according the User Involvement.

Moreover, as presented in Figure 2, automatic query refinement has five materialization ways namely: automatic query formulation helping user to formulate his/her query, query reformulation which proceeds to reformulate the query completely, query expansion through adding some useful terms, query optimization for choosing the better terms and weights combination from the original query terms, query recommendation (or query suggestion) where information retrieval engine

proposes a new query considered to be more adequate to the user intent. It is well recognized that the query formulation is coming to help user for expressing his/her information requirement especially for the users whose the intent is not yet clear while query reformulation has to be adopted in the case where the initial returned results are out of the scope of the user need. For query expansion, it is well suitable for the situation where the results are not enough to satisfy user requirement and needed to be enlarged while query optimization tries to narrow the vagueness of the returned results. Unfortunately, these query refinement types are confused in many works where the schemes are named with roughly speaking. Indeed, query reformulation, for instance, is restrained to query expansion such as in [1] where authors have combined, as a pipeline, query expansion with ranking model based on a neural network. The important contribution of the work introduced in [4] is that each module takes profit from the pseudo relevance feedback of the other. The pre-cited refinement schemes may be partially combined such as in [5] and [6] that combine expansion and terms re-weighting tied to query optimization. The five refinement mechanisms will be further detailed in the following sub-sections.

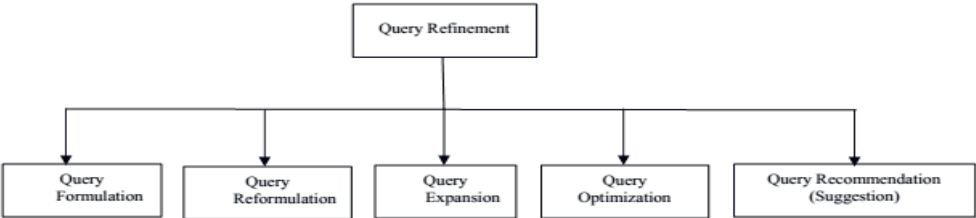


Figure 2. Query Refinement Implementations.

As depicted in Figure 3, there are two query refinement kinds: global query refinement and dedicated-query refinement. This classification is tied to the largeness and the narrowness of two criteria namely: the utilized resource, from where the knowledge is extracted, and the user for who the information retrieval system is addressed. A large resource means that the query refinement is tied globally to the adopted natural language while a resource with specific field refers to the fact that the query refinement is related to the terminology and the nomenclature of the addressed domain. On the other hand, a public user means that the query refinement is tied completely to the query without any additional information about the user while a specific user refers to the fact that the query refinement is adapted to the addressed user taking into account his/her past formulated queries as well as his/her profile.

4. Automatic Query Formulation based on Words Prediction (Query auto-completion)

Words prediction, widely used within text editors coming into digital devices with limited visualization screen and memory space such as smart-phones and tablets, means to guess the missing words that likely follow in a given segment of a text [7] in the purpose to get a desired piece of information quickly and with as little

knowledge and effort as possible. Words prediction, for query formulation, depicted in Figure 4, commonly known as query auto-completion [8], refers to guess the words that the user intends to use or predict the possible completions for user queries in the aim to help the user to formulate his/her query, reduce query entry time, and potentially prepare the search results in advance of query submission [9].

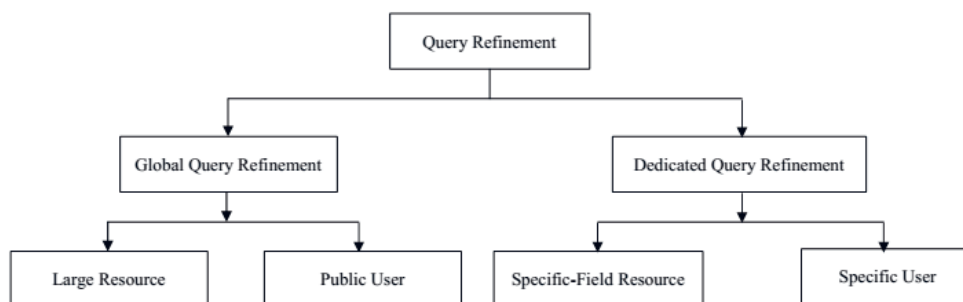


Figure 3. Query Refinement regarding the Largeness and the Narrowness of Utilized Resource and Addressed User.

Indeed, in query auto-completion, a user receives a ranked list of query candidates, by entering a particular prefix including characters or primary words [10]. In [11], authors have considered query auto completion, whose goal is to predict what the searcher is typing, and by extension, what the searcher is seeking based on the current query text string (prefix), as one form of query suggestion, while we consider it, here, as a separate task of query processing and refinement. Information retrieval engines, such as *Google* and its service dedicated for scientific searching that of *Google Scholar*, consider recently words prediction to ease query writing through guessing some words, suggested in a list, to the user, that might be used in that position. The space of possible completions narrows down and thus the prediction probability increases as the user is typing more characters. Commonly, there are three approaches for prediction [7] to help formulation of the query, namely: statistical modelling using word frequency and word sequence frequency, knowledge-based modelling adopting syntactic, semantic and pragmatic aspects, and heuristic or adaptive modelling with short and long learning. In addition, there are two alternatives for query auto-completion regarding the number of query terms implicated in auto-completion, namely: whole-query completions and term-by-term query auto-completion [12]. In [9], authors have compared 11 approaches for ranking candidate queries, in the sense of query auto-completion, namely: *Most Popular Ranker*, *Sentence Occurrence Ranker*, *Time Ranker*, *Most Popular Time Ranker*, *Term Occurrence Ranker*, *Near Words*, *String Similarity Ranker*, *WordNet Similarity Ranker*, *N-Gram Similarity Ranker*, *Kernel Similarity Ranker*, and *Clicked Documents Ranker*. Although *Clicked Documents Ranker* and *N-Gram Similarity Ranker* approaches seem to be more effective, authors concluded that the most effective approach to query auto-completion is largely dependent on the number of characters that the user has typed so far and that personalized information can be used to more effectively rank the query candidate completions. In [13], authors have addressed candidates ranking in query

auto-completion, through considering homologous queries, which share the same terms but ordered differently, and the semantic relatedness of pairs of terms inside a query as well as pairs of queries inside a session. In addition, they have revealed that search engines adopt *Most Popular Ranker* approach for ranking candidate queries when they consider query auto-completion mechanism. For handling unseen prefixes, authors in [14], have proposed a recurrent neural language model that yielded good preliminary performances in a public dataset compared either to traditional methods, handling previously seen prefixes, or to the state of the art query auto completion methods for previously unseen prefixes. In [15], another alternative, for *Most Popular algorithm*, baptized as *NearestCompletion*, which is based on the user context, captured through recent queries and recently visited Web pages, has been introduced. Although the introduced algorithm outperforms clearly *Most Popular Ranker*, its performance tends, unfortunately, to zero when there is no user context. A hybrid algorithm, known as *HybridCompletion*, combining both *NearestCompletion* and *Most Popular Completion*, has been then proposed to tackle the absence of the context. Besides effectiveness character, authors, in [16], have discussed also the efficiency aspect of eBay's query auto completion system. Several optimizations, including the use of a forward index and Front Coding, are adopted.

4.1. Automatic Query Reformulation

Query reformulation, which may reflect the query refinement at all, is the process of altering an initial query through submitting another query with other terms. Although the main task of the query reformulation is to replace partially or totally the original query terms, it may include adding more words to the query (expansion), removing some words from the query (optimization), weighting the words according to its importance in the query, or all of them [17]. In addition, some structural or format aspects, such as stemming, pluralisation [18], acronym expansion, and spelling correction [19], are also addressed by query reformulation. In [20] and [21], authors have addressed manual query reformulation through trying to understand the user reasoning and reflection via examining changes in the logs of the past submitted queries of the same session. According to [22], the query reformulation is classified into two categories: *operational moves*, through reformulation using the same meaning, and *conceptual moves*, via changing the meaning of the query. In [23], authors have extended this categorization, for the case of the web, into four classes: *specification*, *generalization*, *replacement or error correction* as reported in [24], and *parallel movement* with eight types of patterns: *specified reformulation*, *generalized reformulation*, *parallel reformulation*, *building-block reformulation*, *dynamic reformulation*, *multi-tasking reformulation*, *recurrent reformulation*, and *format reformulation*.

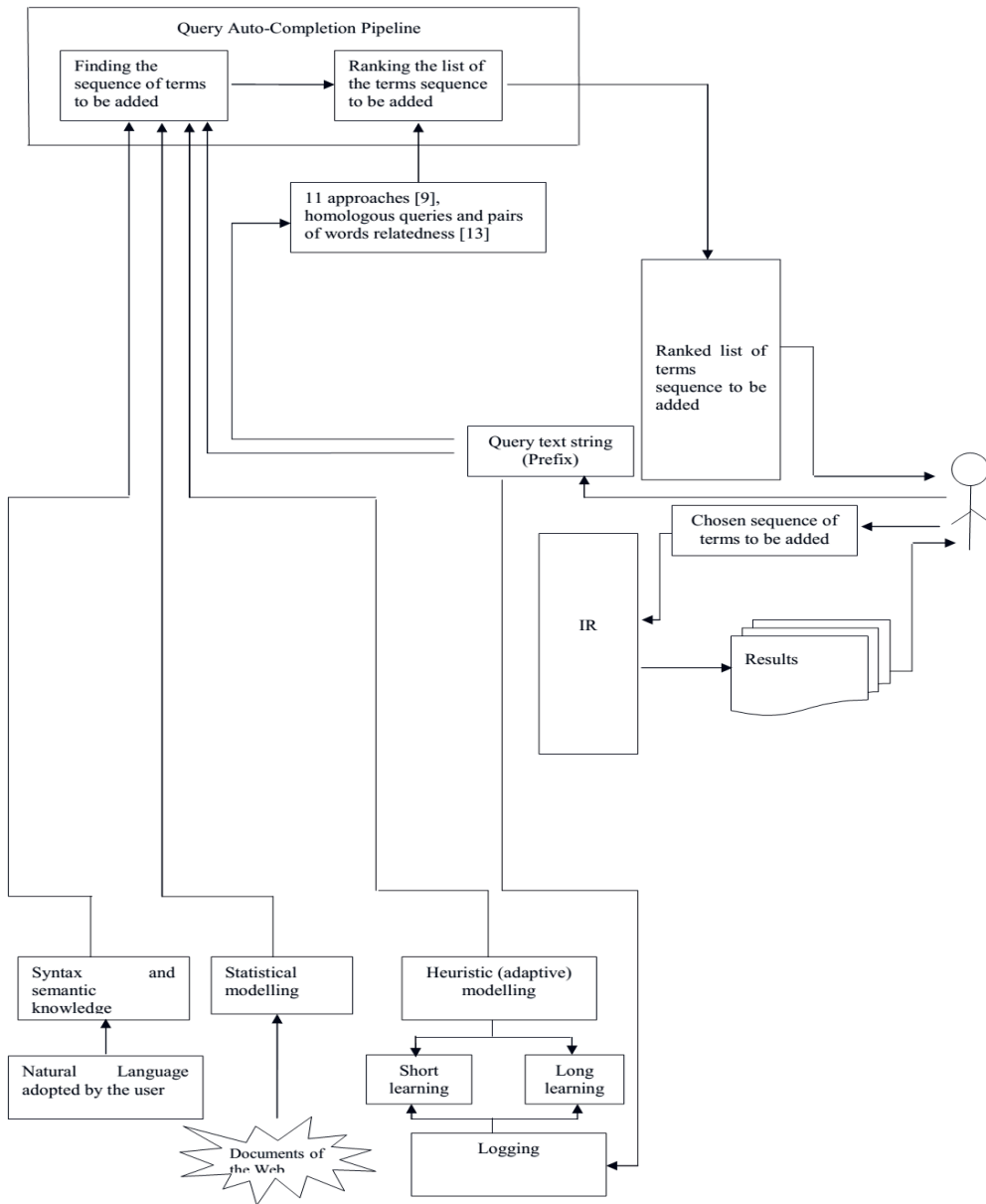


Figure 4. Query Auto-Completion Overview.

There are many resources used to extract terms for performing query reformulation. Using the top ranked documents returned by the system as an answer for the original query, such as what has been in [25], is one of them. Authors [25] have baptized the reformulation in this case as pseudo-query reformulation owing to its pseudo or blind relevance feedback base. However, the set of documents used as a source for extracting terms to reformulate the query may be designed interactively by the user as relevance feedback information such as in [26] where authors have revised the

relevance feedback characterization ideas firstly introduced by Rocchio in [27]. Both pre-cited approaches belong to the local analysis using only a few of documents rather than the whole corpus used in the case of global analysis such as in [28], [29]. Note that the global analysis refers also to use the global context of a concept through considering semantic dictionaries such as WordNet [30]. In [28], authors have employed primitive concepts representing the variety of concepts whose the encoding vectors are orthogonal and that reflect the set of topics either locally into a set of relevant documents or globally into the entire corpus. The terms with which the query is reformulated are extracted then from these primitive concepts on the basis of their own closeness and their combination closeness with the original query. In [31], authors have introduced a reformulation method based only on the original query. This reformulation method, relying on part of speech (POS), may be considered as an optimization for the simple reason that it searches the different terms combination.

4.2. Automatic Query Expansion

Query expansion [32], [33] consists of paraphrasing the concise original query, via adding additional concepts and terms, in order to reach a high level of recall through upgrading the possibility of the search system to get access to more relevant documents. Indeed, the term mismatch problem or vocabulary gap, produced when indexers and users utilize different vocabularies and terminologies because of the natural language richness, in addition to the weakness of the submitted query, composed of few words, for expressing the user need and requirement, as well as the ambiguity, owing to the posed polysemy issue, make query expansion an intuitive and logic operation to be established. Query expansion is performed automatically without any user involvement [32] or interactively through selecting a sub-set of terms to be added from the set of terms suggested by the machine [34]. Results given in [35], where authors have considered automatic and interactive query expansion, reveals the superiority of interactivity, helping to increase recall and especially limiting precision downgrading. Consulting the literature reveals that there are two large approaches for implementing automatic query expansion: (1) statistical approach [36] in the image of adding co-occurred and collocated terms, into different granularity level of windows, using information theoretic measures like mutual information [37], [38], Z score [39], hyperspace analogue to language (HAL) [40] and its quality property notion reflecting relatively the word context, or information flow [41] viewing the entire query as one concept which suggests other terms to be added for expansion based on HAL measure, and (2) semantic approach [42], whose the main issue is word disambiguation, like adopting association rules [34], [35], [43], word embedding [44], based commonly in advanced machine learning techniques, and related linguistic words with closed meaning based on morphological expansion [45] using stemming, part of speech, and synonyms [35], [46] using ontology [47] with its both types: narrow or dependent-domain, and general or independent-domain. Query expansion may be combined with other schemes such as in [48] where the author has combined query expansion with pseudo re-ranking based on voting algorithm.

Unfortunately, improving the recall metric value may be achieved in the count of precision aspect which imposes us to be careful when thinking about adopting query expansion scheme through checking its usefulness regarding the submitted query. Moreover, some difficulties and obstacles tied to the vagueness and the multi-contextual character of natural language, such as polysemy, should be also overcome and tackled.

For pinpointing the query expansion mechanism, we should see it as a pipeline of steps (as depicted in Figure 5) ranges from data acquisition and pre-processing to candidate generation, ranking, and selection.

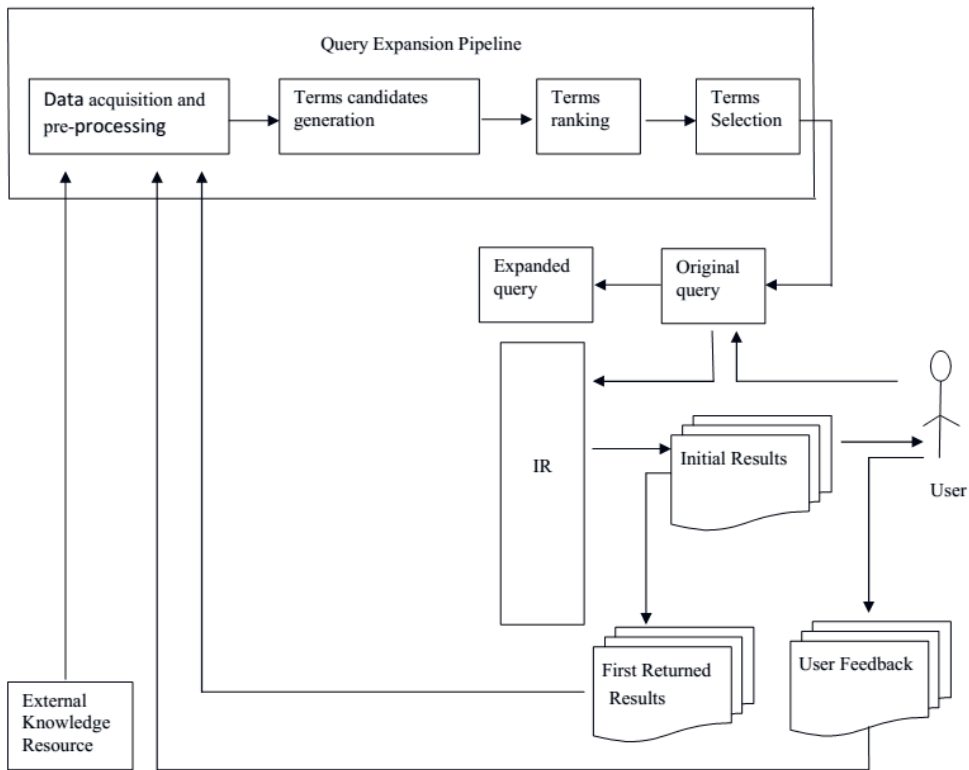


Figure 5. Query Expansion Overview.

The terms to be added for the initial query are, commonly, the discriminative terms generated and selected from the collection itself via global [38], [44] or local dependent-corpus knowledge approach [49] either with the making use of local context analysis (LCA) [50] which uses the highly ranked documents qualified as relevant by the search system with adopting of pseudo relevance feedback [51] or interactively employing user judgment through relevance feedback information [52] injected by the user himself. For avoiding performance degradation especially when relying on pseudo-relevance feedback, automatic documents clustering may be extensively useful such as in [53]. Employing independent-corpus knowledge

approach or external knowledge resources, such as other documents set [54], thesaurus [55], DBpedia [56], Freebase [57], ConceptNet [58], Wikipedia [59], or WordNet [35], [59], [60], is another adopted alternative for generating query expansion terms. The past submitted user queries [54] for the system are also utilized with long-term query logs way either to directly extract terms adopting queries-based analysis approach or indirectly through extracting terms to be added from the highly associated documents adopting document-based analysis approach. These both lastly pre-cited alternatives can be used together to compute the correlation between query terms and their associated returned document terms, for the documents consulted by the user, adopting probabilistic model [61]. This probabilistic model has been implemented differently in [62] with the assumption that starting from the query, the next term to add is tied only to the previous added term, we speak here about Markov chain model.

Unfortunately, the expanded query may degrade information retrieval system performance in some cases especially when relying on non-relevant documents leading to add some terms not semantically associated to the entire sense or the holistic context of the query. In order to get around susceptible effectiveness degradation, some works go in the context of selective query expansion [63] while others adopt collection enrichment [64] through enrich the documents from where the new terms to add are extracted especially in the case of pseudo relevance feedback where the top-ranked documents are poor in information .

4.3. Automatic Query Optimization

As depicted in Figure 6, query optimization, or query reduction, consists of choosing the better sub-set of terms combination from those belonging to the long submitted query as well as their associated weights [65]. In other words, some superfluous terms, from the original query, have to be down-weighted or completely deleted and removed in the hope to obtain better results [66]. In [66], authors have presented query reduction techniques for long web queries that leverage effective and efficient query performance predictors. In [67], authors have provided an algorithm for predicting which word should be deleted from the query. According to [68], the first stage of terms combination is known as quantity control while the second stage, for designating the optimal weights, is referred to as quality optimization. This optimization of the original query is performed based on the distribution of terms into returned relevant documents (pseudo relevance feedback) as well as the distribution in the whole asked collection. As the query optimization issue is qualified as an optimization problem, tools such as genetic algorithm [65], [68], and particle swarm optimization (PSO) [69] have been utilized.

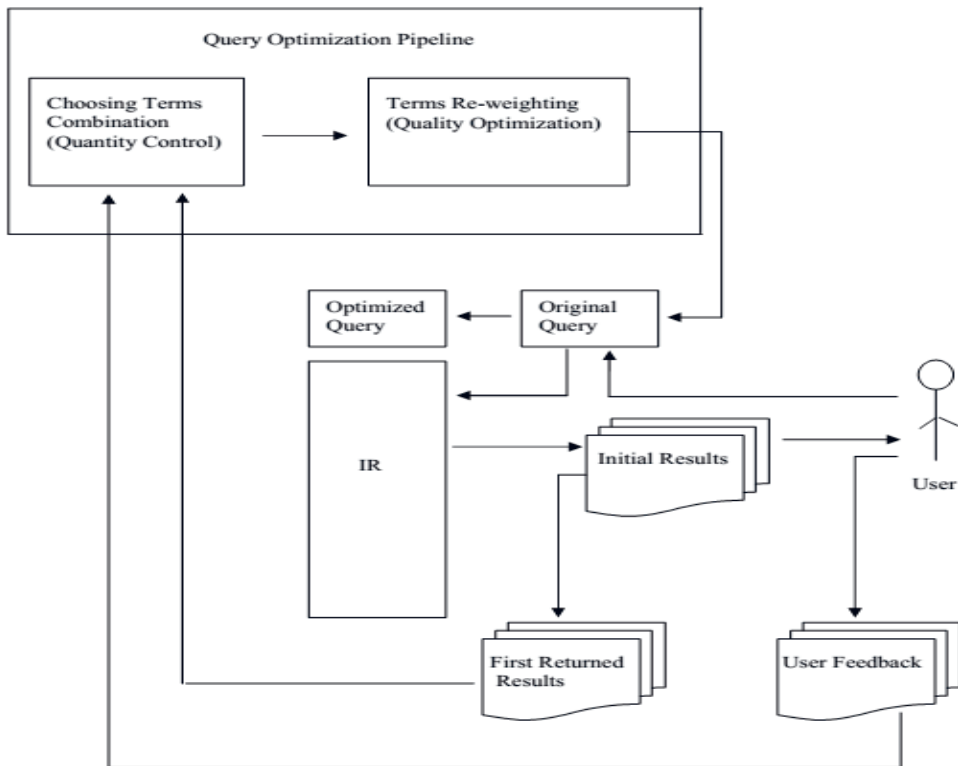


Figure 6. Query Optimization Overview.

4.4. Query Recommendation (Query Suggestion)

As depicted in Figure 7, query recommendation, or query suggestion, commonly provided by information retrieval engines such as Google and its search scientific service Google Scholar, refers to the process of revising the original query through generating, proposing and suggesting a list of related and alternative queries to those submitted by the users. Query recommendation is recently considered as an effective, efficient, and practical way to help and assist users to formulate their queries and consequently aid information retrieval systems to well understand the users' information need let alone to guess the next information requirement. Query suggestion considers, more or less, the slogan "recognition rather than recall" adopted previously by the graphical interfaces in systems interaction field. Indeed, recall is difficult and error-prone while recognition, with navigational character, is so simple and practical.

There are two major issues for query recommendation: (i) how to find the queries to be recommended and (ii) how to select, rank and order them. Some works of the literature address then this first issue, such as in [70], while the rest deal with the second issue of ranking the list of the proposed queries. Commonly, there exist two broad approaches for designating the set of queries to be suggested and recommended:

(i) techniques using session logs, exploiting the user past submitted queries and his/her historical behavioral interactivity let alone what we call ‘wisdom of crowds’, the knowledge mined from search engine query logs which store all the past interactions of users with the search system, and (ii) knowledge-based query recommendation using some resources such as YAGOO [71] and Freebase [71].

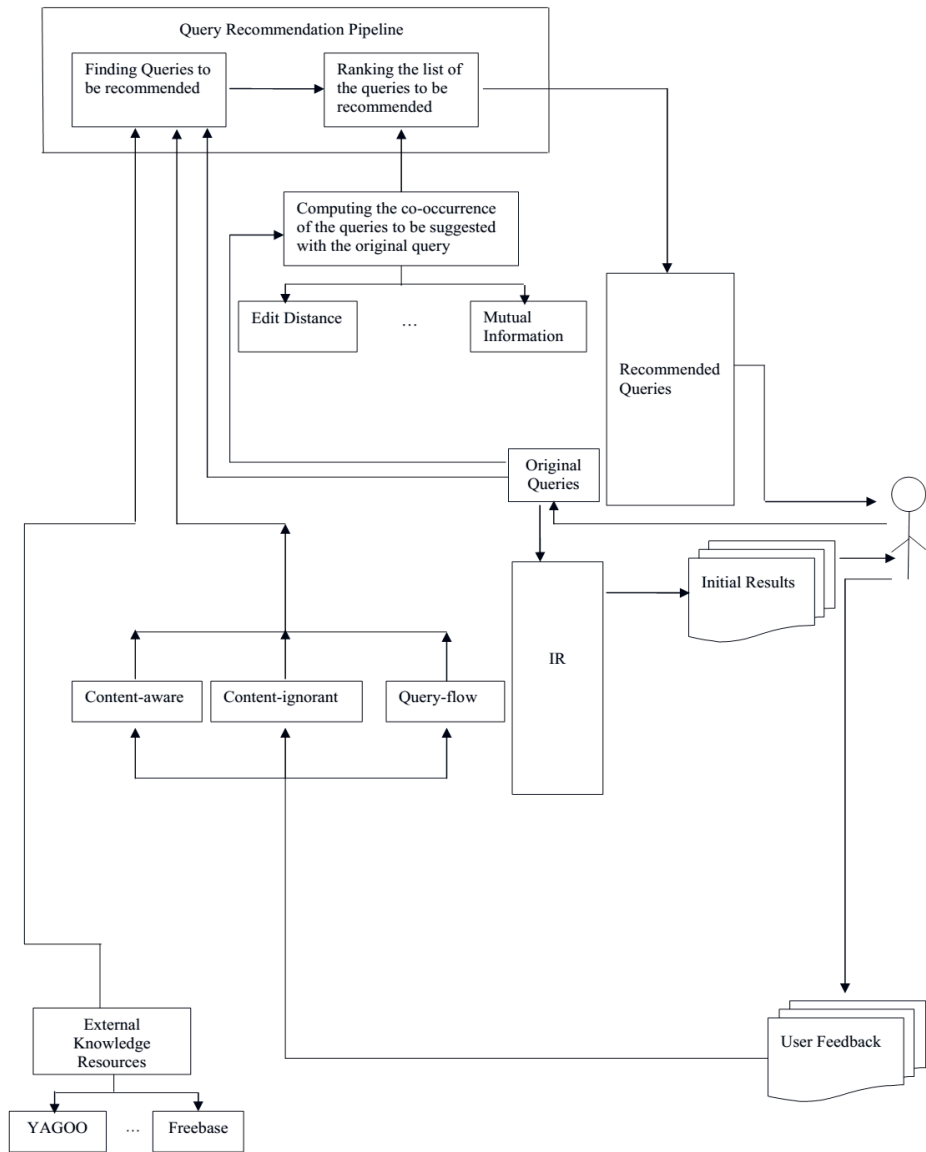


Figure 7. Query Recommendation Overview.

According to [72], there are three approaches for generating query recommendations based on mining query logs: (i) content-aware approaches, relying on search results

or target pages, (ii) content-ignorant approaches that use just common clicked URLs, and (iii) query-flow approaches that consider the users' sequential search behaviour to better understand query intent. For ranking the suggested queries, researchers, such as in [73], consider commonly scores based on the co-occurrence of the queries to be suggested with the original submitted query. this co-occurrences is generally implemented using edit distance and mutual information.

As a personal critic, we do not agree, with scientific literature, that query recommendation and query suggestion are synonyms. We consider that query suggestion should have the outside character and then be based on the user interactivity relying on his/her previous submitted queries as well as words prediction tied to the considered natural language while query recommendation must has the inside aspect and to be based on the available documents to be asked and their vocabulary.

5. Summary and Conclusion

In this paper, we give an overview of some mechanisms handling a user query in the sake to well understand user requirement, namely: query auto-completion, query expansion, query optimization, query reformulation, and query suggestion or recommendation. From its graphical user interface, it is clear that Google and its service namely Google Scholar adopt, at least, query auto-completion and query suggestion. Many works of scientific literature, adopting query processing through one of the considered schemes, for information retrieval system improvement and enhancement, have been addressed here. Unfortunately, some addressed works confuse between the different query processing schemes where they are, roughly speaking, adopted. This work may be then a reference for everyone who deals with the interrogation protocol in information retrieval systems including information retrieval engines addressing the web as an unlimited and an extensible documentary collection.

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The Fundamentals of Metaverse: A Review on Types, Components and Opportunities

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Abstract

The word metaverse is resurfacing and becoming viral after Facebook changed its company name to Meta. A lot of opportunities are offered by the rise of metaverse concept. For example, a library can be presented in the form of metaverse so that visitors do not need to come physically. Metaverse means beyond the universe or in this case beyond our universe. Companies around the world including Microsoft, Facebook, Epic Games, Apple, and Nvidia already invested in the metaverse as a business opportunity, and the top 3 business sectors are technology, education, and finance. Most companies also believe there are many benefits of the metaverse that can overcome the current obstacles on this universe, such as removing the physical limitation to do various activities. This paper will give a fundamental understanding of the metaverse and the opportunity of the metaverse in practice and research in the future. The result of this paper can be a guide for any scholars and practitioners to understand the metaverse starting from the definition to the things that are related to the metaverse.

Keywords: Metaverse, Metaverse fundamentals, Metaverse at a glance, Metaverse concept, Metaverse foundation

1. Introduction

Facebook changed its name to Meta on October 28, 2021, which makes a catalyst for the popularity of the word metaverse. Since then, the metaverse gaining a very significant traction topic on the internet and has drawn a lot of attention from companies as this is seen as a head-turning business opportunity. According to Google Trends, the search term “metaverse” for web search and news search has increased due to the same catalyst [1] (Figure 1). The popularity of metaverse among scholars

is also reflected in the number of papers that's been published from 1992 to 2021 can be seen in Figure 2. Because the metaverse is very attractive to them, based on a survey conducted by statisca.com from companies around the globe that have already invested in the metaverse, about 33% of them allocated approximately 10%-20% of their marketing or innovation budget, and also people believe that there is a real opportunity to make real money in virtual worlds [2], [3].

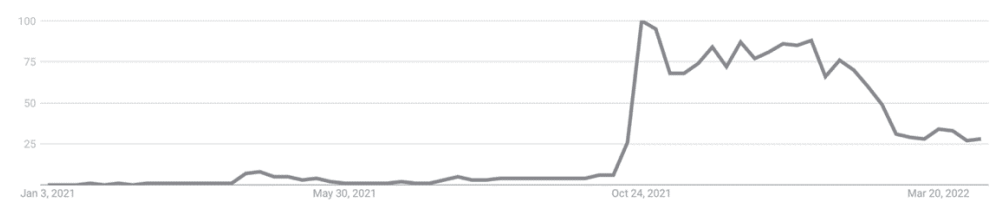


Figure 1. Metaverse trends from January 1st, 2021 to April 15, 2022 [1]

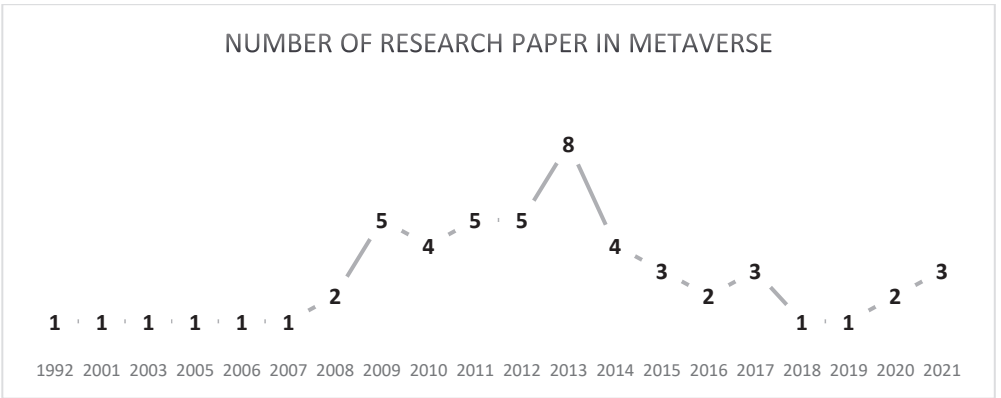


Figure 2. The Number of Research Papers in Metaverse [4]

Big companies such as Microsoft, Apple, Nvidia, Facebook, Unity Engine, Epic Games, and others racing to build their version of the metaverse so they can become the best metaverse in the world. The reason why big companies invest in developing their metaverse is that the metaverse has many advantages that might overcome many challenges in our universe. According to the survey that is shown in Figure 3, has been conducted in late 2021, overcoming many obstacles that prevented them from doing something in real life comes out as the top advantage of the benefit of the metaverse [5]. Because in the real world, there are many possibilities that people cannot do what they want to do because of many reasons, such as geographical location, physical disabilities, or there are no appropriate tools to do a particular task. The second top benefit is enhancing creativity and imagination. This is somehow related to the first benefit, sometimes our mind can imagine something that is beyond what the existing technology can comprehend and because that technology or tool or thing does not exist, it might lead to obstacles. The third top benefit is traveling the world without

moving. In the metaverse, traveling around the world does not require much time and cost, and visiting other countries for any purpose such as a school trip, research, business trip, or just a matter of family vacation or honeymoon, can be achieved easily in the metaverse.

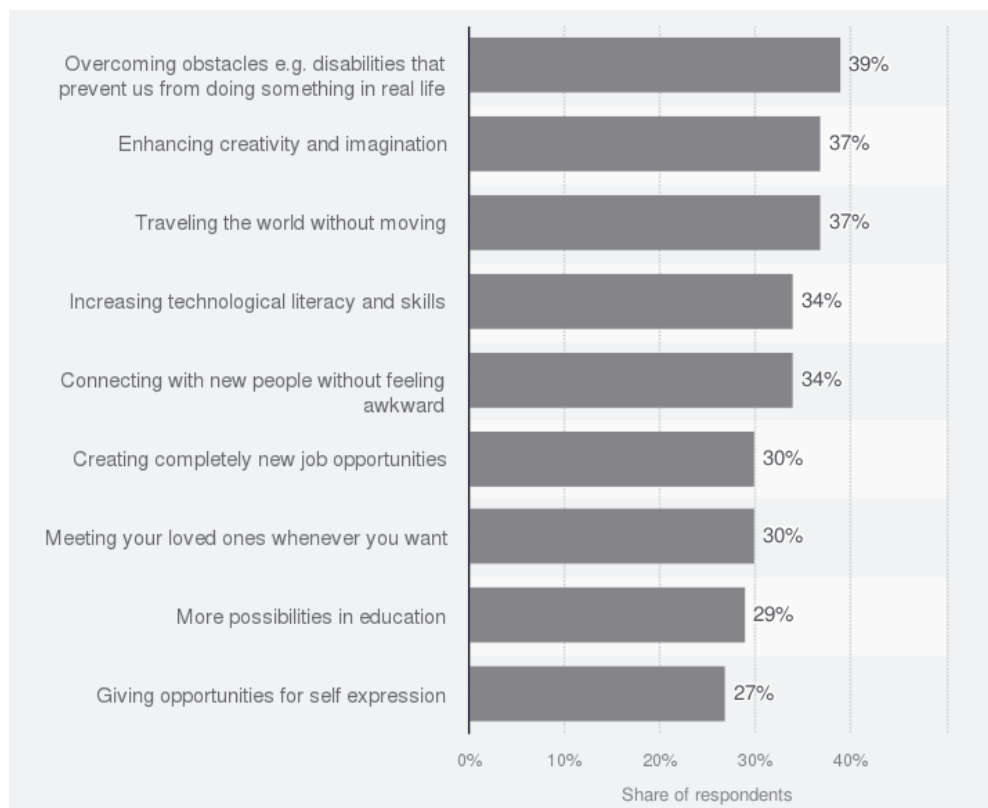


Figure 3. Leading benefits of the metaverse worldwide in 2021 [5]

There are many benefits of the metaverse is the main reason why companies are allocating their budget to invest in the metaverse. Figure 4 shows that computer and Information Technology (IT) is the leading business sector where most like to have done so already. This is due to the metaverse being closely related to or based on computer and IT; therefore, this sector is the leader in the metaverse business investment.

The second top business sector is education. Education has always been the core foundation for the future of any country and future generations and enhancing the education sector will enhance the quality of generation. The education sector can get great benefits from the development of the metaverse to increase the quality of education. According to research, learning with technology is increasing learning engagement which leads to better learning effectiveness [6]. Not just learning with technology that has a positive impact on education but also learning with the metaverse has several benefits as well, such as: giving the students a new experience

and high immersive through the new virtual space to socialize, higher freedom to share, and being creative [7]. The existence of the metaverse will give students to have high-quality education equality because they have the same chance and opportunities [8]. And the learning materials can be personalized according to the student’s needs and to accommodate student-centered learning [9].

The third top leading business sector is finance. As we can live in the metaverse, people will need another currency that can be accepted in the metaverse to do any business transactions. Cryptocurrencies are very popular nowadays and the development of cryptocurrencies is impacting the development of the metaverse, which is depicted in Figure 5. Other than cryptocurrencies, NFT or Non-Fungible Token is also part of the finance business sector. Cryptocurrencies and NFT are the projects that most companies invested in the metaverse.

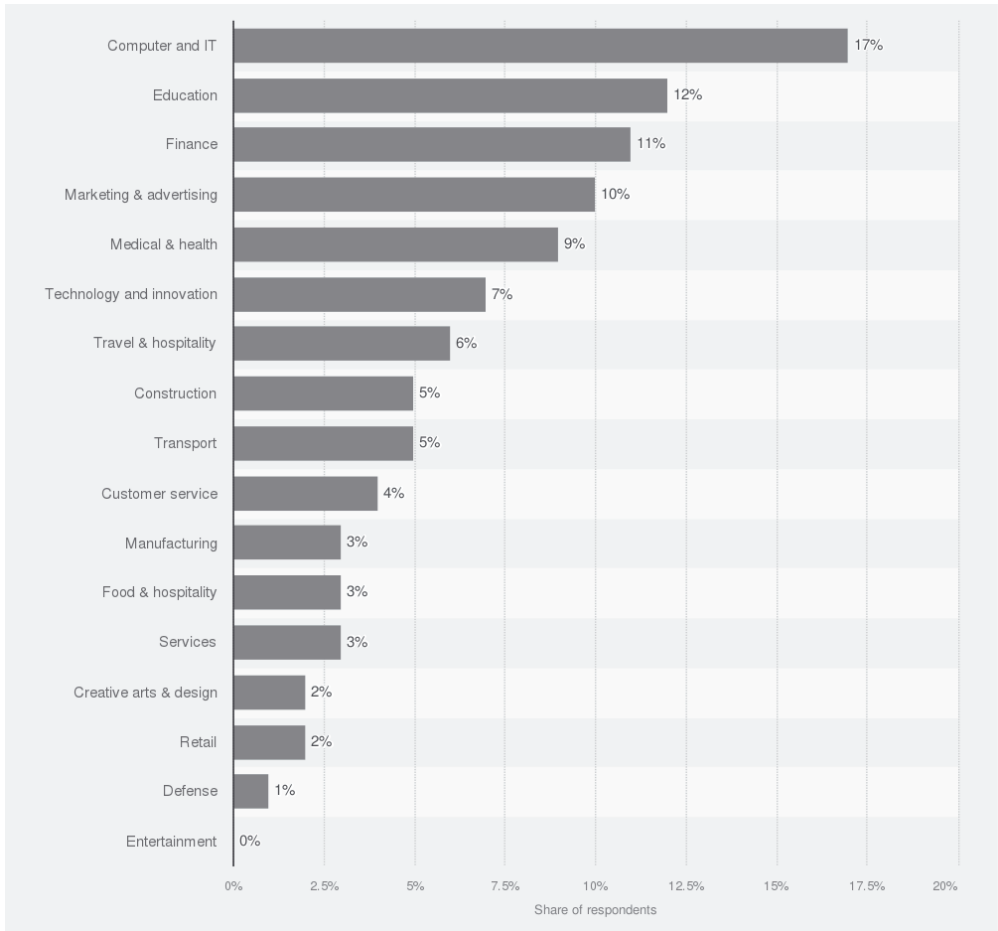


Figure 4. Leading benefits of the metaverse worldwide in 2021 [10]

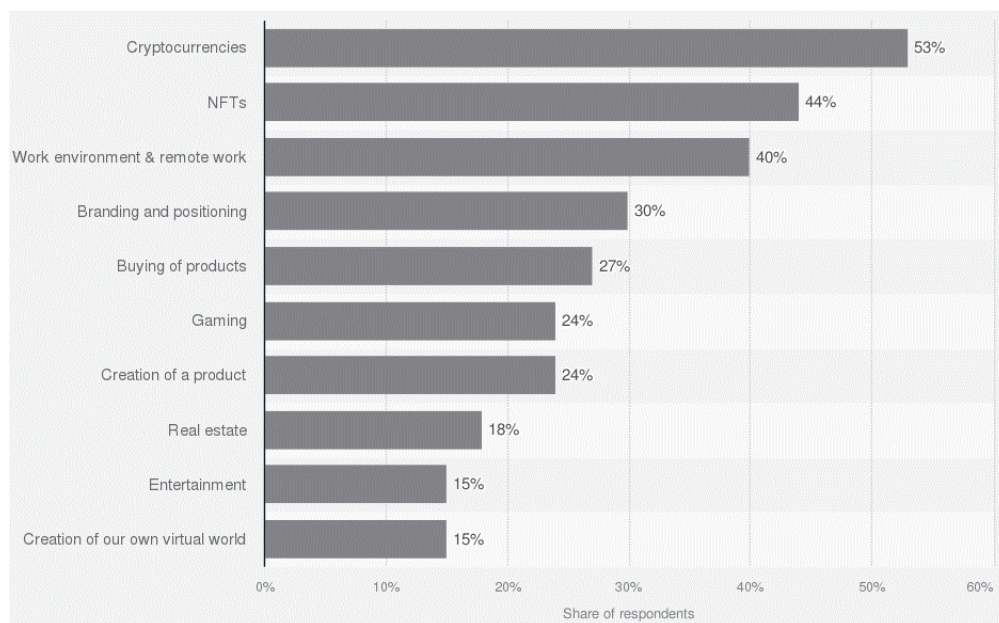


Figure 5. Type of project that the company invested in the metaverse [11]

Even though the metaverse looks very attractive and promising, and despite that many big companies are throwing themselves into this so-called tournament of the metaverse, doubts about the metaverse also exist. The highest doubt that people have is the cyber security and privacy issues [12], and probably if the metaverse is already matured and well developed, where people can have a life there, the second concern by many people nowadays is the digital life taking over the real-life [13].

2. What is Metaverse and Its Timeline

Metaverse is becoming a popular word, and everybody is talking about it, but what is the meaning of metaverse? The sci-fi novel with the title *Snow Crash*, written by Neal Stephenson, was the first time the term metaverse was ever used. The term metaverse is a combination of 2 different words, which are meta and verse. Meta is from Greek, meaning post, after, or beyond and verse is short for the universe[14]. Based on those two words, we can conclude that the metaverse means beyond the universe or our universe since the metaverse is digital. Neal Stephenson in his book imagines the future world where the metaverse is the internet 2.0 and the user can live there and do their activities on daily basis, each user will have their representation of themselves called an avatar. The user activities, movements, expressions, etc. are represented through this avatar.

Metaverse is almost the same as the real world where the user cannot be in two places at once, there are off-limit places and move at a limited speed [15]. Stephenson also defines the metaverse as a virtual world that is similar to the physical world where people can interact with each other [16]. In this paper, we consider the metaverse is a

collection of multiple elements in the three-dimensional world or 3D virtual environments where the user or human is reflected as an avatar where they can live or do any kind of social interaction as if they are living there without any physical limitation [4], [17].

The concept of the metaverse has been brought to be more visual by Stephen Spielberg in the movie called Ready Player One, in this movie, there is an expensive virtual reality universe called OASIS, and people can enter this universe by using the head-mounted display (HMD) for VR rendering, sending, haptic feedback and modeling of a physical world and represent themselves by using an avatar [18], [19]. In the metaverse, people or users can interact for many reasons, not just for playing games but also for social, and cultural activities, economic, political, etc. [4].

Based on [20], the first era of the metaverse is the literature era back in 1974 called Dungeons & Dragons, followed by Neuromancer in 1984. Several years after the literature era of the metaverse, the next era was called the text-based interactive games that started in 1987 until 1992. In this era, the game is played using a PC and a computer graphic to produce a better quality picture. The third era is called Virtual Worlds & Massively Multiplayer Games (MMOG). The MMOG era starts from 1996 to 2011, all the metaverse game in this era requires not just a PC but also massive internet usage and were compatible with or required a touchscreen as an input device, the most popular games in this era are Online traveler, Second Life, and Minecraft to name a few [21]. After the MMOG era ends, the Immersive Virtual Environment on smart mobiles & wearable era kicks in immediately from 2012 to 2017. In this era, new technologies have entered commercial markets such as Virtual Reality and Augmented Reality has been used as the main tools of the game. Pokemon Go! and PlayStation VR is the most popular games in this era. In 2017 the third era of the metaverse has been replaced with the New Era of the Metaverse until now.

3. Types and Examples of Metaverse

As the metaverse is getting more complex, the Acceleration Studies Foundation (ASF) the research organization for the metaverse, stated that 2 axes influenced the metaverse as defined in Figure 6. Axis X is the application and technology axis which ranges from augmentation to simulation and axis Y is the external and internal axis where the external is world-focused, and the internal is identity-focused [22]. Based on those axes, we can classify 4 different technologies, there are mirror worlds, virtual worlds, augmented reality, and last but not least lifelogging [15]. The first three technologies, mirror world, virtual world, and augmented reality known as display technology, and lifelogging is a technology to capture the identity and the behavior of an individual or object.

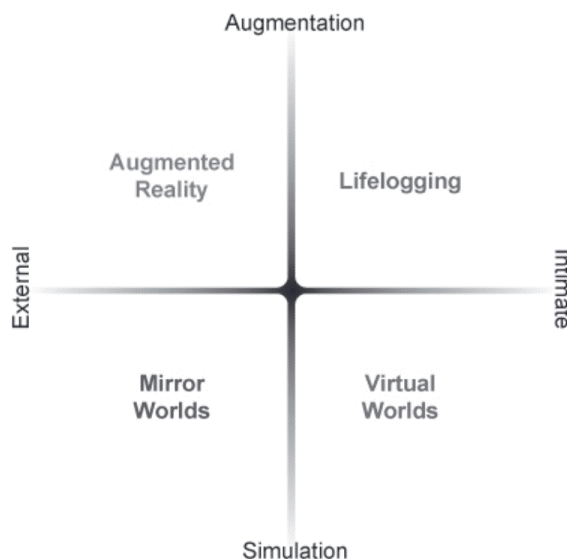


Figure 6. Types of Metaverse Based on Axes [22]

The external can be described as either the technologies being more focused on providing information and controlling the world where the users are and the internal can be described as more focused on individuals or objects whether through the avatar or direct appearance in the system. Augmentation means the capability of adding elements to the real world to provide more information or even control the technology and simulation is making a new digital world and letting the user enter the virtual world and do various interactions and activities.

Augmented reality is an augmentation in the external world. It uses location-based technology and networks to provide suitable information based on the location of the user by mixing between real-world and virtual graphics, such as Virtuali-Tee, medical surgery, etc.

Lifelogging is an augmentation of the inner world because it is more focused on the user itself by recording and sharing their thoughts or activity on the internet such as Twitter, Facebook, Instagram, Youtube, TikTok, etc.

The Mirror world is a simulation of the external world. The Mirror World is also known as a digital twin because everything in the real world, such as information, infrastructure, etc, is converted to make a digital twin of a real-world such as The Foldit (contribute scientific research through games), video conferencing, and Gather.town, etc.

The virtual world is a simulation of the inner world. The virtual world or virtual reality simulates the inner world that consists of avatars, and 3D graphics, instant communication tools. Virtual reality is entirely different from real-world reality such as Zepeto, Roblox, Minecraft, Fortnite, etc

4. The Components of Metaverse

The metaverse is a complex and evolving platform that combines virtual and real-world elements to create a new kind of shared space for social interaction, entertainment, and commerce. Here are the main components that make up the metaverse:

1. Virtual worlds are computer-generated 3D environments with which users can access and interact using specialized software or hardware, such as virtual reality (VR) headsets. Virtual worlds can be immersive and interactive, and they can support a wide range of activities, including socializing, gaming, and education.
2. Avatars: These are digital representations of users in the metaverse, and they can be customized to reflect the user's appearance, personality, and preferences. Avatars allow users to interact with each other and the virtual environment in a more personal and expressive way.
3. Virtual reality refers to computer-generated environments that users can interact with in a way that feels real, typically by wearing a VR headset. Virtual reality can be used to enhance the immersion and interactivity of the metaverse.
4. Augmented reality refers to the overlay of digital information in the real world, often using a device such as a smartphone or AR glasses. In the metaverse, augmented reality can be used to enhance the user's experience of the virtual environment by providing additional context or information.
5. Social media: These are online platforms that allow users to connect and share content. In the metaverse, social media can be used to facilitate communication and collaboration among users.
6. Virtual economy: This refers to the use of virtual currency or assets in the metaverse, which can be traded, sold, or used to purchase goods and services. The virtual economy can provide a way for users to monetize their activities in the metaverse.
7. Virtual reality commerce: This refers to the use of VR technology to facilitate commerce, such as shopping or buying real estate, within the metaverse.

Other possible components of the metaverse include tools for creating and sharing content, such as 3D modeling software; tools for communication and collaboration, such as chat or video conferencing software; and tools for tracking and analyzing user behavior, such as analytics software. The exact makeup of the metaverse will depend on the specific goals and capabilities of the platform.

5. What Can Be Called as Metaverse

The term "metaverse" is often used to refer to a shared virtual space, typically represented in a computer-generated 3D environment that can be accessed and interacted with by multiple users. Examples of metaverses include virtual worlds, such as Second Life and World of Warcraft, which are designed for socializing, gaming, or education; augmented reality (AR) metaverses, such as Pokémon Go and Ingress,

which overlay digital information or elements on the real world; and virtual reality (VR) metaverses, such as VirtualTourist and Google Earth VR, which allow users to explore and experience virtual versions of real-world locations.

In general, a metaverse can be called anything that meets the following criteria:

1. It is a shared virtual space: The metaverse is accessed and interacted with by multiple users, who can communicate and collaborate and the virtual environment.
2. It is represented in a 3D environment: The metaverse is typically visualized in a 3D environment, which can be fully immersive (in the case of VR) or partially augmented (in the case of AR).
3. It is accessed and interacted with using specialized software or hardware: Users access and interact with the metaverse using specialized software or hardware, such as VR headsets or AR devices, which allow them to experience the virtual environment in a more immersive and interactive way.

Overall, a metaverse can be any virtual space that meets these criteria and is designed for social interaction, entertainment, or commerce.

6. Research Opportunities in Metaverse

The development of the metaverse is far from the end and the journey of the new era of the metaverse just began several years ago. The metaverse is having a lot of benefits in many sectors, as explained in the introduction section, and most companies invested in several areas that seem promising, those conditions lead to other research opportunities such as finance, medicine, education, retail, etc.

In finance, the metaverse has its economy and currencies for users to do transactions by using cryptocurrencies and the technology of blockchain as the metaverse tokens to trade virtual assets that will be included in the integration of NFT technology [23]. Virtual currencies may become a common method of exchanging digital products and services as the metaverse grows, sparking fresh studies on their effects on conventional currencies, payment systems, and regulation. Further research may be necessary to understand the valuation and pricing of virtual assets, such as virtual real estate and NFTs, to understand how they compare to traditional assets and how they differ from them. A new topic of research is presented by the social trading and investment made possible by the metaverse, as well as by the optimization of portfolios that contain both virtual and physical assets. Finally, the blockchain technology that powers the metaverse offers a rare chance to investigate how it may be applied to raise the speed and security of financial transactions. In conclusion, the metaverse is a fascinating and active field of research for the financial sector, and it will be intriguing to see how it develops over the next several years.

During the pandemic, e-health services significantly increased because people's mobility has been limited. E-health is the idea of providing medical services through digital activities, having AR, VR, and MR is making e-health services becoming easier, especially when the metaverse technology is already mature, the e-health services will become even more advanced [24].

In the metaverse, education will certainly gain more positive impact, for example, the analysis of the number of students' eye blinks increases when the questions are becoming more difficult, and the teachers can use this data to evaluate students' attitudes [25]. Or when Primary students want to learn about radioactive by using hands-on experiments, the metaverse can accommodate this without endangering the students' health and safety [26], [27].

The retail world will also be evolved with the development of the metaverse from the traditional retailing system to e-retailing to meta-retailing seems unavioded [28]. The new era of -e-commerce is also changing due to this metaverse technology, the metaverse will overcome the limitation of the space into a live broadcast in the world of the metaverse, this will give more experience to the consumers and the seller can be innovative to draw their customers or potential customers attention [29]. Those are just some examples of the positive impact of the development technology of the metaverse, and there will be much more coming that can be developed using the metaverse.

7. Conclusion

As the metaverse is getting popular and there are lots of papers that are discussing the metaverse, the difference with this paper is, this paper intended to be the fundamental understanding of the metaverse which covers many areas. In this paper, the author can conclude that most companies invest in the metaverse between 10% to 20% of their annual budget, and in the coming years, this might increase to above 20%, the author expects that this paper can be their guidelines on what to invest and expected in the metaverse.

The contribution of this paper is two folds. For researchers, this paper can be the reference to cover the basics and conduct advanced research on the metaverse. Most of the preliminary information has been covered in this paper, such as the understanding, popularity, future possible usage, types, components, and timeline. For the practitioners, this paper can the guidelines to develop any technology that is related to the metaverse. For example, to build a library within the metaverse or a workspace within the metaverse.

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Data-Centric Optimization Approach for Small, Imbalanced Datasets

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Abstract

Data-centric is a newly explored concept, where the attention is given to data optimization methodologies and techniques to improve model performance, rather than focusing on machine learning models and hyperparameter tuning. This paper suggests an effective data optimization methodology for optimizing imbalanced small datasets that improves machine learning model performance.

This paper is focused on providing an effective solution when the number of observations is not enough to construct a machine learning model with high values of the estimated magnitudes. For example, the majority of the observations are labeled as one class (majority class), and the rest as the other, commonly considered as the class of interest (minority class). The proposed methodology does not depend on the applied classification models, rather it is based on the properties of the data resampling approach to systematically enhance and optimize the training dataset. The paper examines numerical experiments applying the data centric optimization methodology, and compares with previously obtained results by other authors.

Keywords: imbalanced dataset, classification, data centric, optimization, machine learning, artificial intelligence.

1. Introduction

Highly imbalanced data appears in many real-world domains, such as 1) detection of cardiovascular (heart) and liver diseases, diabetes, 2) detection of oil spills in satellite images, 3) information retrieval and filtering tasks and so on [1], [2]. The task of improving the effectiveness of a class-imbalance problems is very important aspect for averting a threat before it occurs, effectively applying medical treatments etc.

Many authors, working in this direction, proposed different approaches addressing data and algorithmic methodologies. For example, some data methodologies [3] are related to the use of resampling, bootstrapping and feature selection. The application of resampling methods includes neural networks [4], ensemble models [5], time series [6] and others. Resampling procedures for SVM hyper parameter selection are investigated by Wainer [7]. Authors have considered resampling procedures such as an estimate performance based on repeatedly dividing a given set into training and test set.

Azbeq and co-authors have considered bootstrapping, randomly drawing without replacement, to construct a collection of estimators, also known as Random Forest (RF), to improve the diabetes classification algorithmic methodology. Azbeq compared results with different algorithms, such as Support Vector Machine (SVM), K-Nearest Neighbor (KNN), Decision Tree-based (DT), Adaptive Boosting (ADABOOST), Artificial Neural Network (ANN), Logistic Regression (LR), Deep Learning (DL), and concludes it can improve the accuracy of the diabetes classification problems [8].

Singh and co-authors investigated feature selection technique in attempt to evaluate liver diseases and improve classification algorithmic methodology. Feature selection is used for removal of redundant and irrelevant data to increase learning accuracy and reduce noise. The research continues to compare results of both with and without selection technique on different classifiers with resampling procedure, also known as cross validation (CV). Six classifiers have been considered, as follows: LR, Naïve-Bayes (NB), Java implementation of DT C4.5 (J48), Sequential Minimum Optimization (SMO), Weka Abstract Classifier (IBk) and RF [9].

Bohacik and Zabovsky studied a probabilistic implementation with given supervised discretization, utilizing heart disease expert domain knowledge [10]. The algorithmic methodology was applied in Waikato Environment for Knowledge Analysis as class NaïveBayes with Fayyad-Irani's discretization of numerical attributes [11]. The research is based on k-fold ($k=10$) cross-validation, and uses sensitivity, specificity and their sum as measures. Sensitivity (true positive rates) represents the ability of the algorithm to identify true positive (TP) cases in respect to all positive outcomes, with following expression: $\frac{TP}{TP+FN}$. False negative (FN) would be considered as negative cases while actually being positive. Specificity states the ability of the algorithm to identify true negative rates (TN) cases in respect to all negative outcomes, as follows: $\frac{TN}{TN+FP}$. False positive (FP) would be considered as positive cases while actually being negative. Bohacik and Zabovsky use the sum of sensitivity and specificity in [10] as an overall point system to benchmark algorithms.

This paper's intention is to apply a new effective approach centered around the data, also referred as data centric optimization approach, to improve machine learning models (classifiers) [12]. The algorithm resamples from the given data to produce an optimized balanced data sub-set. An optimized balanced data sub-set is derived based on an objective function that minimizes model's error (false positive and false negative error). To ensure proper result comparisons, this methodology is benchmarked against previously discussed approaches and various algorithms using the same datasets, described below in Table 1.

Datasets	Variables	Classes/Observations	Source
Diabetes	8	Class 0 – 500 Class 1 - 268	https://gist.github.com/ktisha/c21e73a1bd1700294ef790c56c8aec1f
Heart	13	Class 1 – 150 Class 2 - 120	http://archive.ics.uci.edu/ml/datasets/statlog+(heart)
Indian Liver Patient Dataset (ILPD)	10	Class 1 – 416 Class 2 - 167	https://archive.ics.uci.edu/ml/datasets/ILPD+(Indian+Liver+Patient+Dataset)

Table 1. Public datasets and sources.

During the optimization phase, the algorithm randomly resamples unique data sub-set from the given data, assuring under-sampling of the majority class and producing a balanced, unique data sub-set. Then data sub-set is divided into train and validation set, according to the classical split of 80% and 20%, respectively, and fitted to a classifier model.

The optimized, balanced data sub-sets (train and validation) are derived and stored based on an objective function, which minimizes model's error, noted as model error rate and stored each iteration for comparison. This process repeats until minimization is reached and/or random sampling is exhausted (ranging between 0 and 100).

Next, during the test (classification) phase, the optimized, balanced data sub-sets will be fitted into a newly instantiated classifier for final model test evaluation. The proposed algorithm is tested in (RAM: 16GM, CPU: 2.6GHz 6-Core Intel Core i7) and illustrated below:

Let:

- $i \in \{0 \dots 100\}$
- r_i – random under-sampling integer
- n – length of the given dataset
- m – minority class length
- R – list of integers
- D_n – given dataset
- X_n – random variable (# of variables in D_n)
- Y_n – response variable (# of classes in D_n), $Y = 1, \dots, K$, where $K \geq 2$
- $D_{i,m}$ – balanced, under-sampled data sub-set:
 $D_{i,m} = ([X_1, Y_1], \dots, [X_n, Y_n] \mid r_i, m)$, where $[X, Y]$ is independent of D_n
- mer - model error rate, $mer = 100$
- T_o and V_o – optimized train and validation sub-sets

ALGORITHM: OPTIMIZATION PHASE

```

1   Initialization of variables listed above.
   set optimized = False
2   while not optimized
3       draw random integer –  $r_i$ 
4       if random integer ( $r_i$ ) not in list of integers ( $R$ )
5           append random integer ( $r_i$ ) to  $R$ 
6            $D_{i,m} = \text{undersample}(D_n \mid r_i, m)$ 
7           split  $D_{i,m}$  into train and validation sets (80/20):
            $T_i, V_i = \text{train\_test\_split}(D_{i,m} \mid .20)$ 
8            $C_i = \text{build classifier}$ 
9           fit train set to  $C_i$  and calculate false positive error (FPE)
           and false negative error (FNE). Keep track of  $C_i$  error:
            $\text{error}_{C_i} = C_i(T_i, V_i) = \Sigma [(FPE_i \mid C_i, D_{i,m}), (FNE_i \mid C_i, D_{i,m})]$ 
10          evaluate current model error rate ( $\text{mer}$ )
           if  $\text{mer}$  is greater than  $\text{error}_{C_i}$ 
11               $\text{mer} = \text{error}_{C_i}$ 
               $T_o = T_i$ 
               $V_o = V_i$ 
12          if length of  $R$  is greater than 100: optimized = True
13  end

```

The idea of optimizing a balanced dataset (minimizing model's error rate) is based on a filtering technique, also known as information gain. Shaltout and co-authors studied information gain (IG) as a feature selection method for the efficient classification of influenza. In their research IG was used to identify the feature(s) possessing the most information, based on a specific class, and was derived from entropy, as entropy is inversely proportional to IG [13],[14]. In this research, minimizing model's error, thru under-sampling of the majority class, plays the role of information gain, i.e., selecting a majority class sub-set possessing the most information. In other words, the data centric optimization approach filters out “bad” and/or “noisy” majority class datapoints from the dataset to produce balanced, optimized sub-sets (training and validation).

2. Numerical Experiments

2.1. Hypothesis

Data centric optimization approach is not effective solving classifications tasks on imbalanced datasets with “small” number of observations. To prove the hypothesis, this paper includes experiments and comparison with methodologies described in the

introductions. Moving forward, experiments and comparisons are combined into three sections, as follows: bootstrapping without replacement, feature selection, and probabilistic implementation with given supervised discretization.

2.2. Bootstrapping with replacement

Diabetes is a common disease and patients living with such illness have to continuously self-control it to avoid fatal consequences. Usual cause of diabetes is high level of glucose (blood sugar). Azberg and co-authors conducted research in an attempt to build a predictive model, Random Forest (RF), to make prediction estimates for patients with diabetes. RF has wide applicability, and along with its ease of use and good performance is considered as a standard method in supervised machine learning. Azberg and co-authors' algorithm (ACA) consists of aggregation a collection of estimators constructed from bootstrap samples with replacement in the training set, also called random weak learners. A RF is an aggregation of randomly generated weak learners and defines a prediction rule that corresponds to the majority vote in classification [8]. The accuracy given from their experiments and comparison is listed in Table 2. Class 0 denotes cases when patients have diabetes.

Datasets	Classes/Observations	ACA RF Accuracy	Our Proposition RF Accuracy
Diabetes 1	Class 0 – 500 Class 1 – 268	78.65	87.04
Diabetes 2	Class 0 – 1316 Class 1 – 684	99.5	99.65
Diabetes 3 (1 and 2 combined)	Class 0 – 1816 Class 1 – 952	99.8	100

Table 2. Results and comparison between ACA [8], and data centric optimization approach.

As seen in the table above, ACA underperforms in comparison with our proposed algorithm, and as the number of observations increases, the accuracy of the RF model increases as well. This is an expected performance, although it is the main idea behind the ACA. The major difference between ACA and our proposition lies in the biasness of the RF model.

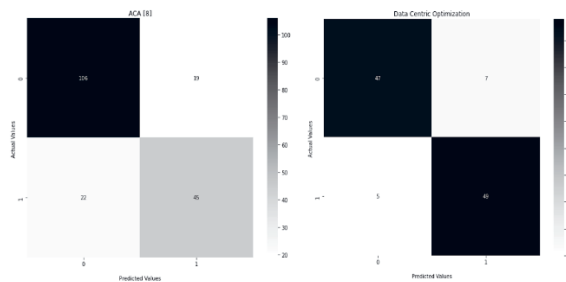


Figure 1. Confusion matrix results comparison for Diabetes Dataset 1.

Looking deeper and analyzing the results from Figure 1, confusion matrix result comparison of Dataset 1, we observe, due to the imbalanced data, that ACA is biased towards cases when diabetes is presents. In other words, ACA’s ability of the algorithm to identify true negative cases, also known as specificity, is 70.31.

This implies that, on average, the algorithm assigns diabetes treatment to patients with no diabetes ~30% of the time. In contrast, the specificity of our proposed algorithm is 87.5, and it will mistakenly assign diabetes treatment, on average, only 12.5 of the time (more than half lesser than ACA).

2.3. Feature Selection

According to Centers of Disease Control and Prevention (CDC), there is 4.5M (1.8%) adults diagnosed with liver disease in the US (with a death rate of 15.7 per 100K) [15]. Singh and co-authors investigated feature selection technique in attempt to evaluate liver diseases and help improve patient treatment.

The research continues to compare results of both with and without feature selection with resampling procedure, considering six classification algorithmic methodologies, as follows: Logistic Regression (LR), Naïve-Bayes, Java implementation of DT C4.5 (J48), Sequential Minimum Optimization (SMO), Weka Abstract Classifier (IBk) and Random Forest (RF) [9].

Indian Liver Patient dataset (ILPD) from the UCI Repository [16] has been used in this research, containing 416 liver (class 1) and 167 none liver patient (class 2) records. Correlation-based feature selection evaluator and Greedy Stepwise were applied, as feature selection and search method with 10-fold cross validation, in WEKA tool [17] resulting in 5 features: Total Bilirubin (TB), Direct Bilirubin (DB), Alkaline Phosphatase (Alkphos), Alamine Aminotransferase (Sgpt) and Asparate Aminotransferase (Sgot) in [9]. Accuracy comparison shown below in Figure 2.

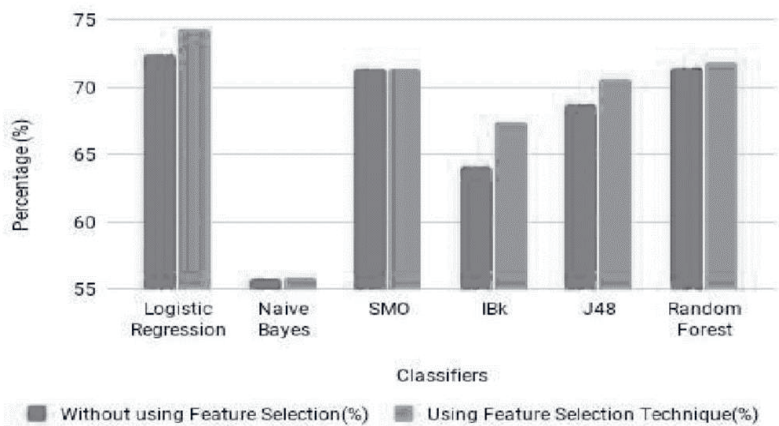


Figure 2. Result comparisons between different classifiers on basis of correctly classified instances [9].

As seen above in Figure 2, LR achieved the highest accuracy with feature selection (FS) or without feature selection technique of 74.36 and 72.5, respectively. Random Forest performance was placed second with 71.87 and 71.53.

This shows that feature selection technique underperforms in comparison with our proposed algorithm. Our proposed algorithm, data centric optimization approach using Random Forest, achieved significantly higher Test Accuracy of 92.54, as seen below in Table 3. In addition, due to accuracy being misleading and not a preferred metric in cases with imbalanced small datasets, we are reporting our data centric optimization approach test results for precision, recall, AUC and F1- Score in Table 4.

Datasets	Classes / Observations	Singh and co-authors LR Accuracy		Singh and co-authors RF Accuracy		Our Proposition RF Accuracy
		No FS	FS	No FS	FS	
Indian Liver Patient dataset (ILPD)	Class 1 – 416 Class 2 – 167	72.5	74.36	71.53	71.87	92.54

Table 3. Results and comparison between Singh and co-authors [9], and data centric optimization approach.

Indian Liver Patient dataset (ILPD)	Our Proposition Test Metric Results AUC = 92.5			
	Accuracy	Precision	Recall	F1
Class 1 (34)	92.54	91.43	94.12	92.75
Class 2 (33)	92.54	93.75	90.91	92.31

Table 4. ILPD Test results for data centric optimization approach, using Random Forest.

2.4. Probabilistic implementation with given supervised discretization.

Bohaick and Zabovsky studied a probabilistic implementation in an attempt to detect heart disease cases. CDC relates the term “heart disease” to several types of heart conditions (most common is coronary artery disease), which is the leading cause of death in United States [18]. Bohacik and Zabovsky research is based on UCI Repository’s Statlog Heart dataset, containing 120 heart (class 2) and 150 none heart disease (class 1) records [19].

Their research employs Equal Frequency Discretization algorithm, with focus on refining preprocessing methods. The research presents improvements of achieved accuracy with added discretization, selected based on the smallest average entropy. Research results and comparisons between the proposed (NB-Mod) and additional

algorithms are derived from the summation of Sensitivity and Specificity, listed in Table 3 below.

Algorithm	Sensitivity	Specificity	Sum
NB-Mod	0.900	0.842	1.742
NB	0.840	0.817	1.657
MLP	0.880	0.800	1.680
DT	0.840	0.692	1.532
NN	0.773	0.717	1.490
Our Proposition of RF	0.96	1.00	1.96

Table 5. Experimental results of Bohacik and Zabovsky approach (NB-Mod) and comparison with other machine learning algorithms in [10].

As seen in Table 4 above, Bohaick and Zabovsky approach achieved the highest Sensitivity and Specificity of .90 and .842, respectively, in comparison with other machine learning algorithms. Our proposed algorithm, data centric optimization approach, outperforms significantly their model reaching Test Sensitivity and Specificity of .96 and 1.0 (Sum of 1.96). In addition, we are reporting our data centric optimization approach test results for precision, recall, AUC and F1- Score in Table 5.

Heart	Our Proposition Test Metric Results AUC = 97.9			
	Accuracy	Precision	Recall	F1
Class 1 (24)	97.9	1.00	95.83	97.87
Class 2 (24)	97.9	96.0	1.00	97.96

Table 6. Satlog Heart Test results for data centric optimization approach, using Random Forest.

3. Conclusion

This research work presented a new approach centered around the data, referred as data centric optimization. Three experiments were conducted using the following datasets: diabetes, liver and heart disease, listed in the Introduction section under Table 1. Research results were tested and compared with various approaches utilizing different classifiers.

Evidently, data centric optimization approach outperformed bootstrapping without replacement (Section 3.2), feature selection (Section 3.3) and probabilistic implementation with given supervised discretization (Section 3.4). This gives strong attention to data centric optimization approach and its effectiveness solving classification tasks on imbalanced datasets with “small”.

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New Information Technologies in the Development of Digital (Electronic) Democracy in Russia

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Abstract

This study is aimed at solving such a fundamental task as the use of modern information technologies in the development of electronic or digital democracy in Russia, as the main direction of the strategy for supporting democratic institutions and democratic processes and spreading democratic values. E-democracy is the basic foundation of the information society, accumulating a number of traditional and innovative tools that are successfully used in the democratic institutions of the modern state in the regulation of socially significant relations. The development of modern democratic processes is based not so much on public authorities, but on civil society, which is gradually transforming into a digital society. For this reason, the issue of searching for and actively implementing mechanisms that contribute to the development of information technology infrastructures, communication systems, and increasing the information literacy of the population seems to be relevant.

Keywords: democracy, digital democracy, digitalization, Internet, electronic state, scientific and technological progress, information and communication technologies

1. Introduction

The relevance of this study is predetermined by the current intensive development of information technologies that are widely used in socio-political processes, the need to improve democratic mechanisms in Russia in the context of the opportunities provided by the information society.

Modern information and communication technologies ensure the rapid dissemination of information of a political nature, a broad public discussion, and the mass participation of the electorate in public activities.

Digital (electronic) democracy is interconnected with good governance, predetermining its effectiveness, efficiency, transparency and accountability as a means of organizing and implementing public authority in electronic format.

The formation of a digital state and the transformation of law in the context of digitalization are a response to the construction of a new time and a new space [1], which we have been observing in recent decades, when there have been significant shifts in the perception of temporal characteristics and the widest expansion of space for both each person and society as a whole. Of course, these phenomena, on the one

hand, open up new opportunities, but on the other hand, they force the transformation of those areas that have not undergone major changes for centuries, and therefore crisis manifestations are possible, caused both by the unwillingness of society to perceive a new digital reality, and the inability to calculate all threats and risks. The concepts of “digital state”, “digital legal environment” are not yet well-established and cause discussion.

In the Russian Federation, there is currently no basic law that would define the concept of a digital state, therefore, only some of its elements are enshrined in the regulatory and legal way [2]. Naturally, this affects the legal sphere. In this regard, doctrinal sources are of great importance.

The generalization of various points of view regarding the digitalization of the state-legal sphere allows us to single out three fundamental approaches.

First, instrumental-technological approach. In this case, digitalization is the use of information and communication technologies by the legislative, executive and judicial authorities, as well as a new way of interaction between authorities and the population.

Secondly, the organizational and managerial approach. In this case, the digital state is considered as a way of organizing state power that meets modern challenges, which is based on the use of information and communication technologies, as well as a new form of information relations between such entities as “state - state”, “state - business”, “state - citizens”.

Thirdly, a procedural approach that advocates the idea of the emergence and development of a new form of democracy - digital democracy, in which the maximum participation of citizens in public administration, in solving local issues, for example, through online voting, becomes possible.

In any case, there is and will be a transformation of law in the following directions.

The first is to ensure the development of the digital economy. According to modern estimates, by 2025 from 40% to half of GDP in developed countries will be created within the digital economy, and this requires the unification of disparate technologies to manage production processes and the environment, which requires appropriate legal support, advantages that were not available previously. The advantages of this area include the emergence of a new source of GDP growth, increasing the efficiency of interaction between the state and citizens, more efficient use of existing resources and the creation of new jobs, reducing the level of fraud in obtaining public services, obtaining Big Data for analyzing social processes, etc.

If we take the Russian experience, then 2017 became a turning point in this direction, when the Strategy for the Development of the Information Society in the Russian Federation for 2017-2030 was first adopted [3], and then the program “Digital Economy of the Russian Federation”, in which platforms and technologies, where competencies are formed for the development of areas of activity, and an environment that creates conditions for the development of platforms and technologies and covers regulatory regulation, information infrastructure, security and personnel, were named among the levels of the digital economy [4].

These programs are quite costly at the first stage. Thus, in the Russian Federation in 2019-2021, 101 billion rubles were allocated from the federal budget for the federal

project “Digital Public Administration”, implemented as part of the national program “Digital Economy” under the supervision of the Ministry of Communications and the Ministry of Economic Development [5], but then it should lead to a sharp decrease in administration costs and the possibility of transferring these funds to other areas, including the social sphere.

Secondly, experts believe that now there is a unique opportunity to put into practice the principle of popular sovereignty, because there have never been such conditions for improving the image of the modern information society. This is manifested in the participation of the population with the help of information and communication technologies in making government management decisions and improving their quality.

Thirdly, the development of the digital state implies a high level of standardization. So, in 2015, the Federal Law “On Standardization in the Russian Federation” was adopted, in the second chapter of which the main directions of the state policy in the field of standardization were determined. This means that every financially secured document of a strategic nature should now contain a section on normative and technical regulation in the field of standardization [6]. The legal sphere will also undergo standardization, while unification, harmonization and reception were previously priority areas.

Fourth, digitalization is somewhat changing our understanding of human rights. In 2011, based on a report by UN Special Representative Frank La Rue, which was compiled after the Syrian authorities shut down the Internet throughout the country on June 3 to prevent the opposition from coordinating their actions [7], the UN adopted a resolution stating that the Internet has become an indispensable tool for the realization of human rights, the fight against inequality and the development of progress, but at the same time, it can be used for copyright infringement, cyber-attacks to take over data, etc.

Fifthly, transformations in the legal sphere are associated with the introduction and development of the use of electronic digital signatures. This introduces significant changes, for example, in the field of civil law. Back in March 1995, the American Bar Association developed a model contract for electronic data interchange between trading partners, and already in May of the same year, the first electronic digital signature law was passed in Utah. In 1997, the legislative consolidation of the electronic digital signature took place in Germany, and in 2000 - in France. In 1999, the European Union Directive on Electronic Signatures [8], repealed on July 1, 2016, was adopted. In 2000, the Interparliamentary Assembly of the CIS Member States adopted the Model Law on Electronic Digital Signature [9]. In 2001, the UNCITRAL Model Law on Electronic Signatures appeared, the purpose of which was to help states in establishing a system for the use of electronic digital signatures [10].

The use of electronic digital signature takes place considering the specifics of national legal systems. For example, in the UK, the principled position of limited state intervention in private affairs has led to the rejection of strict state regulation of electronic document management. In France, on the contrary, the electronic signature was enshrined in the norms of the Civil Code.

This is not a complete list of issues that arise in the process of transforming the legal sphere caused by the digitalization of public relations.

2. Materials and Methods

The purpose of the study is to analyze, generalize and systematize new information technologies in the development of digital (electronic) democracy in Russia, as well as to develop recommendations and proposals for improving the legal regulation of citizens' participation in the implementation of forms of direct democracy in the information society.

The declared topic is interdisciplinary in nature, covering a wide range of scientific and practical areas, in particular, information, constitutional, administrative law. Digitalization in the modern period translates all social processes into cyber-physical space, forming a new scientific and technological paradigm based on digital systems. An interdisciplinary discussion of the most significant issues of transformation and digitalization of the legal regulation of public relations is an ideal platform for solving the problems of regulatory uncertainty in certain areas of the formation of the information society in Russia and abroad. The scientific novelty of the study stems from the lack of systematic scientific knowledge about the mechanisms of e-democracy in Russia, the trends and patterns of its development in the digital age, which are supposed to be filled in the process of the project.

The following results are expected during the study:

- clarification of the nature, necessity and limits of digital (electronic) democracy in Russia;
- definition of the system of digital (electronic) democracy, the relationship of its elements;
- identification of existing problems in the functioning of digital (electronic) democracy in Russia, development of proposals for overcoming them;
- determination of trends in the development of digital (electronic) democracy from the standpoint of domestic and foreign democratic experience.

The methodological basis of the study is made up of general scientific (dialectical, analysis and synthesis, deduction and induction, formal-logical, structural-functional, etc.) and private scientific (comparative legal, historical and legal, formal legal, sociological, statistical, empirical and etc.) methods of scientific analysis.

The significance of the planned results of the study is predetermined by their relevance and novelty, a real contribution to the development of the theory and practice of democratic rule in the country at the federal, regional and municipal public levels. The introduction of e-democracy mechanisms at all levels of government and civic participation in modern Russia will help bring government and society closer together, enhance civic participation in the public sector and social and political decision-making, make authorities more accessible and open to citizens, and create additional incentives for the development of a partnership model interaction between authorities and civil society.

3. Results

The issues of applying new information technologies in the development of digital (electronic) democracy in Russia are interdisciplinary. Digitalization in the modern period of development of society and the state translates all social processes into cyber-physical space, there is a transition to a new scientific and technological paradigm based on digital systems. On the one hand, various physical systems continue to function, and on the other hand, all this goes into the digital space.

The scope of information and communication technologies is constantly expanding and today reaches a large scale that previously seemed unrealistic. Information and digital technologies are increasingly penetrating into modern life, becoming a powerful lever for the development of all areas: the economy, production, logistics, trade, education, medicine, etc. Legal science, in turn, introduces such concepts as digital democracy, electronic voting, online campaigning, information space, network communications, teledemocracy, digital justice, electronic services [11], etc. For the harmonious development of modern society and the state, there is a growing need for the digitalization of the institutions of modern democracy.

E-democracy is understood as such a form of organizing the socio-political activities of citizens, which provides a qualitatively new level of interaction between citizens with each other, with state authorities, local governments, public organizations and commercial structures through the widespread use of information and communication technologies. In this sense, e-democracy should be clearly separated from e-government, which is understood as a new form of organizing the activities of public authorities, providing a qualitatively new level of efficiency and convenience for organizations and citizens to receive public services and information on the results of the activities of public authorities through the widespread use of information and communication technologies.

E-democracy, along with e-government, is one of the basic foundations of the information society.

Internet voting, electronic polls of citizens, provision of electronic public services, electronic collection of signatures (petitions), electronic consultations, electronic petitions, electronic justice, etc. become the means of e-democracy. The possibility of expanding the limits of direct democracy instead of representative appears, the ways of communication between government officials and citizens are simplified, the processes of making official decisions become more transparent through e-democracy.

There is a trend of a more active presence of government representatives in social networks, minimizing the formalism of their communication with citizens, allowing the possibility of direct contact with the official through personal messages on social networks instead of making an appointment. We can confidently talk about the development of a new modern form of democracy, in which citizens take part in managing the affairs of the state through information and communication technologies.

The development of e-democracy observed in modern times is associated with the general processes of digitalization of society and the state, the steady transition of

political and legal phenomena to the digital space, to a new scientific and technological paradigm based on digital systems. At the state-power level, there is a transition from traditional democracy to digital (electronic) forms of implementing the power of the people.

The phenomenon of digital or electronic democracy, although it is relatively new, despite the fact that traditional democracy has been developing for centuries, nevertheless, has received its interpretation in legal science, primarily constitutional law, which has developed many definitions of this concept.

4. Discussion

The concept of electronic (digital) democracy is considered from different positions.

In its most general form, e-democracy is understood as “the exercise of power by the people in electronic form, or, even more simply, as traditional democracy embodied in electronic form” [12]. It is impossible to characterize digital (electronic) and traditional democracy in antagonistic terms, because they pursue the same goal - the exercise of power directly by the people.

E-democracy is a set of forms and means that allow the use of information technology to empower any citizen using information and communication technologies. E-democracy is characterized by “online holding of various campaigns, a high level of self-organization of the online community against the background of the absence of significant social differences between members of the community, online human rights activities, and the use of the electronic environment as a means of disseminating political information” [13].

E-democracy is “designed to expand and deepen the traditional forms of democracy (referendum and free elections) both by modernizing existing democratic procedures (for example, simplifying the organization of a referendum, organizing an electronic referendum and electronic elections) and by introducing fundamentally new democratic procedures (for example, “electronic government”, “electronic parliament”, political decision-making through electronic voting, etc.)” [14].

The main purpose of e-democracy is to attract the population to participate in political life [15]. E-democracy mechanisms should be implemented at all levels of government so that citizens can resolve issues of any scale - from renaming a street in a small village to federal issues (for example, raising the retirement age).

According to Ya.V. Antonov, “electronic democracy provides the population with real opportunities to initiate an effective dialogue with the state, based on the constitutional ideas of democracy” [16].

Digital democracy, “becoming a part of political reality, minimizes the gap between management structures and ordinary citizens, guarantees the latter access to information, participation in the management process” [17].

E-democracy refers to the electronic representation of democratic processes. We are talking about changes in the already existing methods of work of public authorities and local governments through the automation of processes, there is an optimization of some of their functions, carried out through information and communication technologies.

Digital (electronic) democracy is an evolutionary transformation of traditional democracy [18]. At the same time, the possibilities of digital (electronic) democracy in ensuring public participation in public spheres are much wider in comparison with traditional democracy:

- the access of citizens to legislative activities, information on the state of current affairs in the state is expanding;
- the effectiveness of the feedback from the authorities to the society is improved;
- the interest of citizens in the political process is manifested;
- citizens are given the opportunity to establish a form of self-control and interaction with the political institutions of society.

Today, we can confidently say that the development of information and communication technologies will lead to a complete restructuring of public administration systems. The construction of the electronic state is actively continuing. In order for the Russian Federation to be a highly developed, sovereign, prosperous state in the future, it is necessary today to keep pace with scientific and technological progress and safely introduce the tools of digital (electronic) democracy into the political fabric of the country.

Electronic or digital democracy is actively being introduced into the state practice of Russia, “accompanying the traditional institutions of democracy, strengthening the participation of citizens in the political life of society” [19]. We can confidently assume that in the future the tools of e-democracy will replace the mechanisms of exercising the power of the people that are familiar today. With the help of Internet technologies, large communities of citizens get the opportunity to instantly exchange information, free access to this information is provided for each interested person. Achievements of scientific and technological progress make it possible to organize a discussion and conduct a general vote on topical issues online and, based on the results of these votes, assign tasks for execution by state authorities and local governments.

5. Conclusion

To summarize, we note that even a brief analysis of the issue of introducing information and communication technologies into the system of socio-political relations allowed us to identify a number of problems and to offer evidence-based options for resolving them. Firstly, it seems necessary to abandon the use of clearly outdated information technologies in the implementation of direct forms of direct democracy, since their use complicates the process of updating and compatibility of digitalization tools. Nevertheless, the process of integrating new technologies should be approached with caution, without violating the principles of openness and transparency, according to which all applied technologies should be brought to all people in an understandable way. Secondly, it is important to develop regulatory frameworks that regulate the processes of integration and use of new digital technologies, the rights and obligations of the subjects of their use, the processes of digitization and storage of documents in electronic form. Thirdly, in our opinion, it is necessary to develop and include “Information technologies in the activities of public authorities” in the programs of professional education and retraining of lawyers of

special disciplines. Particular attention should be paid to the issue of technical equipment of public authorities and local self-government, including effective information security systems and the organization of generalized information repositories.

Digitalization significantly affects modern democratic institutions, which, on the one hand, contribute to this process, ensure it, but, on the other hand, are transformed under its influence. Significant changes have been outlined in the field of constitutional law, civil law, legal regulation of international trade, etc. Digitalization opens up new opportunities for the democratization of the state and legal sphere, more open interaction between various entities - states, international organizations, legal entities and individuals, reduces the cost of many procedures.

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Usage of Cloud Computing Application by Students from Kurukshetra University: the Current State and Perspectives

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Abstract

The term "cloud computing" refers to a variety of tools and applications used by organizations to manage their work processes online. Apart from providing the expected benefits, the gadgets and applications of the cloud are helpful for education. The purpose of this study is not to examine the outcomes of cloud computing in universities, but to examine how students use cloud applications. A survey research design was used to examine how students of Kurukshetra University use cloud computing applications. 200 students from the streams of science, management, social science, and arts were randomly selected to answer a structured questionnaire. A response rate of 95% was achieved by 48 students in Science, 50 in Management, 48 in Social Science, and 44 in Arts who completed and returned the questionnaire on time. The analyzed data is presented in a table that includes the Likert scale mean, standard deviation, and the cross-table Chi-square test. In the study, most students highly preferred G Suite Cloud (57%) and Microsoft (40%) learning applications. It can be seen from the study that WhatsApp (98%), Facebook (96%), and YouTube (97%) are the most preferred cloud-based social media among the students, most students preferred Google Meet (95%) and Zoom (91%) meeting application, and most students preferred Google Drive (68%) and pCloud (67%) for data storage.

Keywords: Cloud Application, Usage application, Digital era, online learning, University Students, Kurukshetra University, Haryana, India

1. Introduction

Recently, cloud computing has become the motivation and carrying out with the rapid development of the web to support without additional hardware and reduce upfront costs and costs caused by customer service techniques. Cloud computing is being used by just about every field that uses a structured program, hardware, and infrastructure. It refers to the components as processors, data sets, network hardware, and operating systems that extend as SaaS (software as a service), PaaS (platform as a service), and IaaS (information as a service). In today's world of information innovation, cloud computing is the ideal word effect on education that provides better opportunities for meaningful development. In the modern era, thanks to the advanced innovations by students learning throughout the day, they are traveling accordingly and are highly adept mechanically. A growing number of marginal applications are pushing

educational infrastructure toward digital learning. Several institutions are using cloud computing because of virtualized applications on the internet in combination with powerful quantification, better training, and better correspondence. In universities, diversity drives innovation. In order to transform the 21st century into a far better future, they inculcate a mechanical education in their students to prepare them for recognized professions. In order to increase innovation in universities, the most recent open aid program is beneficial. Innovation is a means of studying and monitoring issues that need to be certified daily. It can view mechanically future patterns with the capabilities of teachers and students.

Over the past ten years, Cloud computing applications have significantly changed how students learn. By integrating applications into classrooms, students and teachers are benefiting from improved outcomes and increased engagement. To be competitive in today's world, students need to be masters' essential skills in technology, such as computer literacy, database management, website development, digital marketing, project management, and cyber security. Multiple Cloud applications offer students safety and cost-effective opportunities for innovation. A student can, for instance, upload a video of an assignment they worked on, photograph a piece of artwork they made, or share a document they created. Cloud computing gives students the freedom to show their learning in the manner that best suits them and to use many cloud-based applications, such as Art Applications, File Storage Platforms, Image Editing Applications, Data Storage Applications, Antivirus Applications, Entertainment Applications, URL Conversion Applications, Meeting Applications, Presentation Applications, Social Media Applications, GPS Applications, Accounting Applications, and Teaching/Learning Applications. In the learning process, cloud applications have had the greatest impact, with teachers bearing the bulk of the responsibility for using them. Thus, considering the growing use of Cloud Computing in teaching and learning, a study has been carried out to examine the current status of using cloud applications by university students for education that can confirm and categorize the data.

2. Literature Review

The use of software-as-a-service for data and file storage was preferred over cloud computing because of its high subscription rate, unreliable online payment system, and lack of trading functionality [1]. It was found that perceived ease of use and perceived usefulness of cloud computing influenced students' adoption of cloud computing, which subsequently affected their academic performance [2]. The study found that students found Google Docs both useful and interesting, and also showed that Google Docs could foster communication, improve writing skills, and encourage constructive peer-to-peer discussion among students [3]. Researchers at Iraqi universities found they could improve their use of cloud applications by reducing security risks, enabling authorization and control, and improving performance [4]. The usage of cloud technologies for the educational process as based on communication (Gmail, Viber, and Telegram), store (Google Drive), educational video (YouTube), online classes (Google Meet), social networks (Facebook,

Instagram, TikTok), and literature search (Google Scholar, Science Direct, Web of Science) [5]. Among the Saudi university students, there was found a statistically meaningful difference between the mean scores of the two groups on the post-test of the experimental, while there was no meaningful difference between the mean scores of males and females [6]. Whereas in Nigerian Universities most students were ready-to-use cloud computing and found no meaningful difference between male and female undergraduates' readiness to use cloud computing for learning [7]. Although students of Federal universities in Anambra State were more aware of cloud computing services than State and private Universities students and it is recommended that higher authorities should make organize more ICT education awareness programs for students [8]. It is also found that cloud application services have significance for most students in distance learning with gained effective digital communication, self-organization and leadership, and time management, and they use centralized Moodle platform and G Suit for formal learning [9]. Although most participants preferred cloud applications due to their lower costs compared to traditional approaches, lack of expertise is the main challenge of implementing cloud applications [10]. The most frequent application of cloud computing in university education in Kuwait is in digital cloud libraries, then in electronic archiving of digital repositories, and in scientific research and information management [11]. Cloud computing integration in all aspects of human existence has changed the way people think, behave, communicate, work, and move from a service-oriented approach to a user-oriented approach [12], [13]. Furthermore, most students are aware and widely use the cloud as a storage, backup, and collaboration tool, as well as Google for academic purposes [14]. As technology advances, students are more interested in using social media cloud applications for learning [15]. In order to adopt Cloud Computing services, technology readiness is the most important predictor, followed by security and competitive pressure [16], that changed the way of storage, retrieval, manipulation, transmission, or receiving of any records electronically in a digital shape [17]. In UK HEIs, the adoption of the educational cloud is rising because of its cost savings, scalability, flexibility, mobility, and especially collaboration among students in UK HEIs, while the biggest barriers are security and cultural resistance, which still affect privacy and trust [18]. According to a study conducted at a mid-sized university in Southeast Michigan, perceived ease of use, computer anxiety, computer self-efficacy, and internet self-efficacy were significantly related to cloud applications' perceived usefulness [19]. Also, a study conducted at public universities in Benue State, Nigeria, and found a positive high-level impact of cloud services on students' confidence, affective engagement, and behavioral engagement with a high frequency of usage of smart phones, tablets, and laptops [20]. As Internet evolution has also affected the modern education system without a doubt, and 21st-century students, known as the Internet generation students, are showing great interest in growing educational proficiency. In the web world, it is possible to access all over the world at once with one click on devices connected to the internet [21], [22].

3. Objectives

- To find out the time length of the usage of cloud applications by students.
- To explore the commonly used cloud application by students.
- To explore the preferred cloud application services used by students.
- To explore the reason to use cloud computing services by students.
- To explore the problem faced by students while using cloud computing services.

4. Hypotheses

The following null hypotheses were developed and tested using the Chi-square tool.

H1- Cloud application usage among students is not having a similar time length.

H2- Students' preferences regarding cloud applications usage are not different.

H3- Among students, cloud computing services are not used for various reasons.

H4- Students face similar problems while using cloud computing services.

5. Methodology

It is clear that there are many benefits to cloud implementation and usage in universities, but none discuss how students use the cloud, which is integral to any university. The study is limited to the use of cloud applications by students of Kurukshetra University, Kurukshetra (Haryana). A survey method was used to conduct this study. In order to collect primary data from the students, a questionnaire tool was used. The questionnaires were randomly distributed to 200 students from the science, management, social science, and arts streams. With a 95% response rate, 48 students from Science, 50 from Management, 48 from Social Science, and 44 from Arts completed and returned the questionnaire. Data is presented in a table using percentages, Likert scale mean, standard deviation, and cross table Chi-square test at 0.05 significance level.

6. Data Analysis

Length	Science <i>N</i> (%)	Management <i>N</i> (%)	Social Science <i>N</i> (%)	Arts <i>N</i> (%)	Total <i>N</i> (%)
1 to 2 years	16 (33)	16 (32)	10 (21)	8 (18)	50 (26)
1 year	12 (25)	14 (28)	16 (33)	10 (23)	52 (27)
6 to 12 months	8 (17)	9 (18)	8 (17)	17 (39)	42 (22)
3 to 6 months	5 (10)	5 (10)	3 (6)	3 (7)	16 (8)
1 to 3 months	7 (15)	6 (12)	11 (23)	6 (14)	30 (16)

Total	48 (100)	50 (100)	48 (100)	44 (100)	190 (100)
<i>Notes: $\chi^2 = 14.2^{**}$; $df = 12$, Critical value = 21.02^{**}; Significant at 0.05 level</i>					

Table 1. The length of the use of the Cloud Technology Services

For the study purpose, a question related to the duration of cloud usage was asked to the students, the results of Table 1 show that the maximum number of students (53%) are using the cloud for more than a year, whereas less than 22% of the students are using cloud computing services from 6 to 12 months. Very few students (8%) are using cloud computing for less than 6 months. It is clear from the result of the table that most of the students are using cloud computing for over one year. Chi-square analysis shows a similarity in the time length of cloud application usage among students. Thus the null hypothesis H1 is rejected.

Cloud Application	Frequently N (%)	Sometimes N (%)	Occasionally N (%)	Rarely N (%)	Very Rarely N (%)	Mean	SD
Art Application	109 (57)	46 (24)	23 (12)	9 (5)	3 (2)	1.69	0.96
Learning Mgt S/W	129 (68)	23 (12)	27 (14)	5 (3)	6 (3)	1.61	1.03
Social Media	185 (97)	2 (1)	1 (1)	0 (0)	2 (1)	1.06	0.44
Storage and Backup	22 (12)	14 (7)	12 (6)	72 (38)	70 (37)	3.81	1.32
Image Editing S/W	85 (45)	54 (28)	21 (11)	2 (1)	28 (15)	2.13	1.38
Entertainment	119 (63)	11 (6)	18 (9)	3 (2)	39 (21)	2.12	1.62
Presentation	91 (48)	29 (15)	23 (12)	6 (3)	41 (22)	2.35	1.60
Meeting/Chatting	138 (73)	15 (8)	8 (4)	4 (2)	25 (13)	1.75	1.41
Cloud Antivirus	9 (5)	18 (9)	12 (6)	23 (12)	128 (67)	4.28	1.21
Accounting	14 (7)	13 (7)	7 (4)	120 (63)	36 (19)	3.79	1.06
GPS	182 (96)	4 (2)	2 (1)	1 (1)	1 (1)	1.08	0.43
URL Conversion	2 (1)	3 (2)	6 (3)	9 (5)	170 (89)	1.69	0.96
<i>Notes: $\chi^2 = 2127.5^{**}$; $df = 44$, Critical value = 60.4^{**}; Significant at 0.05 level</i>							

Table 2. Commonly Used Cloud Computing Applications

To know the frequently used commonly cloud computing applications, students were asked which cloud applications frequently they use. It is clear from Table 2 that the Social media cloud application is frequently used by a majority of students (97%) with a mean value of 1.06 and SD being 0.44 followed by GPS (96%) with a mean value of 1.08 and SD being 0.43, Meeting/Chatting (73%) mean value 1.75 and SD 1.41, learning Mgt S/w (68%) with mean value 1.61 and SD being 1.03 and Entertainment by 63% (mean = 2.12, SD = 1.62) of students. Further, the table shows that Art

Application is very rarely used by less of students (2%) with a mean value of 1.69 and SD being 0.96, while 3% of students rarely used Presentation application (Mean=2.35, SD= 1.60) and Image Editing S/W is rarely used by fewer students (1%) with a mean value of 2.13 and SD is 1.38. It is found from the table that very less of students frequently use cloud computing applications are Storage and Backup (12%), Accounting (7%), Cloud Antivirus (5%), and URL Conversion (1%). From the Chai-square result, students' preferences regarding cloud applications are different. Based on the statistical result the structure null hypothesis H2 is rejected.

Teaching/ Learning Mgt S/W	Very High N (%)	High N (%)	Moderate N (%)	Low N (%)	Very Low N (%)	Mean	SD
G Suite	108 (57)	45 (24)	23 (12)	11 (6)	3 (2)	1.72	0.99
Microsoft	76 (40)	55 (29)	45 (24)	5 (3)	9 (5)	2.03	1.08
Cloud Guru	26 (14)	15 (8)	20 (11)	79 (42)	50 (26)	3.59	1.32
Edlio	15 (8)	9 (5)	18 (9)	90 (47)	58 (31)	3.88	1.13
Evernote	59 (31)	39 (21)	32 (17)	55 (29)	5 (3)	2.52	1.27
Coursera	45 (24)	45 (24)	30 (16)	25 (13)	45 (24)	2.89	1.50
Knowledge Matters	62 (33)	29 (15)	21 (11)	25 (13)	53 (28)	2.88	1.64
Muzzy Lane	48 (25)	23 (12)	18 (9)	41 (22)	60 (32)	3.22	1.60
Top Hat's	39 (21)	19 (10)	32 (17)	66 (35)	34 (18)	3.19	1.40
<i>Notes: $\chi^2 = 493.8^{**}$; $df = 32$, Critical value = 46.19^{**}; Significant at 0.05 level</i>							

Table 3. Usage Preference of Cloud-Based Teaching Learning application

Table 3 shows that the G Suite Cloud learning application is very highly preferred by most students (57%) with a mean value of 1.72 and SD is 0.99. G Suite is a tool offered by Google that brings together several Google products like Google Classroom, Google Docs, Google Sheets, Google Slides, Google Forms, and Google Drawings. Students work together, in class or at home, to complete assignments and group projects. Microsoft is the second high preference for 40% of students followed by Knowledge Matters (33%), Evernote (31%), Muzzy Lane (25%), Coursera (24%), and Top Hat's (21%). Whereas, i.e. 14% and 8% respectively highly preferred Cloud Guru and Edlio cloud applications. It can be said that G Suite can fully satisfy all the needs of most students. Microsoft application offered by Microsoft is an application acting similar to G Suite, offered by Microsoft, but much less popular. Also, quite popular are Cloud Guru and Edlio, mainly because of their social dimension and their role. Because of the Chai-square result, students have different preferences regarding the usage of cloud learning applications, since the calculated value of Chai Square is more than the critical value.

Cloud Applications	Very High N (%)	High N (%)	Moderate N (%)	Low N (%)	Very Low N (%)	Mean	SD
WhatsApp	187 (98)	1 (1)	2 (1)	0 (0)	0 (0)	1.03	0.22
Facebook	182 (96)	4 (2)	2 (1)	1 (1)	1 (1)	1.08	0.43
yammer	11 (6)	36 (19)	27 (14)	70 (37)	46 (24)	3.55	1.21

LinkedIn	79 (42)	37 (19)	23 (12)	28 (15)	23 (12)	2.36	1.44
Twitter	115 (61)	40 (21)	17 (9)	13 (7)	5 (3)	1.70	1.06
You Tube	184 (97)	3 (2)	1 (1)	1 (1)	1 (1)	1.06	0.41
<i>Notes: $\chi^2 = 686.3^{**}$; $df = 20$, Critical value = 31.4^{**}; Significant at 0.05 level</i>							

Table 4. Usage Preference for Social Media-based Cloud Applications

Social media are becoming an important part of the student's life by offering a medium to promote their contact, sharing academic materials, and integrated applications that have now expanded beyond contact between friends. The study tries to explore which type of social media is preferred by students for academic purposes. Table 4 depicts that WhatsApp is very highly preferred by the majority of students (98%) with a mean value of 1.03 and SD being 0.22 followed by YouTube (97%) with a mean value of 1.06 and SD being 0.41, and Facebook by 96% of students (Mean 1.08 and SD being 0.43). Twitter is preferred by 61% of students (mean = 1.70, SD = 1.06) followed by LinkedIn (42%) with mean value 2.36 and SD being 1.44. Whereas Yammer is preferred by less number of students (6%) in their academic purpose. It can be said that social media tools i.e. WhatsApp, YouTube, and Facebook very highly preferred by the majority of students in their daily life and they easily can create a group to share their learning materials. Communication is the intended core of social media. It provides excessive opportunities for the higher education sectors to link, share and study. Due to the higher calculated value than the critical value, the Chi-square result indicates students have different usage preferences when it comes to cloud-based social media.

Data Storage/Backup Applications	Very High N (%)	High N (%)	Moderate N (%)	Low N (%)	Very Low N (%)	Mean	SD
Google Drive	129 (68)	20 (11)	11 (6)	18 (9)	12 (6)	1.76	1.27
pCloud	127 (67)	45 (24)	3 (2)	10 (5)	5 (3)	1.53	0.96
Microsoft Drive	67 (35)	49 (26)	27 (14)	28 (15)	19 (10)	2.38	1.36
Sync.com	89 (47)	32 (17)	29 (15)	12 (6)	28 (15)	2.25	1.46
Dropbox	98 (52)	62 (33)	7 (4)	6 (3)	17 (9)	1.85	1.21
Box	102 (54)	58 (31)	9 (5)	12 (6)	9 (5)	1.78	1.10
<i>Notes: $\chi^2 = 140.4^{**}$; $df = 20$, Critical value = 31.4^{**}; Significant at 0.05 level</i>							

Table 5. Usage Preference of Cloud Data Storage and Backup Application

Table 5 shows students' usage of various cloud data storage and backup applications. The result shows that Google Drive is a highly preferred cloud storage application by the majority of students (68%) with a mean value of 1.76 and SD is 1.27. Google Drive is a free file storing application that permits educators to stock and access documents located in the cloud. This app is esteemed as one of the most resourceful

cloud storage services because of its ability to synchronize stored files across mobile devices and PCs. The second preference is pCloud with 127 (67%) numbers of students with a mean value of 1.53 and SD being 0.96 followed by Box (54%) mean value of 1.78 and SD is 1.10. Dropbox is a cloud storage service that is preferred by 52% of students. Dropbox allows educators to store practically any kind of file on cloud servers remotely with the capability to share these files across all PCs or mobile devices. 47% of students preferred Sync.com to store and backup data on the cloud. Whereas Microsoft Drive is a powerful cloud storage service preferred by less number of students (35%) with a mean value of 2.38 and SD is 1.36. Result clearly depicts that Google Drive has the highest usage preference. It is the most popularly used application by students. This App can be accessed through a Google account as long as an Internet connection is present. Students can create a Google account, and they can access it. According to the Chi-square result, students are using cloud storage and backup applications differently preference because the calculated value is higher than the critical value.

Meeting/Chat Application	Very High N (%)	High N (%)	Moderate N (%)	Low N (%)	Very Low N (%)	Mean	SD
Zoom	172 (91)	15 (8)	3 (2)	0 (0)	0 (0)	1.11	0.36
Google Meet	181 (95)	6 (3)	2 (1)	1 (1)	0 (0)	1.07	0.34
Cisco WebEx	142 (75)	26 (14)	19 (10)	1 (1)	2 (1)	1.39	0.77
GoToMeeting	117 (62)	45 (24)	12 (6)	7 (4)	9 (5)	1.66	1.07
Microsoft Teams	21 (11)	19 (10)	60 (32)	65 (34)	25 (13)	3.28	1.15
Whereby	9 (5)	18 (9)	64(34)	70 (37)	29 (15)	3.48	1.01
<i>Notes: $\chi^2 = 676.08^{**}$; $df = 20$, Critical value = 31.4**; Significant at 0.05 level</i>							

Table 6. Usage Preference of Meeting/Chat Cloud Based Applications

Meeting and chatting cloud applications have become part of our everyday lives because of lively interactions such as face-to-face conversations and easy-to-use features. Table 6 shows that students use various chat applications. It is clear from the result that Google meet is a highly preferred application among the majority of students (95%) with a mean value of 1.07 and SD being 0.34 followed by Zoom (91%) mean value of 1.11 and SD being 0.36 and Cisco WebEx (75%) with mean value 1.39 and SD being 0.77. GoToMeeting is preferred by 117 (62%) numbers of students with a mean value of 1.66 and SD is 1.07. Further, the table shows that Microsoft Teams is preferred by less number of students (11%) with a mean value of 3.28, SD being 1.15 and whereby is by 5% (mean=3.48, SD=1.01) of students. Students preferred cloud Meeting/Chatting applications differently according to the Chi-square results because the calculated value is higher than the critical value.

Statements	Agree N (%)	Neutral N (%)	Disagree N (%)	Mean	SD
Additional electronic devices, such as CDs, DVDs, and Pendrive are not required.	180 (95)	4 (2)	6 (3)	1.08	0.37
Data stability and security.	152 (80)	27 (14)	11 (6)	1.26	0.55
It's easy to trace changes and return to a previously saved file.	125 (66)	46 (24)	19 (10)	1.44	0.67
Paper consumption is lower.	169 (89)	10 (5)	11 (6)	1.17	0.51
Reduced physical storage of documents.	172 (91)	16 (8)	2 (1)	1.11	0.34
Saving time by using electronic storage.	179 (94)	9 (5)	2 (1)	1.07	0.29
Reduced printer, toner, and paper costs.	126 (66)	52 (27)	12 (6)	1.40	0.61
Document access without a third party has better employment effects.	110 (58)	46 (24)	34 (18)	1.60	0.77
Use of cloud services is easier.	119 (63)	56 (29)	15 (8)	1.45	0.64
Has a positive impact on the environment by reducing paper, energy, and computer hardware.	156 (82)	21 (11)	13 (7)	1.25	0.57
<i>Notes: $\chi^2 = 225.6^{**}$; $df = 18$, Critical value = 28.8^{**}; Significant at 0.05 level</i>					

Table 7. Reasons for using Cloud Applications by students

Table 7 shows students' opinions toward the usage of Cloud Applications. It is clear from the table result that the highest number of students agree with the statement that the use of the cloud no need to carry around additional electronic devices, the reduced physical storage of documents, and time-saving in using electronic storage. 89% of students (mean= 1.17 and SD= 0.51) agree that cloud applications reduce paper consumption followed by has a positive impact on the environment by reducing paper, energy, and computer hardware (82%) with a mean value of 1.25 and SD being 0.57, and Data stability and security (80%) with mean 1.26 and SD 0.55. Further, the table shows that 66% of students agreed that cloud application is cost savings by reducing the use of printers, toner, and paper followed by trace changes and return to a previously saved file (66%), ease of use of clouds (63%) and Document access without a third party has better employment effects (58%). The calculated value of Chi-square does not indicate any similarity in opinion about using cloud applications among students and structure null hypothesis H3 is accepted.

Statements	Agree N (%)	Neutral N (%)	Disagree N (%)	Mean	SD
Limited technology experience	54 (28)	118 (62)	18 (9)	1.81	0.59
Lack of past experience on using Cloud application technology	90 (47)	63 (33)	37 (19)	1.72	0.77
Lack of motivation	120 (63)	40 (21)	30 (16)	1.53	0.75
Too challenging in usage	68 (36)	88 (46)	34 (18)	1.82	0.71
Lack of instructions	123 (65)	44 (23)	23 (12)	1.47	0.70
Avoiding commonly used online tools such YouTube, Facebook by instructors	24 (13)	152 (80)	14 (7)	1.95	0.44

Living close to educational institutions	79 (42)	67 (35)	44 (23)	1.82	0.78
Wi-Fi Internet Connectivity	29 (15)	153 (81)	8 (4)	1.89	0.43
Security	36 (19)	136 (72)	18 (9)	1.91	0.52
Password Security	30 (16)	20 (11)	140 (74)	2.58	0.75
Cost Management	21 (11)	153 (81)	16 (8)	1.97	0.44
Multi-Cloud Environments	120 (63)	54 (28)	16 (8)	1.45	0.65
Lack of cloud infrastructure in Campus	39 (21)	135 (71)	16 (8)	1.88	0.52
<i>Notes: $\chi^2 = 1023.7^{**}$; $df = 24$, Critical value = 36.4^{**}; Significant at 0.05 level</i>					

Table 8. Barriers faced in using cloud application services by students

There are many problems associated with the use of cloud applications by students. While getting information from the students, they were asked to mention the problems faced by them during the usage of the Cloud Application. Table 8 reveals that the majority of students have faced the problem of lack of instructions (63%) with a mean value of 1.47 and SD being 0.70, lack of motivation (63%) with a mean value of 1.53 and SD being 0.75, and multi-Cloud environments (63%) with a mean value of 1.43 and SD being 0.63 to use the cloud applications. Although the majority of students are neutral with the statement of Wi-Fi Internet Connectivity (81%), Cost Management (81%), voiding commonly used online tools such YouTube, Facebook by instructors (80%), Security (72%), and lack of cloud infrastructure in Campus (71%). Using Chi-square, it is found that there is no similarity in the problems faced by students while using cloud applications and the structure null hypothesis H4 is accepted.

7. Conclusions

In the current years, cloud computing has created imaginative applications that help teachers and students in education structures. In order to improve students' virtual and visual abilities, worldwide educators are using cloud applications. By implementing cloud-based advancements in education and educational experiences, educators are promoting their learning plans and inspiring students to rely on cloud-based applications in their learning processes. A powerful framework is essential to implement cloud enhancements in teaching and learning centers, as they required positive support. In the usage of cloud computing students face can problems with a lack of instructions, motivation, multiple cloud environments, and limited internet Wi-Fi access.

According to the results of the study, the majority of students are familiar with cloud applications and have been using cloud-based services for more than a year. Further, the study shows that most students prefer to use G Suite, Microsoft, and Knowledge Matters cloud learning applications. The findings also show that students prefer to use social media applications for learning, like WhatsApp, Facebook, and YouTube. Most students in the study preferred Google Meet and Zoom for cloud-based meeting software. They offer video conferencing software and other meeting

software, allowing users to get in touch in no time through screen and desktop sharing. In the network-based environment, there are many popular video conferencing and meeting software in the market that attracts users who are looking for a simpler and more affordable option through their free tiers and accessibility. Many students use Google Drive and pCloud to store and secure their data. Study proved that students are facing the problem of instructions, motivation, multiple cloud environments, and limited internet Wi-Fi access while using cloud applications. The study concludes that it is very important to confirm that cloud-based applications support a greater level of goal consistency in the way students learn. Moreover, Kurukshetra University should make its students more educated about cloud services and increase their basic understanding of cloud applications and learning methods by conducted workshops, which will enhance their confidence in utilizing cloud applications for improving learning performance. Also, the university should try to remove the barrier to the usage of cloud application services by students. Because of the findings, cloud-based learning programs are currently in a period of great advancement in mechanical technology and are attracting students' attention. Using cloud-based advancements, the study predicts students' academic performances.

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A Study on Petri Net Supporting Tools for System Modeling and Analysis

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Abstract

Within this work we analyze and compare ten Petri net supporting tools for system modeling and analysis. A short summary of several available overviews of Petri net tools is performed before the tools analysis itself to evaluate the current state in this field. Principal parts of the paper are focused on analysis and evaluation of the selected tools. We provide detailed and practical description of selection of up to date tools, their evaluation based on various criteria, and recommendations for several use cases.

Keywords: analysis, modeling, Petri nets, supporting tools, tool comparison

1. Introduction

Petri nets are a widely adopted formal method [1], [2] for modeling and analysis of various types of systems. Process of modeling using Petri nets is greatly supported by their simple visual representation. On the other hand, they provide powerful modeling and analytical options [3], where some of them are unique to Petri nets. Because of that, when working with Petri nets, a suitable tool should be picked. Therefore, it is useful to have an overview that would describe the Petri net tools to potential users. And even though there are some overviews available, they are often outdated [4], [5], or do not analyze every tool [6]. And because of that, new overviews are needed over time. Therefore, the objective of this paper is to create a new overview of such tools.

Because of their modeling and analytical power, there are several ways, in which Petri nets can be used. The tools in this work were chosen in a way that tries to include up-to-date, freely available tools with a broad variety of supported Petri net types and corresponding modeling and analysis options that can be used in scientific, educational or even professional environment. More details on this work can be found in the related thesis [7].

2. Petri Nets

Petri nets [8] were described by Carl Adam Petri in his thesis in 1962 for the first time. They are instances of bipartite directed graphs that contain two types of nodes – places and transitions that alternate each other. *Places* [8], [9] are used to represent states of the modeled system and are depicted as circles. *Transitions* are used to represent events that may change the current system state and are depicted as boxes or bars. In every Petri net, a set of places and a set of transitions are disjoint sets [10], which means that there is no object that can be a place and a transition at the same time. Places and transitions are connected to each other by *arcs* [11], represented by arrows. Every arc must connect exactly one place and one transition [8]. An arc may also have a positive integer labeled to it [12], expressing its *weight*. The last element that can be found in Petri nets, is a *token* [11] that moves around the net, representing changes of the system's state.

Tokens can be present only in places, never in transitions or arcs, and their movement must be only in the direction of the arcs. This movement is performed by firing transitions [12]. When a firing of a particular transition occurs, a token is removed from every input place and is put to every output place of that transition. If an arc has a weight labeled to it, the number of tokens removed from or added to a place is equal to that particular weight. That means that each input place of a particular transition must contain a number of tokens that is equal than or greater to the weight of the arc that connects that place to the transition before a firing of that transition occurs. If this condition is fulfilled, we say the transition is *enabled* [3].

Any sequential firing of transitions of a Petri net is called a *firing sequence* [12].

2.1. Petri Net Properties

There are two types of Petri net properties [8] – behavioral and structural. Behavioral properties depend on the initial marking of the net. They include *reachability*, *boundedness*, *liveness*, *coverability*, *reversibility*, *persistence*, *synchronic distance* and *fairness*. Structural properties are not dependent on the initial marking of the net, only on the topological structure of the net. They include *structural liveness*, *(complete) controllability*, *structural boundedness*, *conservativeness*, *repetitiveness*, *consistency* and *structural B-fairness*. Further information about these properties can be found in [8].

2.1.1. Property Analysis Tools

There are several ways to analyze some Petri net properties. For example, reachability and coverability can be analyzed using a *reachability tree* [12] that contains all reachable markings or a *reachability graph* [13] that can be created from a reachability tree by representing nodes with the same marking as a single node. Similarly, it is possible to create a *coverability tree* and a *coverability graph* [8].

Incidence matrix [8] $A = [a_{ij}]$ is an $n \times m$ matrix, where n represents the number of places and m the number of transitions. Each matrix entry is a difference of the

weight of the arc directed from a specific transition to a specific place and the weight of the arc directed from that place to that transition.

Invariants [12] can be divided into two groups – *S-invariants* (sometimes called *P-invariants*) and *T-invariants*. An S-invariant [8] is a vector y , consisting of m elements that is a solution of the equation $Ay = 0$. A T-invariant [8] is a vector x , consisting of n elements that is a solution of the equation $A^T x = 0$.

State equation [12] is an equation, which, given the current marking m_k , can predict the following marking m_{k+1} by the k -th firing, where $k \geq 0$.

Model checking [14] is a way of verifying system models. The procedure uses a logical formula φ and a structure M and tries to decide, if M satisfies φ . There are two types of model checking – LTL (or PLTL) [14], [15] and CTL [14]. Their respective grammars are defined e.g. here [16].

When analyzing Free Choice Petri Nets (defined in 2.2), there are two important types of place sets [9]. A *siphon* is a set of places that cannot get back tokens they lost. A *trap* is a set of places that cannot lose tokens, once they get them.

2.2. Petri Net Types

There are several types and extensions of Petri nets. The basic classification can be made by dividing Petri nets into three levels. Types of Petri nets that fall under these levels are listed on the Petri Nets World website [17].

In the remainder of this section, the most important Petri net types are mentioned and described.

Place/Transition (P/T) Petri Nets [17] are Petri nets, where places may contain several simple tokens and can represent integer values. They may also contain places with token capacities and arcs with weights.

State Machine [9] is a Petri net, where every transition has exactly one input place and one output place. *Marked Graph* is a Petri net, where every place has exactly one input transition and one output transition. *Free Choice Petri Net* is a Petri net, where every arc from a place is either the only output arc of that particular place, or the only input arc of a particular transition.

Colored Petri Net [18] is a Petri net, in which every token is assigned a specific color that can represent complex values. Each place and transition has a set of colors, it can interact with. A token color may change after a transition firing.

Workflow Petri Net [19] is a Petri net with only one starting and only one ending place.

There are several Petri net types that can operate with time. *Timed Petri Nets* [20] have a firing duration set for each transition. Some definitions [21] allow setting time durations to places and directed arcs, too. They can be divided into *Deterministic Timed Petri Nets* where those durations are either set, or there is at least an interval, which those durations must fall within, and *Stochastic Timed Petri Nets*, where those durations are randomized. *Generalized Stochastic Petri Nets* are Stochastic Timed Petri Nets that have an exponentially distributed random firing times set that coexist with firing delays. Those delays are deterministically equal to zero. As for Timed Petri Nets in this work, only timed transitions will be considered, if not stated otherwise.

Time Petri Nets [22] have a time interval set for each transition. The time this interval is associated with starts, when the transition that has this time assigned becomes enabled. A particular transition may be fired if enough time has elapsed, since it became enabled. This time, however, cannot go above the upper limit of the interval. *Timed-Arc Petri Nets* [23] are Petri nets, where every token has an age and arcs that go from a place to a transition have set time intervals that allow only tokens with an age in said interval to be moved.

In workflow Petri nets, a new property – *soundness* can be defined. This property is described in [24]. *Soundness* and *strong soundness* in relation to timed-arc Petri nets are described in [25].

2.3. Petri Net Markup Language

Petri Net Markup Language (PNML) [26] is an interchange format for Petri nets, based on XML. It is an international standard. Grammar of the language is available on the official website. The main point of PNML is to allow users to create compatible Petri net files with different tools [27]. For a tool to be considered a PNML supporting one [26], it has to be able to successfully import and export PNML files. Users may also create their own extensions of the language. Those extensions will, however, not be standard-compatible. Nowadays, there are many Petri net tools that accept PNML files [1].

2.4. Existing Overviews of Petri Net Tools

This section describes existing Petri net tools overviews. It will describe their methodologies, the amount of analyzed tools, their recency and their advantages and disadvantages.

2.4.1. Petri Nets Tool Database

This database [4] is very likely the largest overview that exists. It consists of approximately one hundred different tools. Information about the tools includes their homepage, availability, system environments, supported types of Petri nets, features, short tool description and contact details for authors of the tools.

The database also allows its users to view a table with an information summary of the tools and to add their own tool to it.

The biggest drawback of the database is the fact that, because the older tools are no longer reviewed, a lot of the tools are pretty old and, as a result, many times it is impossible to access their homepages.

2.4.2. A Survey of Petri Net Tools

This survey [11] is one of the shorter ones. Tools mentioned there are described very briefly. On the other hand, there is a decent amount of the tools mentioned in the paper. And, what is more, it is still possible to access most of the tools.

There are two tables at the end of the paper. One of them contains a summary of all tools and information about them – supported types of Petri nets, features, environments, they can run on and whether or not they are free of charge. In the other table, there is a list of recommended tools that are mentioned in the survey, for users' operating system and a required Petri net type.

The paper also chose the best tool of the analyzed ones – PETRUCHIO. The homepage of this tool is, however, no longer accessible.

2.4.3. Petri Net Tools – A Comparative Study

This study [5] is one of the longer ones. Before the descriptions of the analyzed tools are presented, the study describes its methodology and a tabular summary of all the tools.

The study evaluates technological and user costs and advantages of the tools. It evaluates the following: analysis options, net dynamisation, generation, user interface, available file formats for export, import, default file format, documentation and other sources of information about the tools, their experience and how the tools may be applied or combined.

The largest drawback of this study is that it is considerably old. It was written in 1996. It is, however, at least possible to take a look at its methodology of analysis and comparison.

2.4.4. A Comparison of Petri Net Simulation Tools

This paper [6] is one of the newer ones. It analyzes three Petri net tools – Pipe 2, CPN Tools and HP Sim. What is more, all three tools are still available at the moment. The overview provides information about the tools, about supporting types of Petri nets, their components and features, required system environments and evaluates their user interfaces.

The biggest disadvantage of this paper is that there are not many tools analyzed. This may not be sufficient for some readers. However, if one does not have very specific requirements while searching for a Petri net tool, this overview may be the one for them, because in others they might have too many options.

2.4.5. Demonstration Tools for Petri Nets

This thesis [28] analyzes six different tools. However, it is designed to find the best tool for educational use. The thesis provides the following information about the tools – origin information, supported Petri net types, distribution, system requirements, documentation, user interface and features of the tools.

The biggest advantages of this thesis are its clarity, because it is easy to find necessary information, thanks to clear paragraph segmentation, the fact that the descriptions contain practical information and screenshots of user interfaces.

A disadvantage of this thesis, as a Petri net tools overview, is that the tool summary and the information about the tools are not placed together. This can make navigating around the document and connecting information a bit more challenging.

2.4.6. *Summary*

One can say that there are quality Petri net tools overviews, although with some flaws. Every one of the overviews, however, had some qualities. If the quality is not information about the analyzed tools, it is at least an analysis and comparison methodology.

3. Tools Overview

The next part is an overview of various Petri net tools. It describes the tools and points out their advantages and disadvantages.

There are following information stated about the tools in this overview: supported Petri net types, available features, system requirements, user interfaces, experience, while using the tools, etc. There results of the review are summarized in tabular form at the end of the paper.

3.1. CPN Tools

CPN Tools [29] is a tool for colored and timed Petri net modeling, simulation and analysis.

When it comes to the Petri net analysis, the tool is able to analyze boundedness, liveness, fairness and perform home state analysis. To view the results, however, it is necessary to generate a file that contains them. The tool also contains state space analysis options [30] that contain an option to generate reachability graphs [29], [31].

When it comes to working with time in CPN Tools, it is possible to create timed colored Petri nets [29] that use timed color sets. Using these color sets, it is possible to set a time stamp to each token and restrict their movement based on a time counter. Time attributes for transitions and arcs can be simple time delays, or in case of arcs that go from a place to a transition, an amount of time that transition can fire earlier, but these attributes may be more complicated expressions, as well. As an example, it is worth mentioning random time delays from a specified interval, or an option to pick a time delay from a set interval [32].

CPN Tools also contains a variety of performance analysis tools and options [29] that include the ability to collect statistical data during simulations, such as an amount of tokens in a place or how many times a particular transition occurs in a simulation. These data may be saved to a file afterwards.

Other functionalities [29] of CPN Tools include the ability to perform model checking using a CTL-like temporal logic, write queries using an ML language and view net statistics [32].

The biggest disadvantage of CPN Tools is that the tool is very complicated to use. Even learning the bare minimum may take the whole day [6] and mastering the tool

much longer. Therefore, it is recommended just to be patient, research information online and experiment with the tool.

It should be noted that development on CPN Tools has been stopped recently [29] and a new tool – CPN IDE [34] has replaced this tool.

CPN Tools is available under GNU GPL v2 license [29].

3.2. Time petri Net Analyzer

Time petri Net Analyzer (TINA) [35] is a tool that, as the name suggests, primarily used for modeling, simulation and analysis of time Petri nets.

When it comes to Petri net analysis, one can analyze boundedness, liveness, reversibility, consistency, create reachability, coverability and marking graphs, perform structural analysis and reachability checking using TINA. The tool also allows performing model checking, as well as other options using commands. A list of command and model checking manuals is present on the official webpage [35].

The analysis results can be exported to various file formats. All of them, except ".ktz", can be basically interpreted as ordinary text files.

Disadvantages of TINA include not very smooth arc design and inability to display most of the special characters. A temporary solution for the latter is copying them from elsewhere and pasting them into the editor. However, after closing and re-opening the application, those characters no longer appear on screen.

In the file README.txt is some information about licensing, or availability, but not the specific license. After communication with Dr. Bernard Berthomieu, it was discovered that TINA is not available under a specific license, but it is distributed as a free-ware.

3.3. TAPAAL

TAPAAL [36], [37] is a tool for modeling, simulation and analysis of timed-arc P/T Petri nets developed at the Aalborg University in Denmark.

It is necessary to have Java runtime Environment v. 11.0 or higher [36] installed to be able to use the tool. However, on some higher versions it is possible that the tool will not run, so it is recommended to have exactly version 11.0 installed.

The tool offers various ways of analyzing Petri nets that include deadlock analysis, analyze k -boundedness for a specific k entered by user, compute minimal possible k , and analyze workflow nets – identify their starting and ending places, determine their soundness, strong soundness. The tool also allows its users to perform model checking, view net statistics and automatically change the net design based on user entered criteria.

An interesting feature of TAPAAL is an option to use Automatic Net Layout, which is an automatic way of changing a shape of a net using criteria set by a user.

The tool parts are licensed differently [36]. The user interface is available under Open Source License 3.0, but other parts are under BSD, or GNU GPL v2 licenses.

3.4. Petri Net Simulator

This tool [38] is a simple web application. It can only model and simulate P/T Petri nets and it does not offer any analysis options or PNML support.

Execution of modeling and simulation is very simple, however, if necessary, there is a video [39] that explains usage of this tool.

One of the biggest disadvantages of this tool is that there is no way to choose, which transition will be fired next. The tool fires all available transitions instead. This may cause unexpected behavior during the simulation of some models. Another drawback is that there is no way to move multiple net components at once. However, if there is a situation, in which it is necessary to extend the drawing board, it is possible to do so by making the webpage smaller by zooming out.

Because the tool is a web application, it does not have to be downloaded and installed. Therefore, it is relatively easy to access it.

3.5. Platform Independent Petri net Editor 2

Platform Independent Petri net Editor 2 (PIPE2) [40], [41], [42] is a tool used for modeling, simulation and analysis of P/T, generalized stochastic and colored Petri nets [40], [43]. It was created as a group project on Imperial College London [40].

The nets, created with this tool, are automatically saved as PNML files in a XML format. However, it is possible to export the nets to PNG format [40].

The tool offers several Petri net analysis options. It can determine whether or not a created net is a marked graph, a state machine, or some other type. The tool offers deadlock and invariant analysis, can calculate minimal siphons and traps and create a reachability/coverability graph and an incidence matrix.

PIPE2 is able to analyze liveness and boundedness of the network, as well, using positive T-invariants. When it comes to the liveness analysis, if the invariants are not used for the analysis, only existence of deadlocks can be checked.

The tool also offers performance analysis and computation of time and state metrics and analysis functions for generalized stochastic Petri nets.

When it comes to colored Petri nets, it is necessary to click the "Specify tokens" icon in the menu, represented by the palette, or press keys Ctrl, Shift and T simultaneously in order to set token colors and manually set arc attributes in order to enable transitions [43].

The latest version is version 5 [43], however, the recommended version is version 4 [40], [43]. The newest version [43] does not offer most of the modules the older one does. Version 5 is available under MIT License [43], version 4 is available under Open Software License 3.0 [44].

3.6. WOLFGANG

This application [45] supports modeling, simulation and analysis of P/T and colored Petri nets. Even though the developers of the tool mention only Java Runtime Environment 1.8 as a necessary system prerequisite [46], it is possible to run the tool

using a higher version, as well, as proven, when the tool successfully ran using OpenJDK 11 and 16.

When it comes to analysis options, the tool is able to analyze boundedness, although it is not possible to compute the number k , determine if a created net is an instance of a workflow net and if it is, it can determine the soundness of it.

Arcs are created by pressing a center of a place or a transition [45]. When creating a new place or a transition, it is possible to either create a new instance from the menu, or to place an arc into an empty space. This feature may rapidly increase modeling speed after a bit of training. It should be also said that when modeling a net, it is recommended to decrease the default size of places and transitions.

The biggest advantage of the tool is the simple way of modeling and analysis of colored Petri nets – setting colors, weights of arcs, or the fact that modeled nets have a very clear design. The tool is available under BSD 3-Clause license [46].

3.7. Snoopy

Snoopy [47], [48] is a tool that supports P/T, colored, time, timed, stochastic and other various kinds of Petri nets. The tool provides users with various modeling and simulation options that are offered based on a type of a modeled Petri net. It was developed at Brandenburg University of Technology, Cottbus-Senftenberg, Germany [49].

The tool is primarily used just for modeling and simulation of Petri nets [47]. For further analysis, tools Charlie and Marcie are recommended. However, as a part of the stochastic simulation, probabilistic LTL model checking can be performed, as described in [50]. Snoopy allows users to draw e. g. reachability graphs [48], too, but is unable to generate them itself.

For the work with colored Petri nets, it is better to read a manual [51], because the way of using colors in Snoopy is quite complex.

If needed, net attributes can be changed after a double click on them. Because of that, when it comes to arcs, it is more practical to draw them longer, or to drag any text further away from it, since the tool may detect the click as a click on that text.

Snoopy also offers a great variety of import and export options for the files.

When installing the tool, it is recommended to create an empty folder beforehand, because the tool will not do so during the installation.

3.8. Charlie

Charlie [49] is a tool that is used to analyze P/T Petri nets. It was created by developers of Brandenburg University of Technology, Cottbus-Senftenberg, Germany and Université Blaise Pascal, Clermont-Ferrand II, France.

The tool allows users to analyze files, created by Snoopy that were exported as ANDL or APNN files, and PNT files of the tool INA [49].

Charlie allows users to analyze structural boundedness, compute P and T invariants, incidence matrix, generate coverability and reachability graphs in graphic form, perform deadlock analysis or find siphons and traps. The tool also allows

analyzing nets using model checking. An interesting analysis function is the ability to find the shortest and the longest path in an analyzed net.

The application also features a table, containing analysis information about the net. The information in this table contain liveness, reversibility, k -boundedness, structural boundedness and conservativeness analysis, whether every transition (or place) has a pre or a post place (or a transition) and some more. Further information, including persistence check, can be found in the generated text protocol, as well.

It is recommended to create an empty folder first, when installing the tool, for the same reason as with Snoopy.

3.9. HPetriSim

This tool [52] is used to model and simulate P/T and timed Petri nets.

It is a modeling and simulation tool only, meaning that there is no way to perform complex analysis of created nets in this tool.

In the menu of the application, the most important options are in the menu "Format", while clicking a place, transition, or an arc. This is, for example, an option to make timed transitions, or to put tokens in places.

However, the biggest problem is that there is no way of choosing, what transition should be fired next. The program chooses it automatically. Because of that, when there is a need to choose a concrete transition from a group of enabled transitions to be fired, the tool may not work properly. Another drawback of this tool is that after a simulation, tokens remain graphically in the places, where they ended, but they are still present in their initial places in the menu "Format". The tool is available under GNU GPL v3.0 license [52].

3.10. WoPeD

WoPeD (Workflow Petri Net Designer) [53] is a tool created by the developers of Cooperative State University Karlsruhe, Germany. It is primarily used to model, simulate and analyze workflow Petri nets.

To run the tool, it is necessary to have Java Runtime Environment 11 or more installed [53].

Like in WOLFGANG, it is possible in WoPeD to create arcs, connected with places or transitions, by simply drawing an arc without connecting it to anything. Since arcs are drawn the same way, as in WOLFGANG, one could assume that while learning, how to use the tool, some unintended places and transitions would be drawn. However, this would most likely not be the case here, since the area, you need to click in order to create an arc, is very small.

For regular P/T Petri nets there are some analysis options in WoPeD. The tool is able to generate net metrics or generate a coverability graph that may be exported as a PNG image. Reachable markings of the net can be displayed by clicking on the nodes of this graph. Other features include analysis of P-invariants, soundness, liveness and boundedness.

When it comes to workflow Petri nets, there are some interesting features present in this tool. It is possible to analyze a plan of real-life events, especially in business. Logic gates can be put in place of transitions. When there is a transition connected to two output places a probability of a system transferring to states, represented by those places, can be set. Every transition may also be given a message, a resource, or a time trigger. It is also possible to compute expected length and resources of every action of a set plan and to set a role to each of those actions. Sound workflow Petri nets may also be converted into a textual description and vice versa. The tool is available under GNU Lesser General Public License [53].

4. Evaluation

This section serves as a brief summary and evaluation of all analyzed tools. It mentions some information about the tools, mostly using tables. It contains recommendations about the usage of the applications, as well.

4.1. Supported Petri Net Types

The Table 1 shows, what types of Petri nets are supported by the tools. In order for a tool to be counted for the column labeled as "Time", a tool needs to support at least one of Petri net types that use time, as described in section 2.2.

	P/T	Time	Colored
CPN Tools	✓	✓	✓
TINA	✓	✓	
TAPAAL	✓	✓	
Petri Net Simulator	✓		
PIPE2	✓	✓	✓
WOLFGANG	✓		✓
Snoopy	✓	✓	✓
Charlie	✓		
HPetriSim	✓	✓	
WoPeD	✓		

Table 1. Supported Petri net types.

The only three tools that support all Petri net types in all three categories are CPN Tools, PIPE2 and Snoopy. Snoopy, however, can support many more types, making it the most versatile tool in this regard.

4.2. Supported Operating Systems

The Table 2 shows, what operating systems are supported by every tool. Please note that the table does not specify concrete operating system versions, so the tools may not work properly on every device, especially, when using an older version of an operating system.

When it comes to Petri Net Simulator, there is no official information on supported operating systems. Since the tool is available online, the whole row is filled with the word "internet".

Most of the tools support all three biggest computer operating systems. Only CPN Tools and HPetriSim support only Windows. It should be noted, however, that the CPN Tools does not support Mac OS X as a whole, but the simulator in the tool is supported for this operating system [29]. This fact is represented by the "*" character in the table. The simulator runs on Linux, too, but this version is unsupported [29], so it is not considered for this table.

	Windows	Linux	Mac OS	Solaris
CPN Tools	✓		*	
TINA	✓	✓	✓	✓
TAPAAL	✓	✓	✓	
Petri Net Simulator	internet	internet	internet	internet
PIPE2	✓	✓	✓	
WOLFGANG	✓	✓	✓	
Snoopy	✓	✓	✓	
Charlie	✓	✓	✓	
HPetriSim	✓			
WoPeD	✓	✓	✓	

Table 2. Supported operating systems [7].

4.3. Supported Petri Nets Properties and Functions

The table 3 shows analysis of what properties is possible in the analyzed tools.

	Rea	Bnd	Liv	Cov	Snd	Rev	Csv	Prs	Cst	Frn
CPN Tools	✓	✓	✓			✓*				✓
TINA	✓	✓	✓	✓		✓			✓	
TAPAAL		✓	✓*		✓s					
Petri Net										
PIPE2	✓	✓	✓	✓						
WOLFGANG		✓			✓					
Snoopy										
Charlie	✓	✓S	✓	✓		✓	✓	✓		
HPetriSim										
WoPeD	✓	✓	✓	✓	✓					

Table 3. Supported Petri net properties. The acronyms in the table have the following meaning: Rea – reachability, Bnd – boundedness, Liv – liveness, Cov – coverability, Snd – soundness, Rev – reversibility, Csv – conservativeness, Prs – persistence, Cst – consistency, Frn – fairness.

Please note that only automated analysis is counted for this table, meaning that e. g. manual modification of place capacity, to make a net k -bounded is not counted. Analysis options using model checking are excluded from the table, as well.

When it comes to analyzing Petri net properties, Charlie could analyze most of them. Its ability to analyze structural boundedness is noted by the letter "S" in the table, whereas TAPAAL's ability to analyze strong soundness is noted by the letter "s". The star characters in the table represent the fact that when it comes to reversibility, CPN Tools can perform home state analysis and when it comes to liveness, TAPAAL can analyze deadlock existence.

When it comes to model checking, the tools that allow users to perform it are TINA, TAPAAL, Charlie and Snoopy, but Snoopy offers model checking only for a fraction of supported Petri net types. However, files, created with this tool, may be exported to other tools that support model checking [54].

The other features worth pointing out are invariant analysis, supported by TINA, PIPE2 and Charlie, and siphon/trap analysis, supported by PIPE2 and Charlie.

There are, obviously, more features that these tools can offer. Those have been mentioned in detailed analysis for each tool. For this summary, only the most important features have been picked.

4.4. PNML Support

PNML is supported by the following of the mentioned tools:

- CPN Tools,
- TINA,
- TAPAAL,
- PIPE2,
- WOLFGANG,
- Snoopy,
- WoPeD.

When looking at the list, it could be assumed that at least every P/T Petri net, exported as a PNML file, created by any one of these tools, could be opened in the others without issues. But that is not always the case. When using CPN Tools, the tool could not open other tools' files and when trying to open PNML files created by CPN Tools, only WoPeD managed to do it, but the text of the net was grouped together in one area. Problems that arose while importing PNML files to Snoopy from other tools were mainly with the net shape and problems while importing to WoPeD were mostly with text that behaved like described in the example with CPN Tools. When trying to import Snoopy's and WoPeD's files elsewhere, there was not a single attempt that would be entirely successful, too. Snoopy's PNML files lacked layout information. TAPAAL handled this task the best, using its Automatic Net Layout feature. WoPeD's PNML files were successfully opened only by PIPE2, WOLFGANG and Snoopy, but the text in PIPE2 and WOLFGANG was scattered, the marking in PIPE2 and Snoopy was not present and Snoopy did not preserve the correct shape of the net.

When it comes to PIPE2, to import/export PNML files from/to other tools, it is necessary to change the file type from .pnml to .xml and vice versa. The only

successful import to this tool was using WoPeD's file which was described earlier. As for exports, files from PIPE2 were successfully opened by Snoopy, but the file lacked marking and was not in the correct shape, and WoPeD, but the tokens and the text disappeared.

It is also important to state that the import of PNML files created by WoPeD and PIPE2 to Snoopy works only using the "Import High-Level Petri Net PNML" option.

When it comes to exports of TINA's PNML files, apart from the problems mentioned earlier, wrong text appeared in TAPAAL and Snoopy. Export to WOLFGANG was a total success. As for imports, TAPAAL's and WOLFGANG's PNML files were imported successfully and Snoopy's file was shown only as text. Imports of other files were not successful.

Using TAPAAL and WOLFGANG, it is possible to perform a successful PNML import and export between these two tools. Problems that arose while performing import to and export from other tools, while using this duo of tools, were covered in the earlier part of this subsection.

4.5. Recommendations

Obviously, not every tool is suitable for every purpose. This part will, therefore, try to recommend tools for different purposes.

For scientific use, the best tools are CPN Tools, TINA, PIPE2, Snoopy and Charlie. CPN Tools and TINA can analyze a broad variety of analysis options, but the tools are not that easy to handle. PIPE2 is very straightforward to use and contains many analysis options. A combination of Snoopy and Charlie may seem complicated at first, but thanks to a massive pool of features it is most likely the best fit for scientific research. Other suitable tools include TAPAAL and WoPeD, thanks to a decent amount of analysis options.

For high school students, the best tools may be PIPE2 and TAPAAL, due to the fact they are not difficult to use and may be used to analyze Petri nets, and Petri Net Simulator because of its simplicity. Other suitable tools are TINA, WOLFGANG and WoPeD.

With all of this said, it is possible that sometimes it will be necessary to use multiple tools at once, because there is simply not a perfect, universal tool containing everything.

4.6. Comparison to Existing Overviews

The main goal of this paper was to create an overview that would contain currently available tools. Obviously, this goal has been successfully achieved.

One of the advantages of this paper is that there was some practical experience mentioned when describing most of the tools. These things are usually absent in most of other overviews.

In "Demonstration Tools for Petri Nets" [28] and "A Comparison of Petri Net Simulation Tools" [6] are some of those facts mentioned, but most of the tools that are mentioned here, are not present in those overviews. In "Petri Net Tools – A

Comparative Study" [5] is not mentioned even one of the tools, analyzed here. And the official database [4] and "A Survey of Petri Net Tools" [11] contain a very limited amount of information on user experience while working with the tools or tips for using them. Therefore, it is possible to say that this paper brings new information to the table.

If there is a need to look up information about a tool, not mentioned here, it is recommended to check out the official database [4]. It is very likely that the tool will be mentioned there.

5. Conclusion

To make the process of modeling and analysis using Petri nets easier, it is very useful to know, what tool is appropriate for this task. Whether a simple interface is enough, or complicated analysis options are necessary. That is what tools overviews are for. And, as it was stated, there are quite a few of them, but there is not a perfect one. Therefore, this overview is just a small part of the group of all overviews.

As the time goes, this overview will become more and more out of date. When the tools here will not be used anymore, because they will be replaced by newer tools, this review will not be needed anymore. Until then, however, this paper may serve as a source of relevant information.

In the future it would be possible to extend this work by additional analysis of selected tools or simply by analyzing other tools that were not included in this paper.

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Managing the Company's Digital Capability: A Case for Operational Excellence

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Abstract

The framework for assessing the company's digital capability includes six key areas that can be individually evaluated to consider the overall maturity of a company's digital capability. According to this framework key areas are innovation capability, transformation capability and IT excellence as digital transformation enablers and customer centricity, effective knowledge worker and operational excellence as digital transformation goals. The focus of this research is the area of operational excellence. The purpose of the paper is to assess how the manufacturing company manages the digital transformation of the operational excellence. In the paper, the digital capability maturity model (DCMM) and its corresponding business transformation management methodology (BTM²) are used for this assessment. The BTM² includes nine management disciplines and each of them is individually evaluated for the case of the operational excellence. These are the following disciplines: strategy management, value management, risk management, business process management, IT management, change management, training management, project management and meta management. According to the obtained assessment results the maturity of management disciplines for the case of operational excellence within the examined company is mostly reactive (maturity level 2). In order to improve the digital transformation of the company's operational excellence, it is necessary to define digital use cases based on the new technologies and map them to the existing maturity model of operational excellence of the company. It is necessary to consider the requirements of stakeholders regarding the benefits and risks of new digital technologies to improve the operational excellence of the company. Accordingly, the company should to define a new strategic plan and align it with the new IT strategy. For this purpose, COBIT 5 framework is used in the paper. The contribution of this research is in the proposed and described three-step approach to managing the operational excellence of companies and improving the level of digital capabilities of companies.

Keywords: operational excellence, DCMM, BTM², COBIT 5, the proposed approach to manage the company's digital capability

1. Introduction

Managing the company's digital capability is a complex process based on the implementation of digital strategies, on improving the user experience and continuously raising the level of maturity of the company's digital capabilities [1].

Information technology (IT) is changing its role. IT becomes a strategic partner for business and influences the development of new products and services, the competitiveness of companies [2], [3]. There is a lot of research in the literature on how to manage a company's digital capability. Accordingly, various models and approaches are being developed.

1.1. Research focus

The research aims to assess the maturity of operational excellence in a manufacturing company using the digital capability maturity model (DCMM) and its corresponding business transformation management methodology (BTM²) (the case study from Croatian business practice). The existing maturity of operational excellence within the company is obtained by evaluating each of the 9 aspects of management according to the BTM² (as-is situation of the company). The scope of the research with regard to the assessment of operational excellence included the core business process of the manufacturing company (purchasing, warehousing, production, distribution and support).

The research results give managers the opportunity to identify the existing gaps in the operational excellence and to initiate improvements by defining the new strategic plans and investment policies in the application of digital technologies (to-be situation of the company).

1.2. Research methodology

For the purposes of the research, the following methodology was applied:

- Digital Capability Maturity Model (DCMM) includes six areas for assessing the company's digital capabilities: *innovation capability, transformation capability and IT excellence* as drivers of digital transformation and *customer centricity, effective knowledge worker and operational excellence* as goals of digital transformation;
- Business Transformation Management Methodology (BTM²) includes nine aspects of management: *strategy management, value management, risk management, business process management, IT management, change management, training management, project management and meta management*; each of the 9 management disciplines of the BTM² contains 3 key areas that should be evaluated (part of the DCMM model);
- Measurement framework includes five maturity levels (1-5) (part of the DCMM model);
- COBIT 5 framework, principle 1 for creating and alignment of business and IT strategy;
- structured interviews with the responsible managers of the business and IT departments.

1.3. Structure of the paper

Regarding the structure of the paper, the general framework for assessing the company's digital capabilities is described in Chapter 2. Digital capability maturity model (DCMM) is described in Chapter 3.

The results of the research related to the assessment of the company's operational excellence using the DCMM are described in Chapter 4.

The proposed three-step approach to manage the operational excellence of the company and improve the level of the company's digital capability is described in Chapter 5. The proposed approach is based on the research results related to the assessment of the digital capability of a manufacturing company and the case of operational excellence. However, the proposed approach can help managers for other case studies in the process of company's digital transformation (case studies such as: innovation capability, transformational capability, IT excellence, customer orientation, effective employees). Concluding remarks are related to the evaluation of the proposed approach to manage the company's digital capability and future research.

1.4. Problem definition

The manufacturing company should assess the existing maturity of operational excellence as one of the key areas of digital capabilities. For this purpose, as mentioned before, the company uses the BTM² as part of DCMM.

The BTM² contains 9 key management disciplines that are separately evaluated for the purpose of providing guidelines and support for the implementation of transformation projects. Strategy management, value management and risk management are *direction management disciplines* [4]. Business process management, IT management, change management, training management and project management are *enablement management disciplines* [4].

Meta management supports managing the business transformation and aligns all individual management disciplines [4].

In the literature, a large number of problems related to the implementation of the BTM² are analyzed for different case studies. It has been identified that a large number of companies are not ready to implement transformation projects [5].

On the other hand, the advantages of this methodology are in the guidance and coordination of managers for the successful implementation of digital business transformation. What's more, managers can assess the existing maturity of digital transformation within their company and suggest the improvements. Accordingly, managers can define the new strategic plans.

This research proposes the three-step approach that will help managers improve the existing company's digital capability and realize the desired digital capability. The proposed three-step approach will be described for the case of the manufacturing company and the maturity results of its operational excellence. The success of the new strategic plans and the implementation of transformation projects in the manufacturing company were not examined in this research. This is the goal of the future research (step 4 of the proposed approach).

2. Framework for assessing the company's digital capabilities

The framework for assessing the company's digital capabilities is shown in Fig. 1[6].

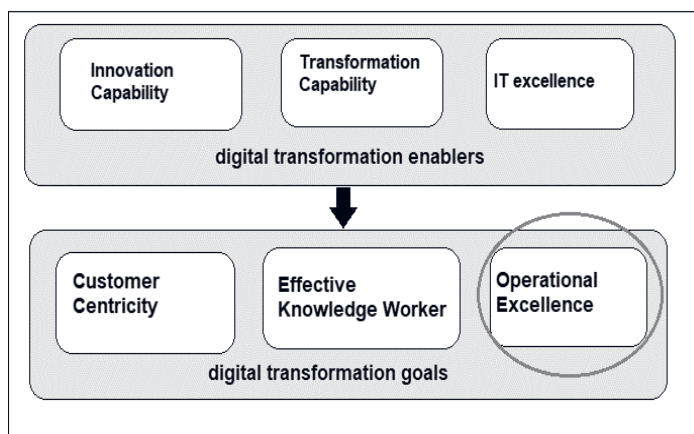


Figure 1. Framework for assessing the company's digital capabilities

This framework includes six key areas of digital capabilities that can be individually evaluated to consider the overall maturity of a company's digital capabilities. Digital transformation enablers are innovation capability, transformation capability and IT excellence. Digital transformation goals include customer centricity, effective knowledge worker and operational excellence. The focus of this research is the area of operational excellence. The features of these 6 areas of digital capabilities are described below [6].

Innovation capability: the capability of a company to transform ideas into new and profitable products and services using digital technologies for better competitiveness. Accordingly, it is necessary to continuously analyze stakeholder requirements regarding the business value of new digital technologies, evaluate potential risks and costs, and map requirements with the company's strategic plans. Innovation capability is a factor that can affect operational excellence as well as customers and employees.

Transformation capability: this area of digital capability enables companies to manage complex changes that need to be evaluated in terms of implementation, required resources and potential risks. The capability to transform means that companies have a vision and plans to implement such a transformation as well as an adequate methodology for managing digital changes. Company management must support the business transformation, and employees must be aware of how important it is for the company's competitiveness.

IT Excellence: this area of digital capability determines whether companies can manage their technological potential and how they use this potential to create greater business value. Any investment in new technologies should be evaluated both in terms of benefits and in terms of costs and risks. It is important that business management has a vision of how to use the potential of digital technology.

All stakeholders should be included in the analysis of the business value of new digital technologies, and their requirements initiate the development of new strategic plans and new IT strategies. It is very important to achieve integration of business processes using digital technologies as well as adequate delivery and support of IT services in accordance with the business requirements. This contributes to the customer satisfaction and the company's financial success.

Customer centricity: one of the digital transformation goals by which companies strive to achieve a better relationship with the customers and a larger market share based on the quality products and services. The application of digital technologies enables new ways of cooperating with customers, and the entire business is focused on their needs and expectations. Companies collect data about the needs and preferences of their customers, and then use it to personalize offers and provide services with the aim of a better customer experience.

Effective knowledge worker: one of the digital transformation goals that companies want to achieve by focusing on their employees, culture, talent, skills and leadership. Companies require new competencies and skills to use digital technology and increase the satisfaction of their employees. Jobs in digital business are designed to encourage creativity and cooperation among employees. Establishing a collaborative and creative work environment allows employees to become more loyal, independent and self-confident. Changes that are important for the company relate to the development of culture, gradual adaptation of employees to work with new technologies. Leadership and its support are very important during the digital transformation process.

Operational excellence: one of the goals of digital transformation and the company's capability to adequately manage business processes by applying new digital technologies. IT is changing its role and becoming a strategic business partner. Accordingly, it is important to continuously improve the operational excellence, identify stakeholder requirements regarding the business value of key digital technologies (mobile connectivity, IoT, big data, cloud computing, social media) that will be integrated into the business processes. The features of key digital technologies for the operational excellence are described below.

Social media use interactive platforms based on Internet technologies that allow users new ways of communication and collaboration. Many companies involve their customers in the process of developing new products and/or services [7]. Companies should analyze the benefits of new technologies and try to map them with the selected business processes in order to improve the operational excellence [8]. There are maturity models that help companies assess the state and agility of their current processes and improve their digital business.

Big data gives companies a clearer understanding of their consumers' expectations and needs in order to offer them specific products or services. This is based on the large amount of data that is collected and analyzed every day [9]. Big data is “a term used to denote an increase in the volume of data that is difficult to store, process and analyze through traditional database technologies. The nature of big data is fuzzy and involves significant processes to identify and translate data into new insights” [10]. In

this sense, big data is "a set of data whose size exceeds the ability of typical database software tools to capture, store, manage and analyze" [11].

Mobile technologies make it possible to achieve the goals of digital transformation and offer transparent interaction with the customers. The current state of technology integration and the use of mobile devices in the business is based on the business needs and is aimed at managing the business processes as efficiently as possible [12].

Cloud computing can be defined as "the application and use of IT products and services that are provided and maintained over a network" [13]. It also enables employees to work, providing them with real-time access to information and facilitating efficient use of resources.

The maturity of operational excellence also affects other business perspectives within the company. These are the customer's perspective (greater customer satisfaction) and the financial perspective (financial success and greater competitiveness of the company).

3. Digital Capability Maturity Model (DCMM)

In this chapter, the structure of the digital capability maturity model (DCMM) is described. The DCMM model is shown in Fig. 2.

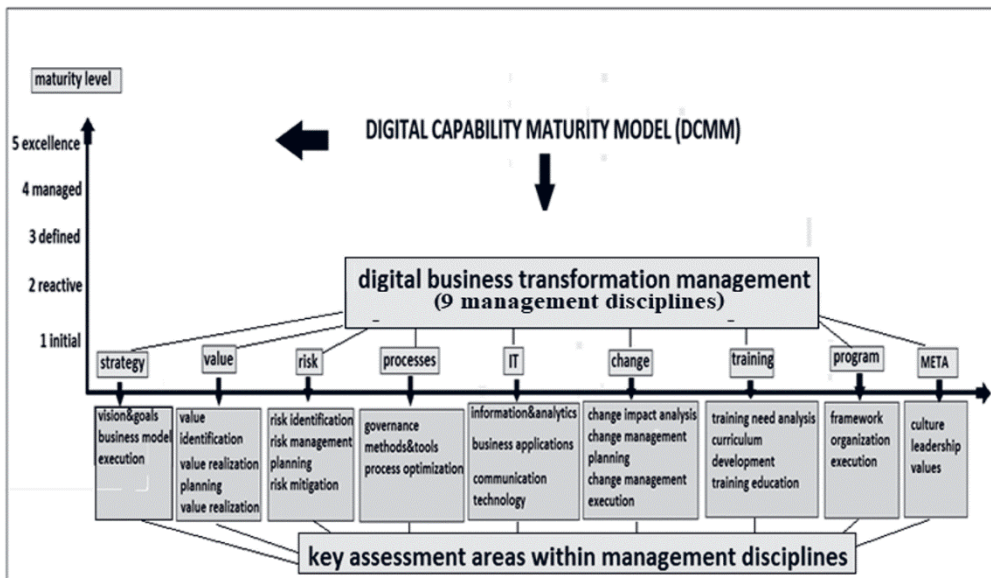


Figure 2. Structure of the DCMM model

The DCMM model contains two dimensions: one dimension refers to the corresponding business transformation management methodology (BTM²). The BTM² is developed by the Thought Leadership Network based on different case studies [14]. The BTM² contains 9 management disciplines. Each of the management

disciplines contains 3 key areas that are evaluated in order to obtain the overall maturity of the company's digital capability.

Each capability area (shown in Fig.1) can be separately assessed using the BTM². The assessed maturity of all 6 digital capability areas represents the overall digital capability of the company. The individual management disciplines are described below.

Strategy management defines the goals of digital business transformation and aligns them with the business goals of the company. Goals should be related to all business processes. All stakeholders should be involved in such processes [15]. Value management should identify the business values of digital transformation and plan their implementation. Risk management should identify key risks associated with digital business transformation projects and determine controls to reduce unacceptable risks. These three management disciplines are the direction management disciplines [4].

Other management disciplines are the enablement management disciplines [4]. Organizational change management should approve new changes in accordance with the stakeholder requirements and monitor their implementation.

Business process management should optimize the business processes by establishing digital transformation projects.

IT management evaluates existing IT performance within the company and makes decisions about the changes based on the new technologies.

Training management should conduct appropriate training and develop programs to support the digital transformation process.

Project management should plan and manage digital transformation projects including objectives such as quality, time and cost.

Meta management supports managing the business transformation and aligns all individual management disciplines. Meta management assesses the company's awareness of the importance and need for digital transformation and assesses management support in the implementation of digital transformation projects.

The second dimension of the DCMM model is a measurement framework that contains 5 levels of maturity. The individual maturity levels are described below. Level 1 (initial) is the lowest level of maturity at which digital transformation projects are not implemented or are implemented up to some 20%. Digital capability is not recognized. Level 2 (reactive) is the level at which the projects are partially implemented in an intuitive way (up to 40%). The goals of digital transformation are partially integrated into the vision of the company. Digital transformation projects are implemented intuitively. Business integration is very low. Level 3 (defined) is the level of maturity at which the digital transformation projects are defined and documented (up to 60%). A digital transformation strategy is defined and the values and risks of digital transformation are assessed. Level 4 (managed): digital transformation projects are managed quantitatively in order to predict (digital) product quality (up to 80%). Digital transformation projects are monitored and improved at level 5 (excellence), (up to 100%).

Maturity models are a valuable tool for IT managers because they enable the assessment of the existing state of the company as well as the identification of necessary improvements [16], [17].

4. Assessment of the company's operational excellence using DCMM: research results

The assessment of the company's operational excellence is conducted in the research using the DCMM model. The structure of the DCMM model is two-dimensional (shown in Fig.2). One dimension refers to the BTM² and 9 management disciplines whose maturity is evaluated for the case of operational excellence within the manufacturing company.

The aim of the research is to obtain results about the maturity of the management of operational excellence within the manufacturing company. The assessment of the existing operational excellence maturity within the production company is conducted on the following core business processes: purchasing, warehousing, production, distribution and support.

The second dimension of the DCMM model is the measurement framework consisting of maturity levels from 1 to 5 (shown in Fig. 2).

4.1. Assessment procedure for the operational excellence

Each of the nine management disciplines according to the BTM² contains three key areas. The research questions are defined for each of the three key areas. The possible answers to each research question are defined according to maturity levels (1-5). According to the provided answers, respondents choose the answer that best corresponds to the existing practice of operational excellence within their company. The assessment results for the strategy management are shown in detail in Fig. 3.

For example, the answer to the first question " *What percentage of the corporate strategy focuses on operational excellence?* (key area: VISION & GOALS) corresponds to the maturity level 2 (reactive) and it is based on the assessment of the respondents (Fig.3).

Due to the scope of the paper, it is not possible to show in detail the respondents' answers for each management discipline of the BTM². Summary assessment results of each management discipline for the case of operational excellence are shown in the Fig.4 and Fig.5.

Figure 4 shows the assessment results of the management disciplines that have the strategic importance for the operational excellence in the company – direction disciplines (*strategy management, value management and risk management*). Figure 5 shows the assessment results of the enablement disciplines (*business process management, IT management, change management, training management, project management*).

Meta management is the basis of the BTM² and has the purpose of harmonizing all individual disciplines (direction and enablement disciplines). Meta management is

the main support in the management of the business transformation. The assessment results for meta management are also shown in Fig. 5.

Key areas for Strategy Management/ Research Questions	MATURITY LEVEL				
	INITIAL 1 (0-20%)	REACTIVE 2 (21-40%)	DEFINED 3 (41-60%)	MANAGED 4 (61-80%)	EXCELLENCE 5 (81-100%)
VISION & GOALS What percentage of the corporate strategy focuses on operational excellence?	Operational excellence is not included in the company's vision and strategy.	Operational excellence is partially included in the company's vision and strategy.	Operational excellence is mostly included in the company's vision and strategy.	Operational excellence is included in the company's vision and strategy.	Corporate strategy focused on operational excellence
BUSINESS MODELS In what percentage is operational excellence related to the company's business processes?	Operational excellence is not related to the company's business processes and their changes.	Operational excellence is partially related to the company's business processes and their changes.	Operational excellence is mostly related to the company's business processes and their changes.	Operational excellence is related to the company's business processes and their changes.	Operational excellence is fully related to the company's business processes and their changes.
EXECUTION What percentage of operational excellence projects are implemented?	Operational excellence projects are not executed.	Operational excellence projects are partially executed.	Operational excellence projects are mostly executed.	Operational excellence projects are executed.	Operational excellence projects are executed. There is strong executive management support and integrated strategy communication.
Average maturity level of strategy management for operational excellence: reactive (2)					

Figure 3. Maturity of the strategy management for the case of operational excellence

Operational Excellence Maturity Model (as-is situation)

DIRECTION DISCIPLINES		
Strategy Management (Reactive 2)	Value Management Reactive (2)	Risk Management Reactive (2)
VISION & GOALS What percentage of the corporate strategy focuses on operational excellence?	VALUE IDENTIFICATION What percentage do you assess the benefits of operational excellence?	RISK IDENTIFICATION Do you identify risks related to the company's operational excellence?
BUSINESS MODELS In what percentage is operational excellence related to the company's business processes?	VALUE REALIZATION PLANNING In what percentage and how do you organize and plan the realization of the operational excellence benefits?	RISK MANAGEMENT PLANNING Are you planning to manage the risks associated with the company's operational excellence?
EXECUTION What percentage of operational excellence projects are implemented?	VALUE REALIZATION What percentage of the operational excellence benefits are realized?	RISK MITIGATION Are you implementing measures to reduce the risk to an acceptable level?

Maturity Levels: **Initial** **Reactive** **Defined** **Managed** **Excellence**

Figure 4. Maturity of the direction disciplines for the case of operational excellence

The research results show a rather low maturity level (reactive) of the direction disciplines for the case of operational excellence (Fig.4). The operational excellence in the examined company is partially recognized as a digital capability that should be continuously improved. Goals for improving operational excellence are partially integrated in the vision/strategy of the company.

Furthermore, the benefits of operational excellence based on the using of digital technologies are very poorly identified in the company. There are no plans to realize these benefits. Digital transformation projects are executed mostly intuitively.

According to the obtained assessment results, risks related to operational excellence are poorly identified. Adequate risk management methods are not used in the company.

Operational Excellence Maturity Model (as-is situation)

ENABLEMENT DISCIPLINES					Alignment of individual disciplines
Business Process Management (Reactive 2)	IT Management (Reactive 2)	Change Management (Reactive 2)	Training Management (Defined 3)	Project Management (Reactive 2)	Meta Management (Reactive 2)
GOVERNANCE In what percentage is the strategic level of business process management achieved?	INFORMATION ANALYTICS What percentage do you use data analytics for the business process improvement?	CHANGE IMPACT ANALYSIS To what extent do you conduct an analysis of the impact of changes on the business?	TRAINING NEEDS ANALYSIS Do you conduct an analysis of the competencies and required transformation skills?	FRAMEWORK Do you apply methods and tools for the operational excellence project management?	CULTURE What is the level of awareness regarding operational excellence improvement needs?
METHODS & TOOLS In what percentage do you use methods, standards, tools for business process management?	BUSINESS APPLICATIONS What percentage of applications and services are integrated into business processes?	CHANGE MANAGEMENT PLANNING Do you implement change management planning?	CURRICULUM DEVELOPMENT Are you developing adequate training programs required for operational excellence?	ORGANIZATION Do you integrate projects into an overall strategic roadmap towards operational excellence?	LEADERSHIP Does the company leadership support the implementation of operational excellence projects?
PROCESS OPTIMIZATION To what extent do you monitor the efficiency of the process for the purpose of optimization?	COMMUNICATION TECHNOLOGY What percentage of communication technologies enable integration of the business processes?	CHANGE MANAGEMENT EXECUTION To what extent is change management implemented?	TRAINING EDUCATION Are the necessary trainings conducted within the company?	EXECUTION 3. What percentage of operational excellence projects are performed?	VALUES Are the values of digital business transformation assessed within the company?

Maturity Levels:

Initial Reactive Defined Managed Excellence

Figure 5. Maturity of the enablement disciplines and meta management for the case of operational excellence

The maturity of the enablement management disciplines for the case of the operational excellence within the examined company is also very low, maturity level is 2 (reactive) (shown in Fig.5). The business processes management generally has a low maturity rating: *there is no defined strategic plan; adequate methods/tools for the business process management are not used; execution of the process is partially monitored and measured; process optimization is poorly implemented.*

IT management has a very low level of maturity within the examined company. The company does not analyze the potential of modern digital technologies for the integration of such technologies into the business processes. The business processes are not integrated.

Change management is also ranked low. The business changes are partially analyzed and approved in an intuitive way.

The management of employee competencies for the case of operational excellence has an estimated maturity level 3 (defined). The company analyzes competencies and plans the education for the purpose of acquiring skills needed for digital transformation and operational excellence.

Project management within the company is ranked low. The company does not apply adequate project management methods for the case of operational excellence. Projects are poorly implemented.

Meta management also has a low level of maturity like most management disciplines (reactive). Employees are not aware of the need to continuously improve the operational excellence and integrate digital technologies into the business processes. The company's leadership partially supports the operational excellence projects.

The described assessment results initiate the need to improve direction disciplines for the case of operational excellence within the examined company (*strategy management, value management and risk management*). It is necessary to apply adequate methods/frameworks of strategic planning within the company. It is necessary to consider the requirements of stakeholders regarding the benefits and risks of new digital technologies to improve the operational excellence of the company.

The assessment results show that enablement disciplines (*business process management, IT management, change management, training management, project management*) should be also improved. Meta management that coordinates *direction and enablement management disciplines* should also be improved.

In the next chapter, the author describes the three-step approach that will help managers improve the existing company's digital capability and realize the desired digital capability. The proposed three-step approach will be described for the case of the examined company and the estimated maturity results of its operational excellence.

5. Managing the company's digital capability: the case for operational excellence

In this chapter, author describes the three-step approach to improve the existing digital

capability of the company and achieve the target digital capability. The steps are described and related to the case of the examined manufacturing company and its estimated operational excellence. The following core business processes within the company are examined: *purchasing, warehousing, production, distribution, support*. The steps are described in the following text. The purpose of the applied model/approach is described for each step.

STEP 1: digital capability assessment of the company's operational excellence

Applied model: Operational Excellence Maturity Model (part of the DCMM model).

Purpose of the applied model: to conduct digital capability assessment for the case of operational excellence within the manufacturing company and analyze the existing results. The procedure of conducting the assessment and the obtained summary results are described in the Chapter 4.

Operational excellence maturity model is shown in Fig. 6. The radar diagram shows the existing maturity levels for each management discipline for the case of operational excellence within the manufacturing company (as-is situation). According to the obtained results the maturity of the management disciplines for the case of operational excellence is mostly reactive (maturity level is 2).

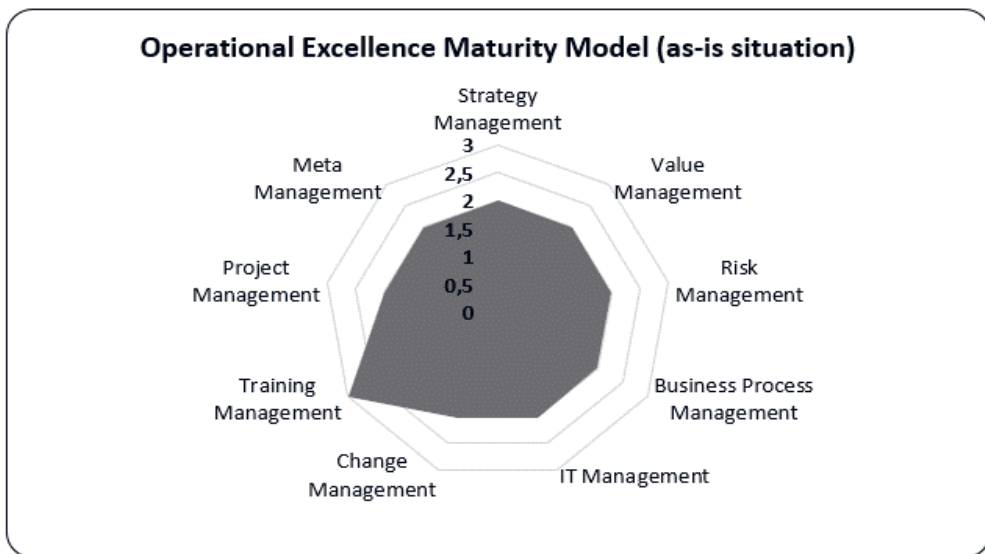


Figure 6. Operational Excellence Maturity Model (as-is situation)

STEP 2: developing digital use cases and mapping to the existing operational excellence maturity model of the company

Applied approach: defining digital use cases based on the new technologies and mapping them to the existing operational excellence maturity model (core business processes).

Purpose of the applied approach: to analyze the benefits of key digital technologies and map them to the existing operational excellence maturity model of the manufacturing company. It is necessary to consider the requirements of stakeholders regarding the benefits and risks of new digital technologies to improve the operational excellence of the company. Digital use cases based on the new technologies and their mapping to the existing operational excellence maturity model are shown in Fig. 7.

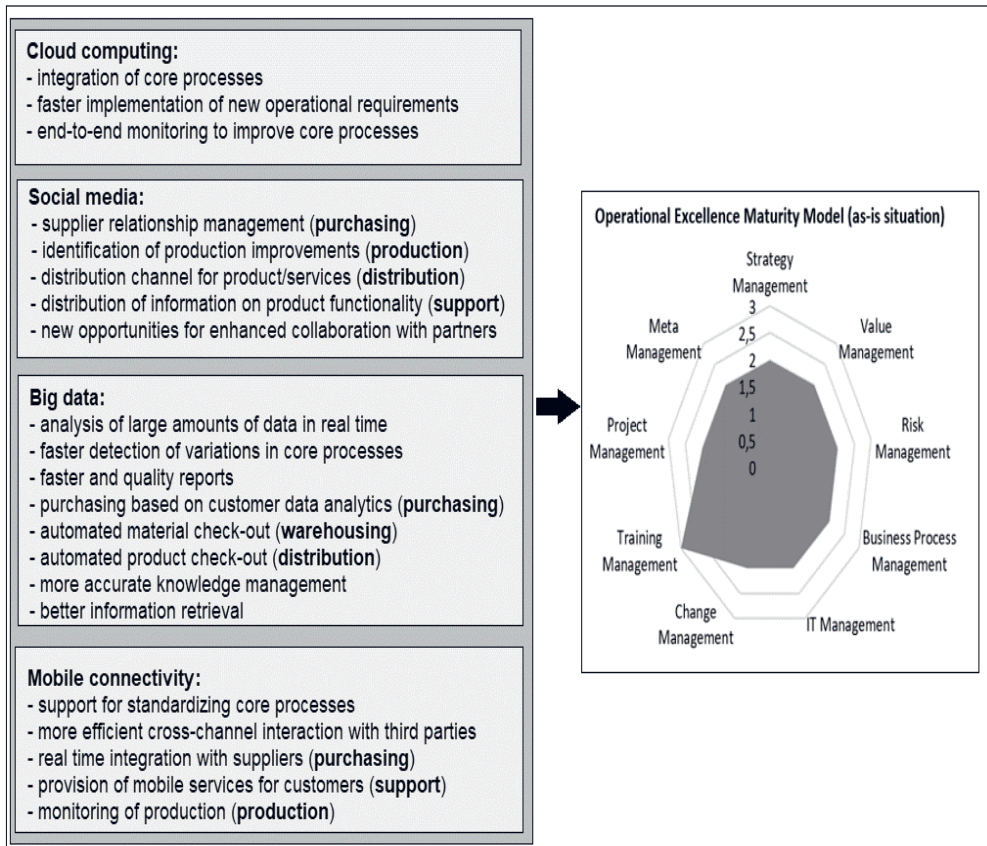


Figure 7. Digital use cases and mapping to the existing operational excellence maturity model (to-be situation)

STEP 3: strategic planning and alignment with the new IT strategy of the company

Applied framework: COBIT 5 principle 1: Meeting Stakeholder Needs

Purpose of the applied framework: to create the new business strategy of the examined company and to align the business strategy with the IT strategy.

The concept of the COBIT 5 -principle 1 is shown in Fig. 8.

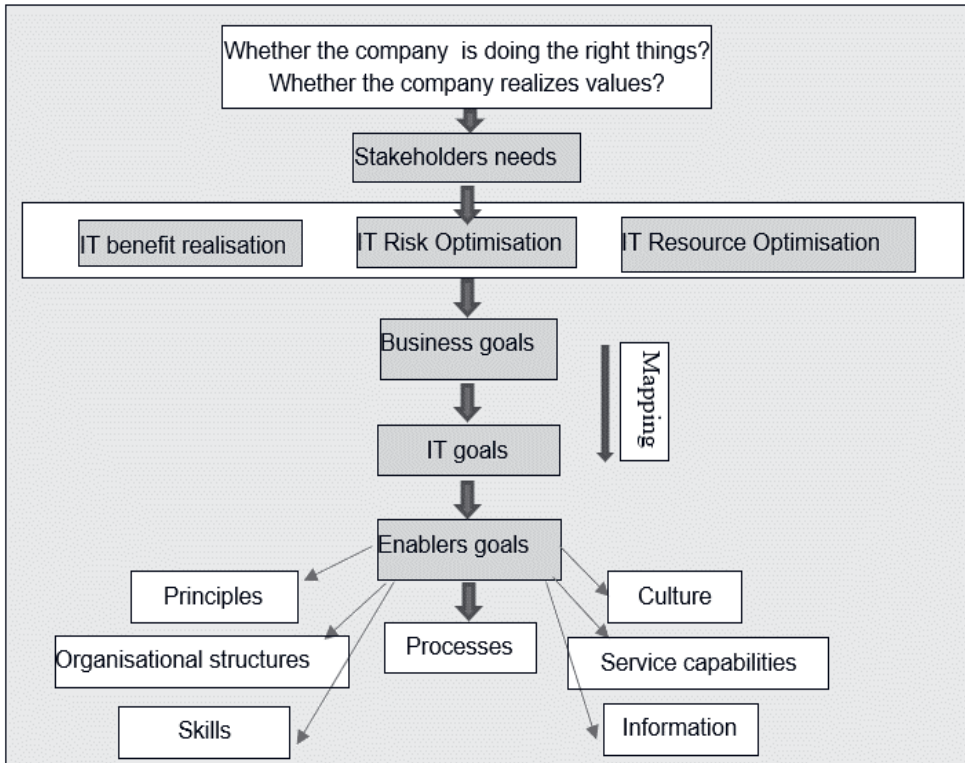


Figure 8. COBIT 5 principle 1 [18]

In general, COBIT 5 framework offers a lot of tools for IT management: align the business strategy and IT strategy using Balanced Scorecard method (BSC), RACI matrix, maturity models, control objectives, process goals and metrics [19]. The COBIT 5 framework offers a generic model for creating a business strategy in any company according to the BSC method (*financial, customers, processes, learning and growth*). Accordingly, COBIT 5 defines 17 strategic goals that the company can select and adapt to its business practice.

The development of the company's strategic plan is based on the collected requirements of stakeholders related to the benefits and possible business contributions of new technologies with optimal risks and costs.

Furthermore, the strategic business goals are connected and aligned with the IT strategy, which is also based on the BSC method. COBIT 5 defines 17 IT goals that the company can also select and align with its business goals. COBIT 5 describes further cascading goals towards IT processes, which is not the focus of this research.

In the following text, it will be described how the manufacturing company creates its new strategic plan with regard to the results from step 2 using COBIT 5 principle 1.

According to the defined digital use cases and mapping to the existing operational excellence maturity model (shown in Fig.7), the stakeholders' needs are mapped with the business goals of the researched company (shown in Table 1).

BSC perspective	Business Goals	Stakeholder Needs (based on the step 2)		
		IT Benefits	Risk Optimization	Resource Optimization
Financial	1. Stakeholder value of business investments	higher revenue growth		
	3. Managed business risks		IT related risk optimization	
Customer	6. Customer-oriented service culture	customer satisfaction		
	7. Business service continuity and availability	IT service quality	warranty of IT services	
	10. Optimization of service delivery costs			IT related cost optimization
Processes (Operational Excellence)	11. Optimization of business process functionality	• faster detection of variations in core processes • end-to-end monitoring to improve core processes and services • identification of process (production) improvements		IT related cost optimization
	13. Managed business change programmes	• integration and standardization of core business processes • distribution of information on product functionalities (new product development) • distribution channel for product/services • modernization of sales channels • new models of decision-making	IT related risk optimization	IT related cost optimization
	14. Operational and staff productivity	more accurate knowledge management; employees can benefit from a better information retrieval		new models of IT resource management
Learning and Growth	16. Skilled and motivated people	educated and competent staff		
	17. Product and business innovation culture	culture of business innovation within the company		

Table 1. Mapping stakeholders needs with the business goals

Stakeholders' requirements include the benefit analysis of new technologies as well as the analysis of possible risks and costs. The benefits of digital technologies, selected from step 2, are mapped with the strategic goals within the perspective of operational excellence (BSC strategic map of the manufacturing company). Therefore, the new strategic plan of the company contains 3 goals for operational excellence: *11. Optimization of business process functionality*, *13. Managed business change programs* and *14. Operational and staff productivity* (shown in Table 1).

The perspective of the operational excellence supports the perspective of the customers and financial. For financial and customer perspective, the company has selected the following strategic goals: *1. Stakeholder value of business investments*, *3. Managed business risks*, *6. Customer-oriented service culture*, *7. Business service continuity and availability*, *10. Optimization of service delivery costs* (shown in Table 1).

Employees and their motivation are important for the operational excellence. Accordingly, the researched company has selected the following two goals for learning perspective: *16. Skilled and motivated people* and *17. Product and business innovation culture* (shown in Table 1). The goals are taken from the COBIT 5 framework [18]. Each strategic goal can be measured by a defined metric.

According to the applied COBIT 5 framework, IT strategy and IT strategic goals should be defined. The results of aligning IT goals and business goals are shown in Table 2. The company has selected the following IT goals from the COBIT 5 framework out of 17 possible goals [18]:

- ✓ *1. Alignment of IT and business strategy*, which primarily supports the business goals 1, 6, 11 and 13 (arranged according to BSC perspectives);
- ✓ *4. Managed IT related business risks* that primarily supports the business goals 3, 7 and 13;
- ✓ *7. Delivery of IT services in line with business requirements*, which primarily supports the business goals 1, 6 and 11;
- ✓ *8. Adequate use of applications, information and technology solutions*, which primarily supports the business goals 10, 11, 14 and 16;
- ✓ *10. Security of information, processing infrastructure and applications*, which primarily supports the business goal 7;
- ✓ *12. Enablement and support of business processes by integrating applications and technology into business processes* that primarily supports the business goal 11;
- ✓ *16. Competent and motivated business and IT personnel* who primarily supports the business goals 14 and 16;
- ✓ *17. Knowledge, expertise and initiatives for business innovation* that primarily supports the business goal 17.

According to the results shown in Table 2, IT goals primarily support the business goals. *The connection between IT goals and the business goals for the case of operational excellence is marked by color and arrows.*

IT goals also have defined metrics that can be used to verify positive or negative correlations between the business and IT. The successful support of IT goals to the business goals and their positive correlation proves the fact that the company achieves the improvements in the area of the operational excellence as well as within other areas: employees, customers and financial. The paper does not describe metrics and does not examine correlations between business and IT goals. This could be step 4 in the proposed approach (measuring IT performance in the company).

Digital transformation is a very complex process and for many companies a very big challenge [20]. There are many models and approaches in the literature that can help managers and practitioners in digital transformation. Each of them has its advantages and disadvantages [21], [22]. The proposed model in this paper will certainly help companies in the process of digital transformation.

IT BSC perspective	IT GOALS	support ⇒ BUSINESS GOALS			
		Financial	Customer	Processes (Operational Excellence)	Learning and Growth
Financial/ Business contribution	1.Alignment of IT and business strategy	1. Stakeholder value of business investments ⇒	6. Customer-oriented service culture	11. Optimization of business process functionality 13. Managed business change programmes	
	4.Managed IT related business risks	3.Managed business risks ⇒	7. Business service continuity and availability	13. Managed business change programmes	
Users of IT services	7. Delivery of IT services in line with business requirements	1. Stakeholder value of business investments ⇒	6. Customer-oriented service culture	11. Optimization of business process functionality	
	8. Adequate use of applications, information and technology solutions		10. Optimization of service delivery costs ⇒	11. Optimization of business process functionality 14. Operational and staff productivity	16.Skilled and motivated people
IT Processes	10.Security of information, processing infrastructure and applications		7. Business service continuity and availability		
	12. Enablement and support of business by integrating applications and technology into business processes	⇒		11. Optimization of business process functionality	
Future orientation	16. Competent and motivated business and IT personnel	⇒		14. Operational and staff productivity	16.Skilled and motivated people
	17. Knowledge, expertise and initiatives for business innovation				17.Product and business innovation culture

Table 2. Mapping IT goals with the business goals

6. Conclusion

The paper assesses and analyzes the operational excellence maturity in the manufacturing company using the Digital Capability Maturity Model (DCMM) and the corresponding Business Transformation Management Methodology (BTM²). Operational excellence is one of the six key areas within the framework for assessing the company's digital capabilities.

The main contribution of the research is in the proposed three-step approach to managing the operational excellence of the company and improving the level of digital capabilities of company.

The steps are described and related to the case of the examined manufacturing company and its assessed operational excellence (the following core business processes are examined: procurement, storage, production, distribution, support).

The maturity of operational excellence within the examined company shows quite low results (reactive 2). The results are obtained by evaluating the maturity of all nine management disciplines according to the BTM² (operational excellence maturity model, as-is situation, Step 1).

In the second step, digital use cases based on the new digital technologies are defined as well as the possibilities of their integration into the core business processes within the examined company (developing digital use cases and mapping to the existing operational excellence maturity model of the company).

In the third step, the company's new strategic plan is defined (based on the analyzed digital use cases and opportunities to improve the operational excellence). The company's new strategic plan is aligned to the IT strategic plan using the COBIT 5 framework, principle 1.

Each of the strategic goals within the new strategic plans has relevant metrics that can be used to examine the support of the IT strategy to the realization of the company's business strategy. In this research, the focus is not on the IT performance assessment. This could be the 4th step in the future research.

The proposed 3-step approach to managing a company's digital capability for the case of operational excellence can help managers in developing the digital business. However, the proposed approach can help managers for other case studies such as: innovation capability, transformation capability, IT excellence, customer focus, competent and motivated employees.

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Keywords: formatting instructions, Microsoft word template, JIOS

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	CPU Speed	Wage
A		
B		
C		

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Appendix A: Title of the Appendix

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References

- [1] IEEEDataPort, "How to Cite References: IEEE Documentation Style" [Online]. Available: http://jios.foi.hr/guidelines/IEEE_Documentation_Style.pdf [Accessed: Jun. 5, 2018].
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