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Application of Decision Science in Business and Management

Edited by Fausto Pedro García Márquez

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Meet the editor

Fausto (https://blog.uclm.es/faustopedrogarcia/) works at UCLM as a Full Professor (accredited as Full Professor from 2013), Spain, Honorary Senior Research Fellow at Birmingham University, UK, Lecturer at the Postgraduate European Institute, and he has been a Senior Manager in Accenture (2013-2014). He obtained his European PhD with a maximum distinction. He has been awarded: Advancement Prize for Management Sci-ence and Engineering Management Nominated Prize (2018), First International Business Ideas Competition 2017 Award (2017); Runner (2015), Advancement (2013) and Silver (2012) by the International Society of Management Science and Engineering Management (ICMSEM); Best Paper Award in the international journal of Renewable Energy (Impact Factor 3.5) (2015). He has published more than 150 papers (65 % ISI, 30% JCR and 92% internationals), some recognized as: "Renewable Energy" (as "Best Paper 2014"); "ICMSEM" (as "excellent"), "Int. J. of Automation and Computing" and "IMechE Part F: J. of Rail and Rapid Transit" (most downloaded), etc. He is the author and editor of 25 books (Elsevier, Springer, Pearson, Mc-GrawHill, IntechOpen, IGI, Marcombo, AlfaOmega, etc), and 5 patents. He is the editor of 5 international journals and a committee member of more than 40 international conferences. He has been Principal Investigator in 4 European projects, 5 National projects, and more than 150 projects for universities, companies, etc. His main interest are: maintenance management, renewable energy, transport, advanced analytics, data science. He is the Director of www.ingeniumgroup.eu.

Contents

Preface

Application of Decision Science in Business and Management is a book that synthesizes the analytical principles with business management practices of Decision Science.

It shows the relationship between the main disciplines of administrative, organizational, and engineering/technology abilities of decision science. It also considers other specialties such as finance economics, risk analysis, decision making, marketing, etc.

Decision science synthesizes the methods and techniques employed in decision-making. They can be qualitative/quantitative, exact or not, etc., and therefore, the solution can be optimal or not. The decisions are generally classified regarding to the period as operational (short period), strategic (long period), and politic (very long period).

The chapters introduce and demonstrate a decision-making theory to practice case studies. It demonstrates key results for each sector with diverse real-world case studies. Theory is accompanied by relevant analysis techniques, with a progressive approach building from simple theory to complex and dynamic decisions with multiple data points, including big data, lot of data, etc. Computational techniques, dynamic analysis, probabilistic methods, and mathematical optimization techniques are expertly blended to support analysis of multi-criteria decision-making problems with defined constraints and requirements.

The book is aimed at graduate students and professionals in business administration, industrial organization, operations management, applied microeconomics, and the decisions sciences, either studying decision-making analysis, or who are required to solve large, specific, and complex multi-criteria decision-making problems as part of their jobs. The work will also be of interest to industrial engineers and engineering designers working with optimization problems, but this is not the main audience, and finally researchers from the academia.

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Chapter 1

The Role of Reviews in Decision-Making

Shaoqiong Zhao

Abstract

With the rise of social media such as blogs and social networks, these interpersonal communication expressed by online reviews has become more and more important as an influential source of information both for the managers and for the consumers. In-depth purchasing-related information is made available to markers. Now we can utilize this new source of information to understand how consumers evaluate products and make decision in relation with it. Since reviews are text data, new ways to analyze the data is needed and text-mining plays the role here together with the help of traditional statistical methods. With these methods, we can examine the contents of reviews and identify the key areas that impact consumers' decision-making.

Keywords: reviews, text-mining, decision-making, consumers, analytics

1. Introduction

We finally enter this technologic era where people and technology integrate with each other. It only took 4 years for Internet to reach 50 million people while comparing to telephone it is 75 years. Especially for Generation Z, majority of them grow up using the Internet and social media. Overall, more than half of the world's population is online. The rise of Internet and especially social media shifted the way people communicate and interact with each other. With the rise of social media such as blogs and social networks, these interpersonal communication expressed by online reviews has become more and more important as an influential source of information both for the managers and consumers. With the rapid growth of comments by consumers over the Internet, in-depth purchasing related information is available to markers. The wide availability of lengthy and numerous text-based online reviews provides a treasure trove of information that can potentially reveal a much wider set of variables that determine the consumers' attitude/evaluation toward the products. There has been numerous of research on how to utilize the information. In [1], the authors investigated consumers' usage of online recommendation sources and their influence on online product choices. Later in [2], Kumar and Benbasat use empirical evidence to demonstrate the influence of recommendations and online reviews on the consumers' perceptions of usefulness and social presence of the websites. As for the firms, online consumer reviews can provide valuable insights and help them improve their products accordingly.

There also have been many research articles (i.e., "for example, see [3–6]") which try to identify the variables that affect the decisions of individuals to make recommendations of product, or not. By their very nature, these studies are only

able to identify a limited number of such determinant variables. In particular, customers' satisfaction has been linked to recommendation to others as in [7], Ladhari et al. identified three drivers—perceived service quality, emotional satisfaction, and image—that are positively related to each other and positively influence loyalty and recommendation. However, almost all studies in the previous research have used numeric variables. So only a limited number of determinants have been studied.

Built upon the previous work, we utilize text-mining method to identify the important product dimensions comparing to the traditional survey method, which are highly related to the quality and thus consumers' attitudes toward the products.

2. Methodology

In this section we describe the methods that we use for analysis of text content. So far text mining has become a very standard procedure to deal with text and here the detailed process is listed for education purpose.

Text classification is a supervised learning process to predict the class of a document based on a set of features describing the document [8]. The predefined categories are given compared to the un-supervised learning process. The prediction model is automatically learned from a training set and can be used to predict new cases. Text classification utilizes various machine-learning algorithms to classify the sentence based text documents into one of the previous defined categories. Suppose we have a set of documents which could be the reviews posted on the websites by consumers, emails by various users, etc. A vector of attributes represents each document as $(X_1, X_2, \cdots, X_n)$. All documents belong to one of predefined categories Y belongs to $(Y_1, Y_2, \ldots, Y_m)$. The attributes are usually term weights from indexing which will be discussed in detail in the following sections. For most cases, we deal with binary situations. Different machine learning algorithms can be used to predict the class of the document $Y = f(X)$. Popular machine learning algorithms such as Naïve Bayes, multinomial Naïve Bayes, Decision tree, and SVM have been applied in text classification problems. Witten and Frank gave the detailed description of these common methods if further information is needed.

2.1 Preprocessing

Before applying the learning methods, several preprocessing steps are necessary to get the data in the ready format for future analysis. The preprocessing of raw data includes: raw text tokenization, case conversion, stop-words removal, and stemming.

Firstly, the raw texts are divided into tokens (single word, special symbols, etc.) using whitespaces (space, tab, newline character, etc.) as separators to break the entire review document into tokens. For example, suppose we have a document "*I like iPhone. It is the first phone I got and I really like the appearance.*" The tokenization step will break this sentence into tokens like "*I*," "*like*," "*iPhone*," "*got*," etc. Secondly, all words are converted to lower cases—case conversion. All the capitalized letters will be converted into lower cases. In our examples, the letter "*P*" is converted to "*p*" and the word "*iPhone*" is converted to "*iphone*." The purpose of case conversion is to reduce the number of redundant words by converting them all into the lower cases. The third step is stop-words removal. The purpose of the stop-words removal is to reduce the size of the classification matrix by reducing the number of irrelevant terms. Lots of overly common used words like "*the*," "*I*," "*to*," etc., are useless in classifying the document into the predefined categories. The efficiency and accuracy of

the classifications can be improved by removing these words. In our study, a general stop-word list, which contains a consequence of standard stop words with manually adaption, is applied. The last step in the preprocessing is the stemming. Word variations are conflated into a single representative form called the stem. For example, *connect* is the stem for *connected*, *connection*, *connecting*, etc. Stemming significantly reduces the number of features and increases the retrieval performance [9]. Here we use a dictionary-based stemmer, which is commonly used in text mining. When a term is unrecognizable, we use standard decision rules to give the word a correct stem.

2.2 Indexing

The result so far is a high-dimensional term-by-document matrix with each cell represents the raw frequencies of appearance for each term in each document. The rows of the matrix correspond to terms (usually terms are words), and the columns represent documents (reviews for example). In [10], Spark Jones showed that there is a significant improvement in retrieval performance by using the weighted terms vectors. The term weight is often decided by the product of the Term Frequency (TF) and the Inverse Document Frequency (IDF) by Spark Jones [11].

The TF measures the frequency of the occurrence of an indexed term in the document [12]. The higher the frequency is, the more important this term is in characterizing the document. Such frequency of occurrence of an indexed word is used to indicate term importance for content representation, i.e., "for example, see [13–15]." In our study, the TF was obtained by the raw term frequency. However, not every word appears equally across the whole set of review documents. Some words appear more frequently than others by nature. The more rarely a term occurs in a document collection, the more discriminating that term is. Therefore the weight of a term is inversely related to the number of documents in which it appears. So IDF is used to take into account of this effect. The logarithm of the IDF was taken to reduce the effect of raw IDF-factor.

Finally the total weight of a term i in document j is given by

$$w_{ij} = TF_{ij} \times IDF_{i.} \tag{1}$$

Here, TF_{ij} is equal to the term frequency of term i in document j; IDF_i is equal to the inverse document frequency of term i.

Mathematically, $TF_{ij} = n_{ij}$ with n_{ij} equals to the frequency of term i in document j and $IDF_i = log_2\left(\frac{n}{df_i}\right) + 1$, with n equals to the total number of document in the entire reviews collection and df_i equals to the number of review documents where term i was present.

2.3 Multi-word phrases

So far the tokenization gives the term-by-document matrix. Each term in the matrix is the frequency of a single word. As most of the cases, multi-word phrases are also important because phrases have more complete context information than individual word. So the most popular class of features used for text classification is n-grams [16]. Word n-gram includes the single word (unigram), and higher order n-grams like bi-grams, tri-grams. Word n-grams have been used effectively in various studies. Unigram to tri-grams have typically been used in text mining and large n-gram phrases set require the following use of attribute selection to reduce the dimensionalities [17, 18]. For instance, we have sentence "*I like iPhone*." We have three unigram "*I*," "*like*," "*iPhone*"; we have two bi-grams "*I like*," "*like iPhone*,"; and

we have one tri-grams "*I like iPhone*." For most cases, multi word phrases are not popularly used due to the low frequency.

2.4 Dimensionality reduction

So far this weighted term-by-document matrix is a high dimensional matrix due to the many distinct terms. Moreover, it is very sparse with many zeros since not all documents contain all terms. Large attribute dimensionality incurs high computational cost and more seriously cause over-fitting problem on many classification methods. We choose Gini index as our method for attributes selection since it is base upon the distinguishing ability of the word as well as importance of the word.

Gini index was proposed and studied by Aggarwal and Chen [19]. It aims to decide which feature variables are decision variables for a decision support application. In the training data the key decision variables are identified and trained to predict the decisions classes. Training dataset D_{trian} contains n reviews and each review q belongs to a predefined class with labels s which is drawn from the set {1...k}. Overall we have a dxn feature-review matrix with each feature is denoted i with i range from 1 to d and each review is denoted by q with q range from 1 to n. In our case since the labels will be a binary situation of recommend or not. Now the Gini index is calculated to define the level of class discrimination among the data points of each feature as follows:

$$G(i) = \sum_{s=1}^{k} f(i,q,s)^2 \tag{2}$$

Then we can use Gini index to help us find the key features that are important to the decisions. With a bigger Gini index, it indicates a higher discriminating ability of that word. So we set a threshold of choosing high value Gini-indexed attributes. In previous research the frequency of occurrence of an indexed word has been used to indicate term importance for content representation [13–15]. So we set another threshold of selecting attributes based on the frequency.

2.5 Classification technique

There are various classification techniques applied in text mining such as Naïve Bayesian, vector support machine (SVM), and decision trees. SVM performs classification more accurately than most other methods in applications, especially for high dimensional data. SVM was invented by Vapnik and Chervonenkis in [20] and has been used a lot in various areas [16, 21]. SVM are supervised learning models that can classify data into the groups. Given a set of training examples, each data record is marked as one or the other of two categories. An SVM training algorithm builds a model that can assign new examples to one category or the other. In our example, we have categories of class: recommend or not recommend the product to others.

2.6 Evaluation criteria

In order to evaluate the performance of different classification models, the most common measure of accuracy is used.

Accuracy: the percentage correctly classified. If *TP*, *FP*, *TN*, and *FN* are, respectively, the number of positive reviews predicted as positive, the number of negative reviews predicted as positive, the number of negative reviews predicted as negative, and the number of positive reviews predicted as negative, the accuracy is

defined as $(TP + TN)/(TP + FP + TN + FN)$. The accuracy should be benchmarked to the proportional chance criteria ($percentage_{positive}^2 + (1 - percentage_{positive})^2$) in order to confirm the predictive capabilities of a classifier [22].

3. Data and analysis results

In order to illustrate the method we proposed, we applied the method on two examples from two industries for generalization—hotel industry and clothing industry.

3.1 Example 1: hotel industry

For hotel industry, the data was obtained from orbitz.com, which is one of the leading websites in the travel industry in US. On the websites, consumers can only leave their reviews, ratings, and recommendation choices after they stayed in the hotel and registered with the hotel. We collected the data of a high quality hotel in Las Vegas: five-star hotel "Venetian." We chose Las Vegas among the various cities across the whole nation because it is one of the most popular tourist cities in the U.S., and attracts a large number of hotel consumers staying and leaving reviews. We pick a five-star hotel because as in Las Vegas, in order to attract visitors, lots of high-level hotels were built and also because of the low price comparing to other locations, five-star hotels are very popular among consumers. **Figure 1** showed an example of the data.

After preprocessing of the raw reviews we get the term (attribute) by document matrix. For each attribute, we calculated the Gini index of that feature and select only the ones with a Gini value higher then 0.75 [19] and also frequency is higher than the average frequency of the words appearance. Through this we are able to find the major attributes that are both important and distinguishing in the evaluations of the hotel. List of feature is shown in **Table 1**.

From the table we see, around 40 features which are both important and distinguishing were extracted from the consumer online reviews. For each feature, we calculated the tf-idf value to reflect the frequency of occurrences of the word features, which indicate the importance of the features for representation of the content of the reviews. The evaluation of importance of features was usually determined by consumer surveys in the past.

Next, classification (SVM) is performed using the selected 38 features as the predictive variables. The accuracy is 91.6%. The high accuracy indicated text reviews could be used to represent the true thinking of the consumers toward the hotel, which can be further used to identify the factors that consumers value as when they evaluate the hotels.

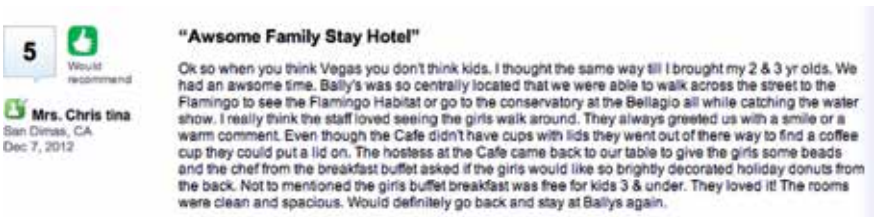

Figure 1.
Review data.

Feature	Mean	SD
77315room	0.615905982	0.840249787
29733stai	0.551547381	0.82165562
88564staff	0.400633212	0.777731114
38586time	0.468865486	1.014960226
3343beauti	0.386801959	0.830438556
105417locat	0.369390225	0.805449742
70746servic	0.398964787	0.993875946
80313strip	0.360965236	0.937546462
78256restaur	0.323249126	0.818511494
55318casino	0.358101524	1.021703983
107009pool	0.366315944	1.102540841
84314shop	0.302824825	0.8928519
105376experi	0.319579518	0.940387285
63878comfort	0.283232639	0.809203564
98053friendli	0.271059238	0.786200556
98561food	0.267736792	0.85655244
66324bathroom	0.265218368	0.859496882
40527bed	0.27890465	0.937873975
84318show	0.265786823	0.903504893
74378price	0.229886661	0.855276916
4056view	0.248388399	1.00651292
44890luxuri	0.221286503	0.832020881
91332getawai	0.19446686	0.748517432
53441spaciou	0.177143261	0.74316694
25711weekend	0.185364962	0.791939957
71300huge	0.177202338	0.777282242
29727star	0.189608358	0.94537057
84647charg	0.193639941	1.107387953
45608fun	0.156195461	0.769228367
16666close	0.146094318	0.717195468
63566coupl	0.136324894	0.694853203
43745shower	0.146251093	0.843647845
105560expens	0.123541624	0.695041725
81315smoke	0.176175837	1.211246955
81581size	0.111322238	0.638559951
78951smell	0.137813083	0.880136225
40,466 bar	0.114751923	0.694104255
79248drink	0.124056133	0.760623902

Table 1.
Venetian Gini selection of words, mean, and SD (n = 2286).

Last, factor analysis was applied using principal axis factoring in order to identify the underlying factors of the two hotels. The principle axis factoring analysis with a Varimax rotation showed 14 factors with an eigenvalue of one or greater for the functions of apps. As stated in **Table 3**, total variance explained by each factor of apps' functions was also revealed. Specifically, the first factor has an eigenvalue of 3.48, which is 21% of the total variance of seven items. The second factor has an eigenvalue of 1.74, which is 16% of the total variance of seven items. Then the next five factors have an eigenvalue bigger then 1.3. The rest has too small values (either below 1 or close to 1) so we did not include them. Normally, eigenvalues greater than 1.0 are recommended as a criterion. First seven factors are chosen as in **Table 2**.

The factors are labeled as: (1) room, (2) value, (3) Las Vegas specific hotel amenity-casino, (4) other amenities, (5) location, (6) staff, and (7) Las Vegas specific hotel amenity-entertainment. Among the 38 items, three items were deleted for appropriate data reduction for future statistical analysis. As you can see in **Table 4**, AF5 (beautiful), AF13 (experience), AF25 (weekend), AF30 (close), and AF33 (expense), were eliminated because they had no significant loading on any of the factors above (factor loading less than 0.20) as in **Table 3**.

3.2 Example 2: clothing industry

In this study, data was obtained from a website which contains information of clothes purchasing and reviews by the consumers.

After preprocessing of the raw reviews we get the term (attribute) by document matrix. For each attribute, we calculated the Gini index of that feature and select only the ones with a Gini value higher then 0.75 [19] and also frequency is higher than the average frequency of the words appearance. Through this we are able to find the major attributes that are both important and distinguishing in the evaluations of the clothes at different category and performed the text classification. The high accuracy (84.9%) indicated text reviews can be used to represent the true thinking of the consumers which can be fatherly used to identify the factors that consumers value as when they evaluate the clothes.

From the narrowed list of both important and distinguishing features, we are able to perform some qualitative diagnostic analysis to identify the determinant attributes for each category and also make the comparisons.

Last, we conduct factor analysis using principal axis factoring in order to identify the underlying factors for each category. As stated in **Table 4**, we showed the factors for each category and their loading score.

Component	Eigen value	% of variance	Cumulative %	SS loadings
1	3.48	21	21	1.53
2	1.74	16	37	1.13
3	1.57	15	53	1.10
4	1.51	13	66	0.95
5	1.41	13	79	0.91
6	1.32	12	91	0.86
7	1.30	9	100	0.66

Table 2.
Total variance explained.

		Factor loadings						
	Features	**1**	**2**	**3**	**4**	**5**	**6**	7
1)	AF1-room	0.46						
	AF14-comfort	0.52						
	AF17-bathroom	0.51						
	AF18-bed	0.58						
	AF22-luxury	0.28						
	AF24-spacious	0.20						
	AF32-shower	0.32						
	AF26-huge	0.20						
	AF35-size	0.26						
2)	AF2-stay		0.22					
	AF7-service		0.28					
	AF20-price		0.21					
	AF27-star		0.25					
	AF28-charge		0.38					
	AF37-bar		0.28					
	AF38-drink		0.35					
3)	AF10-casino			0.52				
	AF34-smoke			0.71				
	AF36-smell			0.35				
4)	AF9-restaurant				0.45			
	AF12-shop				0.47			
	AF16-food				0.31			
5)	AF6-location					0.35		
	AF8-strip					0.70		
	AF21-view					0.34		
6)	AF3-staff						0.60	
	AF15-friendly						0.63	
7)	AF4-time							0.29
	AF11-pool							0.32
	AF19-show							0.19
	AF23-getaway							0.22
	AF29-fun							0.23
	AF31-couple							0.31

Table 3.
Summaries of features and factor loadings.

		Factor loadings							
	Features	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1)	Boot	0.48							
	Cute	0.18							
	Denim	0.38							
	Fall	0.28							

		Factor loadings							
	Features	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	Flat	0.28							
	Jacket	0.61							
	Jean	0.44							
	Sandal	0.40							
	Spring	0.17							
	Sweater	0.15							
	Tights	0.35							
	Winter	0.24							
2)	Knee		0.44						
	Leg		0.22						
	Length		0.57						
	Long		0.35						
	Petite		0.49						
	Regular		0.54						
	Short		0.39						
	Sleeve		0.17						
	Torso		0.24						
3)	Cool			0.31					
	Day			0.35					
	Hot			0.58					
	Light			0.23					
	Summer			0.54					
	Warm			0.26					
	Weather			0.35					
4)	Fit			0.84					
	Medium			0.18					
	Normal			0.23					
	Size			0.71					
	Snug			0.20					
	True			0.46					
	Usual			0.27					
5)	Form			0.84					
	Sexy			0.14					
6)	Casual						0.29		
	Classic						0.12		
	Comfortable						0.17		
	Dinner						0.28		
	Elegant						0.15		
	Event						0.24		
	Glove						0.17		

		Factor loadings							
	Features	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	Heel						0.28		
	Night						0.27		
	Occasion						0.35		
	Party						0.28		
	Perfect						0.34		
	Special						0.31		
	Wedding						0.33		
7)	Black							0.21	
	Blue							0.48	
	Color							0.52	
	Dark							0.36	
	Green							0.37	
	Navy							0.27	
	Orange							0.24	
	Pink							0.27	
	Red							0.34	
	White							0.21	

Table 4.
Summaries of features and factor loadings for dress.

4. Discussions

In marketing, means-end chain theory is a widely applied theory which is a conceptual cognitive model that suggests consumer decision-making process is a series of cognitive developments through linkages between product attributes, consequences, and value [23] In the context of product usage, product it self is the "means" and the value of the products is the "end." The product attributes are

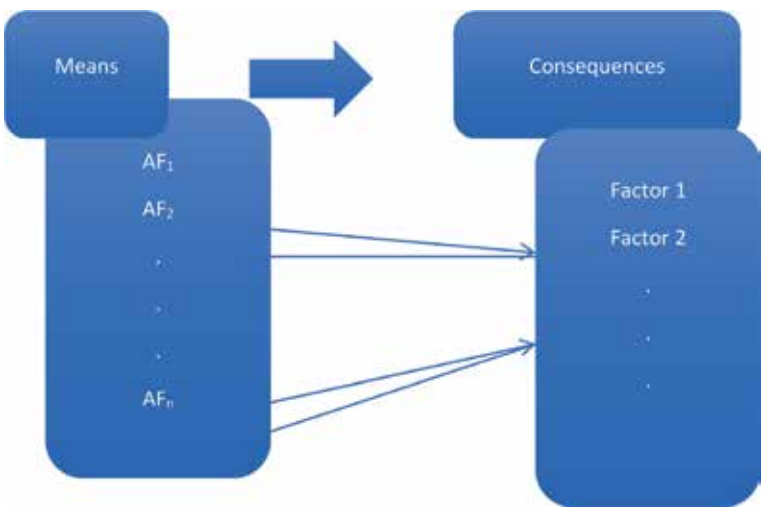

Figure 2.
Means end chain.

retained in the minds of consumers at abstract level and can influence the evaluation of the product by the consumers. Means-end theory has been used a lot e-service quality research [7, 24, 25]. Parasuraman et al. [26] applied this theory as the theoretical foundation to develop and conceptualize e-service quality delivered by websites.

In our study, the means are the attributes of the hotels/clothes extracted from online consumer reviews while the end (consequences) are the key areas categorized by factor analysis based on the importance of the attributes also extracted from online consumer reviews through text mining as indicated in **Figure 2**. Through text-mining and factor analysis, a combination of new and traditional method, we are able to identify the key drivers of consumers decision-making in purchase of two different products.

5. Conclusions

A major finding conclusion of our study is that we can utilize the great volume of reviews online to help us identify the key aspects of different product category. Online reviews of products and services are present all over the Internet. Potential consumers value these greatly. Marketers can also get valuable information from reading these reviews. These reviews predominantly contain text-based information. This can be of great value to the marketers: we can form this standardized line of business analysis procedure which can be applied to any business scenarios and offer business insights for business organizations especially for managing products and advertising.

We can utilize text-mining methodology to show that consumers' attitudes can be accurately predicted by text mining. In addition to making predictions of recommendations, marketers would benefit tremendously by identifying the key information from many thousands of reviews.

A framework was developed by which companies can get this important *diagnostic* information. This framework consists of reliance on the importance of words based on frequency of occurrence and a new way to look at how certain words have greater power to discriminate/distinguish between existence and non-existence of recommendations (Gini index). Factor analysis is conducted to extract the key dimensions for product evaluations.

Advertisers and marketers would be among the prime beneficiaries once they can glean the appropriate information from text-based reviews. The identified information can either be strongly used in advertising or to improve the business.

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Chapter 2

Decision-Making in Fuzzy Environment: A Survey

Hossam Kamal El-Din, Hossam E. Abd El Munim and Hani Mahdi

Abstract

Multi-criteria decision-making (MCDM) is a crucial process in many business and management applications. The final decision is based upon the relative weights to the decision-making team. The analytic hierarchy process (AHP) has found to be one of the most successful approaches for evaluations of the weights and the importance of the criteria. However, most of the evaluated values are not so precise due to the fuzziness of the evaluating environment. This chapter surveys essentially the basic analytic hierarchy process and the fuzzy analytic hierarchy process (FAHP). It depicts through an example the steps for using the original analytic hierarchy process for two levels of criteria. Then, it uses the same example to explain the fuzzy approach in the evaluation. Finally, it compares both approaches.

Keywords: analytic hierarchy process (AHP), fuzzy analytic hierarchy process (FAHP), multi-criteria decision-making (MCDM), Chang's extent analysis

1. Introduction

Multi-criteria decision-making (MCDM) is a discipline that interacts with decisions to select the most optimal alternative with respect to multiple criteria for a specific goal. MCDM is well known for impartially solving problems of decision-making and for comparing the alternative comparatively to deduce the relative priority of the alternatives. Based on the relative priority value, the optimal alternative is defined and selected as a choice that can achieves the decision target.

Different MCDM techniques are in recent times broadly applied and used to resolve various decisions and predictive problems. These techniques are such as weighted sum model (WSM), weighted product model (WPM), analytic hierarchy process (AHP), technique for order preference by similarly to ideal solution (TOPSIS) and fuzzy AHP which is the fuzzification version of the AHP. Among these techniques, we will discuss analytical hierarchy process (AHP) and fuzzy analytical hierarchy process (FAHP) in this chapter.

The main objective of this chapter is to introduce a comparative analysis of analytic hierarchy process (AHP) developed by Saaty [1] and fuzzy analytic hierarchy process (FAHP) developed by Chang [2]. Both techniques will be introduced using a simple example for decision-making.

Saaty introduced an example for determining the type of the job that would be best for the person upon getting his/her PhD. This example was selected to cope with the original work of Saaty about AHP.

In the flow of the chapter, first the classical AHP and fuzzy AHP methods are introduced, then the summary of calculations are presented for AHP and fuzzy AHP as the next section. Finally, the chapter ends with comparison results, findings and comments about these methods.

2. Analytic hierarchy process (AHP)

The analytic hierarchy process (AHP) is developed by Saaty [1] as a multi-criteria decision-making approach, which aids the decision maker to set relative priorities and to make the best decision. AHP has found to be one of the most successful approaches for evaluations the relative priorities of different criteria and for selection between alternatives. It gains recently high attention for many applications; see, for example, Ho and Ma [3]. AHP is especially suitable for complex decisions which involve the comparison of decision elements which are difficult to quantify. It is a technique for decision-making where there are a limited number of choices and these choices are characterized by a set of attributes (criteria). Each of these choices has different attributes' value.

To explain the core of AHP we consider the very simple example for building these relative priorities between three items, although later we will consider the development of priorities using AHP for two levels of criteria and in fuzzy environment. The AHP procedure can be described in an algorithmic way in five steps which give finally the relative priorities between criteria. These steps will be explained using the very simple example as follows:

Step 1: Define the problem: let us say we have three criteria A, B, C and we want to know the relative priorities (importance) between these criteria to achieve a specific goal.
Step 2: Construct a simple decision hierarchy structure to emphasize the goal and the criteria as shown in **Figure 1**. Although, the goals are generally selecting one of different alternatives, here the goal is the simplest one that is generating the relative priorities between the criteria A, B, and C.
Step 3: Construct a set of pairwise comparison methods to all criteria.

A pairwise comparison is a process used to compare the criteria in pairs to judge which criterion is more important than the others using Saaty's nine-point scale of pairwise comparison as shown in **Table 1**.

In general, consider a matrix **Z** with $n \times n$ matrix, where n is the number of evaluation criteria considered. Each entry z_{ij} of the matrix **Z** represents the importance of the ith criterion relative to the jth criterion. If $z_{ij} > 1$, then the ith criterion is more important than the jth criterion and in the otherwise, if $z_{ij} < 1$, then the ith criterion is less important than the jth criterion. If ith criterion and jth criterion have the same importance, then the entry z_{ij} is 1. The entries z_{ij} and z_{ji} satisfy the following constraint:

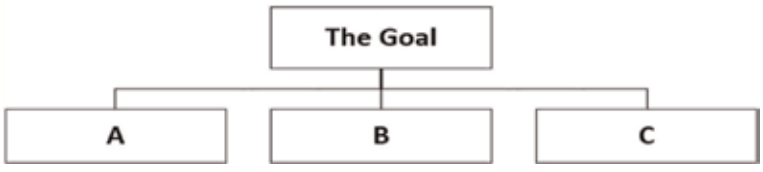

Figure 1.
Simple decision hierarchical structure.

Intensity of importance	Definition
1	Equally important
3	Moderately more important
5	Strongly important
7	Very strongly important
9	Extremely important
2, 4, 6, 8	Intermediate value between adjacent scales

Table 1.
Saaty's nine-point scale of pairwise comparison.

$$z_{ij} \cdot z_{ji} = 1 \tag{1}$$

Assume that the comparisons between the criteria A, B, C are as follows: A is moderately more important than B, A is extremely important than C, and B is moderately more important than C. According to **Table 1**, we will have A = 3B, A = 9C, and B = 3C. This is also means that B = (1/3)A, C = (1/9)A, and C = (1/3)B. The result of these pairwise comparisons is traditionally related to what we call the pairwise comparison matrix as shown in **Table 2**.

Step 4: This is the normalization step which consist of two parts. In the first part, normalization is carried out for each column entries according to the following equation:

$$\overline{z}_{ij} = \frac{z_{ij}}{\sum_{i=1}^{n} z_{ij}} \tag{2}$$

The summation of the very simple example is shown in **Figure 2a** while the results of this normalization part are shown in **Figure 2b**.

	A	B	C
A	1	3	9
B	1/3	1	3
C	1/9	1/3	1

Table 2.
The pairwise comparison matrix for the considered three criteria.

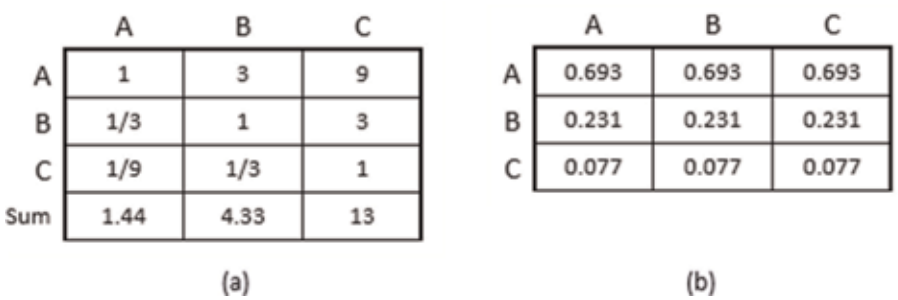

Figure 2.
The normalization step for criteria: (a) summation of columns; and (b) dividing each cell by its columns' summation.

The second part, the weight w_i of the criterion i is calculated by taking the average of the entries on each row of matrix **Z**. This results in the weight vector **W** which in the very simple example becomes $\boldsymbol{W} = \begin{pmatrix} 0.693 \\ 0.231 \\ 0.077 \end{pmatrix}$

$$w_i = \frac{\sum_{j=1}^{n} \overline{\mathbf{z}}_{ji}}{\mathrm{n}} \tag{3}$$

Step 5: The final step is a test to check for the consistency associated with the comparison matrix to examine the extent of consistency by using consistency ratio (CR) using the formula:

$$\text{Consistency ratio } (CR) = \frac{CI}{RI} \tag{4}$$

If CR < 0.1, then the pairwise comparison matrix **Z** is reasonable consistence otherwise it is inconsistence. Here, RI is a random matrix consistency index obtained through experiments using samples with large quantities. Random index (RI) values for the matrix of the order n = [1, 10] are shown in **Table 3**.

The consistency index (CI) indicates whether a decision maker provides the comparison of consistent values in a set of evaluations. CI is calculated using the formula:

$$CI = \frac{\lambda_{max} - n}{(n-1)} \tag{5}$$

The calculation of the CI demands to compute the normalized eigenvector of the matrix and the principal eigenvalue $\lambda_{\max}$ of the matrix, which is obtained from summing the multiplication of the number of weights of all criteria in each column of the matrix with the eigenvector of the matrix.

$$\lambda_{max} = (1.44 \times 0.693) + (4.33 \times 0.231) + (13 \times 0.077) = 3 \tag{6}$$

For $\lambda_{\max}$ = 3 and n = 3, then the value of CI = 0. The consistency here is ideal due to the fact that there is full consistency between the three pairwise comparisons, A = 3B, A = 9C, and B = 3C, which means any of these three equations can be deduced from the other two equations.

As CI = 0, and RI for three elements = 0.58, the CR = 0 < 0.1. This means that the evaluation of the matrix is consistent and all the comparisons of the elements are ideal (as CR = 0). This is the ideal case where the pairwise comparisons are perfect.

What happens if the ranking of the criteria is changed and the pairwise comparison matrix is reconstructed?

The new pairwise comparison matrix and the weight of each criterion are shown in **Figure 3a** and **b**, respectively.

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0	0	0.58	0.9	1.12	1.2	1.32	1.41	1.45	1.49

Table 3.
Values of the random index (RI) for small problems.

	A	B	C
A	1	9	3
B	1/9	1	3
C	1/3	1/3	1

(a)

	A	B	C	Weight
A	1	9	3	0.665
B	1/9	1	3	0.201
C	1/3	1/3	1	0.134
Sum	1.44	10.33	7	1

(b)

Figure 3.
(a) The new pairwise comparison matrix, and (b) the weight of each criterion.

To check the consistency, the values of λ_{max}, CI, RI and CR which are:

$$\lambda_{\max} = 3.619,\ \mathrm{CI} = 0.3095,\ \mathrm{RI} = 0.58 \text{ and } \mathrm{CR} = 0.534 > 0.1 \tag{7}$$

This means that the evaluation of the matrix is inconsistent and all the comparisons of the elements are needed to be reconsidered and the previous steps need to be repeated.

3. Fuzzy analytic hierarchy process (FAHP)

The conventional AHP is insufficient for dealing with fuzziness and uncertainty in multi-criteria decision-making (MCDM) because of inability of AHP to deal with the imprecision in the pairwise comparison process. Hence, the fuzzy AHP technique can be viewed as an advanced analytical method developed from the conventional AHP. The fuzzy AHP is proposed to find the uncertainty of AHP method. Different approaches are suggested as fuzzy AHP. The most two used methods for calculating the relative weights of the criteria are geometric means, which is proposed by Buckley [4], and the extent analysis methods which is proposed by Chang [2].

Fuzzy AHP (FAHP) has been shown successful in many applications [5–7]. The successfulness of FAHP attracts the researches to consider even different membership functions' form instead of using triangular membership functions to represents the fuzzy numbers which will be consider here after [8]. Also, in the following, we will consider only the extent analysis methods for calculating the relative weights of criteria.

The triangular number is denoted by three numbers $A = (l, m, u)$ where "l" represents the lower value, "m" the medium value, and "u" the upper value, respectively $(l \le m \le u)$. The reciprocal triangular number is denoted by A^{-1} and calculated as $A^{-1} = (1/u, 1/m, 1/l)$ as shown in **Table 4**.

The addition and the multiplications of two fuzzy numbers are explained by the following example:

Consider two triangular fuzzy numbers $A_1 = (l_1, m_1, u_1)$ and $A_2 = (l_2, m_2, u_2)$

The addition of two fuzzy numbers is defined by:

$$(l_1, m_1, u_1) \oplus (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \tag{8}$$

And the multiplication of two fuzzy numbers is defined by:

$$(l_1, m_1, u_1) \otimes (l_2, m_2, u_2) = (l_1 l_2, m_1 m_2, u_1 u_2) \tag{9}$$

Crisp importance value	Triangular fuzzy numbers	Linguistic scale for importance	Triangular fuzzy Reciprocal
1	(1, 1, 1)	Equally important	(1, 1, 1)
2	(1, 2, 3)	Intermediate value between 1 and 3	(1/3, 1/2, 1)
3	(2, 3, 4)	Moderately more important	(1/4, 1/3, 1/2)
4	(3, 4, 5)	Intermediate value between 3 and 5	(1/5, 1/4, 1/3)
5	(4, 5, 6)	Strongly important	(1/6, 1/5, 1/4)
6	(5, 6, 7)	Intermediate value between 5 and 7	(1/7, 1/6, 1/5)
7	(6, 7, 8)	Very strongly important	(1/8, 1/7, 1/6)
8	(7, 8, 9)	Intermediate value between 7 and 9	(1/9, 1/8, 1/7)
9	(9, 9, 9)	Extremely important	(1/9, 1/9, 1/9)

Table 4.
The scale of fuzzy AHP pairwise comparison.

We consider the same simple example to explain the core of fuzzy AHP for building these relative priorities. The following section outlines the Chang's extent analysis method on fuzzy AHP.

The fuzzy AHP procedure can be described in an algorithmic way in seven steps which give finally the relative priorities between criteria. These steps are:

Step 1: define the problem. This is the same example as mentioned before in AHP.

Step 2: develop the decision hierarchy like AHP step as mentioned before.

Step 3: construct the fuzzy pairwise comparison matrices to all criteria. Here, the general form of the fuzzy pairwise comparison will be as follows:

$$\mathbf{Z} = (z_{ij})_{.n\times n} = \begin{bmatrix} (1,1,1) & (l_{12}, m_{12}, u_{12}) & \ldots & (l_{1n}, m_{1n}, u_{1n}) \\ (l_{21}, m_{21}, u_{21}) & (1,1,1) & \ldots & (l_{2n}, m_{2n}, u_{2n}) \\ . & . & . & . \\ . & . & . & . \\ (l_{n1}, m_{n1}, u_{n1}) & (l_{n2}, m_{n2}, u_{n2}) & \ldots & (1,1,1) \end{bmatrix} \quad (10)$$

where $z_{ij} = (l_{ij}, m_{ij}, u_{ij})$, $z_{ji} = z_{ij}^{-1} = (1/u_{ij}, 1/m_{ij}, 1/l_{ij})$ for $i, j = 1, \ldots, n$.

Using the linguistic scale for criteria and alternatives as shown in **Table 10** to compare the criteria in pairs to judge which criterion is more important than the others. As we use the same comparisons between the criteria A, B, C, the fuzzy pairwise comparisons between these criteria can be expressed in the matrix form as shown in **Table 5**.

Step 4: calculate the value of fuzzy synthetic extent S_i with respect to the *i*th criterion using the formula:

$$S_i = \left(\frac{\sum_{j=1}^{n} l_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} u_{ij}}, \frac{\sum_{j=1}^{n} m_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} m_{ij}}, \frac{\sum_{j=1}^{n} u_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} l_{ij}} \right) \quad (11)$$

According to the previous example, the values of fuzzy synthetic extent are:

	A	B	C
A	(1, 1, 1)	(2, 3, 4)	(9, 9, 9)
B	(1/4, 1/3, 1/2)	(1, 1, 1)	(2, 3, 4)
C	(1/9, 1/9, 1/9)	(1/4, 1/3, 1/2)	(1, 1, 1)

Table 5.
The fuzzy pairwise comparison matrix for the considered three criteria.

$$S_A = (12, 13, 14) \otimes \left(\frac{1}{21.11}, \frac{1}{18.77}, \frac{1}{16.61}\right) = (0.568, 0.693, 0.842) \quad (12)$$

$$S_B = (3.25, 4.33, 5.5) \otimes \left(\frac{1}{21.11}, \frac{1}{18.77}, \frac{1}{16.61}\right) = (0.154, 0.231, 0.331) \quad (13)$$

$$S_C = (1.36, 1.44, 1.61) \otimes \left(\frac{1}{21.11}, \frac{1}{18.77}, \frac{1}{16.1}\right) = (0.064, 0.077, 0.097) \quad (14)$$

Step 5: compute the degree of possibility for each convex fuzzy number M_1 and M_2 that $M_1 \geq M_2$ which will be denoted by $V(M_1 \geq M_2)$ defined by the following definition.

$$V(M_1 \geq M_2) = \begin{cases} 1 \text{ if } m_1 \geq m_2 \\ 0 \text{ if } l_2 \geq u_1 \\ \dfrac{l_2 - u_1}{(m_1 - u_1) - (m_2 - l_2)} \text{ Otherwise} \end{cases} \quad (15)$$

To compare M_1 and M_2 both possibilities $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$ are needed. Considering **Figure 4** as an example, we have $(m_1 \geq m_2)$ which means that $V(M_1 \geq M_2) = 1$ and

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_1}(d) = D \quad (16)$$

where *hgt* is the highest intersection point, D is its value and d its ordinate as shown in **Figure 4**. Accordingly, D is given by:

$$D = V(M_2 \geq M_1) = \frac{u_2 - l_1}{(u_2 - m_2) + (m_1 - l_1)} \quad (17)$$

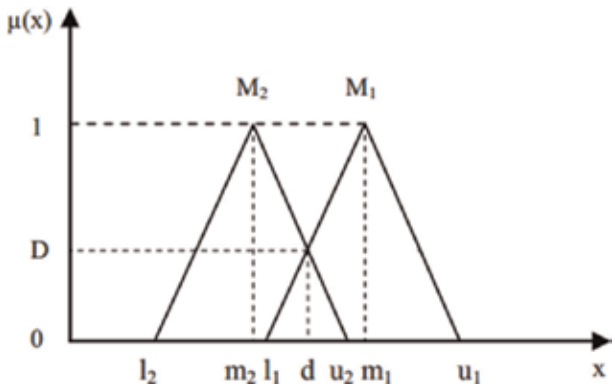

Figure 4.
Linguistic variables for the importance weight of each criterion.

For two fuzzy numbers only two values of possibilities are needed. As the considered fuzzy numbers increase, the numbers of the needed calculated possibilities are increased non-linearly. To compare n fuzzy numbers, we need $n(n-1)$ possible values. Consider the very simple example with the three criteria A, B, and C, the needed possibilities are:

$$V(M_A \geq M_B) = 1, V(M_A \geq M_C) = 1 \tag{18}$$

$$V(M_B \geq M_A) = 0, \quad V(M_B \geq M_C) = 1 \tag{19}$$

$$V(M_C \geq M_A) = 0, V(M_C \geq M_B) = 0 \tag{20}$$

Step 6: the degree of possibility for a convex fuzzy number to be greater than (k) convex fuzzy numbers $M_i (i = 1, 2, ..., k)$ can be defined by the following equation:

$$V(M_i \geq M_1, M_2, ..., M_k) = V((M_i \geq M_1) \text{ and } (M_i \geq M_2) \text{ and} ... (M_i \geq M_k)) = \min V(M_i \geq M_k), (k = 1, 2, ..., n), (i = 1, 2, ..., n), k \neq i \tag{21}$$

The minimum degrees of possibilities for criteria A, B, C are:

$$V(M_A \geq M_B, M_C) = \min (1, 1) = 1 \tag{22}$$

$$V(M_B \geq M_A, M_C) = \min (0, 1) = 0 \tag{23}$$

$$V(M_C \geq M_A, M_B) = \min (0, 0) = 0 \tag{24}$$

Step 7: the normalized weight vector $\boldsymbol{W} = (w_1, ..., w_2)^T$ of the fuzzy comparison matrix **Z** is:

Assuming $d'(z_i) = \min V((M_i \geq M_k))$
For $(k = 1, 2, ..., n)$, $k \neq i$. Then the weight vector is given by:

$$\mathbf{W`} = (d'(z_1), d'(z_2), ..., d'(z_n))^T \tag{25}$$

Via normalization, the normalized weight vector is:

$$\mathbf{W} = (d(z_1), d(z_2), ..., d(z_n))^T \tag{26}$$

Therefore, the weight vector for A, B and C is:

$$\mathbf{W`} = (1, 0, 0) \tag{27}$$

And the normalized weight vector for A, B and C is:

$$\mathbf{W} = (1, 0, 0) \tag{28}$$

4. Examples of applications

The following example is proposed by Saaty about a simple decision for selecting a job [9] and it was selected to cope with the original work of Saaty about AHP. This example is a simple decision examined by someone to determine what kind of job would be best for him/her after getting his/her PhD. The goal is to determine the kind of job for which he/she is best suited as spelled out by the criteria. We will construct the pairwise comparison of criteria from the hierarchy structure shown in

Figure 5, apply AHP method and fuzzy AHP method and then compare the results between these two methods. As shown in **Figure 5**, the hierarchical structure consists of four levels. The first level (the top level) is the goal which is to determine the type of a suitable job, the second level is the criteria, the third level is the sub-criteria and the fourth level is the alternative (the lowest level) which the person will choose the kind of the job from these alternatives [10, 11].

According to **Figure 5**, 12 pairwise comparison matrices need to be stated: one for the criteria with respect to the goal, (flexibility, opportunity, security, reputation and salary), two for the sub-criteria which one of it is for the sub-criteria with respect to the flexibility (location, time and work), and the other is for the sub-criteria with respect to the opportunity (entrepreneurial, salary potential and top level position). Nine comparison matrices for the four alternatives with respect to the criteria and the sub-criteria "the covering criteria" connected to the alternatives (domestic company, international company, college and state university). The covering criteria are: the first six are sub-criteria in the third level and the last three are criteria from the second level. As Saaty listed only three pairwise comparison matrices of 12, we listed the rest of pairwise comparison matrices to emphasize the example and show the result. **Tables 6–8** indicate the pairwise comparison matrices for all criteria and sub-criteria.

Table 9 shows the calculation of the global weight for sub-criteria with respect to its criterion by multiplying weight of each criterion to the weights of sub-criteria that affect its criterion.

After computing the relative weights of criteria and sub-criteria, the next step is to compute relative weights of alternatives. **Tables 10–18** indicate the pairwise comparison matrices for alternatives with respect to the covering criteria.

Once the weight vector of covering criteria $\boldsymbol{W}$ and the weight vector of the alternative **S** have been computed, the AHP obtains a vector $\boldsymbol{V}$ of global scores by multiplying $\boldsymbol{S}$ and $\boldsymbol{W}$ as:

$$\boldsymbol{V} = \boldsymbol{S} \cdot \boldsymbol{W} \tag{29}$$

Finally, the alternative ranking is accomplished by ordering these global scores in a descending order. **Table 19** shows the final weights of the alternatives with

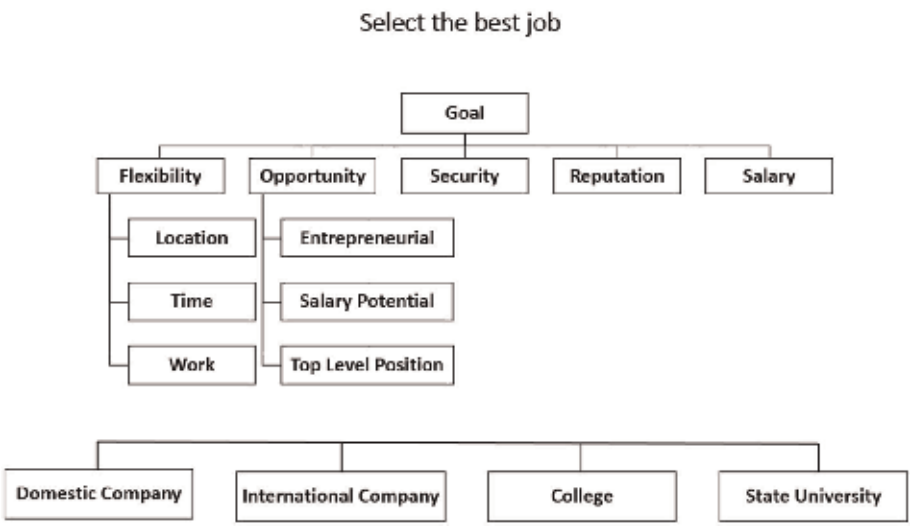

Figure 5.
Best job decision [9].

	Flexibility	Opportunities	Security	Reputation	Salary	Priorities
Flexibility	1	1/4	1/6	1/4	1/8	0.036
Opportunities	4	1	1/3	3	1/7	0.122
Security	6	3	1	4	1/2	0.262
Reputation	4	1/3	1/4	1	1/7	0.075
Salary	8	7	2	7	1	0.506

Table 6.
Pairwise comparison matrix of the main criteria with respect to the goal.

	Location	Time	Work	Priorities
Location	1	1/3	1/6	0.091
Time	3	1	1/4	0.218
Work	6	4	1	0.691

Table 7.
Pairwise comparison matrix for the sub-criteria with respect to flexibility.

	Ent	Sal-pot	Top level pos	Priorities
Ent	1	2	5	0.557
Sal-pot	1/2	1	1/4	0.158
Top level pos	1/5	4	1	0.283

Table 8.
Pairwise comparison matrix for the sub-criteria with respect to opportunity.

Criterion (C)	Local weight (CL)	Sub-criterion (SC)	Local weight (SCL)	Global weight (CL × SCL)
Flexibility	0.0367	Location	0.093	0.0034
		Time	0.221	0.0081
		Work	0.686	0.0251
Opportunity	0.123	Entrepreneurial	0.557	0.0685
		Salary potential	0.158	0.0194
		Top level position	0.283	0.0348

Table 9.
Local weight and global weight for criteria and sub-criteria.

	Domestic Co	Int'l Co	College	State Univ.	Priorities
Domestic Co	1	4	3	6	0.555
Int'l Co	1/4	1	3	5	0.258
College	1/3	1/3	1	2	0.124
State Univ.	1/6	1/5	1/2	1	0.064

Table 10.
Pairwise comparison matrix for the alternatives with respect to salary potential.

	Domestic Co	Int'l Co	College	State Univ.	Priorities
Domestic Co	1	1/5	4	1/3	0.192
Int'l Co	5	1	2	1/4	0.263
College	1/4	1/2	1	2	0.202
State Univ.	3	4	1/2	1	0.343

Table 11.
Pairwise comparison matrix for the alternatives with respect to location.

	Domestic Co	Int'l Co	College	State Univ.	Priorities
Domestic Co	1	1/3	3	6	0.32
Int'l Co	3	1	4	2	0.45
College	1/3	1/4	1	2	0.123
State Univ.	1/6	1/2	1/2	1	0.107

Table 12.
Pairwise comparison matrix for the alternatives with respect to work.

	Domestic Co	Int'l Co	College	State Univ.	Priorities
Domestic Co	1	2	1/3	1/4	0.133
Int'l Co	1/2	1	1/6	1/2	0.092
College	3	6	1	2	0.483
State Univ.	4	2	1/2	1	0.292

Table 13.
Pairwise comparison matrix for the alternatives with respect to time.

	Domestic Co	Int'l Co	College	State Univ.	Priorities
Domestic Co	1	2	4	6	0.502
Int'l Co	1/2	1	3	4	0.3
College	1/4	1/3	1	2	0.124
State Univ.	1/6	1/4	1/2	1	0.074

Table 14.
Pairwise comparison matrix for the alternatives with respect to entrepreneurial.

	Domestic Co	Int'l Co	College	State Univ.	Priorities
Domestic Co	1	1/5	1/3	1/2	0.072
Int'l Co	5	1	3	5	0.54
College	3	1/3	1	2	0.172
State Univ.	4	1/5	1/2	1	0.162

Table 15.
Pairwise comparison matrix for the alternatives with respect to top level position.

respect to the covering criteria. It is clear that the domestic company is the preferred candidate. The second candidate is the college, then the third candidate is the international company and the last candidate is the state university.

	Domestic Co	Int'l Co	College	State Univ.	Priorities
Domestic Co	1	3	2	5	0.47
Int'l Co	1/3	1	1/3	1/2	0.104
College	1/2	3	1	3	0.29
State Univ.	1/5	2	1/3	1	0.129

Table 16.
Pairwise comparison matrix for the alternatives with respect to security.

	Domestic Co	Int'l Co	College	State Univ.	Priorities
Domestic Co	1	4	1/2	3	0.33
Int'l Co	1/4	1	1/6	1/2	0.077
College	2	6	1	2	0.462
State Univ.	1/3	1/2	1/2	1	0.13

Table 17.
Pairwise comparison matrix for the alternatives with respect to salary.

	Domestic Co	Int'l Co	College	State Univ.	Priorities
Domestic Co	1	3	4	5	0.5
Int'l Co	1/3	1	1/2	5	0.197
College	1/4	2	1	2	0.19
State Univ.	1/5	1/5	1/2	1	0.072

Table 18.
Pairwise comparison matrix for the alternatives with respect to reputation.

Alternatives / Covering Criteria	Location (0.0034)	Time (0.0081)	Work (0.0251)	Entrepreneurial (0.0685)	Salary potential (0.0194)	Top level position (0.0348)	Security (0.27)	Reputation (0.081)	Salary (0.49)	Overall weight
domestic company	0.192	0.133	0.32	0.575	0.587	0.072	0.47	0.5	0.33	0.381
international company	0.263	0.092	0.45	0.3	0.248	0.54	0.1	0.197	0.077	0.138
college	0.202	0.483	0.123	0.125	0.15	0.172	0.29	0.19	0.462	0.345
state university	0.343	0.292	0.107	0.074	0.076	0.162	0.129	0.072	0.13	0.123

Table 19.
Final weights of alternatives for AHP method.

As mentioned before, these results of a classical AHP are compared with the results of fuzzy AHP. Therefore, the evaluations are recalculated according to the fuzzy AHP on the same hierarchy structure. The 12 pairwise comparison matrices for all criteria, sub-criteria and alternatives are shown from **Tables 20–32**.

Table 23 shows the calculation of the global weight for sub-criteria with respect to its criterion by multiplying weight of each criterion to the weights of sub-criteria that affect its criterion.

	Flexibility	**Opportunities**	**Security**	**Reputation**	**Salary**	**Priorities**
Flexibility	(1, 1, 1)	(1/5, 1/4, 1/3)	(1/7, 1/6, 1/5)	(1/5, 1/4, 1/3)	(1/9, 1/8, 1/7)	0
Opportunities	(3, 4, 5)	(1, 1, 1)	(1/4, 1/3, 1/2)	(2, 3, 4)	(1/8, 1/7, 1/6)	0
Security	(5, 6, 7)	(2, 3, 4)	(1, 1, 1)	(3, 4, 5)	(1/3, 1/2, 1)	0.237
Reputation	(3, 4, 5)	(1/4, 1/3, 1/2)	(1/5, 1/4, 1/3)	(1, 1, 1)	(1/8, 1/7, 1/6)	0
Salary	(7, 8, 9)	(6, 7, 8)	(1, 2, 3)	(6, 7, 8)	(1, 1, 1)	0.763

Table 20.
Fuzzy pairwise comparison matrix of the main criteria with respect to the goal.

	Location	**Time**	**Work**	**Priorities**
Location	(1, 1, 1)	(1/4, 1/3, 1/2)	(1/7, 1/6, 1/5)	0
Time	(2, 3, 4)	(1, 1, 1)	(1/5, 1/4, 1/6)	0
Work	(5, 6, 7)	(3, 4, 5)	(1, 1, 1)	1

Table 21.
Fuzzy pairwise comparison matrix for the sub-criteria with respect to flexibility.

	Ent	**Sal-pot**	**Top level pos**	**Priorities**
Ent	(1, 1, 1)	(1, 2, 3)	(4, 5, 6)	0.65
Sal-pot	(1/3, 1/2, 1)	(1, 1, 1)	(1/5, 1/4, 1/3)	0
Top level pos	(1/6, 1/5, 1/4)	(3, 4, 5)	(1, 1, 1)	0.35

Table 22.
Fuzzy pairwise comparison matrix for the sub-criteria with respect to opportunity.

Criterion (C)	**Local weight (CL)**	**Sub-criterion (SC)**	**Local weight (SCL)**	**Global weight (CL × SCL)**
Flexibility	0	Location	**0**	0
		Time	**0**	0
		Work	**1**	0
Opportunity	0	Entrepreneurial	**0.65**	0
		Salary potential	**0**	0
		Top level position	**0.35**	0

Table 23.
Local weight and global weight for criteria and sub-criteria.

	Domestic Co	Int'l Co	College	State Univ.	Priorities
Domestic Co	(1, 1, 1)	(3, 4, 5)	(2, 3, 4)	(5, 6, 7)	0.646
Int'l Co	(1/5, 1/4, 1/3)	(1, 1, 1)	(2, 3, 4)	(4, 5, 6)	0.354
College	(1/4, 1/3, 1/2)	(1/4, 1/3, 1/2)	(1, 1, 1)	(1, 2, 3)	0
State Univ.	(1/7, 1/6, 1/5)	(1/6, 1/5, 1/4)	(1/3, 1/2, 1)	(1, 1, 1)	0

Table 24.
Fuzzy pairwise comparison matrix for the alternatives with respect to salary potential.

	Domestic Co	Int'l Co	College	State Univ.	Priorities
Domestic Co	(1, 1, 1)	(1/6, 1/5, 1/4)	(3, 4, 5)	(1/4, 1/3, 1/2)	0
Int'l Co	(4, 5, 6)	(1, 1, 1)	(1, 2, 3)	(1/5, 1/4, 1/3)	0
College	(1/5, 1/4, 1/3)	(1/3, 1/2, 1)	(1, 1, 1)	(1, 2, 3)	0.493
State Univ.	(2,3,4)	(3, 4, 5)	(1/3, 1/2, 1)	(1, 1, 1)	0.507

Table 25.
Fuzzy pairwise comparison matrix for the alternatives with respect to location.

	Domestic Co	Int'l Co	College	State Univ.	Priorities
Domestic Co	(1, 1, 1)	(1/4, 1/3, 1/2)	(2, 3, 4)	(5, 6, 7)	0.508
Int'l Co	(2, 3, 4)	(1, 1, 1)	(3, 4, 5)	(1, 2, 3)	0.492
College	(1/4, 1/3, 1/2)	(1/5, 1/4, 1/3)	(1, 1, 1)	(1, 2, 3)	0
State Univ.	(1/7, 1/6, 1/5)	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1, 1, 1)	0

Table 26.
Fuzzy pairwise comparison matrix for the alternatives with respect to work.

	Domestic Co	Int'l Co	College	State Univ.	Priorities
Domestic Co	(1, 1, 1)	(1, 2, 3)	(1/4, 1/3, 1/2)	(1/5, 1/4, 1/3)	0
Int'l Co	(1/3, 1/2, 1)	(1, 1, 1)	(1/7, 1/6, 1/5)	(1/3, 1/2, 1)	0
College	(2, 3, 4)	(5, 6, 7)	(1, 1, 1)	(1, 2, 3)	0.626
State Univ.	(3, 4, 5)	(1, 2, 3)	(1/3, 1/2, 1)	(1, 1, 1)	0.374

Table 27.
Fuzzy pairwise comparison matrix for the alternatives with respect to time.

	Domestic Co	Int'l Co	College	State Univ.	Priorities
Domestic Co	(1, 1, 1)	(1, 2, 3)	(3, 4, 5)	(5, 6, 7)	0.625
Int'l Co	(1/3, 1/2, 1)	(1, 1, 1)	(2, 3, 4)	(3, 4, 5)	0.375
College	(1/5, 1/4, 1/3)	(1/4, 1/3, 1/2)	(1, 1, 1)	(1, 2, 3)	0
State Univ.	(1/7, 1/6, 1/5)	(1/5, 1/4, 1/3)	(1/3, 1/2, 1)	(1, 1, 1)	0

Table 28.
Fuzzy pairwise comparison matrix for the alternatives with respect to entrepreneurial.

	Domestic Co	Int'l Co	College	State Univ.	Priorities
Domestic Co	(1, 1, 1)	(1/6, 1/5, 1/4)	(1/4, 1/3, 1/2)	(1/3, 1/2, 1)	0
Int'l Co	(4, 5, 6)	(1, 1, 1)	(2, 3, 4)	(4, 5, 6)	0.789
College	(2, 3, 4)	(1/4, 1/3, 1/2)	(1, 1, 1)	(1, 2, 3)	0.211
State Univ.	(1, 2, 3)	(1/6, 1/5, 1/4)	(1/3, 1/2, 1)	(1, 1, 1)	0

Table 29.
Fuzzy pairwise comparison matrix for the alternatives with respect to top level position.

	Domestic Co	Int'l Co	College	State Univ.	Priorities
Domestic Co	(1, 1, 1)	(2, 3, 4)	(1, 2, 3)	(4, 5, 6)	0.573
Int'l Co	(1/4, 1/3, 1/2)	(1, 1, 1)	(1/4, 1/3, 1/2)	(1/3, 1/2, 1)	0
College	(1/3, 1/2, 1)	(2, 3, 4)	(1, 1, 1)	(2, 3, 4)	0.394
State Univ.	(1/6, 1/5, 1/4)	(1, 2, 3)	(1/4, 1/3, 1/2)	(1, 1, 1)	0.033

Table 30.
Fuzzy pairwise comparison matrix for the alternatives with respect to security.

	Domestic Co	Int'l Co	College	State Univ.	Priorities
Domestic Co	(1, 1, 1)	(3, 4, 5)	(1/3, 1/2, 1)	(2, 3, 4)	0.436
Int'l Co	(1/5, 1/4, 1/3)	(1, 1, 1)	(1/7, 1/6, 1/5)	(1/3, 1/2, 1)	0
College	(1, 2, 3)	(5, 6, 7)	(1, 1, 1)	(1, 2, 3)	0.564
State Univ.	(1/4, 1/3, 1/2)	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1, 1, 1)	0

Table 31.
Fuzzy pairwise comparison matrix for the alternatives with respect to salary.

	Domestic Co	Int'l Co	College	State Univ.	Priorities
Domestic Co	(1, 1, 1)	(2, 3, 4)	(3, 4, 5)	(4, 5, 6)	0.649
Int'l Co	(1/4, 1/3, 1/2)	(1, 1, 1)	(1/3, 1/2, 1)	(4, 5, 6)	0.228
College	(1/5, 1/4, 1/3)	(1, 2, 3)	(1, 1, 1)	(1, 2, 3)	0.123
State Univ.	(1/6, 1/5, 1/4)	(1/6, 1/5, 1/4)	(1/3, 1/2, 1)	(1, 1, 1)	0

Table 32.
Fuzzy pairwise comparison matrix for the alternatives with respect to reputation.

Once the weight vector of covering criteria $\boldsymbol{W}$ and the weight vector of the alternative $\boldsymbol{S}$ have been computed, the fuzzy AHP obtains a vector $\boldsymbol{V}$ of global scores by multiplying $\boldsymbol{S}$ and $\boldsymbol{W}$ as:

$$\boldsymbol{V} = \boldsymbol{S} \cdot \boldsymbol{W} \tag{30}$$

Finally, the alternative ranking is accomplished by ordering these global scores in a descending order. **Table 33** shows the final weights of the alternatives with respect to the covering criteria. It is clear that the college is the preferred candidate. The second candidate is the domestic company, then the third candidate is the state university and the last candidate is international company.

Alternatives / Covering Criteria	Local (0)	Time (0)	Work (0)	Entrepreneurial (0)	Salary potential (0)	Top level position (0)	Security (0.237)	Reputation (0)	Salary (0.763)	Overall weight
domestic company	0	0	0.508	0.625	0.646	0	0.573	0.649	0.436	0.469
international company	0	0	0.492	0.375	0.354	0.789	0	0.228	0	0
college	0.493	0.626	0	0	0	0.211	0.394	0.123	0.564	0.524
state university	0.507	0.374	0	0	0	0	0.033	0	0	0.007

Table 33.
Final weights of alternatives for fuzzy AHP method.

5. Conclusions

In this chapter, a comparative analysis of analytic hierarchy process and fuzzy analytic hierarchy process is presented using two levels of criteria example. The analytic hierarchy process method is mainly used in crisp values, the normalized weight of each alternative shows that domestic company has higher priority (0.381) than the other alternatives while the fuzzy analytic hierarchy process used in range values, the normalized weight of each alternative shows that college has higher priority (0.524) than the other alternatives.

The fuzzy analytic hierarchy process approach is preferred by decision makers than analytic hierarchy process approach because fuzzy analytic hierarchy process applies a range of values to incorporate the decision maker's uncertainly. It enhances the potential of the analytic hierarchy process for dealing with imprecise and uncertain human comparison judgments.

The example showed that weight values of some criteria, sub-criteria and alternatives in fuzzy analytic hierarchy process became zero, as shown in **Tables 20–22**, etc., which look odd as results, because normally all given criteria are used in pairwise comparisons and assumed to be evaluated to non-zero values. This is not a strange position because the decision makers may do not take into account one or more criteria for the evaluation even if these criteria are set in the hierarchy. Therefore, the fuzzy analytic hierarchy process approach provides to eliminate the unnecessary criterion or criteria if all of the decision makers assign "extremely important" value when compared with the other criteria and expresses the less important criteria.

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Chapter 3

Business and Information System Alignment Theories Built on eGovernment Service Practice: An Holistic Literature Review

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Abstract

This chapter examines previous studies of alignment between business and information systems holistically in relation to the development of working associations among professionals from information system and business backgrounds in business organization and eGovernment sectors while investigating alignment research that permits the development and growth of information system, which is appropriate, within budget and on-time development. The process of alignment plays a key role in the construction of dependent associations among individuals from two different groups, and the progress of alignment could be enhanced by emerging an information system according to the investors' prospects. The chapter presents system theory to gather and analyze the data across the designated platforms. The outcomes classify that alignment among business and information system departments remains a priority and is of worry in different ways in diverse areas, which provides prospects for the forthcoming discussion and research.

Keywords: theories, practices, goal modeling, IS alignment, working relationships, system integration

1. Introduction

The trend toward globalization of the business and eGovernment sector remains undiminished and has produced philosophical renovations, both internal and external, as mostly business firms and eGovernment sectors seek to establish strong alignment in their value chain while attempting to hearth closer relations with their customers and commercial partners. In answer to, or anticipation of variations in their atmosphere, most of organizations and eGovernment sectors are deploying information system applications for this purpose, at a rising rate [1–4]. Thus, this has elevated a key question vital to the present business and eGovernment paradigm: how can an eGovernment and business organization truly justify its investments on information system in the context of donating to business organization and eGovernment performance, be it in terms of effectiveness, augmented market share, output, or other pointers of structural usefulness?

From the early 1960s information systems have been characterized by rapid development and integration with business becoming essential components of most business organizations and industrial firms. Most business organizations in all sectors of industry, government, commerce, academia, and health in developed countries are fundamentally reliant on their information systems [5, 6]. For business organizations to stay competitive in an active business environment, they have to establish and understand how to manage their information systems systematically. A key contributor to the successful operation of a profitable business in the contemporary business environment is an effectual and efficient information system strategy supporting business strategies and processes [7].

2. Research questions and objectives

The aim of this chapter is to study the process of alignment between business and information systems holistically. This chapter covers general information on alignment in the context of eGovernment practices and summarizes previous research findings, particularly in the context of strategic, structural, social, cultural, and ulterior issues in business organizations as well as engineering requirements to achieve better information system performance. The specific research objectives are as follows:

- To identify the critical success factors of alignment with respect to eGovernment and organizational performance
- To identify the benefits of existing alignment methods and technologies
- To identify the barriers and enablers of alignment of eGovernment with organizational performance

3. Theoretical framework

Literature review indicates that the current studies on the process of alignment among information system and other agencies in eGovernment research delivers three key information system theories in relation to internal and external administrative subjects, and these include process theory, system theory, and network theories.

System theory is the interdisciplinary theory of IS in general, with the aim of determining patterns and clarifying principles that can be distinguished from, and functional too, all types of IS at all nesting levels in all fields of IS research. This theory's main focus is on internal organizational relationships. Process theory is usually used in the form of technical investigation in which events or actions are said to be the outcome of certain input situations leading to a convinced concluding state. This theory also provides a conceptual framework of knowledge creation processes which align all levels of business organization. Network theories examine the business organizational structure in relation to the organizational social aspect. These theories tend to place more emphasis on the business structures and dynamics of social relationships [8, 9].

However, due to the nature of this research, we have used system theory to underpin this study. A system theory in the context of this literature review will reflect a concern to look at possible literature as a whole (holistically). This is in contrast to the technical or engineering method, which tends to resolve problems by breaking

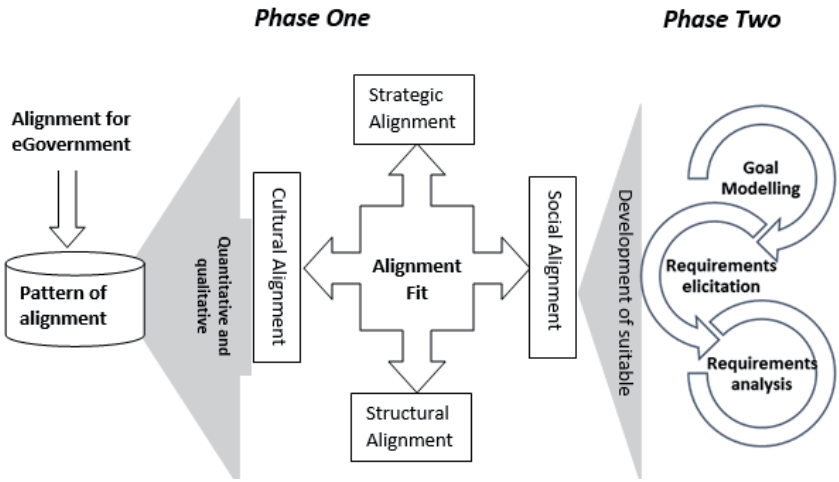


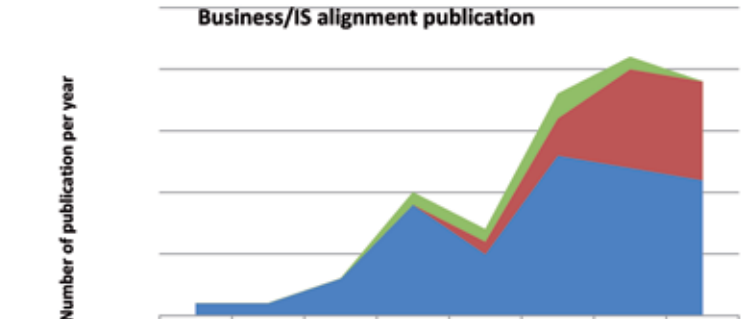
Figure 1.
Theoretical framework of alignment between eGovernment and organizational performance.

them down into smaller and more controllable fragments [10]. After this detailed review, the alignment frame for future research has been proposed as shown in **Figure 1**. Phase one of the framework presents qualitative and quantitative studies of alignment, while phase two presents goal modeling in the context of organizational requirements and the development of suitable eGovernment IS.

4. Method

In this section, a description of the holistic literature review between an organization and its information system alignment plan has been presented. To conduct this study, we followed several steps. First, we searched for manuscripts published in reputed journals and conferences during the period between January 1977 and October 2015 dealing with the government information systems (or eGovernment) or information technology. Our initial list of information systems and information technology journals included the *Academy of Management Journal* (*AMJ*), *Quarterly* (*ASQ*), *Journal of Management* (*JOM*), *MIS Quarterly*, *European Journal of Information Systems*, *Information and Management*, *Journal of Computer and Security*, *International Journal of Information Management*, *Information Technology (IT)*, and *Journal of Strategic Information Systems*. To these we also added the leading practitioner-oriented journals, namely, the *Harvard Business Review* (*HBR)*, *California Management Review (CMR)*, and *MIT Sloan Management Review* (*MSMR*). Focusing on manuscripts that contain the terms "*alignment*" or "*synchronization*" in the title or keywords, our preliminary search revealed 31 manuscripts on business and information system alignment. Out of these, 26 had been published in information systems and information technology journals, while five appeared in *HBR*, *CMR*, *and MSMR*.

However, the selected set of manuscripts on alignment were relatively few which led us to extend our search to the IEEE digital library, Web of Science, and ACM digital library databases. These databases include more than 1000 information system journals, and these databases represent one of the most complete sources on information systems and information technology studies. In our case we searched these databases for academic manuscripts published from January 1977 to October 2015 containing the terms "*alignment*" or "*synchronization*" in the title, abstract,



	1977-1982	1983-1987	1988-1992	1993-1997	1998-2002	2003-2007	2008-2012	2013-2015
Book	0	0	0	1	1	2	1	0
Conference Papers	0	0	0	0	1	3	8	8
Journal Papers	1	1	3	9	5	13	12	11

Figure 2.
Selected publications.

keywords, or conclusion. As a result of this process of searching manuscripts on alignment, we obtained 101 manuscripts, which we added to our preliminary sample of 31 manuscripts. Since 15 of the newly added manuscripts were already present in the preliminary sample, our overall sample remained 117 manuscripts.

The method of inclusion and exclusion starts from a preliminary quick analysis of these manuscripts, performed by reading manuscript titles, manuscript abstracts, introductions, and conclusion which discovered that not all the manuscripts that we identified during this search would be useful for conducting this holistic review on alignment. Several of these manuscripts were summaries of manuscripts published elsewhere and studies in which the alignment between business and information system is not actually the theme of the analysis.

To classify relevant manuscripts, we adopted the following two additional criteria for our review on alignment between business and government information systems (eGovernment). Firstly, a manuscript must refer to the alignment between business and information system as a concept associated with business organizations (e.g., organizational strategy, structure, culture, etc.) to be included in this literature review. Secondly, a manuscript must deal with the alignment notion in a nontrivial and non-marginal way. As a result of this process, we eliminated 42 manuscripts that did not fulfill these criteria, which left us with a sample of 75 manuscripts.

While studying these 75 manuscripts in detail, we identified further work on alignment. For example, some books appeared relevant; however, due to access limitation, we only added books which were easily available. We also found several relevant working papers that our selected databases had failed to reveal and some of which were subsequently published. Moreover, our thorough studying of these manuscripts also allowed us to exclude papers in which the alignment was treated in a rather inconsequential way. Therefore, the final sample of select manuscripts contained 80 studies. **Figure 2** represents the selected articles from 1977 to 2015.

5. The evolution of alignment concept

This section presents an analysis and discussion on the selected articles and includes what we have learnt during the literature review of alignment between business and government information systems. Each selected article was analyzed

in the context of alignment terminologies, alignment origin and motivations, alignment definitions, alignment directions, alignment models, system modeling for alignment and eGovernment, and the future of alignment as shown in **Figure 2**.

Alignment terminologies: The issue of alignment has been studied by researchers from different business perspectives such as health, education, banking, construction, and so on. The concept of alignment was discussed with different terminologies, including alignment [11], fit, marriage, synchronization [2–4], linkage [11, 12], integration [11], harmony [11, 13], and bridge [2–4, 11, 14].

Origin of alignment: The notion of alignment originated from a body of theoretical and empirical work within business organization literature whose primary proposition is that organizational performance is the result of relationships between business and information systems. Maintaining relationships among business and information system departments, linking the communication gap, aligning structure, and improving information system trust within a business organization have become a progressively more important preference for organization CIOs and CEOs [11, 15, 16]. The process of alignment is important to business organizations for several reasons. The key advantage is to simplify the overall business organizational goals and objectives and to professionally identify the role of information systems to better support the business organization to achieve its goals and objectives. The secondary advantage is that alignment of information systems allows business organizations to not only recover their business scope but their infrastructure as well, by harmonizing their relationship with their information system [2–4].

Furthermore, managing information system processes will improve the worth and productivity of the business [2–4, 17]. This synchronization between information system and business will boost over time as information technology starts impacting every stage of the business organization such as the project stage, strategy stage, planning stage, and so on [11]. However, it has been realized that business organizations which were based on conventional business strategies failed to take full advantage of information systems [18, 19], but instead, they used information systems only at the back end or considered it as disbursement rather than as a business organization value enabler [17, 20].

The idea of alignment emerged in the early 1970s [1]. From there, alignment researchers have been under pressure to approach the problem through connecting the business arrangement with the technology arrangement. Early approaches were ad hoc, given the level of displeasure in business organizations regarding their viewpoint on information system departments. These hypotheses have prolonged over time, and nowadays, academics point out many concerns and challenges and have developed dissimilar alignment approaches, techniques, and models.

Alignment definitions: The process of alignment between businesses and information systems involves two key questions: how does the information system align with the business environment? And how does the business organizational environment align with the information system environment within the business organization? Therefore, alignment consists of two elementary concepts, namely, business planning and information system planning [11]. There are various definitions of business and information system alignment in existing literature, but the most prominent ones that have been selected for the purpose of this research are as shown in **Table 1**.

Unexpectedly, however, the alignment is often studied without a clear definition of the concept. Of the 80 alignment articles reviewed, more than one third (35%) do not define the idea of alignment at all. Less than half (43%) explicitly define or conceptualize the process of alignment. The remaining articles (22%) refer to the work of other researchers in defining the alignment concept. This lack of definitional transparency represents a possible source of uncertainty, promoting

Originating author(s), year	Definition	Comments	Other papers citing the definition
Henderson and Venkatraman [7]	Alignment is the "degree of fit and integration among business strategy, IT strategy, business infrastructure, and IT infrastructure"	This definition discusses all factors of alignment, such as strategy, structure, social, and cultural factors of the organizations and fit among those factors	[1, 21, 22]
Broadbent and Weill [23]	Alignment between business and IS is the "degree to which it is allowed, supported, and motivated by information technology strategies"	Definition addresses alignment between businesses and IS strategies	[11, 12, 24]
Smith and McKeen [25]	Strategic alignment of IS exists "when an organization's goals and activities and the information systems that support them remain in harmony"	Strategic alignment in context of IS support in order to achieve organizational goals. The idea is similar to the previous definition of alignment	[2–4, 26, 27]
Campbell [28]	Alignment is the process where "business and IT work together to reach a common business goal"	Definite recommends fit between business and IS sectors; however, organizational factors are not clear in the definition	[11, 29]
Reich and Benbasat [14]	Alignment is the "degree to which the mission, objectives, and plans contained in the business strategy are shared and supported by the IS strategy"	Strategic fit in context of IS support in order to attain organizational goals effectively	[11, 30]
Silvius [13]	Alignment is the "degree to which IS applications, IS infrastructure, business strategy, and processes are enabled and shaped"	This definition of alignment discusses the importance of IS applications in business strategy and infrastructure	[11, 31, 32]

Table 1.
Alignment definitions.

diffusion rather than convergence of viewpoints and obstructing cumulative research evolution on alignment. **Table 1** summarizes some of the most important definitions suggested for the alignment and shows which manuscripts have adopted these definitions.

5.1 Analysis of alignment in relation to its directions

Literature shows that alignment between business and information systems demonstrates that the process of alignment can be studied from multiple viewpoints, including from the organization's strategy, structure, culture, and social directions [11, 14, 23, 33, 34]. To analyze this part of the literature review, we search for articles in the context of four directions of alignment. We searched each direction after we have further divided them into four related keywords as shown in **Figures 4**–**7**. After studying 80 articles, we found that alignment was often studied

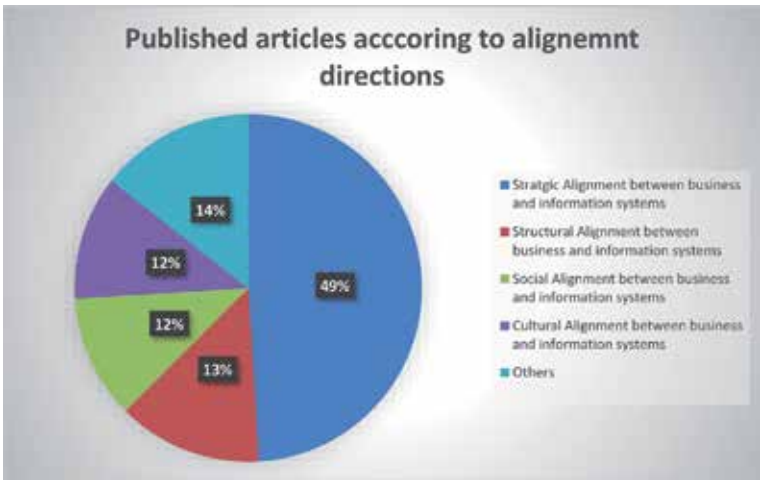


Figure 3.
Alignment directions analysis.

in the context of organizational aspects, as shown in **Figure 3**. Of the 80 articles reviewed, almost half (49%) studied the strategic alignment between business and IS. Thirteen percent of articles discussed the structural alignment between business and IS, twelve percent covered social aspects of alignment, and twelve percent of articles were published on cultural aspects of alignment with the outstanding articles (14%) referring to the work of other aspects of organizational issues such as system modeling in the context of alignment, requirement engineering and alignment, business goals and process modeling, and so on. In this section we briefly describe each of these alignment directions.

Strategic alignment: Today, business organizations are deeply reliant on information system services to increase their business efficiency in almost all areas of the business organization, and to do this, they spend a significant quantity of the company's budget on information system infrastructure. In other words, organizations frequently faced rapid changes in the business environment, mainly in relation to changes in customer services, technologies, and product life cycles. Rapid innovations and rigorous marketplace competition have forced business organizations to update their business strategies in an immediate manner [11, 33, 35] (Hsu et al. 2009).

The idea of business strategy has been extensively studied in the areas of business and information system alignment. According to Lampel et al. (2003), business strategy can be categorized into five different segments: First, a strategy is a plan that is employed to set guidelines in order to implement a proposed course of action. Second, a strategy is a plan that is employed to respond to competition from others. Third, a strategy is a plan that denotes levels of action in business organizations. Fourth, a strategy is a position mentioning to "where" and "when" and needs to be applied to business actions, which could be both internal or external actions of the business organization. Fifth, a strategy is a viewpoint that denotes the differing viewpoints of managers when implementing the business model [36]. The selected articles on strategic alignment between business and information systems were carefully studied and have been added to the reference list. Also, their percentage in the overall topic of alignment is as presented in **Figure 3**, while their presented themes are as shown in **Table 2**. Moreover, **Figure 4** presented the percentage of selected papers according to the studied keywords in this alignment direction.

Alignment direction	Commonly studied themes	References
Strategic alignment between business and information systems	Connection between business and IT plan, strategic alignment, business and IT common strategy, IT strategy, business strategy, IS investment, business performance, government strategy, IS resources, unclear strategies of business and IS, organizational rules, IS involvement in business strategy, IS leadership, suitable IS system, business and IS relationships, IS requirement engineering, IS usage	[16, 33, 35, 37–46]
Structural alignment between business and information systems	Business and IS structure, complexity of organizational structure, centralized business units, lack of IS methodologies, formal business and IS structure, structural differences between business and IS, lack of IS support, importance of IS structure, eGovernment structure	[21, 23, 47–50]
Cultural alignment between business and information systems	Strong involvement of upper level management, good managed working relationship, strong leadership, effective communication, business and IS planning at a lower level, communication gap, cultural relationship, IS in business decision-making, belief in IS, communications maturity, governance, IS maturity, government rules in cultural alignment	[34, 51, 52]
Social alignment between business and information systems	Shared domain knowledge, IS history, communication between business and IS executives, business and IS planning, maintaining IT belief in the business, long-term relationship, relationship between CEOs and CIOs	[11, 14, 53–55]

Table 2.
Studied common themes in alignment directions.

Figure 4.
Strategic alignment according to factors result.

Structural alignment: It is expensive for any business organization to have a large number of managerial personnel and administrative controls. Therefore, it is significant to eliminate pointless managerial work within an enterprise [14, 53]. A business organization structure is a method within which organizations, departments, people, and functions are linked and interrelate with each other in order to attain common business goals. In relation to business achievement, selecting the right structure of the business is significant and requires extensive preparation, because not all kinds of structures are well-matched to all businesses or people [11, 21, 23, 48].

The selected articles on structural alignment between business and information systems were studied and analyzed, and their percentage in the overall topic of alignment is as presented in **Figure 3**. Moreover, **Figure 5** presented the percentage of selected papers according to the studied keywords in this alignment direction.

Cultural alignment: The notion of business culture became prevalent in the early 1980s and was derived from the early humanist associations' view of organizations that arose in the 1940s. Three key elements, beliefs, shared values, and behavioral norms, are required in order to endure a strong organizational culture. Numerous methodologies relating to alignment from a cultural viewpoint have appeared on many previous studies. These studies have addressed the following organizational factors: strong involvement of senior management, well-managed working relationship, strong leadership, belief and effective communication between groups, connection between business and IT functions, cultural relationship at all phases of the business organization, informal business structure, and so on [34]. The selected articles on cultural alignment between business and information systems were studied and analyzed and their percentage in the overall topic of alignment is presented in **Figure 3**. Moreover, **Figure 6** presented the percentage of selected papers according to the studied keywords in this alignment direction.

Social alignment: The social dimension of alignment in the business environment contains several components such as taxes, organizational lifestyles, and the standards that describe the society in which the business organization operates. This dimension impacts the ability of the business organization to gain resources, services, and functions that improve organizational performance [11, 14, 53, 54]. However, in the context of business and information system alignment, the social direction of the organization relates to the degree to which managers understand and are committed to the business and information system mission together with organizations' objectives and plans [34, 51].

Numerous methodologies relating to alignment from a social viewpoint have appeared in many literatures, where researchers have addressed the following organizational factors: shared domain knowledge between business and IT executives, successful history of information systems, communication between business and information system executives, connection between business and information system planning, sharing knowledge between business and

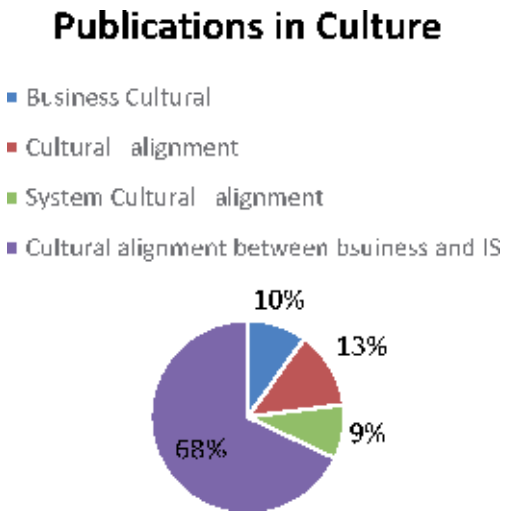


Figure 5.
Structural alignment according to factors result.

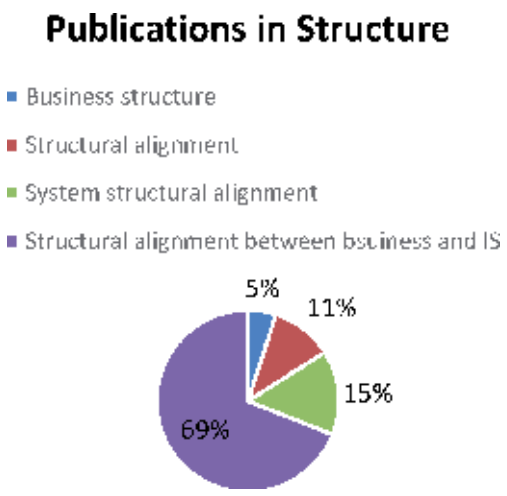


Figure 6.
Cultural alignment according to factors result.

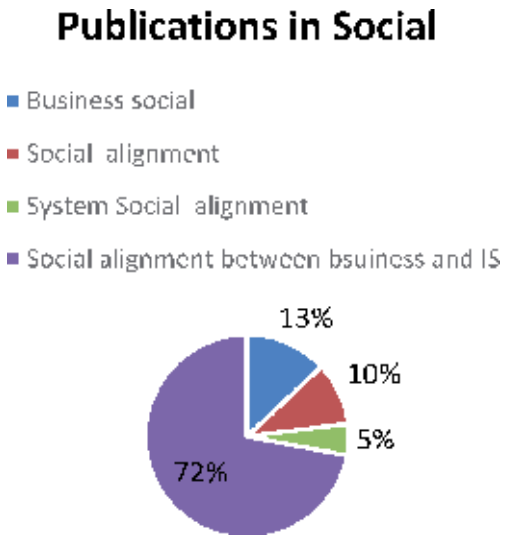


Figure 7.
Social alignment according to factors result.

information system technical people, and maintaining belief in the information system [11, 14]. The selected articles on social alignment between business and information systems were studied and analyzed, and their percentage in the overall topic of alignment is presented in **Figure 3**. Moreover, **Figure 7** presents the percentage of selected papers according to the studied keywords in this alignment direction.

5.2 Alignment models and alignment theory analysis

During this whole process, we found only two articles (2%) that presented alignment models. Henderson and Venkatraman [7] developed a model called the strategic alignment model (SAM). The model is the most widely accepted in the field of business/IS alignment. The model is based on four different strategic domains, namely, strategy, organizational infrastructure, and process, IS strategy

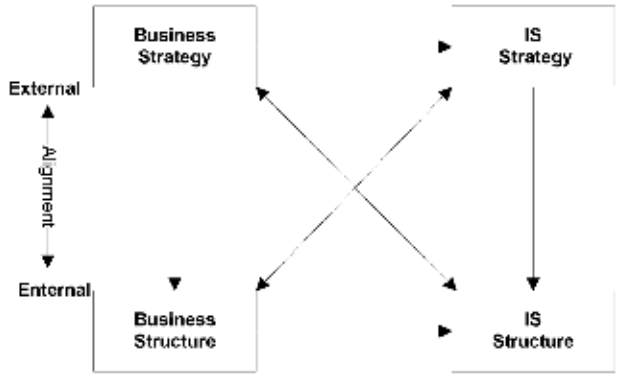


Figure 8.
SAM model of alignment [7].

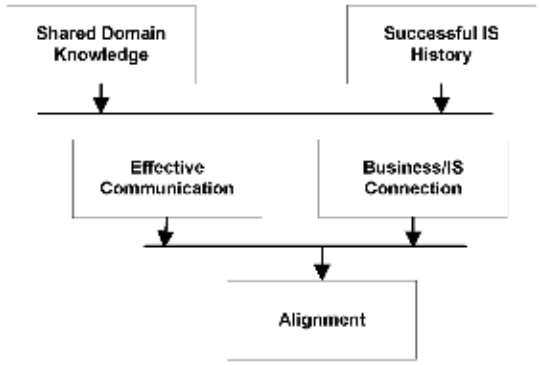


Figure 9.
Cultural alignment model [14].

and IS infrastructure and process, as shown in **Figure 8**. This model received support from the business industry and practitioners.

Reich and Benbasat [14] have conducted work on cultural and social issues of organizations, and they proposed an approach to measure the relationship between business and IS. As shown in **Figure 9**, four different factors of social dimensions were considered, and these are shared knowledge between business and technology executives, the success of technology within the business, communication, and the connection between the business and technology planning process. Moreover, the selected alignment theories and models have been analyzed in the context of their alignment measurement type and study theme, as shown in **Table 3**.

5.3 System modeling in the context of alignment and eGovernment

The term eGovernment refers to the use of information system (IS) services by government agencies that have the potential to transform relationships with industries, citizens, and other arms of the government [56]. IS technologies can serve a variety of different ends such as better government services to citizens, enhanced interactions between the government and business and industry, and management of government administration. However, the process of managing and providing IS services to any government is always a hard job, due to rapid changes in the government environment and a lack of alignment between the government administrations and IS departments [57].

Theory/model	Alignment measurement type	Theme	References
Understanding the impact of business cases on IT investment decisions	Theoretical model	eGovernment	[58]
Alignment model using resource-based view method and COBIT	Case study approach	Business organization	[59]
IT investment management framework of government institution	Empirically proved	eGovernment	[56]
Model of strategic alignment between business and IS	Empirically proved	Business organization	[60]
Links IS plans and business plans and business plans with information system plans	Questionnaire approach	Business organization	[15]
Business goal study in the context of system requirements engineering	Empirically proved	eGovernment	[17]
Strategic use of new Internet technologies in government	Configuration approach	eGovernment	[57]
Connection between business strategy, business structure, and IT strategy structure	Questionnaire approach	Business organization	[23]
Outcomes of strategic IS alignment	Empirically proved	Business organization	[24]
IT governance to fit your context	Case study	eGovernment	[61]

Table 3.
Alignment theories and models analysis.

Study themes	References
Goal modeling and IS requirements	[2–4, 17, 62–64, 70]
Linking business and IS strategies	[2–4, 12, 17, 62–66] De la Vara González and Díaz 2009; De la Vara González and Díaz 2008
Business process management	[64, 65, 67, 68]
Lack of system support	[2–4, 17, 65–66, 69]
Business/IS long-term focus	[2–4, 12, 66]

Table 4.
Previous study approaches in the context of IS requirements and alignment.

One way of developing suitable systems and system processes according to government expectations is the derivation of IS requirements from the government goals and objectives [2–4]. In this study, we analyzed and categorized the previous studies into the following emerging main themes: goal modeling and IS requirements, linking business and IS strategies, business process management, and lack of system support and business/IS long-term focus. **Table 4** summarized the selected methodologies within their main context.

In the context of "goal modeling and IS requirements," Gartlan and Shanks [12] present an alignment framework which is based on the idea of business goal modeling and IS requirements, and its outcome allows IS analysts to monitor

the requirements at an early stage of IS development. Card et al. [70] present their goal-based workflow and GOMS approaches and suggest a business goal and business process-based infrastructure for system requirement elicitations in regard to clarifying the IS and to understanding the current organizational circumstances. More recently, Ullah and Lai [2–4] presented a business goal modeling using an IS requirement engineering approach. The aim of the approach is to help IS developers better understand organizational goals and their expectations of the required IS.

In relation to the "linking business and IS strategies," Bleistein et al. [26], Bleistein et al. [17] and Veres et al. [68] presented an IS requirement-based model called B-SCP that enables the verification and validation of system requirements in terms of alignment and support for organizational strategy. Veres et al. [68] identify that one problem with the B-SCP model is that it is very complex to trace the dependency among IS requirements from the perspective of complex organizational projects. They extend the B-SCP model by describing an ontology data structure in order to represent the IS requirements and to establish the relationship between business and IS strategies. Zowghi and Jin [71] developed a framework for identifying IS requirements, where the framework supports the systematic identification of IS requirements which include the requirements elicitation and analysis [17, 26, 68, 71].

In the context of "business process management," Goto et al. (2005) present a business process-oriented requirement engineering model to understand the association between organizational processes and IS. The model defines three phases of requirements engineering, elicitation and business process verification, where they define the purpose of the organizational process; IS requirements elicitation and verification of detailed organizational processes, where they manage the process-driven IS requirements using a scenario-based approach; and IS elicitation and system specification, where they identify the IS requirements with the customer. Cardoso et al. [72] proposed an organizational process-based model for system requirements and found that modeling organizational processes is a conventional practice in the system requirement field which facilitates problem comprehension (Goto et al. 2005) [72].

Finally, in the context of "lack of system support and business/IS long-term focus," De la Vara Gonzalez and Diaz [65] proposed an IS requirement elicitation approach to improve business/IS alignment and believed that system requirements is the bridge between enterprise and system domains. Weiss et al. (2008) presents an approach known as SIKOSA, where they define a method of system requirements derived from the business environment. Broadbent and Weill [23] and Kaplan and Norton [73] indicate in their methodologies that organizations today are moving quickly toward IS-oriented solutions within their businesses, especially the use of IS in business decision-making [65, 67]. Kappel [66] and Lehtola et al. [69] suggested in their methodologies that the best way of achieving long-term IS planning and alignment is to map system requirements with business planning [66, 69, 74].

6. Discussion and implications

After this detailed literature review of business and information system alignment in the context of eGovernment, we have found that studying complete alignment patterns as shown in our theoretical model in **Figure 1** (i.e., strategic alignment, structural alignment, cultural alignment, and social

alignment) in the eGovernment sector is important as the eGovernment sector of any country would have several pillars with each pillar being interlinked with each other. Evidence from the literature shows that even though there are a relatively large number of alignment methodologies which have been developed in the previous studies, most of these studies merely focused on general IS alignment and businesses, while very few have focused on government information systems (i.e., government) alignment with respect to government organizations and administrations. Therefore, the framework for measuring and attaining alignment remains a serious issue among government organizations and, most especially, in the developing economies as shown in **Figure 3** and **Figures 4**–**7**.

As a result of this problem, most eGovernment information systems have failed to yield appreciable and expected return on investment (ROI) due to the problems of lack of alignment or effective synchronization between the government departments and the information system departments. Consequently, this raises many questions such as how can government organizations better utilize their IS investments so that they are able to achieve high business or organizational performance and grow productivity, raise annual revenue, and improve viability. Given the multifaceted nature of this question, previous investigators have failed to answer most of these questions with respect to government organizations but rather suggested different alignment methodologies in the private sectors. They have argued that IS alignment has an optimistic influence on business organization performance, if it is correctly matched with or fitted to their managerial, structural, social, and cultural strategies [75]. Numerous existing alignment methodologies present distinct patterns for strategic, structural, and cultural alignment, that is, a pattern for strategic alignment among business and IS, a pattern for cultural alignment among business and IS, and a pattern for structural alignment among business and IT [23, 26, 75].

Only a small number of existing alignment methodologies present patterns for alignment of two of these areas, for instance, structural alignment between business and IS together with strategic alignment among business and IS [17, 26]. However, the patterns for aligning one aspect of organization or two are not sufficient for the complete measurement of alignment between business and information systems in the context of eGovernment and to recognize the impact of alignment on Government performance. Therefore, a pattern for the alignment of business and IS in all four areas, strategic, structural, social, and cultural, is of vital importance for any eGovernment sector [34].

IS technologies can serve a variety of different ends such as better government services to citizens, enhanced interactions between the government and business and industry, and management of government administration. However, the process of managing and providing IS services to any Government is always a hard job, due to rapid changes in the government environment and a lack of alignment between the government and IS departments. Strong alignment between IS and other departments of the government can achieve better administration and organizational performance in many ways such as strategic, social, cultural, and structural performance [2–4]. One way of developing a successful IS system is to model the government goal first, as one goal may have several subgoals as shown in **Figure 1** and then derive the system requirements from those goals [2–4, 17, 76].

Literature shows that business organizations can only perform better if they aligned with their information system departments. This chapter presents a literature review of alignment methodologies in the context of business performance and eGovernment. The chapter is anticipated to be suitable for researchers considering conducting research in this area and business executives seeking to assess the detail literature review on alignment.

7. Future research directions

Analysis of previous studies of alignment between business and IS clearly showed that the problems of alignment with respect to eGovernment certainly exist. Furthermore, several previous authors agreed that the successful alignment process promises many benefits to any organization among which are better business performance for the organization, effective strategic planning toward better IS support to the business, a stronger relationship between business and IS, and bridging the communication gap at all levels of the business organization. However, alignment is not a single key to press the button and fix the issue as it is a continuous process. Therefore, details of future research directions are as follows:

1. Researchers in business/government IS alignment have increasingly come to view as resulting from the alternatives that individuals make within an ever rapidly changing business environment. If these alternatives or business choices can be identified, a practical next step in the field of business/eGovernment alignment is to discover the behaviors that herald them. This line of consideration is in agreement with the micro-foundations theory of management and information system where analysis is performed at the behavioral strategy level to incorporate the actions of goal-seeking economic agents. The micro-foundation has been discussed previously; however, the concept remains controversial and subject to considerable academic debate. For example, to advance the micro-foundations concept, alignment researchers would need to tackle the way that strategic alternatives/choices can be aggregated across actors and time to predict business performance.

2. Alignment is the degree to which the IS objectives, mission statement, and plan support are supported by the business organizational objectives, mission statement, and plans. Evidence from the literature shows that the concept of alignment has been studied from various points of view in the context of alignment between business and IS. However, most researchers believe that business/IS alignment research has demonstrated that the issue of strategic differences between business and IS can be resolved using IS requirements techniques. Moreover, many researchers believe that further research is warranted to enhance our understanding of the multidimensional nature of strategic alignment in contemporary organizations with more complex structural forms [2–4].

3. Literature shows that researchers have studied alignment in different contexts, for example, the strategic difference between business and information system, the structural difference among business and information system, and the cultural difference among business and information system. Future research is possible on identifying the complete pattern of alignment which includes alignment between government strategy and IS strategy, alignment between government structure and IS structure, cultural alignment between government organization and IS, and social alignment between government organization and IS.

4. Government organizations constantly faced rapid changes in the business market, particularly in relation to changes in consumer services, technologies, and product life cycles. In this context of rapid modernization and strong market competition, organizations need to change their business strategies and processes which are frequently improved and evaluated. However, this

rapid change affects alignment processes badly due to the IS series which are not on time [2–4, 69].

5. Most of the exiting alignment methodologies are business driven rather than IS driven. Therefore, technology staff often has difficulty in identifying business goals and objectives. Further research is possible on proposing an alignment solution from the IS side [11].

6. The development of a successful IS in the context of alignment is not only necessary for the identification of IS requirements; the organization activities must also be taken into consideration before commencing the development phase of the system; therefore, the organizational goal and process modeling are required. Therefore, further research is possible with the business goal modeling in the context of alignment and better government performance.

8. Conclusion

In this chapter, we have analyzed, categorized, and discussed previous literature on alignment between businesses and information system research by exploring articles from relevant databases. Two main implications can be derived from this review. Firstly, for researchers who are interested in conducting research in the areas of government information system (i.e., eGovernment or public sectors information system) alignment, this article presents directions and a detailed survey from alignment between business (i.e., private sectors) and information system. Therefore, the knowledge derived from the business (private sectors) and information system could serve as a foundational knowledge in the development of workable alignment models for the eGovernment (public sector) platforms. Secondly, for any organizations (private or public), this article describes the significance of alignment for the business organization's success, and also it describes how CEOs and CIOs could measure and maintain the alignment within their organizations.

In conclusion, after this detailed review, we found that the alignment research community has made significant development along many fronts, at the same time, the rapid change from the organization's side, particularly change in product life cycle and consumer services. This increasingly demands raised many new serious alignment research questions. For these reasons, it is a thrilling time to be involved in the field of alignment research.

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Chapter 4

How Does Socio-Technical Approach Influence Sustainability? Considering the Roles of Decision Making Environment

Hadi AL-Abrrow, Alhamzah Alnoor, Hasan Abdullah and Bilal Eneizan

Abstract

Aim/purpose: the current study explains the mediation of ERP in the role of a socio-technical approach and decision-making with firms' sustainable performance. *Background*: despite the existence of existing literature on success and failure factors of ERP, the current work highlights the impact of socio-technical factors and decision-making environment on ERP success. Additionally, the weak research work regarding the mediation of ERP is addressed here in this study and has tried to fill the mentioned gap. *Contribution*: the most important contribution of the study is assessing the mediating role of the ERP system in the linkage of decision-making environment and socio-technical factors. Moreover, the work contributes by examining the moderation of organizational culture while relating the socio-technical environment and ERP system. *Findings*: the study finds that there is a significant role of ERP as a mediator while relating socio-technical elements and the decision-making environment; however, we do not find any significant moderation of organizational culture in the linkage of ERP system and socio-technical elements. *Impact on Society*: the societal implication of the study is that it provides a reference for the firms having the same cultural characteristics while using ERP to overcome the issue of pollution in Iraq.

Keywords: organizational culture, socio-technical approach, decision-making environment, ERP system, sustainable performance

1. Introduction

Many multinational companies came in agreement with Iraq in the mid of 2009 in which they were required to work for sustainable performance and keep the focus on improving environment and standard of living for locals by refraining from what they were previously focusing, i.e., only profit. After this agreement, Iraq agreed to issue licenses for various multinational companies, so they can work for the exploration and production of oil and gas. Now, foreign oil companies in Iraq are seeking for "sustainability." There was very little investment in the Iraq oil industry before this agreement was signed in 2009. Iraq canceled her contracts

with many oil companies which failed to provide value to the environment, and it became the need of the hour for these companies to make internal changes in their processes so greater benefits are brought for the society. A company gets a competitive advantage over others by getting the sustainable performance, and for this purpose, they needed to bring an integration among different components of their organization [1]. To achieve integration in a better way and seek sustained performance, adoption of information technology was needed by these companies [2] in all their processes (both internal and external). Worldwide, a lot of organizations rely on enterprise resource planning (ERP) system to help them integrate their various organizational components [3, 4].

Organizational culture plays a vital role in several organizational processes [5], in which organizational change process is of keen importance. If we discuss organizational culture, then it indicates shared meaning, interpretations, values, norms, and the main thing which directs people [6]. The main thing on which the success or failure of a change process depends is the culture of the organization as to whether it supports or resists when there is some change [7, 6]. For an ERP system to be applied, a complete change process is required in a company for which it needs an organizational culture which supports change. Ref. [8] observed that there should be a supportive environment for decision-making to help in the change process. When an organization is working on change process for the environment, it should focus on creating a culture that supports to have a technological and social change which includes innovation, flexibility, adopting new technology, and opening new ways of entrepreneurship [9]. Then, it will help to evaluate how much success they were in getting the desired results [11].

In the studies up to present date, an ERP system is taken as an IT-based system which tends to replace our old systems and, in this way, help in the change process [12, 13], and organization will get fruitful results when this system is implemented and executed successfully [14]. To increase the chances of success of an ERP, we need to give proper attention to the values of the previous system which include sociocultural elements, decision-making environment, and present organizational culture, and then we will be able to get the desired results.

In the past, researches have been done to discuss the important factors on which success and failure of an ERP system are based and the extent to which it has an impact, but in this study we will consider only two factors, i.e., socio-technical elements and environment of decision-making, and see that their impact on the success or failure of an ERP system means whether or not they are contributing toward a sustainable performance. You will be amazed to know that when we use ERP for a long time, it impacts not only processes positively but also the performance of the firm and thus enables top management and owners to get benefits from this system [15]. Al Dhaafri and Al Swidi [16] observed that to change traditional procedures and get maximum performance from an ERP system, we require nontraditional, risky, innovative, and visionary decisions. You need to be sure about the main reason for implying an ERP system in your firm, and only then, you will be able to get maximum benefits. In the decision-making environment, the decision-makers must be capable enough, and their temperament is highly tested [17]. ERP system serves as an intervening variable in the abovementioned relationship [16]. So, to get positive results, an organization needs to have a good ERP system [17]. There are many precedents in an organization that plays a vital role in the success of this system [18]. When we see the previous studies, they are focused on taking an ERP system as an independent variable which impacts organizational performance, and none of them have taken it as a mediator, and this is where we face a gap between new knowledge and academic research. So, this study is directed to bridge that gap. Moreover the study

will provide the insides of the organizational culture along with the impact on ERP success or failure. Moreover the internal and external environmental factors will be considered in the model [19].

2. Theoretical background

2.1 Configuration model of organizational culture

It was as late as the 1970s and 1980s when the term "organizational culture" was first used in organizational studies [19]. For the success of organizational processes and specifically change process, the culture plays a vital role [5]. Whether or not the culture is supportive to change determines the success of a change process [20].

If we discuss organizational culture, then it indicates shared meaning, interpretations, values, norms, and the main thing which directs people [21]. Of them, good organization culture is one which is very clear for employees and contributes toward the betterment of behaviors in the workplace [22]. There are several culture models such as the configuration model that can be defined as constant progress, which is a continuous process and depends on how we interact with others and the behavior shown by the leadership [23]. Structures, routines, rules and regulations, and norms all form part of it and the bases for guiding and restricting behaviors. Ref. [19] based his organizational culture new model on Hatch and Cunliffe's (2006) and Schein's (1985) model, in which he stated that there are numerous components responsible, both internally and externally, for organizational culture. Assuming the cultural identity of an organization, this model was developed. Moreover the firms' values, strategy, and artifacts and the synergy of the firms' structural design, operational processes, behavioral aspects, and performance were also taken in consideration.

2.2 Socio-technical approach

Due to the development in technology and innovation, now organizational scholars use the term "organizational context" a lot in their research domains [24]. Kling and Lamb [25] state that now, we know that a fit between social and technological environment is of keen importance and has been named as "socio-technical approach." It suggests that there is consistency between human and technological behaviors. Another proposal made states that any change in technological behavior will have its impact on social relationships, feelings, and attitudes [26]. If there is already a system existing in any organization, then changing it with the developments in technology requires a lot of hard work. This is because the employees stick to the previous system and the change will impact them, while the development needs to be highly customized to align with the social behaviors of the organization [27].

When a technological change is introduced, system components find it very difficult and complex to cope up with it, and this is because of their dynamic relationship with the existing environment [27, 13]. No matter how deep socio-technical systems are, you need to completely restructure them, and to do so, you need to highly engage social components with the new environments to lower the resistance against the change. The better your social system is integrated with the new technological system, the better results you achieve [14]. The basis for sustainable performance, which is the main objective of firms, is when social system is correctly integrated with the new technological system [24], and thus it will enable to rebrand yourself by reengineering the business [12].

2.3 Decision-making environment

Managers are required to take risks and make daring decisions more often than before, and this is because nowadays, there is a rapid increase in technological changes as we are uncertain about these changes [28, 29]. This change has made problems for organizations. This scenario requires wise decisions that have minimal cognitive biases in them, and having a decision-making environment helps it [28].

There are a set of factors (bases) of any decision-making environment which includes the level of education, synergy, the capacity to analyze, and available information and resources, and they tell how efficient and effective the decision a manager will make [29]. Barney [30] argues that you can say that when you are deciding, the sum of internal and external factors needs to be considered. The factors such as people, organizational units, and other factors are classified as internal, while customers, suppliers, competitors, sociopolitical factors, and technological developments all are external factors [8, 31].

To make improved decisions, the physical variables and the socioeconomic ones require a close interaction for a better decision-making environment [29, 32]. Decision-makers must have the idea about all decision-making environment components like its effects, issues related socially, nature of decision made, and information processing [32, 33]. This increases the importance of environmental components for making efficient decisions [31]. The basis of the decision-making environment is the managerial ability of evaluation and implementation of various plans from decision-makers' past experiences [32, 34]. According to Hsu and Chen [35], the success or failure of any decision-making environment is dependent upon opinion's accuracy and divert sources.

2.4 ERP systems

Installing an enterprise system is not an easy job as it is not only complex but also costly and time taking [36, 37]. If the project is not handled correctly in technical terms, it may turn into a horror story for the business and managers know the consequences of a failed system. To avoid any mishap, organizations are spending too much on ERP systems [38]. It helps a lot in coping with problems related to inventory and working capital. It also bridges the gap between what the customer needs and what the company thinks by providing recent information and helps manage widespread suppliers at a single place [39, 37]. If your ERP system is implemented properly, it will provide you all business data in real time and thus also help in cost reduction which is an important factor in developing countries like Iraq [40]. You need to be aware of the evolution of ERP systems and their strengths, weaknesses, and challenges related to its implementation before you can successfully implement it in developing countries like Iraq [41].

2.5 Sustainable performance

Pollution has increased, natural resources are being depleted, and there are a lot of social problems for businesses, so a big question around the world is about "sustainability" [21]. Since organizations are operating in distinctly different environments, customized strategies work better in achieving "sustainability" for them now than general market strategies [42, 43]. Preventing environment to get damaged and investing in processes and products that are environmentally friendly are a big concern for organizations nowadays and require a huge investment [42]. Stakeholders are also pressurizing organizations in devising their processes and

perform their corporate activities in such a way as to achieve sustainability [44, 45]. A big point of discussion is raised on how to continue the social responsibilities of an organization in general, along with achieving corporate sustainability [46, 47].

To get economic, social, and environmental goals for an organization, managers are working on sustainability performance management to effectively and efficiently use organization resources [48, 45]. There are a lot of standards, nowadays, regarding the environment, human rights, and corporate governance imposed by both national and international bodies, and companies are required by law to follow them. However, sustainability is much more than these legalities [42].

Studies have indicated that there is a need to adopt technology for information and communication sectors as it is of primary importance in improving sustainability. Sustainability is significantly impacted by technology quality, management, and information culture [49]. Ziemba [50] also researched on sustainability information society index and found this index an important one. Greenhouse gas emissions are increasing in Iraq from the energy sector, and there is no government effort in regularizing companies in this regard, as assessed by [51].

2.6 Socio-technical approach, decision-making environment, ERP system, and sustainable performance

When you are installing any technological system in an environment which is socio-technical, you need to give more importance to its elements as they are the deciders for success [52, 53]. Social and technological factors held keen importance for an ERP system to succeed as indicated by research [54, 36]. It is very important to bring change; to do so you need to align technological and social systems and thus bring better coordination among business units which is of primary importance [53]. However, this alignment is not an easy task to perform, because it may have a significant relationship with perceptions, attitudes, and willingness to embrace change [36]. This is more important when implementing ERP requires collective efforts [54]. When decision-making is in process, your communication with the stakeholder becomes of keen importance [53]. Stakeholders are much concerned about the success of implementing ERP systems and taking maximum benefits from it through their perception and knowledge [36, 55].

As evident by prior suggestions, there is a slight decline in outcomes in the shape of operational and economic performance of a firm after it implements ERP system, but the decline is for short term; after that decline, firms are going to achieve better targets in the future [37]. The lag and success after ERP implementation are often the cause of new procedures, software, and channels of information [56]. Clemmons and Simon [57] have recognized ERP system as a way for new information channels, new ways of growth, innovation, and entrepreneurship, and thus it is far more than just a cost-cutting tool. Proper market investigation and exploration of external opportunities can be done by having to access data from customers and market which will help attain sustainable performance in the long run [58]. From operation side to strategic benefits, ERP system adds value in a wide range for a company. You will not see sudden fruitful results in terms of cost-cutting, learning, or other factors, and you need a complete analysis of your organization to get more benefits [59, 60]. The decision-making environment also impacts in achieving sustainable performance as indicated by researches [61]. The social environment needs to be harmonized with new methods to implement new systems successfully and achieve sustainable performance [62]. Sustainable organizational performance is increased when social and technological systems are aligned [63].

2.7 Mediating effects of ERP system

There are some important factors for business performance improver, and gains of an ERP system are highly dependent on them [18]. You will be amazed to know that when we use ERP for a long time, it not only impacts our processes positively but also contributes toward the overall performance of the firm and thus enables top management and owners to get benefits from this system [15]. Al Dhaafri and Al Swidi [16] observed that to change traditional procedures and get maximum performance from an ERP system, we require nontraditional, risky, innovative, and visionary decisions. To gain more advantages from your ERP system, you need to know why you have installed this system. Job characteristics and job satisfaction are also impacted by an ERP system [64]. The perception of people who are running an ERP system has a great impact on the success or failure of an ERP system. Whether they are intended toward its success for better performance or not will be decided by their perception. Alignment and human material fit are required for it.

2.8 Moderating effects of organizational culture configuration

If system elements are interacted closely, chances of ERP system success increase. You first need to create a culture in an organization which will accept and support change and helps in implementing your ERP system successfully [53]. It means that if your ERP system and organization culture are not aligned, then the system is more likely to face failure. The complex interactions that occur in social and technological systems are affected by organizational culture [55]. Understanding and grasping the ERP system by individuals and groups within the organization is determined by organization culture [64]. Performance and competitive advantages are impacted by organizational culture, and it is the decisive factor in determining whether your ERP system will succeed or not [65, 66]. It is the organization culture which has an influence on socio-technical elements of an organization, and it also determines the interaction people will have with technology and the way technology will have an impact on job design and structure [67].

3. Main components of change program

The organizational change program is the combination of different contents, contextual and process [68]. It is required for the purpose of attaining the change process in the organization that should be aligned with the organizational objectives, process, features, and other factors as a whole [69]. As far as the process factors are concerns that are associated the action that is being taken by the managers to execute change in the organization. Process factors are used in order to bring change and how is being implemented such as selecting the best approach to bring change. The selected approach should realize and develop understanding about the benefits of the change implication and ensure them that change approach is highly effective and affirmative for them and for the organization as well [70]. Content is the other feature that emphasizes upon the factors that are required to be changed and will bring positive change on the effectiveness and efficiency in the organization. Content factors are used in assessing the relations between strategic objectives of the organization with the organizational culture like substitute strategic orientation, hierarchy of the organization, and performance-based reward system. It is evident that content factors highly impact upon the organizational and lead their mission and focus adequately [71]. As far as the contextual factors are concerned, they are based upon the environmental factors. These factors include the internal

that focuses upon the culture of the organization like professional approach, management behavior regarding change, hierarchy of the organization, cultural values, and others [69]. As far as the external factors are concerned, it is based upon the outside of the organization like competitive rivalry and government rules and regulation [70]. In the organization external contextual factors are the largest fare for the management to face. The reason is that the organization is not having control on the outside factors [72]. From the management perspective, it is highly important that management should focus upon the developing urgency and readiness to undertake the change execution that will reduce the resistance in the organization and will be effective to make it successful. Readiness is being illustrated such as it revokes the tendency and factors of resistance to be reduced by allowing the change to replace the system [73]. It is required that management should communicate that change in the organization will bring stability and create the difference between current and future positions of the organization. It is evident that change program is meant to reduce the gap between the current and future performances of the organization. Those individuals in the organization that perceive change is better and effective for the organization are always keen to contribute in the change process and make it successful adequately [17]. The study that was conducted in Korean and that selected 72 organizations as the sample where 350 employees were working that suggested readiness to change is the biggest success for the organization to break resistance and make the organizational environment effective and conductive to implement change or ERP system [10]. The benefit of the readiness to change brings the dedication and increases personal approach to adopt change, as far as the behavior of the organizational change process is concerned and the readiness to change is relying upon individual characteristics such as knowledge and gender [72]. The behavior of the individual toward the change process of the educational history suggests that individuals that are having less education are more likely to be the part of the bringing of the change in the organization, and they are supportive to it [69]. Gender and age are also factors to support the change program. Young and energetic employees are keener to adopt the change than the old generation. Those individuals are married, having a close relation with their seniors and colleagues in the organization [36]. It is the management's responsibility to undertake the individual issues and concern because it is an important feature for the development of job design, performance appraisal, and development of reward strategies to motivate the best performance [70].

In order to develop the study, the capability to handle and make the ease in the application of change process of BPR is being used as the readiness to change; the BPR is associated with the organizational employee's ability to have the positive behavior toward the requirement of the BPR system of the organization to adopt the change and have the positive behavior accordingly to make it successful.

Bruch et al. (2005) state that only about 50% of all change programs are successful. The achievement of successful change program is still a puzzle. Therefore, the managers should ask how organizations could ensure successful change processes [30]. For instance, the Dutch "D-Check" program aimed to find a good mechanism to insure success in change process. The program consisted of four phases. The first phase was designing the change. In this phase, the managers asked "what is the right change for the company." In order to achieve that goal, the program was built on the Lufthansa's strategic need. The second phase was focusing the change agenda. The Lufthansa's management built a clear agenda based on clear priorities for the change processes in order to keep it manageable. Therefore, the company identified the right change the company needed. The third phase was to do what the company really is ready to commit to. The company recognized the important role of the credibility of the top management. The top management asked itself at the

designing phase the crucial questions: "What can credibility implement?" "What kind of change are we able to commit to?". Finally, in order to succeed in change processes, company designed a change program according to its current culture [31]. Because BPR implies significant organizational changes in terms of organizational structure, organization's cultures, as well as process management, effective change management is considered a tool to manage and achieve these changes [26].

4. Change and social approach

From the perspective of this approach, change in the organization will be due to the organizational factors but also social factors such as human factors particularly. It is being suggested that successful change will only be possible if the individuals are supporting toward the readiness to change and have the positive intention adequately [74]. Readiness of the employees toward change requirement is required to have the belief, behavior, and intention regarding the change program. There is a need that the organization should develop motivation among the employees regarding their behavior about the change, and it will be effective for the organization to achieve the short- and long-term organizational objectives [57].

Organizational development theory focuses on the main feature of the social approach to bring change [12]. The organization focuses upon the development or organization and employees as well [50]. OD is the approach of behavioral science for the development of organizational process to facilitate organizational performance. It focuses upon the behavioral features that are important to be used in the change process such as culture, leadership, operations, and collaboration between employees along with the external change factors to implement change [71]. From the social perception, change requires a thorough difference in the behavior, and it will impact upon the people's ability and urge two-way communications. It is evident change did not have time period to be implemented the process of change adequately. The study discusses or analyzes the humanistic side of BPR [74]. It is also argued that there are different factors that can reduces and human are the most priority feature to be focused in BPR. It is evident that lack of management practices and lack of ability to not able to break the resistance in the change process and lack of approach to deal with the BPR with the individual are important for the purpose of changing human approach which should be considered adequately in the case of BPR. The study analyzes that BPR is the main aspect in the HRM because individuals are the main source of implementing change in the organization; individuals are being treated differently which creates resistance and bad behavior toward change implementation [64]. From the perspective of the technological approach, the BRP is highly effective in reducing resistance, and it complements the effectiveness of BPR with the technology and brings the behavioral change toward the attitude of the individual to adopt technology quickly.

5. Socio-technical perspective of BPR

From the socio-technical perspective, the organization has the combination of technical and social systems. The purpose of having social and technical perspectives is to develop harmony of human and technology with each other. The socio-technical system is based upon combination of human and technology [68]. There are social factors that are included such as motivation, loyalty status, power, and others; technological factors are process and system of technology that should be assimilated [64]. This assimilation encourages the management to collaborate both systems into the process

of change. Technology and social feature combination is beneficial for the organization in the long run and for the change process. The purpose of focusing upon the socioeconomic system is to use the right person and right technology that should support the organizational processes and value of the organization. STS is helpful in coordination with the engineering, social, anthology, and behavioral sciences [75].

In view of the BPR, socio-technical system is the right approach to assimilate the engineering operations. The STS system includes the social and technology features simultaneously. The technical system involves the tool, information, education, and ability to accomplish the objectives that help attaining the required products or services. As far as social system is concerned, it includes norms, attitude, beliefs, and relation with the individual and groups as well. To increase the feasibility of the system, restructuring is needed with the technical and social systems and developing the equation among the people and technology to use technology with the authority [41].

The socio-technical features suggested that there are different rules that should be used to execute the BPR system. These rules are as follows: abilities should be math that can help the organization to achieve objectives; the standards should be at the minimum level that can be able to produce required performance and redesign it adequately; variance control should be done in order to resolve the issues socially and technologically; the system should be developed that includes flexibility which facilitates the efficiency to be as per expectation; responsibilities should be designed accordingly, and coordination and communication with each other should be encouraged; flow of information should be adequate which helps the management to control the employees, and effective results are produced; the comparative system is developed which increases the feature of building infrastructure such as adequate development of the reward system; human value system is developed that suggests development in the organizational objectives and providing the effective and quality workplace adequately to the employees [75].

Argued that the transition according to socio-technical approach must occur in a multilevel perspective. The socio-technical system is involved in three components: socio-technical regime forms the representation of the rules that organize and coordinate the direction of social group activities and marinate the stability of socio-technical system. For instance, the organizational commitment positively contributes to the stability of the organization. However, because the stabilization concept disagrees with the radical innovation change (in this study BPR) within socio-technical system, the second component, niches, is represented as a locus or "incubation rooms" of radical innovation change. The niches might be small market niche form that bases on the specific criteria from the existing regime or technological niche forms that need high resources and investments and are wide changes resulting in social, economic, and technological changes. The final component is the socio-technical landscape that refers to the broader exogenous environment that affects the development of the socio-technical system [70].

6. Methodology

6.1 The sample and data collection

The study focuses on three companies existing in Iraq, i.e., British Petroleum, Lukoil, and Eni. All of them are multinational companies. The data collection instrument was a close-ended survey questionnaire which was distributed to 600 employees working in the abovementioned companies; however, 233 filled questionnaires were received. In the beginning only 238 were received; however, 5 of them were not having sufficient responses or not properly filled, and it was decided

that they were to be discarded; hence 233 questionnaires were left. According to Hair et al. [76] for performing structural equation modeling, a sample of 200 is sufficient in order to get reliable results. The data collection was done during the first quarter of 2017. To collect the data, special consent was taken from the human resource department of the abovementioned companies. Moreover the HR departments in the companies also cooperated to collect the data from the employees. There were 180 male respondents, while the number of female respondents was 53, which constitutes 77.25 and 22.75% for males and females' share in total responses, respectively. As far as the positions of the respondents are concerned, they include managers around 21%, officers around 25.8%, professionals around 32%, and technical support around 21%. The average age of the respondents was around 41% showing that on average the respondents were matured enough to respond on the basis of their experience. The education of the respondents shows that around 25% of the respondents were having secondary education, while those who did diploma were 30%, and around 35% were having the bachelors' degree; however those who had postgraduate level of education were only 10.2%. There were 102 items in the question; all of them were developed on 5-point Likert scale from 1 = strongly disagree. The number of items is a bit high; however, researchers like [77] state that for achieving the generalization of the outcomes of data analysis and sufficient level of validity and reliability, detailed instrument is required.

6.2 Measurements of variables

Organizational Culture: This construct has 3 dimensions and 21 items in a scale developed by Schien (1985). Out of the 21 items, there are 5 artifacts, 8 norms, and

Construct	Dimensions	Items	References
Socio-technical elements	Information sharing	4	Safarnia et al.'s (2012)
	Organizational culture	4	
	Process improvement	4	
	Customer satisfaction	3	
Total items			**15**
Decision-making environment	Types of decisions	5	Duncan's (1972)
	Information needed	5	
Total items			**10**
ERP system	System quality	11	Ifinedo's (2007)
	Information quality	8	
	Individual impact	6	
	Workgroup impact	7	
	Organizational impact	8	
Total items			**40**
Sustainable performance	Environmental sustainability	6	Crutzen's (2011)
	Economic sustainability	3	
	Social sustainability	7	
Total items			**16**

Table 1.
Number of items included in each construct.

8 items related to the basic values. The measurement of different construct along with their dimensions and number of items is present in a summarized form in **Table 1**.

6.3 Data analysis

The study utilized SPSS 22 and AMOS 22 for data analyses which were aimed to understand the demographic profile of the respondents, descriptive characteristics of the data, and testing the measurement and structural model. The model fit was assured along with the reliability and validity statistics found to be with the benchmark values. For testing the hypothesized relationships of the study, path model was tested [20].

7. Discussion

The study was aimed to examine the impact of human and technology relation on the grounds of sustainable performance in the existence of an ERP system. The focus of the study was on the perception of moderating act of the organizational culture design with the relation between the elements such as socio-technical, decision-making environment, and ERP system. In the above section there are different results extracted and suggested that organization has to be effective in considering the technological system might have an impact when it interacting with the employees for sake of attaining the expected results. The organizational purpose is to focus upon the sustainable performance and use the new technology to attain the objectives of it. In this regard, the suggestion and discussion of management along with the experts are valuable in order to use the new technology into the system.

The general perception is that systems are developed to facilitate the attainment of the certain task with the high performance. This system will not be effective if the humans have no understanding about the new system. That is the reason the researcher is suggesting the system should be analyzed thoroughly in order to undertake that system is effective for the attainment of success [54, 36]. Here it is highly important that humans that are using the system should be competent and no resistance should exist if the change is being implemented [36]. As far as the implementation of the new system is concerned, the socio-technical factor in how humans will perceive the new technology in their operations is required to be undertaken. Quality, innovation, and effective decision should be undertaken in the supportive decision-making environment [21]. The analyzing of the advantages and disadvantages regarding the implementation of the ERP system from the organizational and employee perspective is important [19]. Humans should be aware that after implementing the ERP, they will not be affected, and it will increase their effectiveness at the workplace. It can be suggested that human and technological features should be assessed prior to the implementation of the ERP system that will impact upon the success on the sustainable performance in future [18].

It is also confirmed that organizational culture should be flexible and employees should be adopting the change adequately. It is necessary that organizational culture should be bearing the resistance to change at an acceptable level. It is evident if the organization is aiming to bring change, then it is feasible that the implementation of new system will bring success in to the organization [12, 13, 60, 58]. The results of the study endorse the same feature that organizational culture should be flexible enough to accept the new ERP system to ensure success. The culture of the organization describes about the communication style in the organization. As far as the employees are concerned, it also illustrates the internal environment of the

organization and its communication with the employees as well [55]. It will illustrate the relation between organization's culture and decision-making environment of the organization along with the organizational adoption of the culture toward the new system adoption.

8. Conclusion

ERP is being used in different organizations around the world, and this type of system needs some features that contribute to its success. Therefore, there is a need to develop and update the system periodically to ensure that system will produce quality results and success for the organization and meet the sustainable performance adequately with the help of ERP system. The most important aspect is the human and technological interaction which is highly important for the sake of getting success. The planning of the new system should be done adequately before the implementation phase of the ERP system. The organizational culture is the most evident feature to illustrate the organizational success when the ERP system is being implemented in the organization. This research study is having high contribution toward the literature, that is, it analyzes that the ERP system is a moderate construct in the model that has not been considered prior to this study. The research also analyzes the participation of the organizational culture as a moderator. In the previous study, the selected model was not implemented on the oil industry; this study is applying this model into the oil industry, because it is an important sector that contributes heavily in the economy. This will be the first study that is being applied in the context of Iraq along with the developed research model.

Recommendation of the study is being done through the help of extracted findings. Managers are required to undertake different factors prior to the implementation of the ERP system in the organization. The system should be implemented slowly because the change can impact upon the success of the organization, and employees will be given proper training and knowledge about it. The system evaluation should be conducted periodically for the purpose of identifying and exploring the issues that impact the organizational success that should require correction. Management should discuss about the new system internally and externally in order to get the expected results.

As far as Iraq is concerned, it is a developing country which requires ERP system that can achieve the sustainable performance if the ERP system should be incorporating the change management and organizational development features; the purpose of that is to attain the employee's skills, capabilities, and training of the system. This study is based upon the oil sector of Iraq that might impact adversely the organizational success; therefore, the need is to have a slow speed and bring change in the organizational culture as well.

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Chapter 5

A Framework for Detecting the Proper Multi-Criteria Decision-Making Method Taking into Account the Characteristics of Third-Party Logistics, the Requirements of Managers, and the Type of Input Data

Patricija Bajec and Danijela Tuljak-Suban

Abstract

The aim of the paper is to propose a framework for improving the process of choosing an appropriate multi-criteria decision-making (MCDM) method in the selection of a third-party logistics provider (3PLP). A systematic combining process was used, along with two literature reviews, one empirical survey and a case study. A four-step framework was proposed, starting with identifying common criteria that are harmonised to the 3PLP selection process, followed by analysing all aspects of the 3PLP selection problem and the selected MCDM methods in view of common criteria, finishing with a decision tree, divided into seven branches that orient the decision-maker towards his decisions. The paper also contributes to the theory by identifying and evaluating criteria that characterise 3PLP decision-making and by suggesting a suitable order of criteria. A numerical example was implemented to evaluate a proposed framework.

Keywords: third-party logistics provider (3PLP), multi-criteria decision-making (MCDM) methods, selection process, supply chain

1. Introduction and background

Competitive supply chain management is largely dependent on the efficient management of the logistics chain [1]. Since companies (shippers) spend more and more time focusing on core competencies, they increasingly outsource logistics in parts or in their entirety to 3PLPs, which assist them in gaining competitive advantage [2–4]. However, logistics outsourcing can fail if not done properly, which can be very costly, even fatal.

There are many reasons for outsourcing failures. Of the most frequently is relationship failure between the buyer and the provider of logistics outsourcing

[5, 6], caused by 'possible defects in a partner, perception of opportunistic behaviour, lack of understanding between partners, conflict risk, lack of competence, loss of core proprietary capabilities and encroachment risk' [7, 8], lack of expertise of a partner, lack of information, etc. [9].

Some features of 3PLP come to light when performing outsourcing and are therefore difficult to predict in advance. But many risks related to 3PLP can be predicted and eliminated, reduced or elided in the early build-up stage of 3PL relationship development. This is the stage during which potential 3PLP are selected by the buyer to negotiate and develop a contract. This study is only focused on the 3PLP selection process, which covers the selection of criteria, of the appropriate decision-making method or methods to evaluate the criteria, and final selection of potential 3PLP [10–14]. Negotiations and development of a contract were not considered in this article.

Identification of selection criteria, representing the first phase of the selection process, was outlined in two the authors' previous papers [15, 16]. Four groups of criteria (C_1, C_2, C_3 and C_4) were proposed. The C_1 group covers vitally important criteria for the success of the supply chain, C_2 are very important criteria, C_3 group are important criteria and C_4 are less important elements and therefore completely left to the discretion of the decision-maker.

The second phase of the 3PLP decision-making problem relates to the selection of the appropriate method. There is a wide range of MCDM methods, but not every method can be used for solving every decision-making problem. The characteristics as well as the advantages and disadvantages of each method are very different. The use of different methods can therefore result in different solutions to the same problem [17]. The approach for selecting the appropriate method should be tailored to each single decision-making process and not vice-versa [18]. Thus, the selection of the appropriate method is one of the most difficult problems in the selection process [19–22].

A very extensive and deep review of the literature on the most frequently used MCDM for selecting the 3PLP (108 scientific papers, published from 1999 (when the first articles in this field began to appear) to 2016, were systematically reviewed) revealed that many MCDM methods and combinations of methods have been used. The most frequently used method was the analytic hierarchy process (AHP), followed by the technique for order of preference by similarity to ideal solution (TOPSIS), analytic network process (ANP), Linear programming, data envelopment analysis (DEA), VIKOR, DELPHI, quality function deployment (QFD), decision-making trial and evaluation laboratory (DEMATEL), the preference ranking organisation method for enrichment of evaluations (PROMETHEE), elimination and choice expressing reality (ELECTRE) and interpretive structural modelling (ISM). Other methods were used once or never.

A vast array of MCDM methods has been applied. The applied methods have very different characteristics, which raises doubts over whether the method is harmonised with the characteristics of the 3PL industry, the single selection process and its objective. Discussions regarding the harmonisation of the applied MCDM with the 3PL characteristics or even single selection process have been very sparse. Explorations of the concrete use of MCDM methods, from the point of view of the decision-makers, have been very limited as well. Authors [23] in one of their studies assume that the MCDM method is still selected arbitrarily (the method is popular). Authors [18] share very similar opinion, arguing that decision-makers have an affinity for the chosen MCDM method, or they apply it, because it is easy to use. However, no research has yet been launched into the real circumstances of the reasons for choosing a particular method, problems associated with the use of different methods, plus challenges and needs of decision-makers.

To solve these issues an e-survey was used. A preliminary survey questionnaire was firstly developed and distributed to three researchers from three different logistics faculties, and to three decision-makers, familiar with the subject topic area, to ensure the survey was thorough and understandable. Following several modifications from this first review, the web-based survey was developed and then sent to producers, retailers, and suppliers located in Slovenia. Only companies that have had experiences with logistics outsourcing and only employees familiar with the selection process were contacted. Of the 50 e-mails 2 were not delivered and 25 were fully answered. The survey examined three main topics: the first was general (number of participants in the selection process, insourcing or outsourcing of selection process; the second relates to those that outsource the selection process and the third to those that insource selection process. Close-ended and open-ended questions were used. The following results were outlined:

The 3PLP selection process is mainly done by the buyers of outsourcing (16 of 25 companies). They are used to it and they are familiar with the used methodology. However, they are not satisfied with the method's ability or with its results. It seems that they are familiar with the method they are using but not with other methods that exist (**Table 1**).

Those that outsource the selection process either because it is time and staff consuming or because of lack of knowledge and experience request tailor made solutions regarding the type of results and methods used, but are disappointed with

Reasons for not outsourcing the selection process / Reason for dissatisfaction with the results of selection process	Time consuming.	Method is not able to use any type of data.	The results were not in the form we desired.	Too few possibilities that are offered by the method.	Complex software.	Method is not able to manage subjectivity.
We are doing the selection process ourselves from the very beginning.	21	20	18	16	15	14
We are familiar with the methodology.	21	20	18	16	15	14
Don't trust external company (fear to lose the input data).	17	16	14	12	11	10
Too high cost of external company.	15	14	12	10	9	8
We were not satisfied with the external company.	8	7	5	3	2	1

Table 1.
Correlation between reasons for not outsourcing the selection process and reasons for dissatisfaction with the results of the performed selection process.

Reasons for outsourcing / Reasons for dissatisfaction with the selection process	External provider was not able to offer tailor made selection process.	We were not able to influence the choice of methodology because we are not familiar with.	Poor communication between the partners.	The results were not in the form we desired.	We were not sufficiently involved in the selection process.	We were not able to influence the choice of methodology of the selection process, although we would	The selection procedure was not explained to us at all.	Inaccurate input date because of fear to loss them.
Time consuming.	9	8	8	7	7	7	6	6
Human resource consuming.	9	8	8	7	7	7	6	6
Don't have software and any other tools.	9	8	8	7	7	7	6	6
Don't have knowledge nor experience.	8	7	7	6	6	6	5	5
Fear to fail.	6	5	5	4	4	4	3	3
Rarely implementation of the selection process.	5	4	4	3	3	3	2	2

Table 2.
Correlation between reasons for outsourcing and reasons for dissatisfaction with the selection process.

the performance of the external provider (**Table 2**). It seems they are very well aware of the abilities the process of selection can offer, but have a lack of knowledge and experience.

Both those that insource and those that outsource the selection process are not satisfied. The selection process is dissatisfactorally performed. Moreover, the final result of the selection process may not be appropriate. This increases the risk of relationship failure. Again, more than half of logistics partnerships end within three to 5 years [24]. Decision-makers therefore need a reliable means for choosing the right method or combination of methods.

In summary, the extensive literature review found: (1) a lack of critical analysis of the published knowledge on the MCDM methods which would help to reveal the appropriate methods or group of methods for the logistics industry and (2) a dearth of studies determining the specific context of the 3PL industry and 3PLP decision-making. The empirical survey furthermore indicated that companies are setting up more tailor made requirements.

The main research questions (RQ) of this research are therefore three:

RQ1. What are the characteristics of the 3PLP decision-making?

RQ2. What are the most appropriate criteria for selecting MCDM method in the 3PLP decision-making?

RQ3. How can decision-makers combine the characteristics of the 3PLP decision-making with criteria and their individual requirements to help them choose the most appropriate MCDM method?

In line with the above thinking and research questions, the purpose of this paper is to propose a framework to help detect the appropriate MCDM method or methods in the selection of 3PLP within the early build-up stage of 3PL relationship development.

2. Research methodology

The aim of this article is not new theory development but grounded theory refinement and adaptation to the 3PL industry. The authors aim to discover potential new criteria and determine a new hierarchical order of criteria appropriate for MCDM method selection in 3PLP decision-making process within grounded and general theory.

Although the article contains a bit of testing of the current theory, 'which suggests a deductive approach, and although a quasi-deductive theory testing means is used [25], the paper is ultimately closer to the inductive approach, which helps the researchers to delineate important variables and directs interpretation of findings' [26], but does not help to develop new theory. Mixed method research, which uses both quantitative and qualitative data, is preferred for allowing a better understanding [27] and spurring progress in a new field, but is not so fruitful for theory development and does not investigate the relationship between reality and grounded theory [26].

A systematic combining process was, on the other hand, found to be particularly useful in the refinement of existing theories and even in matching theory and reality [26, 28]. It was therefore used in this paper for the creation of the framework that facilitates the choice of a MCDM method in 3PLP selection. In line with the systematic combining process a five-phase methodology was adopted, as shown in **Figure 1**.

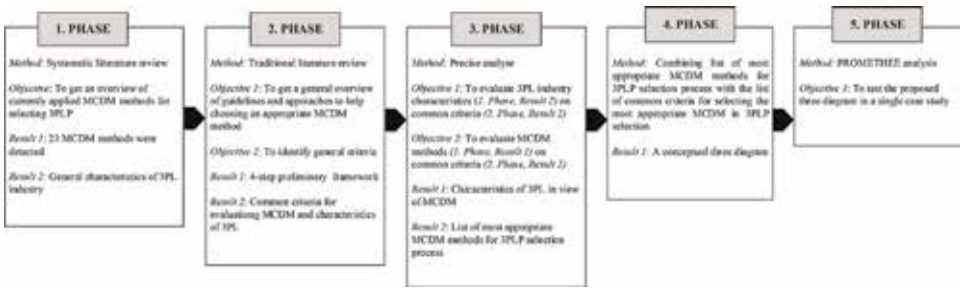

Figure 1.
Phases of the research.

3. A framework facilitating choosing an appropriate MCDM method

A framework proposed in this article builds on the interactive decision support system (IDSS) of [29], on the general tentative guidelines of [21], on the multi-criterion evaluation approach of [23] and on two rather new studies, by [20, 30].

Authors [29] stated that the particular IDSS should be based on a set of selected methods and on a suitable approach for the specific problem. Authors [23] proposed defining common criteria as a basis for establishing a correspondence between

characteristics of the spatially-referenced decision problems and characteristics of the multi-criterion aggregation procedure. Authors [23] suggested starting the study of MCDM methods first by identifying a set of criteria for each method. After that a comparative study using a carefully crafted simulation is made.

The selection of the MCDM method depends on specific characteristics of the decision-making problem, characteristics of MCMD methods and resource constraints [19, 21–23, 29]. To select an appropriate MCDM method all three groups of characteristics should correspond among themselves and correspondence should be established in accord with common criteria [21–23, 29].

Keeping in mind the views of these researchers, the following 4-step framework is proposed: (1) Identifying common criteria (limits, conditions of application for MCDM method) for evaluation and identification of the characteristics of the 3PLP selection process and characteristics of MCDM groups of methods or single methods that are harmonised in regard to the 3PLP selection process. (2) Analysing all aspects of the 3PLP selection problem in view of common criteria. The result of this step is to elucidate the characteristics of the 3PLP selection problem. (3) Analysing the selected MCDM methods in view of common criteria, which highlights the appropriate groups of methods or a single MCDM method. (4) Proposing a decision tree to facilitate selecting the appropriate MCDM method.

3.1 Identifying common criteria

Authors [23] suggested the evaluation of the decision problem and MCDM methods based on three common criteria: (1) type of decision problem, (2) nature of the set of alternatives and (3) nature and features of input information. Authors [29] stated that the particular decision-making system should be based on the set of ordinary criteria, pseudo-criteria and quasi-criteria. Authors [21] identified the following groups of common criteria: (1) the input data, (2) the preference elucidation, (3) the aggregation procedure, (4) the quality and quantity of the input information, (5) the compensation degree of the method and (6) the decision support system (software, user friendly aid packages).

Authors [30] claimed that the choice of criteria is very dependent on the decision-making context. A crucial parameter in their view is the adaptation of the type of results the method is expected to deliver, following with the correct handling of input information and adaptation of the degree of compensation.

In view of these findings two groups of common criteria were identified: primary and secondary (**Figure 2**). Criteria are presented in a hierarchical order (from the most important to the least important) to help the decision-maker chose the most appropriate method. However, the order of criteria within the key criteria related group is not mandatory.

The decision-maker can choose mainly between following types of results: a numerical value that is, available for each potential action, ranking of potential actions, without assignment of a numerical value for each potential action, selection of a subset of actions in preparation for making a final choice and assignment of actions to some a priori defined categories.

Kind of input information determines whether the information is qualitative, quantitative or mixed. An information feature deals with the information determinism or non-determinism (certain, uncertain, ambiguous, non-ambiguous information, etc.) [21]. There are three crucial types of problem statements:
(1) The choice problem statement in which one or more alternatives are selected.
(2) The sort problem statement in which various alternatives are sorted in classes.
(3) The rank problem statement that ranks alternatives according to a preference structure [22, 29].

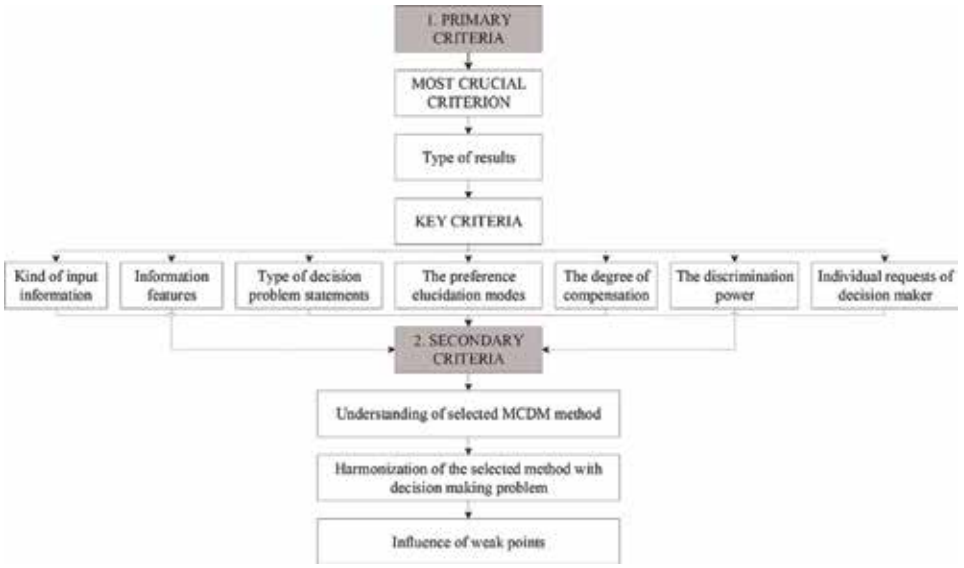

Figure 2.
Classification of common criteria.

MCDM methods have different forms of preferences: trade-offs, assessment of lotteries, direct rating and pairwise comparison, presence of veto, etc. The degree of compensation which concerns the 'trade-offs; that is, the possibility of offsetting a "disadvantage" of some criterion with a sufficiently large "advantage" of another criterion—whereas smaller advantages would not do the same' [22].

There are also some criteria that determine the use of the MCDM method but are totally dependent on the need or request of each individual decision-maker. These criteria often relate to user-friendliness [21, 31], intelligibility and the structure of the method [18], ease of computation and costs of adopting methods [31].

Authors [20] suggested also using secondary parameters in case the decision-maker after taking into account various parameters still hesitates between several methods.

3.2 Analysing all aspects of 3PLP selection problem in view of common criteria

A literature review on selection criteria in 3PL found that the number of criteria vary from 6 to more than 20 [15]. In all reviewed articles mixed types of criteria (qualitative and quantitative data) were applied. Costs were found to be the most frequently used criterion, closely followed by many qualitative criteria [16]. Based on these results, it is clear that the 3PL industry is characterised by the mixed types of input data (quantitative and qualitative) and many input data which are usually conflicting (lower costs, high quality).

The most frequently used method was found to be the AHP, followed by TOPSIS and ANP. DEA, VIKOR, DELPHI, DEMATEL, QFD, ISM, PROMETHEE and ELECTREE were used more rarely [15]. Based on these results, it is clear that the pairwise comparison of criteria is the most desired preference elucidation mode. The results of decision-making are most frequently presented as numerical values (score for each alternative) or as ranked alternatives.

The fuzzy optimised method has been applied the most frequently (in 38 of 108 articles) [15]. Based on this fact, it is clear that the 3PL industry is characterised by input data, which are usually uncertain.

In 35% of the reviewed articles, software tools were used. Frequent use of software tools may prove that user friendly solutions are required. Moreover, ease of use and low level of complexity are desired.

3.3 Analysing the selected MCDM methods in view of common criteria

A selection of MCDM methods has been made on the basis of the literature review. Twenty-six methods in total, used in the 3PLP selection process, were found to exist, but only the most frequently used (in 75% of cases) were selected to be evaluated according to the criteria presented in the section "Identifying common criteria".

The comparison of the methods (**Table 3**) is based on a review of the literature [18, 20, 22, 29, 32–37] and not on expert study of each of the methods. Any method not considered in this table can be added to the table and analysed in the same way.

According to comparative analysis, the AHP, ANP, TOPSIS, ISM, VIKOR, DEMATEL and ELECTRE methods were found to be the most appropriate for the 3PLP decision-making problem and were later used in typological decision tree.

3.4 A typological decision tree diagram for the selection of the appropriate MCDM method

Based on the insights presented mainly in Sections 3.1, 3.2 and 3.3, the three diagram (**Figure 3**) which helps decision-maker to narrow down opinions following the branches was prepared [21, 29, 38]. A typological tree was used, because of its ability to capture all the sides of the decision-making problem (different methods, many parameters, extensive information) [21].

On the top of the tree are listed MCDM methods that, in Section 3.3 were found to be most appropriate in the selection of 3PLPs. The tree structure is then divided into seven nodes with questions which guide decision-makers in selecting the most appropriate MCDM. Questions are criteria identified in Section 3.1. The questions

MCDM method	Type of results	Kind of info	Type of problem statement	The preference elucidation mode	Compensation
AHP	numerical value	mixed	choice, ranking	pairwise comparison	yes, partially
TOPSIS	numerical value	mixed	choice, ranking	direct rating	yes, totally
ANP	numerical value	mixed	choice, ranking	pairwise comparison	yes, partially
DEA	ranking	mixed	ranking	pairwise comparison	yes, partially
VIKOR	numerical value	mixed	choice, ranking	trade-offs/rating	yes, partially
DEMATEL	ranking	mixed	ranking	pairwise comparison	yes, partially
ELECTRE	ranking	mixed	ranking	pairwise comparison	yes, partially
PROMETHEE	ranking	mixed	ranking	pairwise comparison	yes, partially

Table 3.
Comparison of selected MCDM methods on the basis of common criteria.

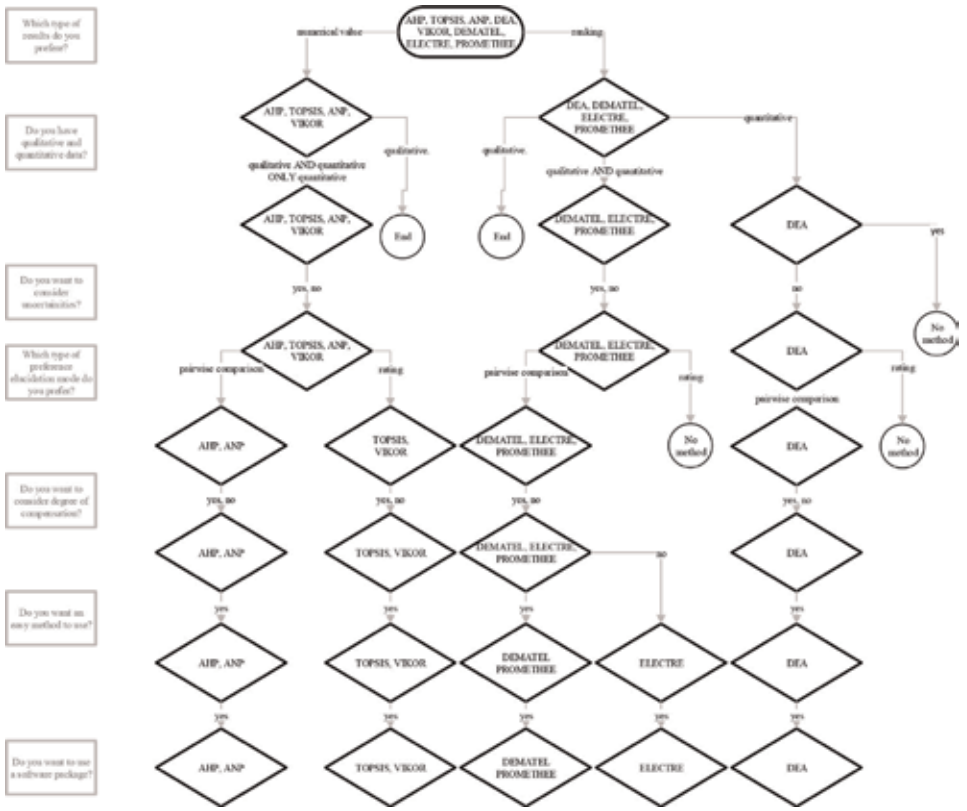

Figure 3.
The decision tree for selecting MCDM method in 3PLP decision-making.

are in a hierarchical order, from the most general and pertinent to the least pertinent [20].

The tree diagram can include any other method and may be upgraded with additional questions from the third group of parameters as well.

4. Validation of the proposed decision tree using a case study of local spare parts for a construction and agricultural machinery dealer

To validate the usefulness and practicality of the proposed approach we present a case study of a local spare parts company dealing with construction and agricultural machinery. The management intends to outsource all parcel delivery and occasionally value added services (repackaging of goods) to a single 3PLP. Thus far they have worked with five domestic and international parcel distributors. Due to a large number of contacts, different pricing, operating conditions and even quality of services, the situation can be quite chaotic at times. The dealer therefore decided to cooperate with one or at most two logistics providers who are favourable, offer a high quality of service particularly in terms of time, quality and quantity of package accuracy, flexibility, responsiveness, high frequency of delivery, etc.

To define the criteria set, the list of the most frequently used criteria detected by [15] was submitted to the top management of a spare parts dealer. According to the dealer's requirements and the nature of its business, the following criteria were

selected: costs (C_1), warehouse services (C_2), added value services (C_3), accurate time, quality and quantity (C_4), flexibility (C_5), responsiveness (C_6), frequency of delivery (C_7), staff quality (C_8), information exchange capability (C_9). Some of them are qualitative, some quantitative. Mixed types of data were therefore used in this selection process, which answered the second question of a tree diagram proposed in Section 3.4.

Selection of the most appropriate MCDM started with answering the six questions of the decision tree, since the second question was already answered with the selection of the criteria for choosing the 3PLP. The top management was not familiar with MCDM methods. The authors, therefore, need to explain questions 1, 3, 4, 5, 6 and 7 of the decision tree in order to receive proper answers. The top management preferred to have 3PLPs ranked from the best to the worst. They wished to eliminate subjectivity. Pairwise comparison and not direct rating was selected. They wanted to take into account compensation and preferred to use an easy method. Using the tree diagram proposed in **Figure 3**, the PROMETHEE and DEMATEL methods were found to be the most appropriate for the requirements of the top management. But since 'PROMETHEE shows better balance between theory and implementation, it is easier to use and the software is simple to understand [18] the present decision-making process used PROMETHEE.

PROMETHEE requires the use of weights of relative importance $\{w_1, w_2, ..., w_m\}$ to associate with the criteria set $C = \{C_1, C_2, ..., C_m\}$, $m = 9$. The following weights are obtained with the AHP method: $w_1 = 0.24$, $w_2 = 0.06$, $w_3 = 0.05$, $w_4 = 0.20$, $w_5 = 0.11$, $w_6 = 0.10$, $w_7 = 0.18$, $w_8 = 0.03$, $w_9 = 0.03$. They are based on the nine stage Saaty comparison scale [39] and form the pair-wise comparison matrix M.

The consistency index (CI) of the comparison matrix M is computed using the normalised principal Eigen vector method and the approximate value of the maximum eigenvalue λ_{max} which is 9.83 [40]. The consistency index is $CI \cong 0.1$, divided with the random consistency index (RI), which is 1,45, results in the consistency ratio $CR \cong 0.07$, which is <10%. Therefore, the comparison matrix M is consistent and the weights have been properly computed. In the next step, the set of alternatives $A = \{a_1, a_2, ..., a_n\}$ must be evaluated with respect to the proposed criteria. In the case study $n = 5$ and $\{a_1 = TNT, a_2 = DHL, a_3 = GLS, a_4 = Posta\ SLO, a_5 = FEDEX\}$. Evaluations are defined in the matrix $\{f_i(a_j), 1 \le i \le 9\ ; 1 \le j \le 5\}$ and values of evaluation (**Figure 4**) are based on the five stage scale where intermediate evaluations are also allowed (1 = very low,..., 5 = very strong).

Now the preference structure of the PROMETHEE method is defined. For this purpose the range of evaluations of alternatives is computed with respect to each criterion:

$$d_k(a_i, a_j) = f_k(a_i) - f_k(a_j) \tag{1}$$

and the preference function $P(x)$ is defined as:

$$P(x) = \begin{cases} 0, & x \le q \\ \dfrac{x-q}{p-q}, & q \le x \le p\ ; \\ 1, & x \ge p \end{cases} \tag{2}$$

where q and p are, respectively, the smallest and the largest threshold deviation values sufficient to generate a full preference. In our case $q = 0.2$ and $p = 0.6$.

Preferences are values between 0 and 1 and are defined as:

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
a_1	4	5	5	3.5	4	3	3	4	4
a_2	4	5	4	4	4	3	4	4	4
a_3	4	5	4	3.5	3	3	4	4	4
a_4	3	4	3	3	3	2	3	4	3
a_5	4	5	4	3.5	3	3	3	4	4

Figure 4.
Evaluation matrix.

$$P_k(a_i, a_j) = P\left[d_k(a_i, a_j)\right]. \tag{3}$$

The preference degree of criteria a_i with respect to a_j is defined as:

$$\pi(a_i, a_j) = \sum_{k=1}^{m} P_k(a_i, a_j) w_k \tag{4}$$

and the preference degree of criteria a_j with respect to a_i is defined as:

$$\pi(a_j, a_i) = \sum_{k=1}^{m} P_k(a_j, a_i) w_k. \tag{5}$$

The multi-criteria preference flows (out and in) are defined as:

$$\phi^+(a) = \frac{1}{n-1} \sum_{i=1}^{n} \pi(a, a_i); \tag{6}$$

$$\phi^-(a) = \frac{1}{n-1} \sum_{i=1}^{n} \pi(a_i, a); \tag{7}$$

The positive preference flow ϕ^+ measures the given alternative's global preference with respect to the preferences of all other alternatives. The negative preference flow ϕ^- measures the global preference of all the other alternatives with respect to a given alternative. The PROMETHEE complete ranking is obtained by ordering the actions according to the decreasing values of the flow scores:

$$\phi(a) = \phi^+(a) - \phi^-(a);\ \phi(a) \epsilon [0, 1] \tag{8}$$

For functions defined by Eq. (1)–(8), it has been verified that all request conditions are fulfilled [41]. Using Eq. (6) the out multi-criteria preference flows are computed: $\phi^+(a_1) = 0.11$, $\phi^+(a_2) = 0.01$, $\phi^+(a_3) = 0.09$, $\phi^+(a_4) = 0.75$, $\phi^+(a_5) = 0.18$. Then using Eq. (7) the in multi-criteria preference flows are computed: $\phi^-(a_1) = 0.27$, $\phi^-(a_2) = 0.46$, $\phi^-(a_3) = 0.28$, $\phi^-(a_4) = 0$, $\phi^-(a_5) = 0.15$. The ranking of alternatives is obtained using Eq. (8): $\phi(a_4) = 0.75 \geq \phi(a_5) = 0.04 \geq \phi(a_1) = -0.15 \geq \phi(a_3) = -0.18 \geq \phi(a_2) = -0.45$. The best alternative is Posta SLO and the least useful is DHL.

To check the usefulness of the proposed framework and the obtained results the authors asked the spare parts dealer to validate five logistics service providers using

customer relationship management (CRM) software. The software enables management of the database of logistics service providers and also offers some extra services including an evaluation of the service providers. In order to be as objective as possible authors decided not to inform the dealer of the results of the PROMETHEE ranking. Authors suggested they use the same criteria as in the PROMETHEE ranking, while everything else was left to their choice. Posta SI was found to be the best alternative, followed by FEDEX, TNT, GLS and DHL. The same results were obtained using the PROMETHEE method.

5. Discussion

After proposing a typological tree and testing its usefulness it can be concluded that the tree cannot be simply used by a decision-maker in the same way as it was presented, but must be tailored to each specific 3PL selection process. Each 3PL selection process is unique and each decision-maker has different requirements in regard to the questions (criteria) and also different levels of knowledge about MCDM methods.

Moreover, due to the diversity of methods, the answers to the questions presented in the tree are often quite complicated. The comparison of MCDM methods presented in Chapter 3.3 also revealed that by some criteria methods cannot simply be compared [20] because of diversity of calculation, lack of an approach, for example, to characterising the degree of compensation, etc. [22] etc.). Authors [21], therefore, argue that a comparative analyse of different MCDM can only be used to identify in what circumstances (by which criteria) one method is appropriate.

Accordingly, it is impossible to describe all the 3PL decision-making situations and to formulate a tree diagram with a family of questions that would simply allow choosing the appropriate method [20]. The tree diagram presented here, as a final stage of the proposed framework, is therefore not a miraculous tool which enables the choosing of the proper methods, but only a general guideline that facilitates the choice of the proper methods.

The proposed framework is based on three different characteristics: 3PL characteristics; those of MCDM methods; and individual requirements of each single decision-making process. When selecting an appropriate method all three characteristics need to be matched [22], which is not an easy task, one requiring knowledge of the MCDM methods. The MCDM methods resulting from the tree diagram are frequently also equivocal, which requires a deep and axiomatic study in order to confidently make a choice.

6. Conclusion

Decision-making in 3PLP selection has an important impact on logistics outsourcing success. Therefore, the appropriate MCDM method or methods must therefore be used to select the most appropriate 3PLP. Because of the sheer volume and variance among MCDM methods, decision-makers face a difficult dilemma.

To solve this problem a four step approach facilitating the choosing of an appropriate method was proposed. The first two steps relate to criteria identification, the third to the identification of the right MCDM methods for 3PLP selection and the last combines all of the first three steps' results on order to construct a typological tree.

The typological tree is divided into branches (simple questions) which orients the decision-maker, guiding him towards an eventual opinion. The questions relate the characteristics of the logistics industry, aspects of MCDM methodology and the

preferences of the decision-maker. The order in which questions follow is chosen according to the priorities in making choices. The authors argue that the most relevant criteria to consider is the type of the results, followed by the type of data, elimination- or degree of limitation- of subjectivity, preference elucidation mode, degree of compensation, and finally, the ease of use and the availability of software. The tree diagram could be upgraded with additional branches but it will nevertheless remain easy to understand, even for those decision-makers who are not familiar with MCDM methods.

The proposed guideline was illustrated by a single case study of a local spare parts company. The decision-making process was made using the PROMETHEE. The PROMETHEE ranking of alternatives was at the end compared with results obtained by the CRM software tool. The evaluation of the framework in the case study demonstrated its utility.

The paper upgrades the general theory of IDSS and tailors it to the 3PL purposes, contributing to the theory by firstly suggesting a novel framework for facilitating the selection of the MCDM method. Further, it identifies and evaluates the criteria that characterise 3PLP decision-making in view of MCDM as well as individual criteria. The paper also suggests a suitable order of criteria and makes a comparative analysis of MCDM based on the criteria.

From a managerial perspective, this paper provides a kind of a tool for guiding decision-makers selecting an MCDM method. A decision-maker should first decide how many and which criteria are relevant for the decision-making process. Then, a decision-making tree helps the decision-maker focus on the proper MCDM method.

Moreover, the proposed framework makes a significant contribution to the choice of the 3PLP that best suits decision-maker needs and consequently decreases relationship risks and increases performance outcomes for the 3PLP and its buyer.

The paper has some limitations. First, the drawback of a single-case design is its inability to provide a generalised conclusion. To strengthen the external validity of guideline, further empirical studies are necessary. The authors suggest testing the guideline in other case studies. Second, an issue that remains open, one that was not considered in this paper, is the importance of each criterion within the framework. Not all criteria are equally important. Further studies that will measure the weight of each criterion should be conducted.

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Chapter 6

Decision Rule Induction Based on the Graph Theory

Izabela Kutschenreiter-Praszkiewicz

Abstract

The graph theory is a well-known and wildly used method of supporting the decision-making process. The present chapter presents an application of a decision tree for rule induction from a set of decision examples taken from past experiences. A decision tree is a graph, where each internal (non-leaf) node denotes a test on an attribute which characterises a decision problem, each branch (also called arc or edge) represents the outcome of a test (attribute value), and each leaf (or terminal) node holds a class label which can be interpreted as a decision type. In the presented approach, the object-attribute-value (OAV) framework will be used for decision problem characteristics. The chapter presents a method of optimal decision tree induction. It discusses the Iterative Dichotomiser 3 (ID3) algorithm and provides an example of the decision tree induction. Also, rules supporting the decision-making in engineering will be developed in this chapter.

Keywords: decision tree, decision rule induction, ID3 algorithm, QFD, dependence network

1. Introduction: decision problems in industry

In order to solve decision problems, we need knowledge, information and data. Data are understood as a set of discrete objectives, facts and events. Information represents a relationship between some pieces of data. For data to be transformed into information, raw data should be cleaned, corrected and processed while considering the context of a decision. Knowledge can be defined as application of the relevant information to address specific problems. Knowledge in decision problems is developed based on the decision-maker's experiences. Hence, data gathering and analysis is one of the necessary stages of decision support systems development with the use of artificial intelligence.

The main issues related to decision support with the use of artificial intelligence are:

- Representing knowledge as close as possible to the human way of thinking.
- Knowledge representation should be easy to use and updated with computer software.

Decision problems in industry may be classified into one of the following decision categories:

- Structured
- Unstructured
- Semi-structured

Structured decisions are routine, and there are usually specific procedures or actions that can be identified to help make the decision. In case of unstructured decisions, decision scenarios often involve new or unique problems, and an individual has little or no programmatic or routine procedure for addressing the problem or making a decision. In semi-structured decisions, decision scenarios involve both some structured and some unstructured components.

According to the data analysed by Iyer et al. [1], in product design, only 20% of parts are new, while 80% of them are reused or modified [2], so knowledge management focused on knowledge reuse related to product and production process is an important field of analysis and can influence the effectiveness of production process preparation.

Knowledge representation is a field of artificial intelligence that focuses on designing computer representations that capture knowledge which can be used to solve problems.

A knowledge representation should be:

- Rich enough to express the knowledge needed to solve the problem
- As close to the problem as possible
- Compact, natural, and maintainable
- Easy to see the relationship between the representation and the domain being represented
- Able to conduct efficient computation, which usually means that it is able to express problem features that can be exploited for computational gain and able to trade off accuracy and computation time
- Able to be acquired from people, data and past experiences

According to formalism used for knowledge representation, knowledge can be classified as:

- Procedural knowledge, which defines algorithms that help to achieve given goals
- Declarative knowledge, which gives the solution without analysing the problem structure

Taking into consideration knowledge transfer to another person, knowledge can be divided into:

- Tacit, which is difficult to express by words or equations
- Explicit, which is easy to formulate and transfer

The object-attribute-value (OAV) model is a knowledge representation framework. Objects are understood in OAV as entities that are items being described. Attributes are understood as features, properties, characteristics or variables of a given object. Value is understood as a numerically discreet or linguistically defined attribute esteem.

OAV can be used in artificial intelligent methods as a framework of data analysis useful for data preparation for applying chosen knowledge representation method. A data analysis schema is presented in **Figure 1**.

Knowledge representation methods include:

- Decision rules—which transform premises (e.g. observations expressed in the OAV framework) into conclusions (e.g. decision expressed in the OAV framework).

- Decision trees—which are graph representations of the decision process. Inspecting the conditions in the decision path starts from the beginning node called the root and to the leaves which give the decision.

- Frames—which are used when information units are characterised by many important features. The structure of a simple frame contains three different lines: a heading with the frame name, a pointer to another frame with appropriate relation and slots defining attribute names and values.

- Semantic networks—which capture knowledge in form of a graph in which nodes represent pieces of information (objects, concepts or situations in the problem domain) and the arcs represent relations or associations between them.

- Artificial neural networks (ANNs)—which are inspired by neurons in the brain and have become a popular target representation for learning. The idea of ANN usage is to create a learning set which includes data characterised by input and output features. During training, ANNs create a model which is able to transform input features into output features of a data set.

Literature presents different methods of formal knowledge representation which have been successfully applied to support various decision problems. Joshi and Dutta [3] use rule-based method to recognise and simplify features in freeform surface models for automatic finite element mesh generation. Cakir et al. [4] apply

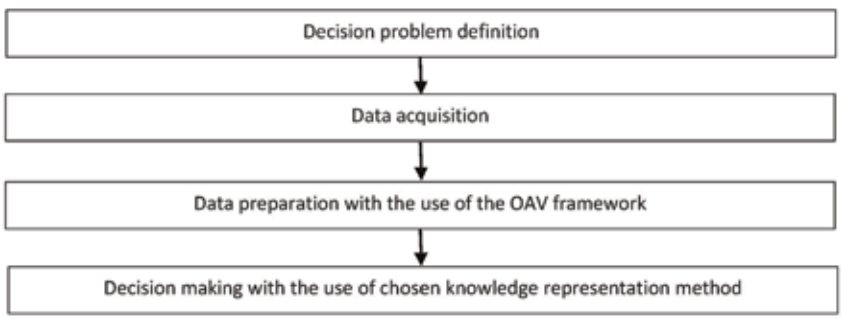


Figure 1.
A data analysis schema.

rule-based expert system for die and mould making. According to Trabelsi et al. [5], decision trees are recognised as effective and efficient machine learning approaches which have been successfully applied to solve real-world problems [5].

2. Data preparation for decision problem solving

One of the phases of knowledge acquisition processes based on a learning data set is the feature selection phase [6].

Obtaining data and selecting features for a given problem can be supported by means of the quality function deployment (QFD) method. QFD was developed to link product users and engineering attributes [7, 8]. QFD can be used for attribute identification not only in product development but also for decision support.

QFD helps to build a partnership between decision-makers and experts who are able to solve a given decision problem.

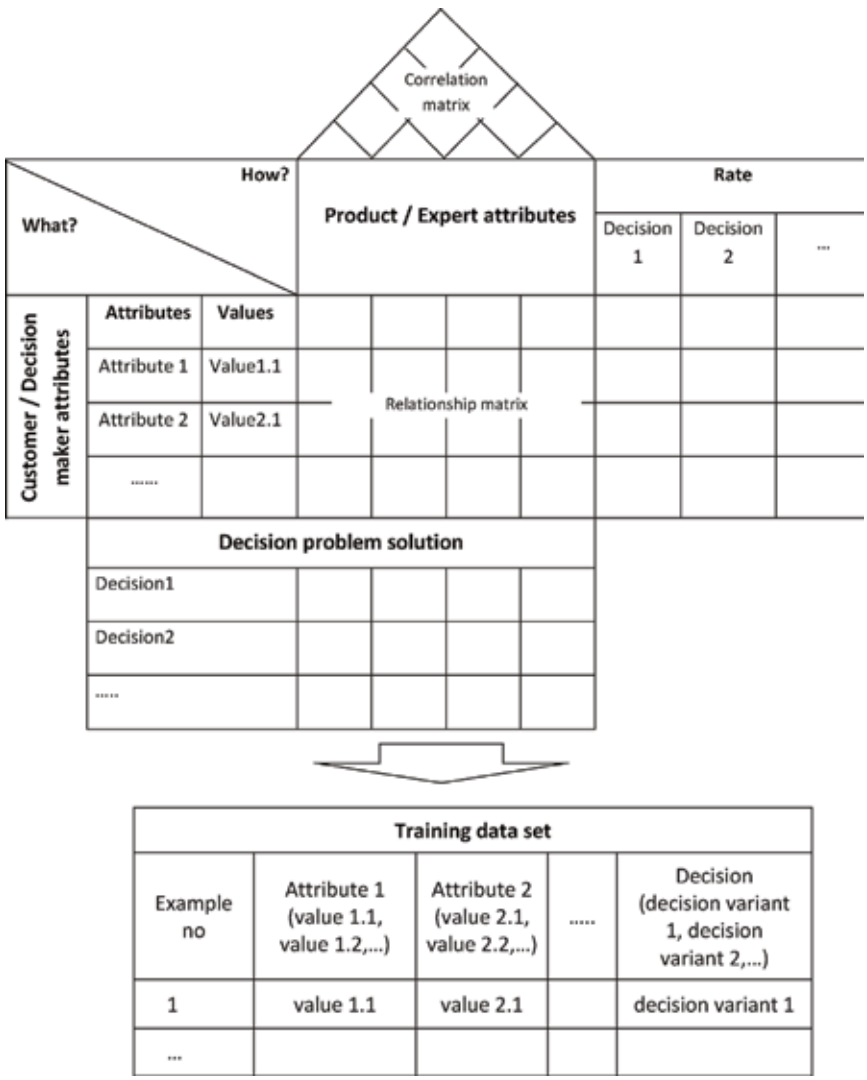


Figure 2.
QFD for DSS attribute identification and training data set development.

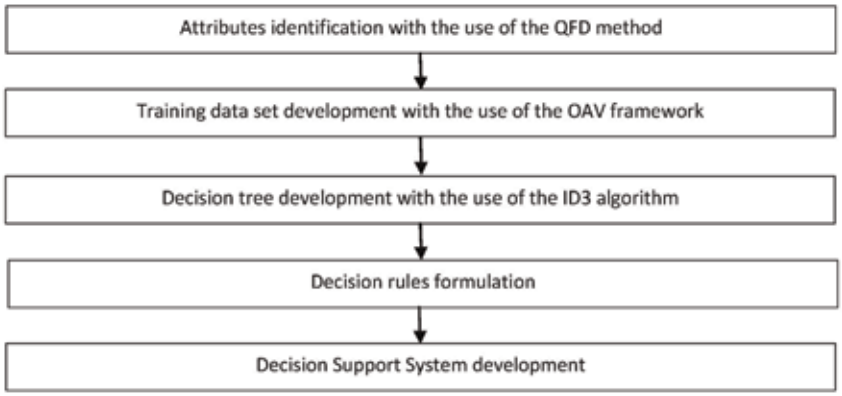


Figure 3.
Decision-making with the use of chosen knowledge representation methods.

The structure of the QFD matrix was presented in **Figure 2**. The attributes identified in the QFD matrix can be used for obtaining data and developing a training data set.

Decision-making can be supported with the use of an algorithm presented in **Figure 3**.

3. Decision tree development with the use of the ID3 algorithm

Decision tree is a commonly used decision support tool. It is built with the use of training data set which contains examples of a decision problem solved in the past, characterised with the use of the OAV framework. A decision tree example is presented in **Figure 4** [9].

A proper decision tree uses meaningful attributes in the decision-making process. In the presented approach, decisions are generated by a decision tree built with the use of the ID3 (Iterative Dichotomiser 3) algorithm, which helps to feature selection to avoid keeping too many or too few attributes than is appropriate [10–12]. The basic idea of the ID3 family algorithms is to develop decision trees by growing them from the most important attribute, which is on the root, and selecting the next best attribute for each new decision branch added to the tree [12].

The ID3 algorithm [13, 14] uses entropy, which is understood as a measure of the amount of uncertainty in the training data set and which is calculated according to Eq. (1):

$$I = \sum_{i=1}^{n} (-p_i \log_2 p_i) \tag{1}$$

where:
p probability that an element from *i* class occurs
Entropy of a given attribute is calculated according to Eq. (2):

$$I(C/A_k) = \sum_{j=1}^{M_k} p(a_k, j) \bullet \left[-\sum_{i=1}^{N} (p(c_i/a_{k,j}) \bullet \log_2 p(c_i/a_{k,j})) \right] \tag{2}$$

where M_k number of values taken by attribute A_k; N number of classes; k number of attributes; $p(a_k, j)$ probability that a_k takes value j; $p(c_i/a_{k,j})$ probability that class c_i occurs, when $a_k = j$.

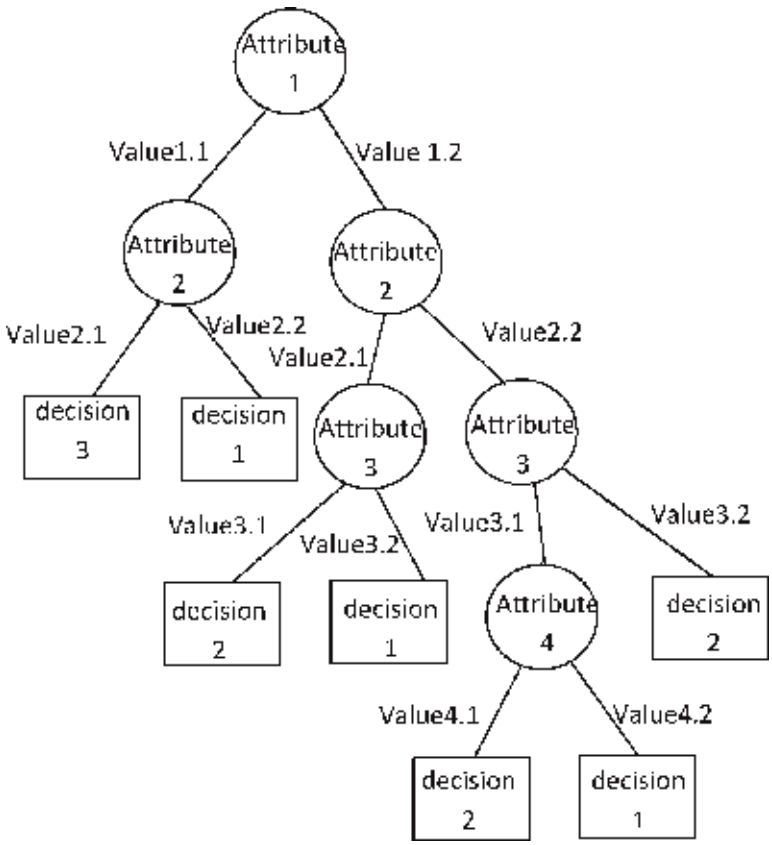


Figure 4.
A decision tree example.

Information gained is calculated according to Eq. (3):

$$\triangle I(A_k)=I - I(C/A_k) \tag{3}$$

A decision tree starts from the root node which is created with the use of the most meaningful attribute for which information gain is the highest. The next node in a decision tree is created with the use of the attribute for which information gain has a high value.

A pseudocode for ID3 algorithm includes the following stages:

- Calculating entropy for the training data set (Eq. 1).
- Calculating entropy for each attribute (Eq. 2).
- Calculating information gain for each attribute (Eq. (3)).
- Creating the root node in the decision tree with the attribute for which information gain is the highest.
- Creating decision tree branches using attribute and their values for which information gain is high.

- Classifying examples from the training data set, taking into consideration the given attribute and its values.
- If all cases for the given attribute and values lead unambiguously a decision, a decision leaf should be added at the end of the decision tree branch.
- If it is not possible to classify all cases from the training data set in a given decision tree branch to a decision, it is necessary to add a new node with the attribute which has high information gain.

The two last steps should be repeated until all branches in a decision tree will end with a decision leaf.

4. Decision rule formulation

4.1 Formulating and transforming rules

Basing on a decision tree, it is possible to formulate decision rules which consist of premises and a conclusion. The rule can be formulated as follows:

If *premise 1* **and/or** *premise 2* **and/or** *premise…* **then** *conclusion.*

where in the OAV framework *premise* is expressed as *attribute… = value…conclusion* is expressed as *decision = decision variant….*

Each premise consists of an attribute (a decision tree node) and a value (a decision tree branch) which create the given path (branch sequence) in a decision tree. A conclusion is understood as a decision leaf at the end of a given path in the decision tree.

The rules directly coming from a decision tree transform each decision tree branch into a given rule, so the obtained set of rules can include some rules which consist of different premises and the same conclusions. In such a case, it is necessary to transform the rules.

The rules which come directly from a decision tree use the operator "and" between the premises. Rule transformation focuses on conjoint premises with the same conclusions and develops a complex rule with the use of the operator "or" between the premise sequences from a given decision tree path. The algorithm for rule formulation is presented in **Figure 5**.

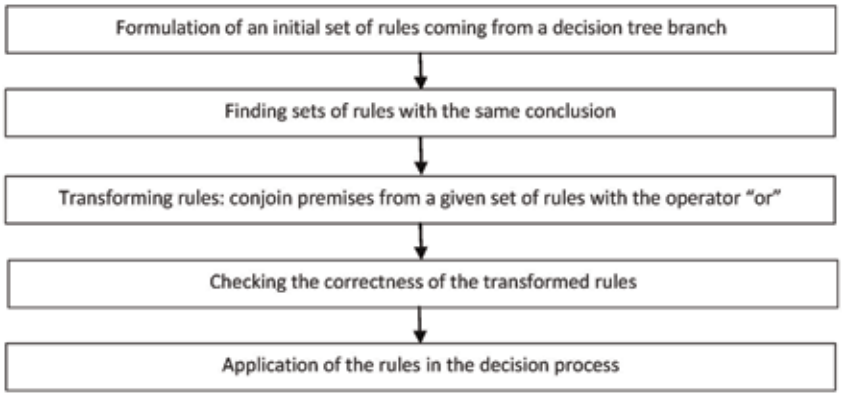


Figure 5.
Rule formulation algorithm.

4.2 An example of decision rule transformation

In the example, a set of initial rules comes from the decision tree presented in **Figure 4** and includes seven rules:

Rule 1:

If attribute 1 = value 1.1 **and** attribute 2 = value 2.1 **then** decision = decision 3.

Rule 2:

If attribute 1 = value 1.1 **and** attribute 2 = value 2.2 **then** decision = decision 1.

Rule 3:

If attribute 1 = value 1.2 **and** attribute 2 = value 2.1 **and** attribute 3 = value 3.1 **then** decision = decision 2.

Rule 4:

If attribute 1 = value 1.2 **and** attribute 2 = value 2.1 **and** attribute 3 = value 3.2 **then** decision = decision 1.

Rule 5:

If attribute 1 = value 1.2 **and** attribute 2 = value 2.2 **and** attribute 3 = value 3.1 **and** attribute 4 = value 4.1 **then** decision = decision 2.

Rule 6:

If attribute 1 = value 1.2 **and** attribute 2 = value 2.2 **and** attribute 3 = value 3.1 **and** attribute 4 = value 4.2 **then** decision = decision 1.

Rule 7:

If attribute 1 = value 1.2 **and** attribute 2 = value 2.2 **and** attribute 3 = value 3.2 **then** decision = decision 2.

The set of rules has to be transformed into complex rules with the use of the operator "or". The number of complex rules is equal to the number of decision variants.

Rule 1:

If (attribute 1 = value 1.1 **and** attribute 2 = value 2.2) **or** (attribute 1 = value 1.2 **and** attribute 2 = value 2.1 **and** attribute 3 = value 3.2) **or** (attribute 1 = value 1.2 **and** attribute 2 = value 2.2 **and** attribute 3 = value 3.1 **and** attribute 4 = value 4.2) **then** decision = decision 1.

Rule 2:

If (attribute 1 = value 1.2 **and** attribute 2 = value 2.1 **and** attribute 3 = value 3.1) **or** (attribute 1 = value 1.2 **and** attribute 2 = value 2.2 **and** attribute 3 = value 3.1 **and** attribute 4 = value 4.1) **or** (attribute 1 = value 1.2 **and** attribute 2 = value 2.2 **and** attribute 3 = value 3.2) **then** decision = decision 2.

Rule 3:

If attribute 1 = value 1.1 **and** attribute 2 = value 2.1 **then** decision = decision 3.

4.3 Checking the completeness of the rules

Rule completeness can be checked with the use of a dependence network which consists of the components presented in **Figure 6** [13].

An example of a dependence network is presented in **Figure 7**.

Formal correctness of the rules can be verified by a dependence network, but substantial correctness can be verified by using the rules in the knowledge-based system (KBS).

KBS is essentially composed of two subsystems:

- The knowledge base
- The inference engine

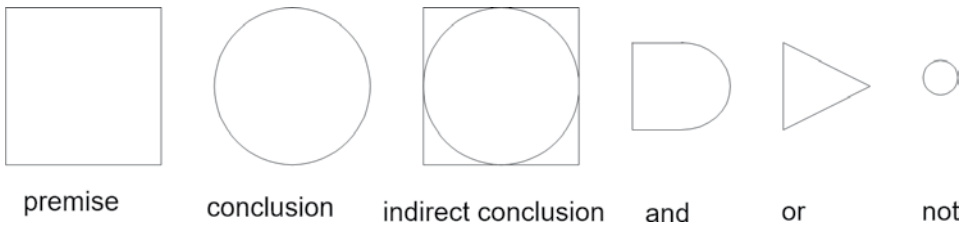


Figure 6.
Components of a dependence network.

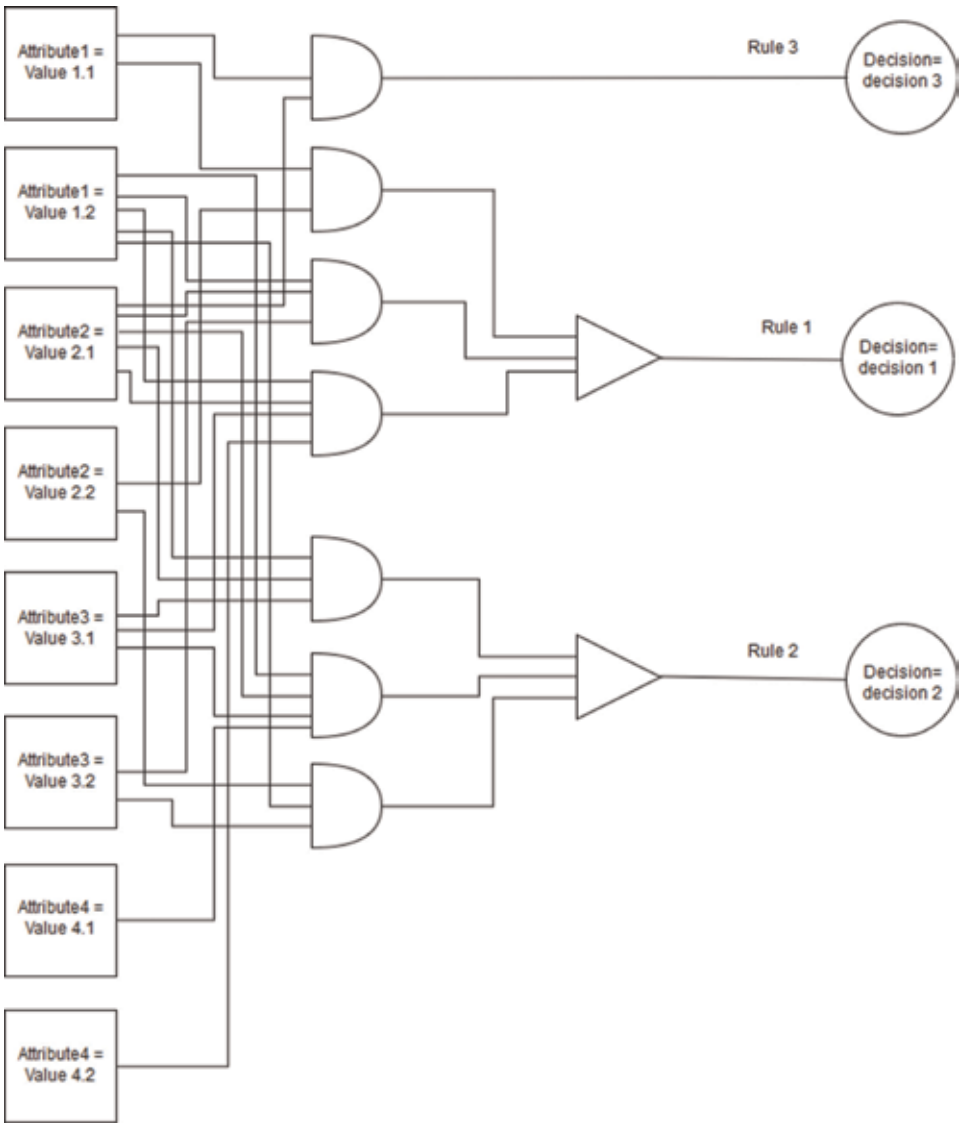


Figure 7.
An example of a dependence network.

The knowledge base consists of rules, whereas the inference engine is an automated reasoning system that evaluates the current state of the knowledge base, applies relevant rules and then asserts new knowledge into the knowledge base.

There are primarily two modes for the inference engine:

- Forward chaining
- Backward chaining

In case of backward chaining, the system looks at possible conclusions and works backwards to see if they might be true.

Forward chaining starts with the available data and uses inference rules to extract more data until a goal is reached.

Software tools for KBS include:

- Programming languages (e.g. Pascal, C++, Java, LISP, Prolog, etc.)
- Expert system shells (e.g. Sphinx)

5. An example

The decision problem analysed in the example is to find the right component—bearing to the toothed gear. The QFD matrix for a decision problem is presented in **Figure 8**.

The data from the matrix presented in **Figure 8** creates the first record in the training data set presented in **Table 1**. The data from the matrix was transformed according to the schema presented in **Figure 9**.

The training data set was presented in **Table 1**.

The meaning of the attributes was set with the use of the ID3 algorithm (**Table 2**).

An example of information gain calculation for Ak = principal dimensions (Eqs. 4–6):

$$I = 3/8 \times LOG_2 3/8 – 5/8 \times LOG_2 5/8 = 0{,}954. \tag{4}$$

$$\begin{aligned} I(C/A_k) = {} & 3/8 \times (-2/3 \times LOG_2 2/3 – 1/3 \times LOG_2 1/3) + 3/8 \\ & \times (-2/3 \times LOG_2\, 2/3 – 1/3 \times LOG_2\, 1/3) + 2/8 \\ & \times (-1/2 \times LOG_2\, 1/2 – 1/2 \times LOG_2\, 1/2) = 0{,}939. \end{aligned} \tag{5}$$

$$\Delta I(A_k) = 0{,}015. \tag{6}$$

The decision tree for the training data set in the example was presented in **Figure 10**.

Decision rule induction based on the decision tree presented in **Figure 10** is as follows:

Rule 1:

If basic dynamic load rating = small **then** decision = w1.

Rule 2:

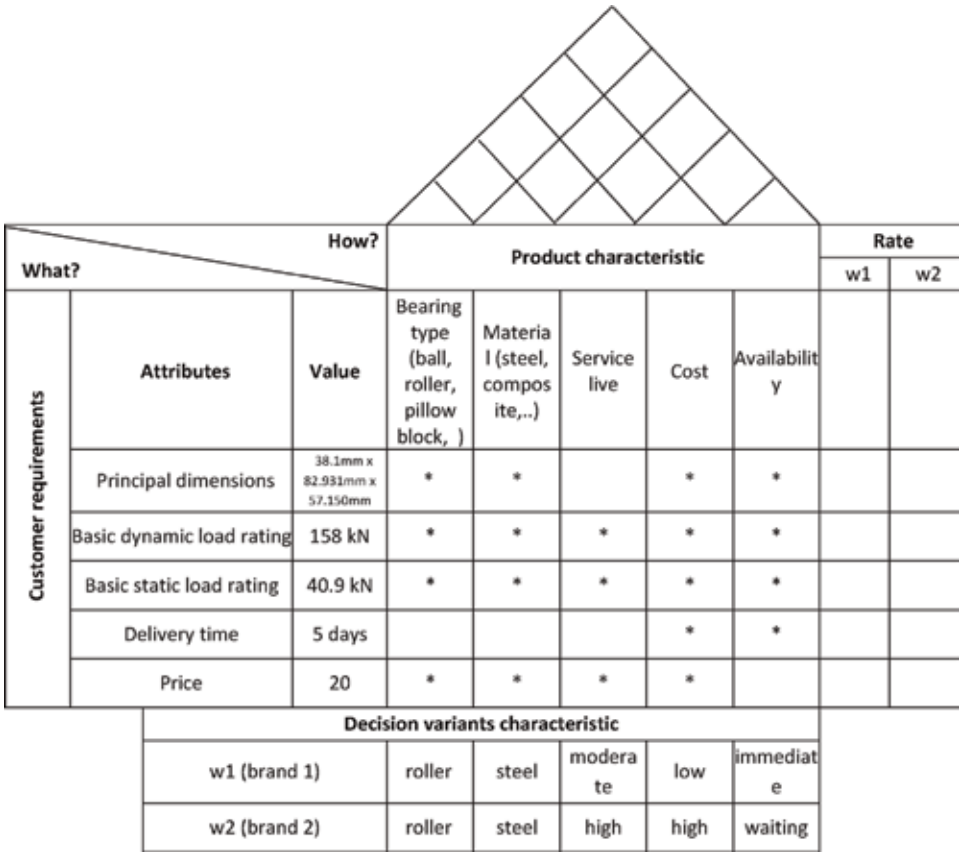
If basic dynamic load rating = big **and** basic static load rating = small **then** decision = w2.

Rule 3:

If basic dynamic load rating = big **and** basic static load rating = big **and** delivery time = long **then** decision = w2.

Rule 4:

If basic dynamic load rating = big **and** basic static load rating = big **and** delivery time = short **and** price = high **then** decision = w1.



What? \ How?			Product characteristic					Rate	
								w1	w2
Customer requirements	Attributes	Value	Bearing type (ball, roller, pillow block,)	Material (steel, composite,..)	Service live	Cost	Availability		
	Principal dimensions	38.1mm x 82.931mm x 57.150mm	*	*		*	*		
	Basic dynamic load rating	158 kN	*	*	*	*	*		
	Basic static load rating	40.9 kN	*	*	*	*	*		
	Delivery time	5 days				*	*		
	Price	20	*	*	*	*			
	Decision variants characteristic								
	w1 (brand 1)		roller	steel	moderate	low	immediate		
	w2 (brand 2)		roller	steel	high	high	waiting		

Figure 8.
An example of the QFD matrix.

No	Attribute/(value 1, value 2,…)					Decision
	Principal dimensions (small, medium, big)	Basic dynamic load rating (small, big)	Basic static load rating (small, big)	Delivery time (short, long)	Price (high, low)	
1	Small	Big	Small	Short	High	w2
2	Medium	Big	Big	Short	High	w1
3	Medium	Big	Big	Short	Low	w2
4	Small	Small	Big	Long	High	w1
5	Medium	Small	Small	Short	Low	w1
6	Big	Big	Small	Long	High	w2
7	Big	Small	Big	Long	Low	w1
8	Small	Big	Big	Long	Low	w1

Table 1.
A training data set example.

Figure 9.
An example of the OAV framework for a training set.

Entropy of the system I	Entropy of the attribute $I(C/A_k)$				
	Principal dimensions	**Basic dynamic load rating (BDLR)**	**Basic static load rating (BSLR)**	**Delivery time (DT)**	**Price**
0.954	0.939	0.607	0.796	0.906	0.906
Information gain $I(A_k)$					
	0.015	0.347	0.158	0.048	0.048
Attribute importance (ranking)					
	5	1	2	3	4

Table 2.
Information gain calculation.

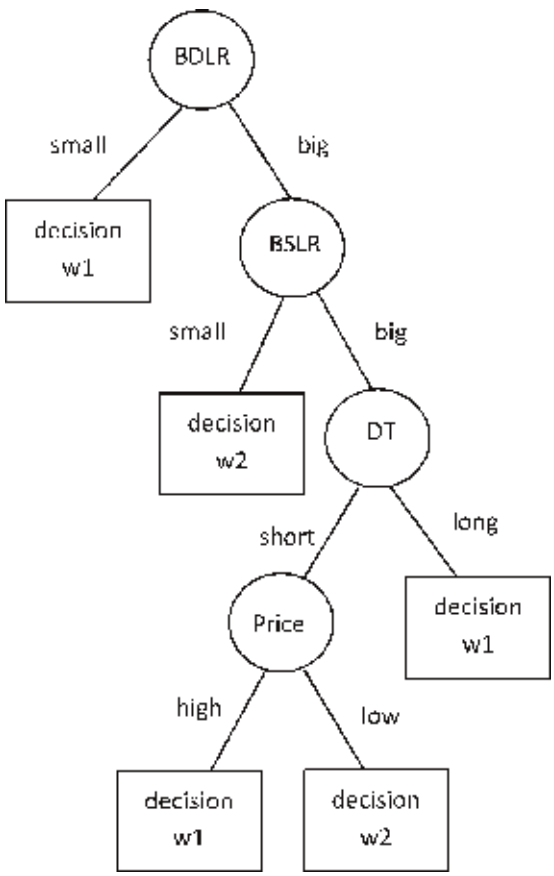


Figure 10.
An exemplary decision tree.

Rule 5:

If basic dynamic load rating = big **and** basic static load rating = big **and** delivery time = short **and** price = low **then** decision = w2.

The transformed rules:

Rule 1:

If (basic dynamic load rating = small) **or** (basic dynamic load rating = big **and** basic static load rating = big **and** delivery time = short **and** price = high) **then** decision = w1.

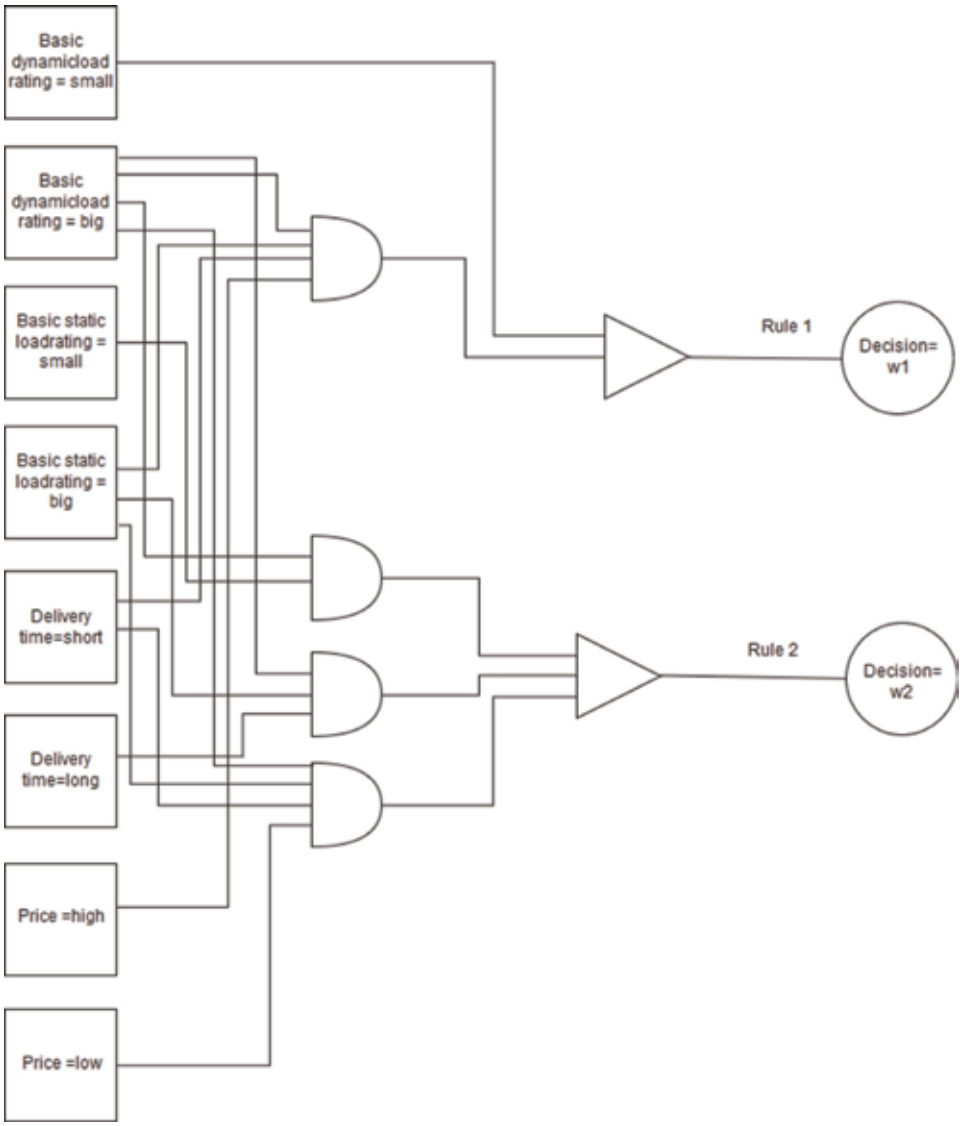


Figure 11.
Dependence network.

Rule 2:

If (basic dynamic load rating = big **and** basic static load rating = small) **or** (basic dynamic load rating = big **and** basic static load rating = big **and** delivery time = long) **or** (basic dynamic load rating = big **and** basic static load rating = big **and** delivery time = short **and** price = low) **then** decision = w2.

The dependence network for checking the transformed rules was presented in **Figure 11**.

6. Conclusions

The decision-making process in enterprises needs knowledge, information and data. A decision-maker's knowledge is developed based on past experiences and can be supported by means of artificial intelligence methods, such as rules which are

the widely used methods of knowledge representation. Decision trees are an efficient method of rule formulation. This chapter presents the methodology of decision tree induction with the Iterative Dichotomiser 3 algorithm, as well as rule formulation and checking with the use of dependence network.

A useful method for data analysis in the decision process is Quality Function Deployment, which organises data both from the customer and expert perspectives. The data was analysed with the object-attribute-value framework in which attributes and their values are used for building a training data set.

An example related to bearing selection was presented to illustrate the decision process.

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Chapter 7

Inventory Policies for Deteriorating Items with Maximum Lifetime under Downstream Partial Trade Credits to Credit-Risk Customers by Discounted Cash Flow Analysis

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Abstract

Getting loans from banks are almost impossible after 2008 global financial crisis. As a result, about 80% of companies in the United Kingdom and the United States offer their products on various short terms, free-interest loans to customers. To compute the interest earned and charged during the credit period but not to the revenue and other costs which are considerably larger than the interest earned and charged, numerous researchers and academicians apply merely the discounted cash flow (DCF) analysis. In addition, some products deteriorate continuously and cannot sell after expiration date. However, a little number of researchers have considered the product lifetime expectance into their models. In this chapter, a supplier-retailer-customer chain model is developed. The supplier provides an upstream full trade credit to the retailer, and the credit-risk customer gets a downstream partial trade credit from the retailer. The non-decreasing deterioration rate is 100% near particularly close to its expiration date. To compute all relevant costs, DCF analysis is applied. The retailer's optimal replenishment cycle time is not only exists but also unique that demonstrated in this proposal and that has been shown by the numerical examples.

Keywords: supply chain management, deterioration, expiration dates, trade credit, discount cash flow, credit-risk customer

1. Introduction

In traditional business transactions, it was implicitly assumed that the buyer must pay the procurement cost when products are received. However, in today's competitive markets, most companies offer buyers various credit terms to impel sales and hence reduce inventory. In the United Kingdom, "estimates suggest" that more than 80% of the business transactions are which made on credit, while about

80% of the United States' firms offer their products on trade credit, has been stipulated by Seifert et al. [1]. Conversely, trade credit decreases the inventory holding cost, therefore affecting order quantity of buyer.

In literature for inventory models with trade credit financing, Goyal [2] derived the retailer's optimal EOQ when the supplier provides a permissible delay in payment. Aggarwal and Jaggi [3] elongated the EOQ model for nondeteriorating items to deteriorating items. Jamal et al. [4] elaborate the model considering shortages. Teng [5] modified the previous models by using sales revenue to compute the interest earned from sales. Huang [6] then explored the problem to a supply chain system in an upstream and downstream trade credit environment. Liao [7] further generalized Huang's model with an unlimited replenishment rate with a limited replenishment rate for deteriorating items. Min et al. [8] proposed an EPQ model with both upstream and downstream trade credits when the demand is stock dependent. Teng et al. [9] extended the constant demand rate to product's life cycle dependent demand pattern. Under different credit terms, Chern et al. [10, 11] discussed Nash two-player equilibrium solutions between the supplier and the retailer. Chen et al. [12, 13] contributed the retailer's optimal model. Liao et al. [14] and Wu et al. [15] discussed optimal strategy for deteriorating items with capacity constraints.

The products like volatile liquids, blood banks, fruits, fashion merchandises, vegetables, and high-tech products deteriorate continuously due to evaporation, spoilage, and obsolescence, among other reasons. An exponentially decaying inventory model is built by Ghare and Schrader [16]. The constant deterioration rate is extended to Weibull failure rate by Covert and Philip [17]. Dave and Patel [18] proposed linear time functional demand. For shortages, Sachan [19] further generalized the EOQ model. The demand is log-concave with time dependent derived by Hariga [20]. Teng et al. [21] further expanded allowing shortages and continuous type demand pattern. Teng et al. [22] have permitted partial backlogging. For deteriorating products, Dye [23] investigated the effect of technology investment on refrigeration. No one of the above cited papers took the expiration date into consideration before Chen and Teng [24], Sarkar [25], Wang et al. [26], Wu et al. [27], and Sarkar et al. [28].

DCF is an important tool in inventory management. Researchers such as Hill and Pakkala [29], Chung and Liao [30], Dye et al. [31], Chang et al. [32], Mousavi et al. [33] work related to DCF analysis. Recently, Chen and Teng [34] and Duari and Chakraborti [35] applied the DCF analysis to obtain the optimal lot size and credit period in a supply chain with upstream and downstream trade credit financing.

A credit-worthy retailer generally gains a permissible delay on the entire purchasing quantity, in reality. However, a retailer often asks for credit-risk customers to cover a fraction of the purchasing cost at the time of placing an order and then provides a permissible delay (downstream credit). To reduce default risks with credit-risk customers, they use downstream partial trade credit as a strategy that has received relatively little attention by the researchers. Additionally, the majority of the recent studies consider merely the opportunity loss of trade credit. Most of the time, they ignore to take the opportunity loss of the other different costs in their study in order to take the effect of inflation and time value of money. For an exquisite and sharp analysis, the DCF analysis must be used on all relevant revenue and costs. Due to this fact, here a supplier-retailer-customer supply chain model is proposed. The supplier provides an upstream full credit period of S years to the retailer and the retailer gives to the customer a downstream partial credit period of R years. The deteriorating rate is constant or increasing and closer to 100% near expiration date. With time-dependent demand, the DCF analysis is applied to

study the effects of inflation and time value of money. Weibull non-decreasing deterioration rate is considered mostly as a special case of the proposed generalized deterioration rate. The retailer's objective function is formulated under different possible alternatives, in this study. We derived an algorithm to get optimal solution to each alternative using the existing theorem on concave functions. Finally, two numerical examples are solved in order to illustrate the problem.

The remaining of the paper is follows as: Section 2 defines notations and makes necessary assumptions. Section 3 gives the mathematical model; Section 4 derives the present value of the retailer's annual total profit under each alternative. Section 5 provides the required algorithm which simplifies the search for the optimal solution. Section 6 presents numerical study. Finally, the conclusions and the future research direction are provided in Section 7.

2. Notation and assumption

The following notation and assumptions are used in this model.

2.1 Notations

The following notations are used in this model:

α	fraction of the purchasing cost must be paid at the time of placing an order, $0 < \alpha < 1$
C	cost per unit
D	demand
h	holding cost per unit
I	interest per
M	expiration time or maximum lifetime
OC	ordering cost per order
p	selling price per unit
R	downstream credit period in years by the retailer
S	upstream credit period in years by the supplier
T	time
Ic	interest charged by the retailer
Ie	interest earned by the supplier
T	replenishment cycle time

Functions:

Q(t)	order quantity level at time t
$\theta(t)$	deterioration rate at time t
I(t)	inventory level at time t
D(t)	demand rate, $D = (a + bt)$
PTP(T)	present value of annual total profit

For convenience, the asterisk symbol on a variable is denoted the optimal solution of the variable. For instance, T^* is the optimal solution of T.

2.2 Assumptions

The following assumptions are made to build the mathematical inventory model:

a. In a supplier-retailer-customer supply chain system, the retailer obtains a full upstream credit period of S years from his/her supplier and in turn gives a partial downstream trade credit to his/her credit-risk customers who must cover α portion of the purchasing cost at the time of placing an order and then get a credit period of R years on the outstanding quantity. For reliable customers, just set $\alpha = 0$, the retailer may provide a full trade credit.

b. The retailer deposits the sales revenue into an interest-bearing account after time R, if $S \geq R$. When $S \geq (T + R)$, the retailer pays off the entire purchasing cost and collects all sales revenue at time S. Both, the credit payment sold by SR and the cash payment, are obtained from time 0 to S for $S < T + R$. To use the other activities and begin paying for the interest charges on the items sold, the retailer pays the supplier and retains the profit after $(S - R)$.

c. The retailer gets cash payments from customers and immediately deposits those into an interest-bearing account until time S, if $S \leq R$. As to credit payments, the retailer must finance $(1 - \alpha)c(a + bt)\ T$ at time S and then pay off the loan from time R to time T + R.

d. A deteriorating item deteriorates continuously and cannot be sold after its maximum lifetime or expiration date. Therefore, its deterioration rate is percent near to its expiration date. As a result, it is assumed without loss of generality that the deterioration rate $\theta(t)$ at time t, $0 \leq t \leq m$, satisfies the following conditions:

$$0 \leq \theta(t) \leq 1, \theta^{|}(t) \geq 0 \ and \ \theta(m) = 1. \tag{1}$$

We assume the deterioration as

$$\theta(t) = \frac{1}{(1 + m - t)}, 0 \leq t \leq m \tag{2}$$

a special case of (1):

e. It is assumed without loss of generality that both upstream and downstream credit periods R and S and the replenishment cycle time T are less than or equal to the expiration date m, since the deterioration rate reaches 100% after expiration date

$$R \leq m, S \leq m, \text{and } T \leq m \tag{3}$$

f. No shortages allowed.

g. Replenishment rate is instantaneous.

3. Mathematical model

The inventory level is depleted by demand and deterioration, during the replenishment cycle [0, T], and hence governed by the following differential equation (**Figure 1**):

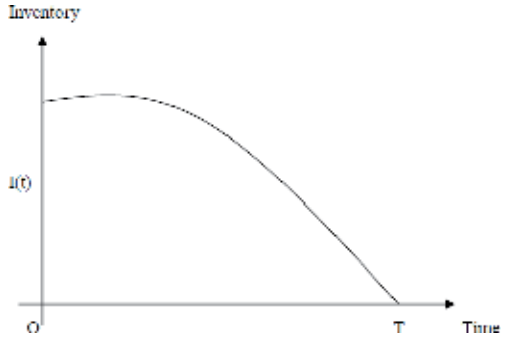

Figure 1.
Graphically shows the model.

$$I^{|}(t) = -D - \theta(t)I(t), 0 \le t \le T, D = (a + bt) \tag{4}$$

With the boundary condition I(T) = 0. Note that the prime symbol on a variable is denoted the first order derivative with respect to the variable throughout the paper. Solving the differential Eq. (4), we get

$$\begin{aligned} I(t) &= e^{-\delta(t)} \int_t^T e^{\delta(u)}(a + bt)\,du, \text{where } \delta(t) = \int_0^t \theta(u)\,du \\ &= \left(1 + m - \frac{t}{1+m}\right)(1+m)(b(t-T) \\ &\quad + (a + b + bm)(\text{Log}[1 + m - t] - \text{Log}[1 + m - T])) \end{aligned} \tag{5}$$

3.1 Sales revenue

The customers get a downstream credit period of R years from the retailer. Thus, the retailer receives the cash payment for the time 0 to T. Also the retailer receives the credit payment from R to T + R. Hence, the present value of sales revenue per cycle time T of the retailer is

$$SR = p\left[\alpha \int_0^T (a + bt)e^{-it}dt + (1 - \alpha) \int_R^{T+R} (a + bt)e^{-it}dt\right] \tag{6}$$

$$= p\left[\frac{\begin{array}{r} e^{-i(R+T)}\left(b + ai + biR - e^{iT}(b + ai + biR) + biT\right)(-1 + \alpha) \\ +\left(b + ai - e^{-iT}(b + ai + biT)\right)\alpha \end{array}}{i^2}\right] \tag{7}$$

3.2 Different costs

3.2.1 Ordering cost

At time 0, the retailer orders deteriorating items. Hence, the present value of the retailer's ordering cost per cycle time T is

$$\text{OC} \tag{8}$$

3.2.2 Purchasing cost

Since the upstream trade credit is S years, the retailer must pay the supplier the whole purchasing cost cQ at time S. As a result, the present value of the retailer's purchasing cost per cycle time T is

$$\begin{aligned} PC &= ce^{-iS}Q = ce^{-iS}I(0) = c\int_0^T (a+bt)e^{\delta(t)-iS}dt \\ &= ce^{-iS}(1+m)^2(-bT+(a+b+bm)(\text{Log}[1+m]-\text{Log}[1+m-T])) \end{aligned} \tag{9}$$

3.2.3 Holding cost

The present value of the retailer's holding cost per cycle time T is

$$\begin{aligned} HC &= h\int_0^T e^{-it}I(t)dt = h\int_0^T\int_t^T (a+bt)e^{\delta(u)-\delta(t)-it}dudt \\ &= h\left(-\frac{b(1+m)^2\left(-1+e^{-iT}+iT\right)}{i^2}+\frac{be^{-iT}\left(2+iT+e^{iT}(-2+iT)\right)}{i^3}\right. \\ &\quad +\frac{e^{-i(1+m)}(1+m)^2(a+b+bm)\begin{pmatrix}-\text{ExpIntegralEi}[i(1+m)]\\ +\text{ExpIntegralEi}[i(1+m-T)]\\ +e^{i(1+m)}\text{Log}\left[\frac{1+m}{1+m-T}\right]\end{pmatrix}}{i} \\ &\quad \left.-\frac{e^{-i(1+m)}(a+b+bm)(e^{i(1+m)}-e^{i(1+m-T)}-(1+i+im)\text{ExpIntegralEi}[i(1+m)]}{i^2}\right. \\ &\quad \left.\left.+(1+i+im)\text{ExpIntegralEi}[i(1+m-T)]+e^{i(1+m)}\text{Log}\left[\frac{1+m}{1+m-T}\right]\right)\right) \end{aligned} \tag{10}$$

According to the values of R and S, there are two potential cases:

Case I: R $\leq$ S.
Case II: R $\geq$ S.

Both cases are discussed separately.

3.2.4 Case I: when $R \leq S$

Based on the values of S, T, and T + R, three sub-cases can occur:

i. $S \leq T$.

ii. $T \leq S \leq T + R$.

iii. $T + R \leq S$.

Notice that for both cases (i) $S \leq T$ and (ii) $T \leq S \leq T + R$, the case S = T is applicable.

Similarly, the condition S = T + R is applicable for cases (ii) $T \leq S \leq T + R$ and (iii) $T + R \leq S$.

The interest earned and the interest charged for the above three cases are investigated accordingly.

3.2.4.1 Sub-case 1a: $S \leq T$

In this sub-case, the retailer gets revenue and receives interest from the two possible sources: (a) the cash payment for the time 0 to S and (b) the credit payment for the time R to S. So, the present value of the interest earned per cycle is

$$IE = pI_e\left[\alpha\int_0^S t(a+bt)e^{-it}dt + (1-\alpha)\int_R^S (t-R)(a+bt)e^{-it}dt\right]$$

$$= pi_e\left[\frac{e^{-i(R+S)}\left(e^{iS}(ai+b(2+iR)) + e^{iR}\begin{pmatrix} ai(-1+i(R-S)) \\ +b(-2+i(R+iRS-S(2+iS))) \end{pmatrix}\right)(1-\alpha)}{i^3}\right.$$

$$\left. + \frac{\left(2b+ai+e^{-iS}(-ai(1+iS)-b(2+iS(2+iS)))\right)\alpha}{i^3}\right] \tag{11}$$

The retailer provides his customers a credit period of R years and gets customers' credit payments from time R through (T + R), on the other hand. The retailer obtains $\alpha c(a+bt)$S dollars from cash payment and (1-α)c$(a+bt)$(S-R) dollars from credit payment, at time S, and therefore pays his/her supplier [$\alpha c(a+bt)$S+(1-α)c$(a+bt)$(S-R)] dollars. Consequently, the retailer must finance all items sold after time S for the cash payment and (S – R) for the credit payment at an interest charged I_c per dollar per year. So, the present amount of the interest charged per cycle is given by

$$IC = cI_c\left[\alpha\int_S^T (T-t)(a+bt)e^{-it}dt + (1-\alpha)\int_S^{T+R} (T+R-t)(a+bt)e^{-it}dt\right]$$

$$= ci_c \left[\frac{\left(\begin{array}{l} e^{-i(R+T)}(ai + b(2 + i(R+T))) + (1-\alpha)e^{-iS} \left(\begin{array}{l} ai(-1 + i(R-S+T)) \\ + b \left(\begin{array}{l} -2 + i(R-2S+T) \\ +i^2 S(R-S+T) \end{array} \right) \end{array} \right) \end{array} \right)}{i^3} \right.$$

$$\left. + \frac{\left(\begin{array}{l} e^{-iT}(ai + b(2 + iT)) \\ +e^{-iS} \left(\begin{array}{l} \cdot \\ +b(-2 + i(T + S(-2 + i(-S+T)))) \end{array} \right) \end{array} \right) \alpha}{i^3} \right] \tag{12}$$

4. Total profit of the model

4.1 Profit of the first sub-case of the model

As a result, the present value of the retailer's annual total profit by using (7)–(12) is

$$\begin{aligned} \mathbf{PTP_1(T)} &= \frac{\mathbf{1}}{\boldsymbol{T}}(\boldsymbol{SR} - \boldsymbol{PC} - \boldsymbol{HC} - \boldsymbol{OC} - \boldsymbol{IC} + \boldsymbol{IE}) \\ &= \frac{1}{\mathrm{T}} \left\{ \mathrm{p} \left[\alpha \int_0^{\mathrm{T}} (\mathrm{a} + \mathrm{bt}) \mathrm{e}^{-\mathrm{it}} \mathrm{dt} + (1-\alpha) \int_{\mathrm{R}}^{\mathrm{T+R}} (\mathrm{a} + \mathrm{bt}) \mathrm{e}^{-\mathrm{it}} \mathrm{dt} \right] \right. \\ &\quad - \mathrm{c} \int_0^{\mathrm{T}} (\mathrm{a} + \mathrm{bt}) \mathrm{e}^{\delta(\mathrm{t}) - \mathrm{iS}} \mathrm{dt} - \mathrm{h} \int_0^{\mathrm{T}} \int_{\mathrm{t}}^{\mathrm{T}} (\mathrm{a} + \mathrm{bt}) \mathrm{e}^{\delta(\mathrm{u}) - \delta(\mathrm{t}) - \mathrm{it}} \mathrm{dudt} - \mathrm{O} \\ &\quad - \mathrm{cI_c} \left[\alpha \int_{\mathrm{S}}^{\mathrm{T}} (\mathrm{T} - \mathrm{t})(\mathrm{a} + \mathrm{bt}) \mathrm{e}^{-\mathrm{it}} \mathrm{dt} + (1-\alpha) \int_{\mathrm{S}}^{\mathrm{T+R}} (\mathrm{T} + \mathrm{R} - \mathrm{t})(\mathrm{a} + \mathrm{bt}) \mathrm{e}^{-\mathrm{it}} \mathrm{dt} \right] \\ &\quad \left. + \mathrm{pI_e} \left[\alpha \int_0^{\mathrm{S}} \mathrm{t}(\mathrm{a} + \mathrm{bt}) \mathrm{e}^{-\mathrm{it}} \mathrm{dt} + (1-\alpha) \int_{\mathrm{R}}^{\mathrm{S}} (\mathrm{t} - \mathrm{R})(\mathrm{a} + \mathrm{bt}) \mathrm{e}^{-\mathrm{it}} \mathrm{dt} \right] \right\} \end{aligned} \tag{13}$$

4.1.1 Sub-case 1b: $T \leq S \leq T + R$

The retailer accumulates revenue and obtains interest from two sources: (a) the cash payment starting from time 0 to S and (b) the credit payment starting from time R to S. So, the present value of the interest earned per cycle is

$$IE = pI_e \left[\alpha \left(\int_0^T t(a + bt) e^{-it} dt + \int_T^S T(a + bt) e^{-it} dt \right) + (1-\alpha) \int_R^S (t - R)(a + bt) e^{-it} dt \right]$$

$$= pi_e \left[\frac{e^{-i(R+S)}\left(e^{iS}(ai+b(2+iR))+e^{iR}\begin{pmatrix} ai(-1+i(R-S)) \\ +b(-2+i(R+iRS-S(2+iS))) \end{pmatrix}\right)(1-\alpha)}{i^3} \right.$$
$$\left. + \left(\frac{e^{-i(S+T)}\left(-e^{iT}(b+ai+biS)T+e^{iS}T(b+ai+biT)\right)}{i^2} \right.\right.$$
$$\left.\left. + \frac{2b+ai+e^{-iT}(-ai(1+iT)-b(2+iT(2+iT)))}{i^3} \right)\alpha \right] \tag{14}$$

By time T ($\leq$ S), the retailer receives all cash payments so that there is no interest charged for the cash payment. However, the retailer must pay up all items sold during the interval [S–R, T]. Therefore, the annual interest charged is

$$IC = (1-\alpha)\int_S^{T+R}(T+R-t)(a+bt)e^{-it}dt]$$

$$= \frac{\begin{pmatrix}(e^{-i(R+T)}(ai+b(2+i(R+T)))+e^{-iS}(ai(-1+i(R-S+T)) \\ +b\left(-2+i(R-2S+T)+i^2S(R-S+T)\right)))\end{pmatrix}(1-\alpha)}{i^3} \tag{15}$$

4.2 Profit of the second sub-case of the model

From (7)–(10), (14), and (15), it is known that the present value of the retailer's annual total relevant profit is

$$\boldsymbol{PTP_2(T) = \frac{1}{T}(SR - PC - HC - OC - IC + IE)}$$
$$= \frac{1}{T}\left\{ p\left[\alpha\int_0^T(a+bt)e^{-it}dt + (1-\alpha)\int_R^{T+R}(a+bt)e^{-it}dt\right] - c\int_0^T(a+bt)e^{\delta(t)-iS}dt \right.$$
$$- \left[h\int_0^T\int_t^T(a+bt)e^{\delta(u)-\delta(t)-it}dudt - OC - (1-\alpha)\int_S^{T+R}(T+R-t)(a+bt)e^{-it}dt \right]$$
$$\left. + pI_e\left[\alpha\left(\int_0^T t(a+bt)e^{-it}dt + \int_T^S T(a+bt)e^{-it}dt\right) + (1-\alpha)\int_R^S(t-R)(a+bt)e^{-it}dt\right] \right\} \tag{16}$$

4.2.1 Sub-case 1c: T + R ≤ S

The retailer receives all the cash and credit payments before the supplier's upstream credit period S and no interest charged. However, the present value of the interest earned per cycle is given by

$$IE = pI_e\left[\alpha\left(\int_0^T t(a+bt)e^{-it}dt + \int_T^S Te^{-it}dt\right) + (1-\alpha)\left(\int_{T+R}^{S} T(a+bt)e^{-it}dt \int_R^{T+R} (t-R)(a+bt)e^{-it}dt\right)\right]$$

$$= pi_e\left[\left(-\frac{e^{-i(R+T)}\left(ai\left(1-e^{iT}+iT\right)+b\left(2-e^{iT}(2+iR)+i^2T(R+T)+i(R+2T)\right)\right)}{i^3}\right.\right.$$
$$\left.+\frac{e^{-i(R+S+T)}\left(-e^{i(R+T)}(b+ai+biS)T+e^{iS}T(ai+b(1+i(R+T)))\right)}{i^2}\right)(1-\alpha)$$
$$+\left(\frac{e^{-i(S+T)}\left(-e^{iT}(b+ai+biS)T+e^{iS}T(b+ai+biT)\right)}{i^2}\right.$$
$$\left.\left.+\frac{2b+ai+e^{-iT}(-ai(1+iT)-b(2+iT(2+iT)))}{i^3}\right)\alpha\right] \tag{17}$$

4.3 Profit of the third sub-case of the model

So the present value of the retailer's annual total profit is

$$\boldsymbol{PTP_3(T) = \frac{1}{T}(SR - PC - HC - OC + IE)}$$
$$= \frac{1}{T}\left\{p\left[\alpha\int_0^T (a+bt)e^{-it}dt + (1-\alpha)\int_R^{T+R}(a+bt)e^{-it}dt\right]\right.$$
$$-c\int_0^T (a+bt)e^{\delta(t)-iS}dt - h\int_0^T\int_t^T (a+bt)e^{\delta(u)-\delta(t)-it}dudt - OC$$
$$+pI_e\left[\alpha\left(\int_0^T t(a+bt)e^{-it}dt + \int_T^S Te^{-it}dt\right)\right.$$
$$\left.\left.+(1-\alpha)\left(\int_{T+R}^{S} T(a+bt)e^{-it}dt + \int_R^{T+R}(t-R)(a+bt)e^{-it}dt\right)\right]\right\} \tag{18}$$

Combining (13), (16), and (18), the present value of the retailer's annual total profit is given as

$$PTP(T) = PTP_1(T)\ if\ S \le T$$
$$PTP(T) = PTP_2(T)\ if\ S - R \le T \le S$$
$$PTP(T) = PTP_3(T)\ if\ T \le S - R \tag{19}$$

It is clear from (13), (16), and (18) that

$$PTP_1(S) = PTP_2(S), and\ PTP_2(S-R) = PTP_3(S-R) \tag{20}$$

This implies that PTP(T) is continuous in $T \ge 0$.

4.3.1 Case II: when R ≥ S

The following sub-cases may occur based on values of S and T: S ≤ T, and S ≥ T.

4.3.1.1 Sub-case 2a: S ≤ T

As R ≥ S, there is no interest earned from the credit payment. However, the present value of the annual interest earned from the cash payment is

$$IE = \alpha p I_e \int_0^S (a+bt)te^{-it}dt$$

$$= \frac{p\left(2b+ai+e^{-iS}(-ai(1+iS)-b(2+iS(2+iS)))\right)\alpha i_e}{i^3} \tag{21}$$

At time S, the retailer should finance (1-α)c$(a+bt)$T for the credit payment and αc$(a+bt)$ (T–S) for the cash payment, respectively. Then, the retailer renders the loan for the cash payment at time T and pays off the loan for the credit payment at t = T + R. So, the present amount of the interest charged per cycle is

$$IC = cI_c\left[\alpha\left(\int_S^T (T-t)(a+bt)e^{-it}dt + (1-\alpha)\left\{\int_S^R T(a+bt)e^{-it}dt + \int_R^{T+R}(T+R-t)(a+bt)e^{-it}dt\right\}\right]$$

$$= ci_c\left[\left(\frac{e^{-i(R+S)}\left(-e^{iS}(b+ai+biR)T+e^{iR}(b+ai+biS)T\right)}{i^2} + \frac{e^{-i(R+T)}\left(ai+b(2+i(R+T))+e^{iT}(ai(-1+iT)+b(-2+i(T+R(-1+iT))))\right)}{i^3}\right)(1-\alpha) + \frac{\left(e^{-iT}(ai+b(2+iT))+e^{-iS}(ai(-1+i(-S+T))+b(-2+i(T+S(-2+i(-S+T))))\right)\alpha}{i^3}\right]. \tag{22}$$

4.4 Profit of the first sub-case of the second case of the model

Consequently, the present value of the retailer's annual total profit is

$$\boldsymbol{PTP_4(T) = \frac{1}{T}(SR - PC - HC - OC - IC + IE)}$$

$$= \frac{1}{T}\left\{p\left[\alpha\int_0^T (a+bt)e^{-it}dt + (1-\alpha)\int_R^{T+R}(a+bt)e^{-it}dt\right] - c\int_0^T (a+bt)e^{\delta(t)-iS}dt - h\int_0^T\int_t^T (a+bt)e^{\delta(u)-\delta(t)-it}dudt - OC\right.$$

$$-cI_c\left[\alpha\left(\int_S^T (T-t)(a+bt)e^{-it}dt+(1-\alpha)\left\{\int_S^R T(a+bt)e^{-it}dt+\int_R^{T+R}(T+R-t)(a+bt)e^{-it}dt\right\}\right)\right]+\alpha pI_e\int_0^S (a+bt)te^{-it}dt \tag{23}$$

We then discuss the last sub-case in which R ≥ S ≥ T.

4.4.1 Sub-case 2b: S ≥ T

Similarly, the present value of the interest earned from the cash payment per cycle is

$$IE = pI_e\left[\alpha\left\{\int_0^T t(a+bt)e^{-it}dt+\int_T^S T(a+bt)e^{-it}dt\right\}\right]$$

$$=p\left(\frac{e^{-i(S+T)}\left(-e^{iT}(b+ai+biS)T+e^{iS}T(b+ai+biT)\right)}{i^2}+\frac{2b+ai+e^{-iT}(-ai(1+iT)-b(2+iT(2+iT)))}{i^3}\right)\alpha i_e \tag{24}$$

For the cash payment, there is no interest to charge. On the other hand, the retailer must finance (1–α)c$(a+bt)$T for the credit payment at time S and start paying off the loan from time R to T + R.

Hence, the present amount of the interest charged per cycle is

$$IC=(1-\alpha)cI_c\left[\left\{\int_S^R T(a+bt)e^{-it}dt+\int_R^{T+R}(T+R-t)(a+bt)e^{-it}dt\right\}\right]$$

$$=ci_c\left[\left(\frac{e^{-i(R+S)}\left(-e^{iS}(b+ai+biR)T+e^{iR}(b+ai+biS)T\right)}{i^2}+\frac{e^{-i(R+T)}\left(ai+b(2+i(R+T))+e^{iT}(ai(-1+iT)+b(-2+i(T+R(-1+iT))))\right)}{i^3}\right)(1-\alpha)\right.$$

$$\left.+\frac{\left(e^{-iT}(ai+b(2+iT))+e^{-iS}(ai(-1+i(-S+T))+b(-2+i(T+S(-2+i(-S+T))))\right)\alpha}{i^3}\right] \tag{25}$$

4.5 Profit of the second sub-case of the second case of the model

Consequently, the present value of the retailer's annual total profit is

$$\boldsymbol{PTP_5(T)=\frac{1}{T}(SR-PC-HC-OC-IC+IE)}$$

$$
\begin{aligned}
&= \frac{1}{T}\left\{ p\left[\alpha \int_0^T (a+bt)e^{-it}dt + (1-\alpha)\int_R^{T+R} (a+bt)e^{-it}dt \right] \right. \\
&\quad - c\int_0^T (a+bt)e^{\delta(t)-iS}dt - h\int_0^T\int_t^T (a+bt)e^{\delta(u)-\delta(t)-it}dudt - O \\
&\quad \left. - (1-\alpha)cI_c\left\{ \int_S^R T(a+bt)e^{-it}dt + \int_R^{T+R} (T+R-t)(a+bt)e^{-it}dt \right\} \right] \\
&\quad \left. + pI_e\left[\alpha\left\{ \int_0^T t(a+bt)e^{-it}dt + \int_T^S T(a+bt)e^{-it}dt \right\} \right] \right\}
\end{aligned} \tag{26}
$$

Combining (23) and (26), we know that the present value of the retailer's annual total relevant profit is

$$
\begin{aligned}
PTP(T) &= PTP_4(T), \text{if } S \le T \\
PTP(T) &= PTP_5(T), \text{if } S \le T
\end{aligned} \tag{27}
$$

It is clear that PTP(T) is continuous in T and has the following properties:

$$
PTP_4(S) = PTP_5(S) \tag{28}
$$

5. Algorithm

We developed the following algorithm to find the optimal solution of the problem. The algorithm is as follows:

Step 1: Input all the parameters values.

Step 2: Assimilate the values of R and S. If R ≤ S then go to Step 3, otherwise go to Step 5.

Step 3: Compute all $PTP_j\left(T_j^*\right)$, for j = 1, 2, and 3.

Step 3.1: Find the unique root T_1 in (30). If $S \le T_1$ we set $T_1^* = T_1$ else, we set $T_1^* = S$. Calculate $PTP_1\left(T_1^*\right)$ by (13).

Step 3.2: Find the unique root T_2 in (31). If $T_2 \le S - R$; we set $T_2^* \le S - R$. If $S - R \le T_2 \le S$; we set $T_2^* = T_2$. If $T_2 \ge S$, ; we set $T_2^* = S$. Calculate $PTP_2\left(T_2^*\right)$ by (16).

Step 3.3: Find the unique root T_3 in (32). If $T_3 \le S - R$; we set $T_3^* \le T_3$. Otherwise we set $T_3^* = S - R$. Calculate $PTP_3\left(T_3^*\right)$ by (18).

Step 4: Find the maximum among $PTP_j\left(T_j^*\right)$ for j = 1, 2, and 3, set the optimal solution $\{T^*, PTP(T^*)\}$ accordingly, and then stop.

Step 5: Compute $PTP_j\left(T_j^*\right)$, for j = 4 and 5.

Step 5.1: Find the unique root T_4 in (33). If $S \le T_4$ we set $T_4^* = T_4$ else we set $T_4^* = S$. Calculate $PTP_4\left(T_4^*\right)$ by (23).

Step 5.2: Find the unique root T_5 in (34). If $S \ge T_5$ we set $T_5^* = T_5$ else we set $T_5^* = S$. Calculate $PTP_5\left(T_5^*\right)$ by (26).

Step 6: Find the maximum among $PTP_j\left(T_j^*\right)$ for j = 4 and 5, Set the optimal solution $\{T^*, PTP(T^*)\}$ accordingly, and then stop.

6. Numerical examples

Example 1: Let us assume that $\theta(t) = \frac{1}{(1+m-t)}$, m = 1, α = 0:20, c = $10 per unit, a = 50 units per year, b = 30 units per year, h = $15 per unit per year = 0.4, $I_e = 0.4, I_c = 0.5$, p = $10 per unit, R = 0.25, and T = 0.18. Optimal solutions when $\theta(t) = \frac{1}{(1+m-t)}$ and $S \geq R$ (**Figure 2**).

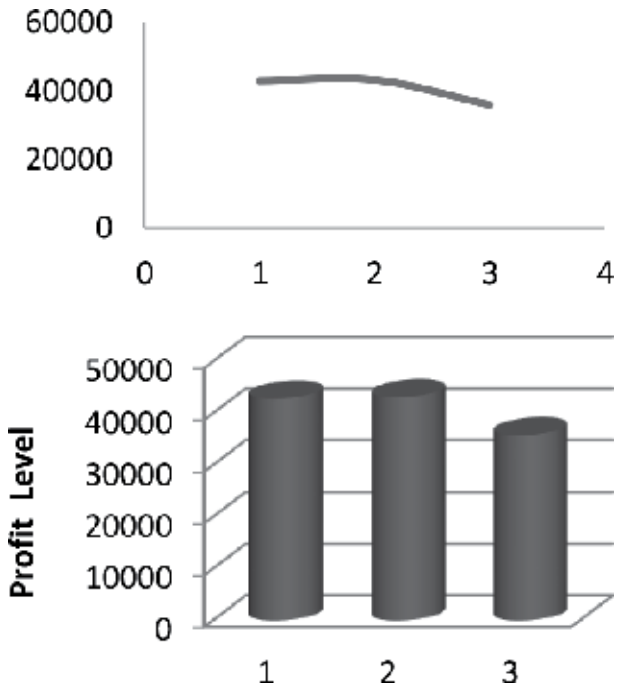

Figure 2.
Graphically the results of sub-cases of the first case.

Case I	Q_i^*	T_i^*	PTP_i^*
1a(1)	21.91	0.18	42861.95
1b(2)	**21.91**	**0.18**	**43119.31**
1c(3)	21.91	0.18	35794.41

Table 1.
The optimal solution to the three sub-cases of case I.

Case II	Q_i^*	T_i^*	PTP_i^*
2a(4)	22.21	0.18	30994.26
2b(5)	**22.21**	**0.18**	**31892.34**

Table 2.
The optimal solution to the two sub-cases of case II.

By using the proposed algorithm, we obtain the optimal solutions of each case shown in **Table 1**. As a result, for S = 0.74, then the optimal solution to the problem is $Q^* = 21.91\ units, T^* = 0.18, years = 25\ days, and\ PTP^* = 43119.31$.

Example 2: Using the same data as those in Example 1 except R = 0.45 years again using the proposed algorithm, we obtain the optimal solutions for S = 0.18 and 0.44, respectively, each case shown in **Table 2**. Optimal solutions when $\theta(t) = \frac{1}{(1+m-t)}$ and $S \leq R$ (**Figure 3**).

As a result, at S = 0.44, the optimal solution to the problem is $Q^* = 22.21$ units, $T^* = 0.18$ yrs $= 45$ days and Total Profit$^* = 31892.34$. Considering all the sub-cases, we can conclude that the second sub-case of the first case is more

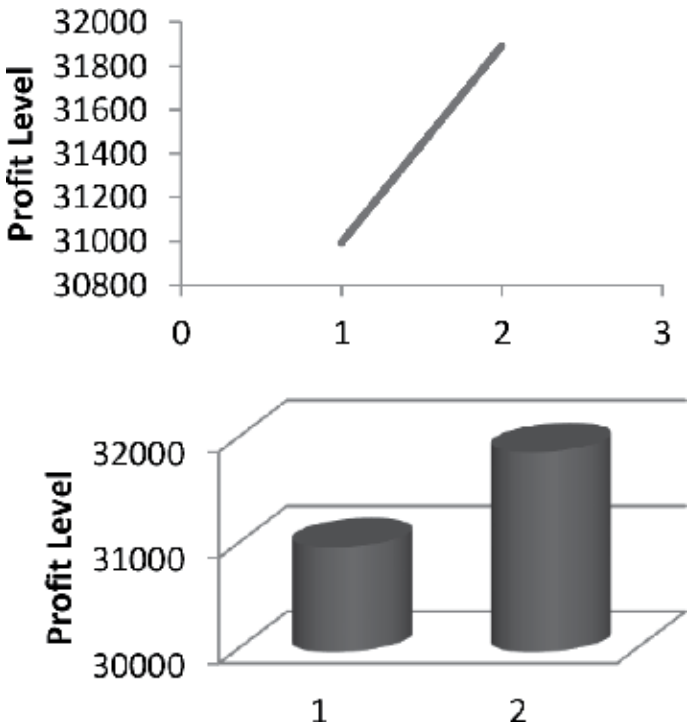

Figure 3.
Graphically the results of sub-cases of the second case.

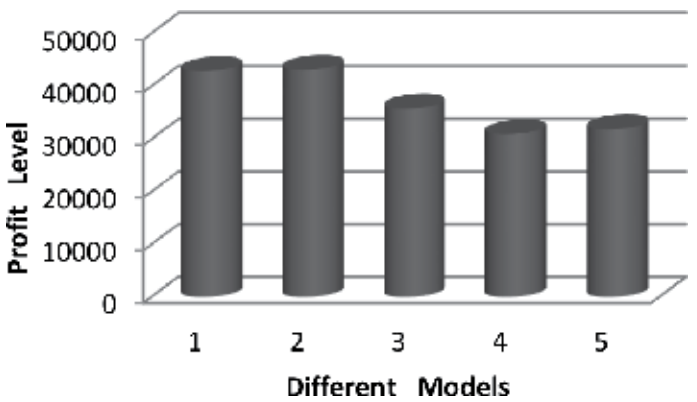

Figure 4.
Graphical comparison of profit functions of both cases I and II.

profitable for the retailer. Consequently, the background and the conditions to take the best policy of that model are better than irrespective of all other cases (**Figure 4**).

7. Conclusions and future research

Usually, the retailer uses a downstream partial trade credit as a strategy to reduced fault risks with credit-risk customers. The deterioration rate is time dependent and near cent percent near expiration date. We have investigated an EOQ model for deteriorating items in a general framework that Goyal [2], Teng [5, 36], Huang [6], Teng and Goyal [37], Chen and Teng [24], Wu and Chan [38], and Wu et al. [15] did special cases. In addition, to reflect the effects of inflation and time value of money, a discounted cash flow analysis has been adopted to obtain the present value of the total profit for time-dependent demand. By applying the existing theoretical results in concave functions, we have demonstrated the proper algorithm to find the optimal solution for possible alternatives. Then we have used the two most commonly used deterioration rates to run several numerical simulations. With increase in the purchasing cost, the holding cost, or the interest rate reduces the order quantity, the cycle time and the annual total profit is sensitive. In contrast, along product maximum life-span elevates the order quantity, the cycle time, and annual total profit is also sensitive. In addition, the total profit is very sensitive to the selling price. Consequently, to prolong product life-span and increase profit, retailers must negotiate with suppliers for low purchase cost and invest in preservation technology (such as refrigeration).

If time approaches to the expiration date, it may be profitable to have a closeout sale at a markdown price. One may extend the model from zero-ending inventory to nonzero-ending inventory. Furthermore, a researcher might consider allowing for shortages, allow partial backlogging, and allow for failure, scrap, and rework. Finally, the proposed model with a single player can be extended to an integrated cooperative model for both the retailer and the customer.

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Chapter 8

The Role of Wealth in Gain and Loss Perception: An Empirical Analysis

Andrea Lippi

Abstract

People with significantly different initial starting capitals may perceive gains and losses differently. In order to test this hypothesis, we consider and compare two samples of investors: retail investors as those with a maximum of €500,000 worth of assets under management (AUM) and private investors as those with more than €500,000 AUM. Based on the answers obtained from specifically devised questionnaires, we test the differences in gain and loss perception and check the level of satisfaction/dissatisfaction in situations of gain and loss. The results obtained demonstrate that private and retail investors perceive gains and losses differently.

Keywords: perception of gain, perception of loss, decision-making, private investors, retail investors

1. Introduction

A plethora of experiments (e.g., [1, 2]) demonstrate that decisions made in an economic and financial setting are influenced by subjective perceptions. The framing effect [3] is a perceptual phenomenon implying that different presentations of the same information may lead to different choices. Chen et al. [4], Del Vecchio et al. [5], Gourville [6], Levin et al. [3], McKechnie et al. [7], Sinha and Smith [8], Tombu and Mandel [9] and Tversky and Kahneman [10] have investigated how the framing effect could influence the decision-making process. DelVecchio [11], DelVecchio et al. [5], Gourville [6], Kahneman [12, 13], McKechnie et al. [7] and Mellers [14] have examined the incoherence of judgement when faced with similar or indifferent situations. Kahneman and Tversky [15], Kühberger [16] and Olsen [17, 18] demonstrate that the framing effect can influence the decision-making process so as to cause a shift from 'risk-adverse' to 'risk-seeking' and vice versa, the so-called risky-choice framing effect. The framing effect is predicted by Kahneman and Tversky [15] in their prospect theory. According to this theory, individuals' choices are always made considering the gains and losses compared with an initial starting capital (reference point). Kahneman and Tversky [19] argue that investors decide by mentally referring to their status quo (i.e. the current level of wellbeing). In any situation in which it risks being altered, the decision-making procedure is adjusted [10, 20] in order to preserve it as far as possible [15]. According to Kahneman and Tversky [15, 19], the absolute value perceived of losses appears to be

more consistent than that of earnings of the same amount (loss aversion). Kahneman et al. [21] and Tversky and Kahneman [22] demonstrate that the distress experienced on losing a sum of money is almost twice that of the pleasure associated with gaining the same amount. Bearing in mind these conclusions, we believe it is rational to suppose that two people with significantly different amounts of initial capital (reference points) may perceive gains and losses differently. Since the initial level of wealth is the reference point on which a judgement in wealth variation is based, it is logical to forecast that perceived changes in wealth are different for private and retail investors, because as is well known, private investors have a higher level of wealth than their retail counterparts. The former have a large amount of wealth in financial assets (minimum US$ 500000.00[1]), an expensive lifestyle and sophisticated needs in terms of diversification of asset allocation, which include real estate, luxury collectibles, artworks and passion investment; in contrast, retail investors do not have these characteristics. We consider as retail investors those with a maximum of €500000.00 worth of assets under management (AUM) and private investors as those with more than €500000.00 AUM. The aim of this chapter is to test whether private and retail investors perceive gains and losses differently.

Our analysis tests the differences in gain and loss satisfaction/dissatisfaction perceived by private and retail investors; moreover we compare the levels of satisfaction/dissatisfaction declared by private and retail investors.

The conclusions of this survey are significant from two different perspectives. First, the paper extends existing literature on the topic of gain and loss perception by comparing private and retail investors, an important distinction in the banking and financial sector. Second, the results obtained should be taken into consideration by banks, financial intermediaries, consultants and asset managers aiming to improve their relationships with clients and to develop the most suitable financial products for different types of clients.

2. Literature review

A plethora of experiments (e.g., [1, 2]) demonstrate that decisions made in an economic and financial setting are influenced by subjective perceptions. The framing effect [3] is a perceptual phenomenon implying that different presentations of the same information may lead to different choices. Chen et al. [4], Del Vecchio et al. [5], Gourville [6], Levin et al. [3], McKechnie et al. [7], Sinha and Smith [8], Tombu and Mandel [9] and Tversky and Kahneman [10] have investigated how the framing effect could influence the decision-making process. DelVecchio [11], DelVecchio et al. [5], Gourville [6], Kahneman [12, 13], McKechnie et al. [7] and Mellers [14] have examined the incoherence of judgement when faced with similar or indifferent situations. Kahneman and Tversky [15], Kühberger [16] and Olsen [17, 18] demonstrate that the framing effect can influence the decision-making process so as to cause a shift from 'risk-adverse' to 'risk-seeking' and vice versa, the so-called risky-choice framing effect. The framing effect is predicted by Kahneman and Tversky [15] in their prospect theory. According to this theory, individuals' choices are always made considering the gains and losses compared with an initial starting capital (reference point). Kahneman and Tversky [19] argue that investors decide by mentally referring to their status quo (i.e., the current level of wellbeing).

[1] Capgemini, The World Wealth Report, www.worldwealthreport.com

In any situation in which it risks being altered, the decision-making procedure is adjusted [10, 20] in order to preserve it as far as possible [15]. According to Kahneman and Tversky [15, 19], the absolute value perceived of losses appears to be more consistent than that of earnings of the same amount (loss aversion). Kahneman et al. [21] and Tversky and Kahneman [22] demonstrate that the distress experienced on losing a sum of money is almost twice that of the pleasure associated with gaining the same amount. Bearing in mind these conclusions, we believe it is rational to suppose that two people with significantly different amounts of initial capital may perceive gains and losses differently.

3. The sample selection

During the 2015, we contacted approximately 100 financial advisers and asked if they were willing to forward the questionnaires we had prepared to some of their private and retail clients (see Appendices A and B). We asked each financial adviser to contact at least two private and two retail investors so as to obtain a minimum of 400 completed questionnaires. The questionnaire, delivered to investors in a closed envelope, was anonymous; only age, sex, geographical provenance and the amount of asset under management were the required fields; it was very simple, comprising only two pages of multiple-choice questions. We decided to let the investors answer alone in their own homes so as to receive uninfluenced answers [23] and gave them 3 days to return the questionnaire either to their financial advisers or directly to us, recommending in both cases the use of a sealed envelope. We rejected those without any indication of quantity of assets under management. The others were used to identify two groups of sample investors, as shown in **Table 1**.

The questions in the questionnaires were designed taking inspiration from the examples and experiments discussed in the literature [5, 11, 15, 19, 21, 24]. In particular, we focused our investigation on the level of perception of gains and losses starting from an initial amount of wealth. In order to ask questions consistent with the goals of this paper, we asked advisers to give a prior indication of the average assets under management of their private and retail clients. The information obtained allowed us to design questions for a hypothetical private investor with €3000000.00 average assets under management and his/her hypothetical retail counterpart with about €300000.00 average assets under management. Thus, we designed two questionnaires: one for private investors (see Appendix A) and one designed for retail investors (see Appendix B). When formulating the questions, we bore in mind the fact that semantic cues [25–30] can influence or

	Private	**Retail**
Average AUM (euros)	3002000.00	315198.00
AUM standard deviation (euros)	1260349.48	179908.00
Average age	61.68	55.66
Age standard deviation	6.94	6.28
% male	86	85
% living in northern/central Italy	80	80
Number of observations	100	100

Table 1.
Description of sample groups.

alter answers. For this reason, when possible we used neutral semantic cues and scenario questions that do not present any probability, so as to avoid 'one-stage' or 'two-stage' problems [31]. In this way each question follows a linear programme model [32], with the aim of not creating any gambling element in the investors' minds.

4. Declaration of satisfaction/dissatisfaction: retail vs. private investors

This analysis is based on the answers obtained for questions 1–4 in the questionnaires (see Appendices A and B). The private sample was asked to express a degree of 'satisfaction' or 'dissatisfaction' concerning an achieved performance, first in terms of percentage (+3%) and then in terms of absolute value (+ €90000.00)[2]. We did not express any start value parameter in the questions, so investors could express their real degree of satisfaction/dissatisfaction bearing in mind their wealth. The same questions were then presented first in the case of a loss in absolute value (− €90000.00) and then as a loss quantified as −3%. The same situation was presented to the retail sample, first considering a + 3% performance and a €9000.00[3] gain and then in the case of a loss in absolute value (− €9000.00) and a loss quantified as −3%; in this case too, we did not express any start value parameter for the above reason. The results are shown in **Figure 1**.

Figure 1 seems to show different perceptions of gains and losses depending on whether these are expressed in terms of absolute value or as a percentage, even if these represent the same amount, both among investors belonging to the same sample and when comparing private and retail investors. In fact, in the case of a positive scenario (**Figure 1**, upside), the gain expressed in absolute value seems to be perceived by both samples with more satisfaction than the same amount expressed as a percentage. More specifically, it seems that retail investors perceive more dissatisfaction than private investors when faced with gains expressed as percentages. **Figure 1** in a negative scenario (downside) confirms that losses expressed in absolute values and as percentages, even if of the same amount, are perceived differently both by private and by retail investors. However, in this case, **Figure 1** shows that the loss expressed in euros is perceived with more dissatisfaction by retail investors than by private investors. With the aim of testing the evidence in the graph, **Table 2** presents the statistical analysis of the perceptions of the two samples examined in the case of a positive (upside) or a negative (downside) situation.

Table 2 confirms the existence of some statistically significant differences between the two analysed samples. The satisfaction perceived when faced with a gain expressed as a percentage is different between private and retail investors ($p = 0.0767$), while in the case of a negative scenario, the dissatisfaction perceived when faced with a loss expressed in terms of absolute value differs between private and retail investors ($p = 0.0702$). As previously demonstrated in many studies [5–7, 11–14], our results also reveal a clear inconsistency in judgement, similar for and common to both samples. This situation can be explained by the way the assessment parameters were presented and by the investors' internal reference points [4, 8, 33].

[2] ± €90000.00 is about ±3% of the private sample average asset under management.

[3] ± €9000.00 is about ±3% of the retail sample average asset under management.

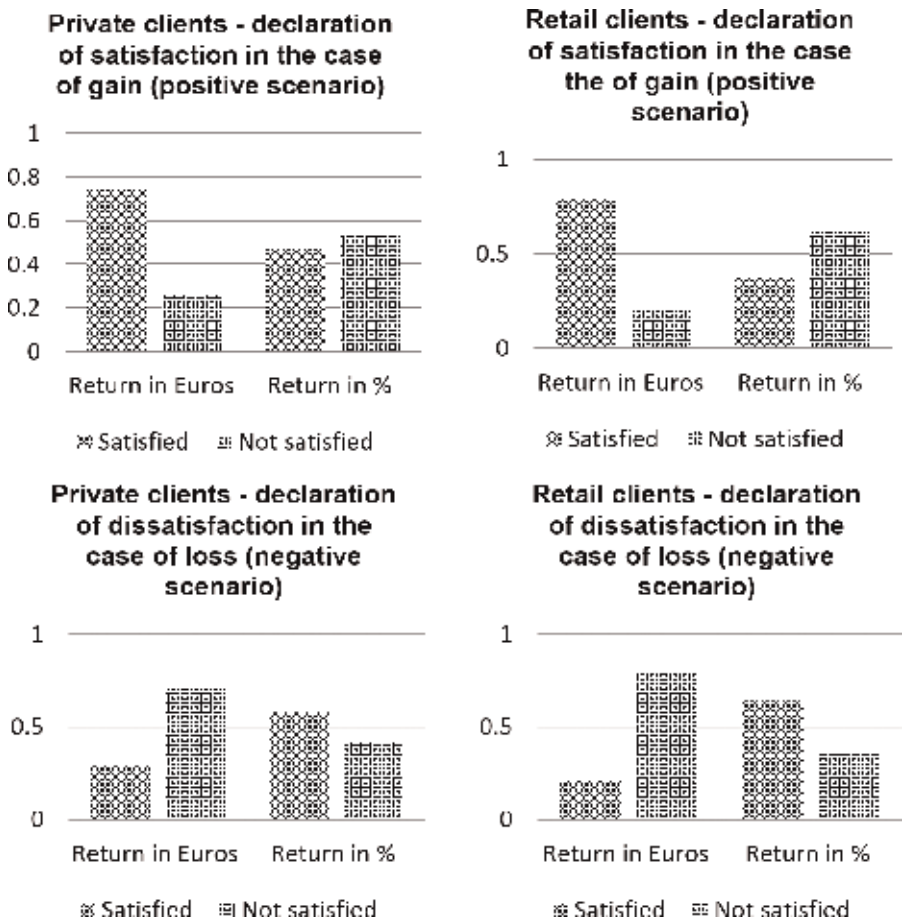

Figure 1.
Satisfaction/dissatisfaction as perceived by private and retail investors in terms of gains (upside) and losses (downside).

	Mean retail	Mean private	Diff.
In the case of a gain (positive scenario)			
Declaration of satisfaction faced with a gain situation expressed as a percentage	0.37	0.47	−0.10*
Declaration of satisfaction faced with a gain situation expressed in terms of absolute value	0.78	0.74	0.04
In the case of a loss (negative scenario)			
Declaration of dissatisfaction faced with a loss situation expressed as a percentage	0.63	0.58	0.05
Declaration of dissatisfaction faced with a loss situation expressed in terms of absolute value	0.20	0.29	−0.09*

**Statistically significant at 10%.*

Table 2.
Gain and loss perception comparing private and retail investors.

5. Level of satisfaction/dissatisfaction declared by retail and private sample investors

This analysis is based on the answers obtained from questions 5 and 6 in the questionnaires (see Appendices A and B). We would like to test our survey samples' perception of loss and gain by asking them to identify the degree of 'satisfaction'/ 'dissatisfaction' experienced, on a scale from 0 to 10, when faced with a positive/ negative variation of wealth in terms of absolute value (± €90,000 per private investor and ±€9000 per retail investor). The results are shown in **Figure 2**.

A horizontal reading of **Figure 2** shows that the level of satisfaction declared by retail and private investors faced with a gain is almost the same, while there is an obvious difference in the case of a loss, when retail investors appear more dissatisfied than private investors. **Table 3** presents the statistical analysis of this difference

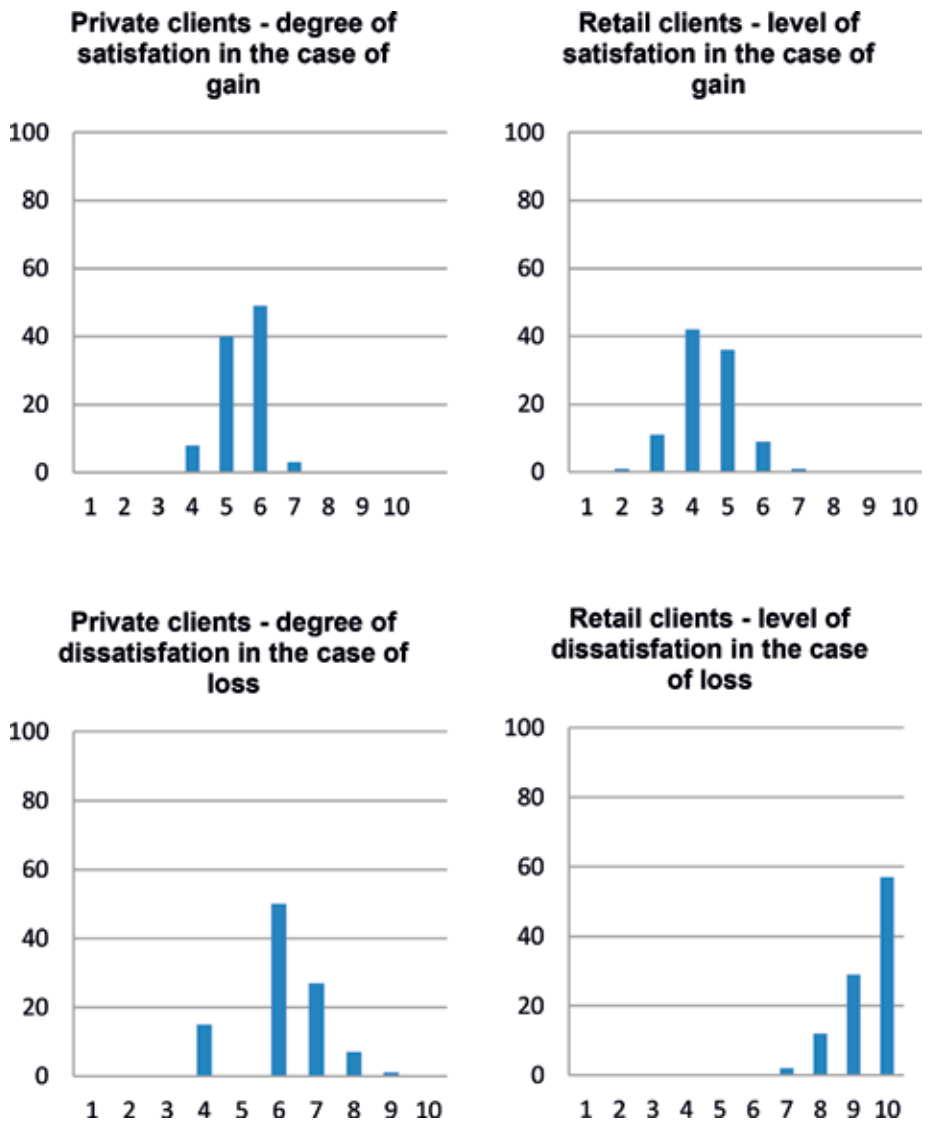

Figure 2.
Satisfaction and dissatisfaction perceived by private investors (on the left) and retail investors (on the right) in the case of gain (upside) and loss (downside).

	Mean retail	Mean private	Diff.
Level of satisfaction on a scale from 0 to 10 when faced with a gain situation	4.44	4.47	−0.03
Level of dissatisfaction on a scale from 0 to 10 when faced with a loss situation	9.41	6.14	3.27***

****Statistically significant at 1%.*

Table 3.
Gains and losses: the level of satisfaction/dissatisfaction declared by private investors and retail investors.

and confirms our impression: the level of difference in dissatisfaction declared by private and retail investors is statistically significant ($p = 0.000$).

Figure 2 is read vertically, that is to say the level of satisfaction/dissatisfaction declared by private investors and by retail investors in the case of gains/losses offers an important point of analysis. With reference to the retail investor sample, the empirical thesis [21, 22], according to which the disappointment experienced on losing a sum of money appears to be about twice that of the pleasure associated with gaining the same amount, seems to be valid. In fact, the weighted average degree of satisfaction on gaining is 4.44, while dissatisfaction on losing the same amount is on average 9.41. Instead, with reference to the private sample, the dissatisfaction a private client experiences on losing a sum of money does not appear to be twice that of the pleasure associated with gaining the same amount (gain satisfaction weighted average = 4.47 vs. loss dissatisfaction weighted average = 6.14). Thus, the Kahneman and Tversky [15] value function, which is steeper for losses than for gains, seems to be valid for the retail sample but not for the private one. This conclusion must take into account the initial 'anchor' level of wealth [4, 8, 15, 19, 33], which is high for the private investors interviewed and by which economic changes are evaluated. The results therefore lead us to consider the possibility that very wealthy people could show a limited degree of indifference towards gains and losses [34].

6. Conclusions

The results presented in this chapter demonstrate that private and retail investors evaluate financial performance (gains and losses) differently. In particular, the results presented in this chapter show that investors, whether retail or private, perceive gain and loss expressed in terms of absolute value and as a percentage differently, even if the gain/loss is of the same amount. However, we demonstrate that loss expressed in euros is perceived with more dissatisfaction by retail investors than private investors.

The comparison of results obtained in the analyses conducted shows significant changes in evaluations of gains and losses. However, the quantification of satisfaction/dissatisfaction declared by private and by retail investors in the case of gains/losses demonstrates that the disappointment expressed by retail investors on losing a sum of money appears to be about twice that of the pleasure associated with gaining the same amount. This situation is not confirmed with reference to private investors. This is due to the fact that the two groups start from different initial levels of wealth, which provide the parameter used to determine satisfaction or dissatisfaction.

The results presented in this chapter suggest some considerations we believe should be taken into account by banks, asset managers, private bankers and financial planners in order to improve the range of products offered and their

relationships with clients. First, it is fundamental to map an investor's entire wealth with meticulous accuracy in order to identify the real (or approximate) current status quo. Second, negative change in wealth must be identified, so that immediate action can be taken in order to avoid psychological pressure on the investor. In this context, the creation of financial or insurance products with 'stop loss' or guaranteed invested capital could be a very useful support. Finally, we believe it is very important to check the risk level sustainable by each investor (private or retail) and verify whether the portfolio asset allocation is suitable for the investor.

Appendix A: The private investors' questionnaire

Dear investor,

This questionnaire is a tool used to collect information about the reaction of investors in the face of possible market scenarios, for research purposes. The questionnaire is anonymous, and to ensure it remains so, we suggest you fill it in alone, in your own home, and return it in a sealed envelope either to your financial planner or directly to Andrea Lippi, c/o Università Cattolica del Sacro Cuore, Via Emilia Parmense 84, 29122 Piacenza. Please answer truthfully to avoid falsifying our research results. Thank you in advance for your cooperation.

_____.

Age _____ Sex M ☐ F ☐ Geographic Area North/Center ☐ South ☐

Please declare your total assets under management (i.e., mutual funds, Sicav, asset management, shares, bonds, financial insurance).

€ _____

1. Bearing in mind your current level of wealth, in the case of a positive performance equal to +3% per year, would you consider yourself: (*Please put an X in the appropriate box*)

Satisfied	
Not satisfied	

2. Bearing in mind your current level of wealth, in the case of a profit equal to €90,000 per year, you would consider yourself: (*Please put an X in the appropriate box*)

Satisfied	
Not satisfied	

3. Bearing in mind your current level of wealth, in the case of a negative performance equal to −3% per year, you would consider yourself: (*Please put an X in the appropriate box*)

Satisfied	
Not satisfied	

4. Bearing in mind your current level of wealth, in the case of a loss equal to €90,000 per year, you would consider yourself: (*Please put an X in the appropriate box*)

Satisfied	
Not satisfied	

5. Bearing in mind your current level of wealth, on a scale from 0 to 10, how satisfied would you feel with a €90,000 gain? (*Please put an X in the appropriate box*)

0	1	2	3	4	5	6	7	8	9	10

No satisfaction, low satisfaction, medium high satisfaction, very high satisfaction

6. Bearing in mind your current level of wealth, on a scale from 0 to 10, how dissatisfied would you feel with a €90,000 loss? (*Please put an X in the appropriate box*)

0	1	2	3	4	5	6	7	8	9	10

No dissatisfaction, low dissatisfaction, medium high dissatisfaction, very high dissatisfaction

Appendix B: The retail investors' questionnaire

Dear investor,

This questionnaire is a tool used to collect information about the reaction of investors in the face of possible market scenarios, for research purposes. The questionnaire is anonymous, and to ensure it remains so, we suggest you fill it in alone, in your own home, and return it in a sealed envelope either to your financial planner or directly to Andrea Lippi, c/o Università Cattolica del Sacro Cuore, Via Emilia Parmense, 84, 29122 Piacenza. Please answer truthfully to avoid falsifying our research results. Thank you in advance for your cooperation.

_____.

Age _____ Sex M ☐ F ☐ Geographic area North/Center ☐ South ☐

Please declare your total assets under management (i.e. mutual funds, Sicav, asset management, shares, bonds, financial insurance).

€ _____

1. Bearing in mind your current level of wealth, in the case of a positive performance equal to +3% per year, you would consider yourself: (*Please put an X in the appropriate box*)

Satisfied	
Not satisfied	

2. Bearing in mind your current level of wealth, in the case of a profit equal to €9000 per year, you would consider yourself: (*Please put an X in the appropriate box*)

Satisfied	
Not satisfied	

3. Bearing in mind your current level of wealth, in the case of a negative performance equal to −3% per year, you would consider yourself: (*Please put an X in the appropriate box*)

Satisfied	
Not satisfied	

4. Bearing in mind your current level of wealth, in the case of a loss equal to €9000 per year, you would consider yourself: (*Please put an X in the appropriate box*)

Satisfied	
Not satisfied	

5. Bearing in mind your current level of wealth on a scale from 0 to 10, how satisfied would you feel with a €9000 gain? (*Please put an X in the appropriate box*)

0	1	2	3	4	5	6	7	8	9	10

No satisfaction, low satisfaction, medium high satisfaction, very high satisfaction

6. Bearing in mind your current level of wealth, on a scale from 0 to 10, how dissatisfied would you feel with a €9000 loss? (*Please put an X in the appropriate box*)

0	1	2	3	4	5	6	7	8	9	10

No dissatisfaction, low dissatisfaction, medium high dissatisfaction, very high dissatisfaction

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Chapter 9

Saving Time in Portfolio Optimization on Financial Markets

Todor Atanasov Stoilov, Krasimira Petrova Stoilova and Miroslav Dimitrov Vladimirov

Abstract

The time management is important part for tasks in real-time operation of systems, automation systems, optimization in complex system, taking explicit consideration in time constraints, scheduling of tasks and operations, making with incomplete data, and time management in different practical cases. The limit in time for taking appropriate decisions for management and control is a strong constraint for the implementation of autonomic functionalities as self-configuration, self-optimization, self-healing, self-protection in computer systems, transportation systems, and distributed systems. Time is an important and expensive resource. The time management in financial domain is a prerequisite for high competitiveness and an increase in the quality of the investment activities. It is the popular phrase that time is money, and particularly, the portfolio optimization targets its implementation in real cases. This research targets the identification of portfolio parameters, which are strongly influenced by time. We restrict our considerations only on portfolio optimization task, and we identify cases, which are strongly influenced by time constraints. Thus, the portfolio optimization problem is discussed on position how the time can influence the portfolio characteristics and solutions. This chapter starts with the description of the object portfolio management, which provides the cases where time in explicit way influences the portfolio problem.

Keywords: data driven analysis, real-time portfolio optimization, decision making, automation in information systems

1. Introduction

The time management is important part for tasks in real time operation of systems, automation systems, optimization in complex system, taking explicit consideration in time constraints, scheduling of tasks and operations, making with incomplete data, time management in different practical cases. The limits in time for taking appropriate decisions for management and control is a strong constraints for the implementation of autonomic functionalities as self-configuration, self-optimization, self-healing, self-protection in computer systems, transportation systems, distributed systems. Time is an important and expensive resource.

The time management in financial domain is a prerequisite for high competitiveness and increase of the quality of the investment activities. It is the popular phrase that "time is money" and particularly the portfolio optimization targets its

implementation in real cases. This research targets the identification of portfolio parameters, which are strongly influenced by time. We restrict our considerations only on portfolio optimization task and we identify cases, which are strongly influenced by time constraints. Thus, the portfolio optimization problem is discussed on position how the time can influence the portfolio characteristics and solutions. This chapter starts with description of the object "portfolio management" which provides the cases where time in explicit way influences the portfolio problem.

2. Portfolio optimization problem

The task, which is resolved by the portfolio optimization of financial resources, is related with maximization of the return and simultaneously minimization of the investment risk. The portfolio optimization can be applied also to assets, which belong to the stock markets, because the same valued characteristics are used for portfolio optimization. The goal of the portfolio problem is to share the amount of investments among a set of securities, which are chosen to enter into the portfolio. The portfolio goal is to allocate in optimal manner the parts of the investment for buying securities. The time management problem initially arises with its complexity on the stage of the portfolio definition. The investment procedure has to be implemented at time t_0 (now). The assets' characteristics can be evaluated for this time moment t_0, **Figure 1**.

The portfolio management insists to make decision for buying (or selling) assets at the current time t_0. Then after a period of time $\Delta t > 0$ at time moment $T = t_0 + \Delta t$ the investor has to sell (or buy) the assets from the portfolio and must receive positive return

$$Return(T) = \frac{Receipt(T) - Expenditure\ (t_0)}{Expenditure\ (t_0)} \tag{1}$$

The value of the *Receipt* is defined in the future time T and the *Expenditure*—on the current time t_0. The portfolio problem arises according to the difference of the time moment $t_0 < T$. The investment decisions are based on the assets' characteristics for the moment t_0, $\mathbf{A}(t_0)$. But in time T these characteristics will be $\mathbf{A}(T)$ and in common case they will differ in values $\mathbf{A}(t_0) \neq \mathbf{A}(T)$. These differences strongly influence the portfolio return at time T. In general, the assets' characteristics are the return and risk, $A_i(t_0) = A_i(Return_i(t_0), Risk_i(t_0))$, $i = 1, ..., N$, N is the types of assets in the portfolio which are evaluated for the current time t_0. But the portfolio return is evaluated at the end of the investment period T. Respectively, the assets' characteristics at time T are different $A_i(T) = A_i(Return_i(T), Risk_i(T))$, $i = 1, N$. Hence, the final portfolio returns from (1) becomes

Figure 1.
Time schedule of the portfolio investment.

$$Portfolio\_Return = \frac{Return[\mathbf{A}(T)] - Expenditures[\mathbf{A}(\mathbf{t_0})]}{Expenditures[\mathbf{A}(\mathbf{t_0})]} \tag{2}$$

Following (2) for the implementation of the portfolio investment, the investor has:

- to choose the types and number of assets N, which will participate in the portfolio;
- to assess the assets' characteristics $Risk_i(t_0)$ and $Return_i(t_0)$, $i = 1,\ldots, N$ at the current time t_0;
- to choose the duration Δt of the investment, which defines the final investment time T;
- to forecast the assets' characteristics $Risk_i(T)$ and $Return_i(T)$, $i = 1,\ldots, N$ for the end of the investment period T;
- to define and solve the portfolio optimization problem which will give the relative weights w_i, $i = 1,\ldots,N$ of the investment, allocated for buying (selling) asset i. The relative values of weights introduce the analytical constraint

$$\sum_{i=1}^{N} w_i = 1 \tag{3}$$

and w_i are the solutions of the portfolio optimization problem. To move ahead about the time management problem and to recommend relations between t_0, Δt and T there is a need to analyze the character of the portfolio optimization problem.

3. Modern Portfolio Theory

The Modern Portfolio Theory (MPT) was quantitatively introduced from Markowitz, with his seminal work [1]. The problems, introduced for the portfolio optimization are defined with two formal descriptions:

- maximization of portfolio *Return* by finding optimal values of the assets' weights w_i, $i = 1,\ldots,N$, satisfying constraints about portfolio *Risk* to stay below a predefined value

$$\underset{\mathbf{w}}{\boldsymbol{max}} \begin{bmatrix} \mathbf{E}^T\mathbf{w} \\ \mathbf{w}^T\boldsymbol{\Sigma}\mathbf{w} \le \sigma^2_{max} \end{bmatrix} \tag{4}$$

- and/or minimization of portfolio *Risk* by finding optimal assets' weights w_i, $i = 1,\ldots,N$, satisfying constraints about the portfolio *Return* to stay over a predefined value

$$\underset{\mathbf{w}}{\boldsymbol{min}} \begin{bmatrix} \mathbf{w}^T\boldsymbol{\Sigma}\mathbf{w} \\ \mathbf{E}^T\mathbf{w} \ge E_{min} \end{bmatrix}. \tag{5}$$

The notations used concern

E_i—the mean return of asset $i = 1,...,N$, $\mathbf{E}^{\mathbf{T}} = (E_1, ..., E_N)$,

$\sum -$ is the covariance matrix of the assets' returns, square symmetrical $N \times N$ matrix,

σ^2_{max}—the maximal portfolio risk, which the investor can afford for problem (4),

E_{min}—the minimal portfolio return which the investor expects from the investment,

$\mathbf{w}^{\mathbf{T}} = (w_1, ..., w_N)$—a vector of relative weights of the investment, which will be allocated to asset $i = 1,...,N$, for buying or selling.

Particularly, additional nonnegative constraints are aided, $w_i \geq 0$, $i = 1,...,N$, which means that asset i will be bought for the portfolio. The case with negative weights, $w_i < 0$ means that the investor will sell asset i at time t_0 and at the end of the investment period T the will buy these assets to recover his wealth. During these operations the investor has to achieve positive portfolio return. The case of portfolio optimization with negative weights is named "short sells" but it is allowed only for special types of investors [2]. That's the reason that MPT mainly applies an additional constraint for nonnegative weights $\mathbf{w} \geq \mathbf{0}$ to problems (4) and (5).

To be able to solve problems (4) and (5) the parameters $\mathbf{E}$ and $\sum$ have to be numerically evaluated. These parameters are strongly influenced by time. The estimation of the mean assets' returns E_i, $i = 1,...,N$, has to be made for historical period. The portfolio manager must use a time series of assets' returns

$$\begin{matrix} R_1 = \left[R_1^{(1)}, R_1^{(2)}, ..., R_1^{(n)}\right] \\ ... \\ R_N = \left[R_N^{(1)}, R_N^{(2)}, ..., R_N^{(n)}\right] \end{matrix}, \tag{6}$$

where $R_i^{(m)}$ is the return of asset i at time m, $i = 1,...,N$, $m = 1,...,n$; n-discrete points from the return history. These return values could be on daily, monthly, weekly basis for a past period of time. Because for that case the time is defined as integer number of days/months/weeks, the number n describes the length of the historical period, taken by the portfolio manager to estimate the mean assets' returns E_i, 1,...,N. The value of n is a discrete time and it influences the values of the assets' characteristics. For a discrete time diapason $1 \div n$ the mean assets' returns are

$$E_i = \frac{1}{n-1}\sum_{m=1}^{n} R_i^{(m)}, \forall i = 1, ..., N. \tag{7}$$

Having the values E_i, $i = 1,...,N$ from (7) the covariance matrix $\sum$ is calculated as

$$\mathbf{COV}(.) = \sum = \begin{vmatrix} c_{11}... & c_{1N} \\ ... & ... \\ c_{N1}... & c_{NN} \end{vmatrix}, c_{ij} = \frac{1}{n-1}\sum_{m=1}^{n}\left(R_i^{(m)} - E_i\right)\left(R_j^{(m)} - E_j\right), \forall i, j = 1, ..., N. \tag{8}$$

The covariance coefficient c_{ij} has meaning, which defines how the time series of the assets' returns i and j behave. The case of positive correlation $c_{ij} > 0$ means that if the time series of returns R_i of asset increase (or decrease) the same simultaneous change of increase (or decrease) takes place for the time series of returns R_j. For the case of negative correlation $c_{ij} < 0$, the time series R_i and R_j move in opposite directions. If the time series R_i increase (or decrease) the time series R_j decrease (or increase). The negative correlation has advantage in usage by the portfolio

managers to decrease the total risk of the portfolio. Because $c_{ij} = c_{ji}$ from (8), the covariance matrix $\sum$ is symmetrical. For the case $i = j$ the value c_{ii} is the variation of the row R_i, $c_{ii} = \sigma_i^2$, σ_i—standard deviation of row R_i. Thus, the covariance matrix on its diagonal gives the variation of the assets' returns. The components c_{ij} define the behavior of the time series of returns R_i and R_m. The portfolio theory applies the variation σ_i^2 as quantitative values of the risk of asset i. The graphical interpretation of mean return and risk of asset i is given in **Figure 2**, where.

R_i is the dynamically changed return of asset i,

E_i—the mean value of return for the time period $[t_1, t_2]$,

σ_i—standard deviation of R_i towards E_i and give value of the risk of asset i.

The risk of the asset graphically represents the diapason $[+\sigma_i, -\sigma_i]$ between which the real asset returns R_i generally stay around the mean value E_i. After definition of the vector of mean assets' returns $\mathbf{E^T} = (E_1, \ldots, E_N)$ and the covariance matrix COV(.) = $\sum$, the portfolio return E_p analytically is evaluated as

$$E_p = \sum_{i=1}^{N} w_i E_i = \mathbf{E^T}\,\mathbf{w} \text{ or } R_p = \sum_{i=1}^{N} w_i R_i = \mathbf{R^T}\,\mathbf{w}. \tag{9}$$

The value of the portfolio risk is calculated by the quadratic term

$$\sigma_i^2 = \sum_{i=1}^{N}\sum_{j=1}^{n} c_{ij} w_i w_j \text{ or } \sigma_p^2 = \mathbf{w^T} \sum \mathbf{w}. \tag{10}$$

The MPT uses and integration of the portfolio problems (4) and (5) by definition of a common optimization problem

$$\begin{aligned} &\underset{\mathbf{w}}{\boldsymbol{min}} \left\{\frac{1}{2}(1-\Psi)\mathbf{w^T}\sum \mathbf{w} - \Psi \mathbf{E^T}\,\mathbf{w}\right\} \\ &\sum_{i=1}^{N} \mathrm{w_i} = 1,\ \mathrm{w_i} \geq 0,\ \mathrm{i} = 1, \mathrm{N}. \end{aligned} \tag{11}$$

The value of Ψ is the "risk aversion" coefficient, which is normalized for the numerical diapason [0, 1].

- For the case $\Psi = 0$ the investor doesn't care about the portfolio return and his goal is to achieve minimal portfolio risk.

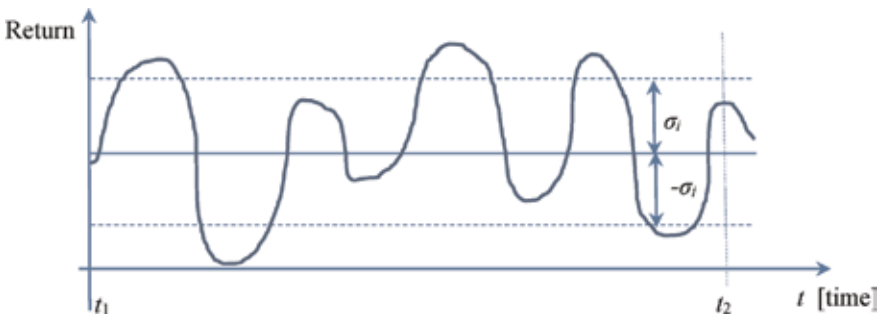

Figure 2.
Graphical interpretation of the risk and mean return of asset.

- For the case $\Psi = 1$ the investor targets maximization of the portfolio return without considering the portfolio risk, because $\mathbf{min}\ (-\Psi \mathbf{E}^{\mathrm{T}}\mathbf{w}) \equiv\ \mathbf{max}\ (+\Psi \mathbf{E}^{\mathrm{T}}\mathbf{w})$.

By changing $\Psi \in [0, 1]$ different solutions $\mathbf{w}^{opt}(\Psi)$ are found from problem (11) which gives corresponding returns $E_p = \mathbf{E}^{\mathrm{T}}\mathbf{w}^{opt}(\Psi)$ and risk $\sigma_p^2 = \mathbf{w}^{opt\ \mathrm{T}}(\Psi) \sum \mathbf{w}^{\mathbf{opt}}(\Psi)$ for the portfolios. These set of solutions can be presented as a set of points $[\sigma_p^2, E_p]$ in this space which in continuous case origins the "efficient frontier" curve, **Figure 3**.

The efficient frontier has quadratic character but it is not a smooth line [3]. This non-smooth character origins from the existence of non-negative constraints $w_i \geq 0$, $i = 1,...,N$ in problem (11). Hence, the MPT recommends to be defined and solved portfolio problem (11). Because the investors have different ability to undertake risk, the portfolio manager has to estimate the correct value of the "risk aversion" parameter. Because such identification is strongly subjective influenced, the MPT recommends to be evaluated the "efficient frontier" of portfolios. The investor can choose appropriate point from the frontier, which corresponds to the relation *Risk/Return*, which the investor is willing to accept. The portfolio, applied in problem (11) is named also "mean-variance" (MV) portfolio model. From the time management considerations, the cases which are influenced by the time, for the portfolio problems are summarized as:

- the portfolio manager has to choose the time for the portfolio implementation;
- he has to decide the duration of the investment $\Delta t = T–t_0$; T—final investment time;
- he has to choose the duration n of the historical period, which will be used for the evaluation of the mean assets' returns E_i, $i = 1, N$ and the covariance matrix $\mathbf{COV}(.) = \sum$ of the assets' returns. The diagonal values of matrix $\sum$ gives assets' risks σ_i^2, $i = 1, ..., N$.

Thus, the time is very important parameter, which influences the definition and implementation of the portfolio investment and optimization.

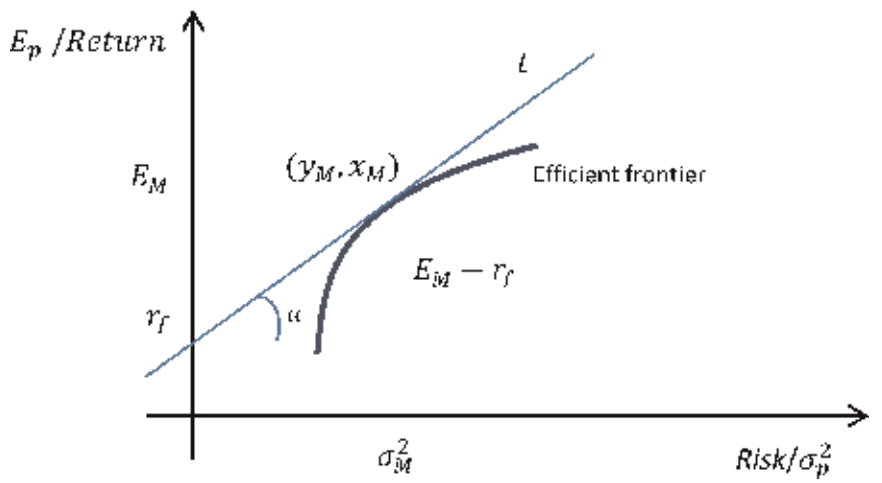

Figure 3.
The curve of "efficient frontier" and the market point.

4. Capital Market Theory

The MPT originated by the works of Markowitz has its further developments. The next important stage of MPT is the definition of the Capital Market Theory, [2]. The Capital Market Theory introduces a new point on the "efficient frontier," named "market portfolio." It has analogical portfolio characteristics as market return E_M and market risk σ_M^2. This theory derives new analytical relations with the market characteristics, which are formal part of the Capital Asset Price Model (CAPM). This model added three additional linear relations named Capital Market Line (CML), Security Market Line (SML) and cHaracteristic Line (HL).

The graphical representation of the CML is given in **Figure 3**. It starts from the point $(0, r_f)$ which is a riskless asset with mean return r_f. The market point $\left(E_M, \sigma_M^2\right)$ is a tangent one over the "efficient frontier." The CML gives relations between the portfolios returns and risks for a particular market, assessed by the characteristics r_f, E_M, σ_M^2. Analytically, the CML is a linear relation between E_p and σ_p,

$$E_p = r_f + \frac{E_M - r_f}{\sigma_M}\sigma_p. \tag{12}$$

By estimating the market parameters r_f, E_M, σ_M^2 the investor has information about the level of risk σ_p^2, which has to be undertaken by means to obtain portfolio return E_p. This prevents the investor to have unrealistic expectation about the potential mean return, which has to be achieved by a portfolio. The values of the market parameters, E_M, σ_M^2 are defined mainly according to the behavior of market index (S&P500, Dow Jones Industrial Average, NASDAQ Composite, NYSE Composite, FTSF100, Nikkei225, IPC Mexico, EURONEXT 100 and others). On each market the risk-free assets (deposits, long time bonds) has its own value r_f.

The SML introduces linear relations between the mean return of a particular asset E_i and the market return E_M

$$E_i = r_f + \left(E_M - r_f\right)\beta_i. \tag{13}$$

The coefficient "beta" (β_i) is a value of the relation

$$\beta_i = \frac{cov\ (i, M)}{\sigma_M^2}, \beta_i \in [-1, 1] \tag{14}$$

The "beta" coefficient takes normalized values from the diapason $[-1, 1]$. Numerically, it defines how strong the mean return value E_i is related with the market return E_M. If the return E_i is strongly related to the market behavior, the coefficient β_i has high value, close to 1, if the covariation coefficient $cov(i,M)$ is positive. The case of $\beta_i < 0$ means that the covariance between the series of returns R_i and R_M are in opposite directions.

The HL line makes additional clarification between the current value of the asset return R_i and market one R_M

$$R_i = r_f + \beta_i\left(R_M - r_f\right). \tag{15}$$

Relation (15) is timely influenced. If the market value R_M is changed/predicted, the corresponding asset return R_i of asset i can be estimated and/or predicted.

The CAPM does not apply explicit inclusion of time in its characteristics. Time explicitly influences only the values of the market return E_M and market risk σ_M. Applying the same considerations which take place for the evaluation of the assets' characteristics E_i, σ_i i = 1,...,N the historical period for the evaluation of the market characteristics is recommended to be the same, with n discrete historical values of the market return $R_M = \left[R_M^{(1)}, R_M^{(2)}, ..., R_M^{(n)}\right]$.

5. Black-Litterman model for estimation of portfolio characteristics

The Black-Litterman (BL) model is based on both achievements of the MV portfolio model and CAPM. The idea behind the BL model is the ability to use additional information by means to estimate and to predict the assets' characteristics $E_i(T)$ and $\sigma_i(T)$, i = 1,...,N [4–6]. The difference and the added value N for the future time moment T when the portfolio investment will be capitalized e of the BL model is graphically interpreted in **Figure 4**.

The MV model estimates the assets characteristics E_i, σ_i, i = 1,...,N using historical data from n discrete points of the assets' returns $R_i^{(m)}$, $i = 1, ..., N$, $m = 1, ..., n$. The BL model allows additional information to be used by means to modify the mean values of return $\mathbf{E^T}$ = (E_1, ..., E_N) as the assets' risk characteristics, given by the covariation matrix $\sum$. The modification of $\mathbf{E^T}$ to a new vector $\mathbf{E_{BL}^T} = (E_{BL1}, ..., E_{BLN})$ is made by two additional numerical matrices **P** and **Q**. These matrices are evaluated from expert views, who make a subjective assessment about the future levels of assets' returns at time T, when the portfolio investment should be capitalized.

P is a $k \times N$ matrix, which contains k expert views. The vector **Q** defines quantitative information about the k-th expert view for increase or decrease the mean return E_i of i-th asset. The elements p_{ki} of **P** defines the view of k-th expert about the change of the E_i return of asset i. The component p_{ki} takes value +1 for the case of increase, and respectively −1 for decrease.

The BL model added a new contribution to the MPT by introducing new characteristic of the portfolio asset: "implied return," Π_i, $i = 1, ..., N$ ("implied excess return," when the return is evaluated according to the level of risk-free asset r_f). These returns differ from the historically evaluated mean returns E_i, i=1, ..., N. The assumption behind these new "implied returns" is related with the existence of market point (E_M, σ_M). For the case of market equilibrium, the CAPM asserts that all assets, which participate on this market should have appropriate mean returns $\mathbf{\Pi^T} = (\Pi_1, ... \Pi_N)$ and market weights $\mathbf{w_M^T} = (w_{M1},..., w_{MN})$. Hence from the market values (E_M, σ_M) it follows exact values of **Π** and **w**. But the market is a stochastic system and it endues a lot of noises, which change the values of the "implied

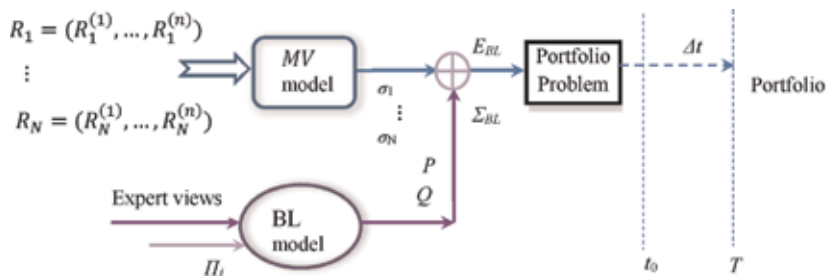

Figure 4.
Additional modification of portfolio parameters by BL model.

returns." These returns Π_i, $i = 1, ..., N$ are values, which "should be." But the noises make changes to Π_i and the BL model evaluates the unknown mean values $\mathbf{E_{BL}}$ which are the "best approximation to Π_i." These considerations origin the matrix linear relation in BL model

$$\mathbf{\Pi} = \mathbf{E}_{\mathrm{BL}} + \boldsymbol{\varepsilon}\ ,\ \mathbf{E}_{\mathrm{BL}} = \begin{vmatrix} E_{BL1} \\ \vdots \\ E_{BLN} \end{vmatrix}, \tag{16}$$

where the noise $\boldsymbol{\varepsilon}$ is assumed to be with normal distribution, zero mean and volatility proportionally decreased from the historical covariance matrix, $\varepsilon \sim \boldsymbol{N}(0, \tau\mathbf{\Sigma})$, $0 < \tau < 1$. The subjective views formally are introduced by the linear stochastic relation

$$\mathbf{Q} = \mathbf{P}\,\mathbf{E}_{\mathrm{BL}} + \boldsymbol{\eta}, \tag{17}$$

where $\mathbf{Q}$ is the quantitative assessment of the experts' views about the value with which the historical returns will change; $\mathbf{P}$ identifies which assets' returns will be changed. The expert views contain also noise $\boldsymbol{\eta}$. Due to the independence of the expert views the noise $\boldsymbol{\eta}$ is assumed with zero mean and volatility $\mathbf{\Omega}$, $\boldsymbol{\eta} \sim \mathbf{N}(0, \mathbf{\Omega})$. The matrix $\mathbf{\Omega}$ is *kxk* square one with only diagonal elements because of the independence of the expert's views. The matrix $\mathbf{\Omega}$ is presented mainly in the form [7].

$$\mathbf{\Omega} = \tau\ \ diag\left(\mathbf{P}\sum\mathbf{P}^{\mathbf{T}}\right) \tag{18}$$

The goal of the BL model is the evaluation of the returns $\mathbf{E}_{\mathrm{BL}}$ which have to approximate in maximal level the stochastic relations (16) and (17). The values of the vectors and matrices $\mathbf{\Pi}$, $\mathbf{Q}$, $\mathbf{P}$, $\boldsymbol{\varepsilon}$, $\boldsymbol{\eta}$ are assumed to be known and/or estimated. The definitions of these parameters are given in the next paragraph.

6. Definition of the "implied excess returns"

Using [8, 9] the assumption is made that the "implied excess return" $\mathbf{\Pi}$ must satisfy the market portfolio. The goal function of the portfolio problem for that case is

$$\underset{\mathbf{w}}{\mathbf{min}}\ \left\{\frac{1}{2}\lambda\mathbf{w}_{\mathbf{M}}^{\mathbf{T}}\sum\mathbf{w}_{\mathbf{M}} - \mathbf{w}_{\mathbf{M}}^{\mathbf{T}}\Pi\right\}, \tag{19}$$

where $\lambda = \frac{1-\psi}{\psi}$ is not normalized value of the risk aversion coefficient, $\lambda \in (0, \infty)$. Because the market point is used in (18) according to the CAPM the relation $\mathbf{w}_{\mathbf{M}}^{\mathbf{T}}.\mathbf{1} = 1$ is satisfied, $\mathbf{1}^{\mathbf{T}} = (1, ...1)$ is a unity *Nx1* vector. The unconstrained minimization of (19) gives solution

$$\lambda\sum\mathbf{w}_{\mathbf{M}} - \Pi = 0. \tag{20}$$

By multiplication from left of the both sides of (20) with market capitalization weights $\mathbf{w}_{\mathbf{M}}^{\mathbf{T}}$ it follows

$$\lambda\mathbf{w}_{\mathbf{M}}^{\mathbf{T}}\sum\mathbf{w}_{\mathbf{M}} = \mathbf{w}_{\mathbf{M}}^{\mathbf{T}}\Pi. \tag{21}$$

The right component of (21) contains the market "excess return" $E_M - r_f$, according to (9). The left side gives the market volatility (risk) σ_M^2, (10) or

$$\lambda = \frac{E_M - r_f}{\sigma_M^2}. \tag{22}$$

Substituting (22) in (21) the "implied excess return" results as

$$\mathbf{\Pi} = \frac{E_M - r_f}{\sigma_M^2}\, \mathbf{\Sigma w_M}. \tag{23}$$

The "implied return" $\mathbf{\Pi}^*$ is the value of $\mathbf{\Pi}$ to which the riskless return is added

$$\mathbf{\Pi}^* = \mathbf{\Pi} + r_f. \tag{24}$$

This manner of definition of $\mathbf{\Pi}$ is known as "inverse optimization" because the market risk and return are known, but we need to calculate the asset returns.

7. Definition of P and Q from scientific views

Following [10] absolute and relative manner for the formalization of the expert views are applied. The explanation of these forms of formalization is given with a simple example. Let's the portfolio contains $N = 4$ assets. Assuming that an expert expects that the first asset will increase its return with 2%; a second expert makes conclusion that the fourth asset will decrease its return with 3% the formalization of **P**, **Q** are

$$\mathbf{P} = \begin{vmatrix} 0\,1\,0\,0 \\ 0\,0\,0\,-1 \end{vmatrix}, \ \mathbf{Q} = \begin{vmatrix} 2 \\ -3 \end{vmatrix}. \tag{25}$$

The relative form of views applies comparisons between the assets' returns. Let's the first expert expects that the first asset will outperform the third one with 2.5%; the second expert makes view that the second asset will outperform the fourth one with 3.5%. The formalization of matrices **P** and **Q** are

$$\mathbf{P} = \begin{vmatrix} 1\,0\,-1\,0 \\ 0\,1\,0\,-1 \end{vmatrix}, \ \mathbf{Q} = \begin{vmatrix} 2.5 \\ 3.5 \end{vmatrix}. \tag{26}$$

The two types of formalization of expert views is widely mention in references dealing with the BL model [7, 10]. A new form of expert views has been developed in [11]. It has been applied a weighted form for the definition of matrix **P**, where its components can take values different from ±1. To provide this new formalization of the expert views the matrix **Ω** is analyzed. This matrix formalizes the variation of the expert views. Using relation (18) let's assume that the portfolio contains three assets, $N = 3$ and two experts $k = 2$ make views in relative form formalized in the matrices **P** and **Q**

$$\mathbf{P} = \begin{vmatrix} 1\,0\,-1\,0 \\ 0\,-1\,0\,1 \end{vmatrix}, \ \mathbf{Q} = \begin{vmatrix} 2 \\ 4 \end{vmatrix}. \tag{27}$$

Hence it follows

$$\boldsymbol{\Omega} = \tau \ diag\left(\mathbf{P}\sum \mathbf{P}^{\mathbf{T}}\right) = \tau \ diag\left(\begin{vmatrix} 1\,0 & -1\,0 \\ 0 & -1\,0\,1 \end{vmatrix} \sum \begin{vmatrix} 2 \\ 4 \end{vmatrix}\right), \tag{28}$$

where $\sum$ is a symmetrical 4×4 matrix $\begin{vmatrix} \sigma_1^2 & \sigma_{12} & \sigma_{13} & \sigma_{14} \\ \sigma_{21} & \sigma_2^2 & \sigma_{23} & \sigma_{24} \\ \sigma_{31} & \sigma_{32} & \sigma_3^2 & \sigma_{34} \\ \sigma_{41} & \sigma_{42} & \sigma_{43} & \sigma_4^2 \end{vmatrix}$. The matrix multiplications results in 2×2 matrix $\boldsymbol{\Omega} = \begin{vmatrix} \omega_1 & \mathbf{0} \\ \mathbf{0} & \omega_2 \end{vmatrix}$ where

$$\omega_1 = \tau\left(\sigma_1^2 + \sigma_3^2 - 2\sigma_{13}\right), \omega_2 = \tau\left(\sigma_2^2 + \sigma_4^2 - 2\sigma_{24}\right). \tag{29}$$

Relations (29) have analytical structure with the risk relation of portfolio with two assets, $N = 2$, and negative correlation, [2] $\sigma_p^2 = w_1^2\,\sigma_1^2 + w_2^2\,\sigma_2^2 - 2w_1\,w_2\,\sigma_{12}$ where σ_1^2 and σ_2^2 are the volatilities of the two assets, σ_p^2 is the volatility of the portfolio, σ_{12} is the covariation between the two returns. Assuming equal weights in the portfolio, $w_1 = w_2$, the portfolio risk is evaluated as

$$\sigma_p^2 = 0.25\left(\sigma_1^2 + \sigma_2^2 - 2\,\sigma_{12}\right). \tag{30}$$

The comparisons between relations (29) and (30) can be interpreted that in (29) ω_1 and ω_2 are the values of risks of two virtual portfolios. The first one contains assets one and three. The second portfolio has the second and fourth assets. Thus, the values $\omega_i\ i = 1, 2$, which formalize the risk of expert views are proportional to virtual portfolios with corresponding two assets, which have negative correlations and equal weights.

Now let's assume that the matrix **P** contains weighted components $\boldsymbol{\alpha}_i$, which differ from the values ± 1. To simplify the formal notations we assume that the matrix **P** is on the form.

$\mathbf{P} = \begin{vmatrix} \boldsymbol{\alpha}_1\ 0 & -\boldsymbol{\alpha}_3\ 0 \\ 0 & -\boldsymbol{\alpha}_2\ 0\ \boldsymbol{\alpha}_4 \end{vmatrix}$. The weighted coefficients satisfy the equalities

$$|\boldsymbol{\alpha}_1| + |\boldsymbol{\alpha}_3| = 1 \text{ and } |\boldsymbol{\alpha}_2| + |\boldsymbol{\alpha}_4| = 1. \tag{31}$$

For that case the corresponding values of the components $\omega_i\ i = 1, 2$ are

$$\omega_1 = \tau\left(\boldsymbol{\alpha}_1^2\sigma_1^2 + \boldsymbol{\alpha}_3^2\sigma_3^2 - 2\boldsymbol{\alpha}_1\boldsymbol{\alpha}_3\sigma_{13}\right), \quad \omega_2 = \tau\left(\boldsymbol{\alpha}_2^2\sigma_2^2 + \boldsymbol{\alpha}_4^2\sigma_4^2 - 2\boldsymbol{\alpha}_2\boldsymbol{\alpha}_4\sigma_{24}\right). \tag{32}$$

Relations (32) interpret that for the weighted form $\mathbf{P}(\boldsymbol{\alpha})$ of the expert views the corresponding components $\omega_i\ i = 1, 2$ of the variation of the expert views are proportional to the risk of a portfolio with two assets and negative correlation, and the assets weights $\boldsymbol{\alpha}$ are normalized because equalities (31) hold. The ability to define matrix **P** with components different to ± 1 allows the expert views to be generated not only by subjective assessments, but also with additional considerations, which are based on objective criteria, estimations and assessments.

This research makes several additions to the numerical definition of **P** and **Q** matrices.

1. Formalization $\mathrm{P}(\boldsymbol{\alpha})$ based on the difference Π_i–E_i, $i = 1,\ldots,N$, normalized by the i-th volatility.

Following [11] a row of matrix **P** concerning the view of an expert is defined in the form $p_s = |0...\boldsymbol{\alpha}_i\ 0...0 - \boldsymbol{\alpha}_j...0|$, 1x$N$ vector. The values $\boldsymbol{\alpha}_i$ and $\boldsymbol{\alpha}_j$ must satisfy the normalization equation $|\boldsymbol{\alpha}_i| + |\boldsymbol{\alpha}_j| = 1$. The value $\boldsymbol{\alpha}_i$ is chosen from the maximal difference

$$\boldsymbol{\alpha}_i > 0 \equiv \underset{i}{\boldsymbol{max}} \left(\frac{\Pi_i - E_i}{\sigma_i^2}\right), i = 1, ..., N. \tag{33}$$

Relation (33) presents that the mean history' return of asset i, E_i, is lower from its "implied excess return" and the investor has to expect that the return of asset i has to increase. The same considerations, but for decrease of the mean return E_j is made from the difference

$$\boldsymbol{\alpha}_j < 0 \equiv \underset{j}{\boldsymbol{min}} \left(\frac{\Pi_j - E_j}{\sigma_j^2}\right), j = 1, ..., N. \tag{34}$$

Asset j is over performed and the investor has to expect decrease of the historical mean return E_j towards the level of the "implied excess return" Π_j.

The value of the component from matrix **Q** is

$$q = \underset{i,j}{\boldsymbol{min}} \left(|\Pi_i - E_i|, |\Pi_j - E_j|\right). \tag{35}$$

2. Formalization P($\boldsymbol{\Pi - E}$) based on the difference Π_i–E_i, i = 1,...,N without normalization with volatilities.

For that case relations (33) and (34) are slightly modified with lack of volatility normalization

$$\boldsymbol{\alpha}_i > 0 \equiv \underset{i}{\boldsymbol{max}} \left(\frac{\Pi_i - E_i}{|\Pi_i - E_i| + \Pi_j - E_j}\right), i, j = 1, ..., N \tag{36}$$

$$\boldsymbol{\alpha}_j < 0 \equiv \underset{j}{\boldsymbol{min}} \left(\frac{\Pi_j - E_j}{|\Pi_i - E_i| + \Pi_j - E_j}\right), i, j = 1, ..., N$$

3. Formalization of **P**($\boldsymbol{\Pi}$) based only on the value of Π_i, i = 1,...,N.

$$\boldsymbol{\alpha}_i > 0 \equiv \underset{i}{\boldsymbol{max}} \left(\frac{\Pi_i}{|\Pi_i| + |\Pi_j|}\right), i, j = 1, ..., N \tag{37}$$

$$\boldsymbol{\alpha}_j > 0 \equiv \underset{j}{\boldsymbol{max}} \left(\frac{\Pi_j}{|\Pi_i| + |\Pi_j|}\right), i, j = 1, ..., N$$

4. A particular case can arise when all differences $\boldsymbol{\alpha}_i = \Pi_i - E_i$, i = 1, N have equal sign (+) or (−). Hence all assets' returns have to be increased, when $\boldsymbol{\alpha}_i > 0$ or decreased if $\boldsymbol{\alpha}_i < 0$.

For that case absolute views can be assign. The matrix **P** will be square NxN identity matrix. $\begin{vmatrix} 1 & ... & 0 \\ \cdots & 1 & ... \\ 0 & ... & 1 \end{vmatrix}_{N \times N}$. The **Q**, N×1 vector will have components equal to $\boldsymbol{\alpha}_i = \Pi_i - E_i$, i = 1,...,N.

Thus, for the formalization of p. 2 the matrices **P** and **Q** are

$$\mathbf{Q} = \begin{vmatrix} \Pi_1 - E_1 \\ \dots \\ \Pi_N - E_N \end{vmatrix} N \times 1, \mathbf{P} = \begin{vmatrix} 1 & \dots & 0 \\ \cdots & 1 & \dots \\ 0 & \dots & 1 \end{vmatrix} \mathrm{N} \times N. \tag{38}$$

$$\text{or } \mathbf{Q} = \mathbf{\Pi} = \begin{vmatrix} \Pi_1 \\ \dots \\ \Pi_N \end{vmatrix} \tag{39}$$

for the case of p. 3. These four forms of weighted formalization of matrix $\mathbf{P}(\boldsymbol{\alpha})$ allows to be overcome the need to have subjective expert views. With these formalizations the assets' characteristics are evaluated not only by historical returns and covariances but by adding data, which in this case concerns differences from the "implied returns." The |BL model incorporates such additional source of information, **Figure 4**. The formalism $\mathbf{P}(\boldsymbol{\alpha})$ allows to be compared portfolio solutions, based on MV model and BL one because subjective influences in BL model now are missing. The BL model integrates different sources of information, concerning future assets' characteristics, but this information is not subjectively generated and it origins from real and actual behavior of the market.

8. BL modification of the assets' characteristics

Using relations (22) and (23) the BL returns $\mathbf{E_{BL}}$ are found by means to approximate in best way these two linear stochastic relations. For simplicity additional notation are used in the next matrix relations

$$\mathbf{Y} = \boldsymbol{X}\mathbf{E}_{\mathrm{BL}} + \boldsymbol{\psi}, \tag{40}$$

where

$$\mathbf{Y} = \begin{vmatrix} \mathbf{\Pi} \\ \mathbf{Q} \end{vmatrix}, \mathbf{X} = \begin{vmatrix} \mathbf{I} \\ \mathbf{P} \end{vmatrix}, \boldsymbol{\psi} = \begin{vmatrix} \boldsymbol{\varepsilon} \\ \boldsymbol{\eta} \end{vmatrix}, \overline{\boldsymbol{\psi}} = \begin{vmatrix} \tau\mathbf{\Sigma} & 0 \\ 0 & \mathbf{\Omega} \end{vmatrix}. \tag{41}$$

The general least square method with the minimization of the Mahalanobis distance

$$\mathbf{E}_{\mathrm{BL}}^{\mathbf{min}} \equiv \boldsymbol{arg} \left\{ \begin{matrix} min \\ \boldsymbol{E}_{\mathbf{BL}} \end{matrix} \left[(\mathbf{Y} - \mathbf{X}\mathbf{E}_{\mathbf{BL}}]^T \, \overline{\boldsymbol{\psi}^{-1}} [(\mathbf{Y} - \mathbf{X}\mathbf{E}_{\mathbf{BL}}] \right\} \tag{42}$$

gives solution

$$\mathbf{E}_{\mathrm{BL}} = \left[(\tau\mathbf{\Sigma})^{-1} + \mathbf{P}^T\mathbf{\Omega}^{-1}\mathbf{P}\right]^{-1} \left[(\tau\mathbf{\Sigma})^{-1}\mathbf{\Pi} + \mathbf{P}^T\mathbf{\Omega}^{-1}\mathbf{Q}\right] \tag{43}$$

and volatility $\mathbf{Vol}(\mathbf{E_{BL}}) = \Delta_{\mathbf{BL}} = \left[(\tau\mathbf{\Sigma})^{-\mathbf{1}} + \mathbf{P^T\Omega^{-1}P}\right]^{-\mathbf{1}}$.

Taking into account the riskless return, the final BL assets' returns and covariance matrix are

$$\mathbf{E}_{\mathbf{BL}}^{\boldsymbol{final}} = \mathbf{E_{BL}} + r_f \text{ and } \overset{\boldsymbol{final}}{\underset{\mathbf{BL}}{\mathbf{\Sigma}}} = \mathbf{\Sigma} + \Delta_{\mathbf{BL}} \tag{44}$$

Using these modified assets' characteristics, the portfolio problem (11) is solved and appropriate point from the efficient frontier is chosen. It is recommended the best portfolio to be taken with weights w_i^{opt}, $i = 1, ..., N$, which belongs to portfolios with characteristics

$$\text{Maximal Sharp excess ratio, } \max_{w} \left(\frac{E_p - r_f}{\sigma_p^2} \right) \tag{45}$$

$$\text{or maximal information ratio, } \max_{w} \left(\frac{E_p}{\sigma_p} \right) \tag{46}$$

9. Numerical simulations and comparisons between MV and BL portfolios solutions

The numerical simulations are performed with real data from the Bulgarian Stock Exchange [12]. The riskless investment for several years gives very low or even negative return. That is, the reason for the investors to start to apply portfolio optimization with risky assets. Currently, the risky investments are performed with a set of about 125 mutual funds in Bulgaria nowadays. The mutual funds are operated by different business and economics entities. The goal of all mutual funds is to manage their portfolios by means to achieve positive return or to decrease the losses in nonfriendly behavior of the financial market. The success or not successful management of the mutual funds can be seen by their historical data about achieved returns and risks in their investments. Thus, our portfolio simulations will start with historical return data of a set of chosen Bulgarian mutual funds. It has been chosen

month 2018	CONCORD	ELANA	PROFIT	TEXIM	LIDER	PATRIM	GROWTH
January	0.7298	0.312	0.132	0.197	-0.054	-0.021	0.791
February	-0.2581	-0.414	0.134	0.181	-0.244	-0.924	-0.917
March	-0.411	-0.197	-0.206	-0.304	-0.494	-0.899	-0.448
April	0.0193	0.159	0.147	0.256	0.107	0.174	-0.063
May	-0.4491	-0.362	0.046	-0.136	-0.024	0.416	-0.299
June	-0.062	0.173	-0.062	-0.134	-0.246	-0.041	-0.429
July	-0.0869	0.045	0.033	0.108	0.086	0.205	0.473
August	0.0446	-0.055	-0.03542	-0.251	-0.151	0.176	-0.079
September	0.2544	0.174	0.105	0.264	-0.135	-0.339	-0.322
October	-0.0728	0.148	-0.026	-0.003	-0.121	-0.553	-0.661
November	-0.5829	-0.525	-0.378	-0.393	0.109	0.379	0.099
December	0.7244	0.111	0.58	0.758	-0.308	-1.021	-0.038
E	-0.012525	-0.03592	0.039132	0.04525	-0.12292	-0.204	-0.15775
STD	0.417379	0.273612	0.229691	0.318346	0.18279	0.526381	0.469805
COV	CONCORD	ELANA	PROFIT	TEXIM	LIDER	PATRIM	GROWTH
CONCORD	0.159688	0.08155	0.066914	0.094008	-0.00751	-0.05295	0.080864
ELANA	0.08155	0.068625	0.026653	0.040608	-0.00075	-0.00987	0.040523
PROFIT	0.066914	0.026653	0.048362	0.063314	-0.0061	-0.04621	0.007817
TEXIM	0.094008	0.040608	0.063314	0.092899	-0.00322	-0.06888	0.017825
LIDER	-0.00751	-0.00075	-0.0061	-0.00322	0.030628	0.070669	0.039516
PATRIM	-0.05295	-0.00987	-0.04621	-0.06888	0.070669	0.253988	0.113633
GROWTH	0.080864	0.040523	0.007817	0.017825	0.039516	0.113633	0.202324

Figure 5.
Monthly and annual returns, and the covariance matrix of the mutual funds for 2018.

seven mutual funds to participate in the portfolio: Concord Asset Management (CONCORD), Elana Asset Management (ELANA), Profit Asset Management (PROFIT), Texim (TEXIM), Central Cooperative Bank Lider (LIDER), Asset Management UBB Patrimonium (PATRIM), Asset Management DSK Growth (GROWTH). They invest both in currencies and shares. The Bulgarian Association of Asset Management Companies [13] and the Government Financial Supervision Commission [14] regularly record and update the activities of the Bulgarian mutual funds. For the simulation experiments it has been taken the mean monthly return of these 7 mutual funds for 2018-year, **Figure 5**.

The calculations in this research have been performed in MATLAB environment. The mean years returns and the covariance matrix are given also in **Figure 5**. The simulations apply multiperiod investment policy, described in **Figure 6**.

9.1 Initial evaluation of historical data

The monthly mean returns of the mutual funds for the first 8 months of 2018 were taken as historical period. It has been calculated the average return for each fund for this historical period, $n = 8$. The average returns and the corresponding covariance matrix are given in **Figure 7**.

The portfolio manager has to pay attention for the different values of mean returns and covariance, given in **Figures 5** and **7**. The first case is evaluated for $n = 12$, 12 time period. While the second evaluations are made for a shorter period, $n = 8$. That is, a case where the time management is important for the estimation of the assets' characteristics.

9.2 Evaluation of the efficient frontier with MV model for the first 8 months

By changing the values of $\Psi \in [0, 1]$ the portfolio problem (11) is repeatedly solved. The interim values of the portfolio return, risk and portfolio weights are stored in working arrays in MATLAB environment. The evaluation step of changing

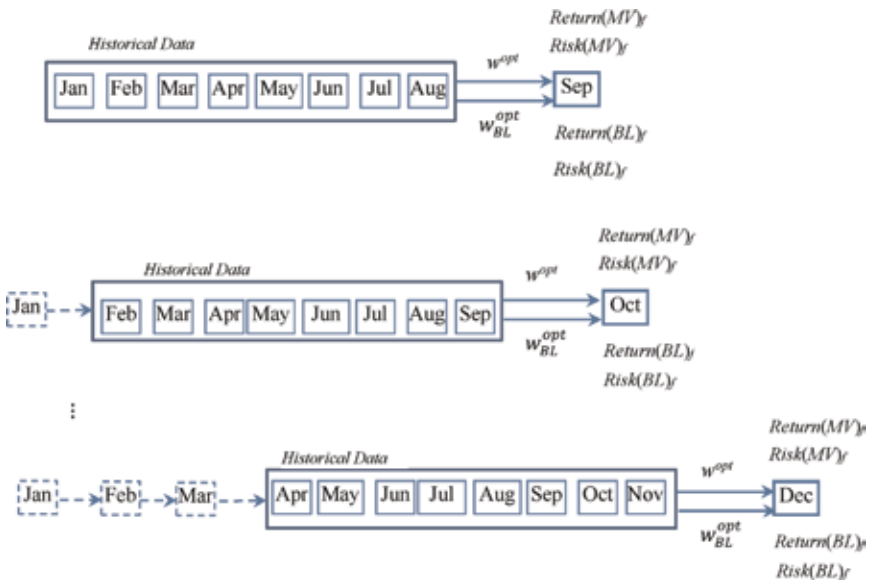

Figure 6.
Multi period investment with flowing historical window.

$\mathbf{E}^T$ = [-0.0592; -0.0424; 0.0238; -0.0105; -0.1277; -0.1141; -0.1216];

Σ =[

0.1365	0.0778	0.0199	0.0388	0.0258	0.0497	0.1507
0.0778	0.0694	0.0048	0.0185	0.0192	0.0550	0.1034
0.0199	0.0048	0.0148	0.0239	0.0178	0.0183	0.0170
0.0388	0.0185	0.0239	0.0487	0.0281	0.0092	0.0386
0.0258	0.0192	0.0178	0.0281	0.0400	0.0807	0.0626
0.0497	0.0550	0.0183	0.0092	0.0807	0.2626	0.1556
0.1507	0.1034	0.0170	0.0386	0.0626	0.1556	0.2939];

Figure 7.
Mean returns and covariance matrix for the first 8 months of 2018.

Ψ was chosen $\Psi = 0.01$ resulting in 100 solutions of problem (11). The graphical presentation of the MV "efficient frontier" is given in **Figure 8**.

The Sharpe excess ratio (45) and the information ratio (46) are presented in **Figure 9**.

It is estimated the maximum Sharpe_excess_ratio = 4.321. This value corresponds to a portfolio with characteristics:

$$Return = 0.0218,\ Risk = 0.0143,\ \mathbf{w}^{\mathbf{optT}} = [0;\ 0.0304;\ 0.9696;\ 0;\ 0;\ 0;\ 0]. \quad (47)$$

These results recommend that the portfolio manager has to allocate his investment only in two mutual funds: the second in the portfolio (ELANA) and the third one (PROFIT). This recommendation is valid for the investment month of September 2018.

9.3 Evaluation of the assets' characteristics for the BL model

9.3.1 Definition of the risk-free return r_f

In this research for the risk-free return r_f has been used an official index, evaluated and maintained by the National Bank of Bulgaria. The index is named

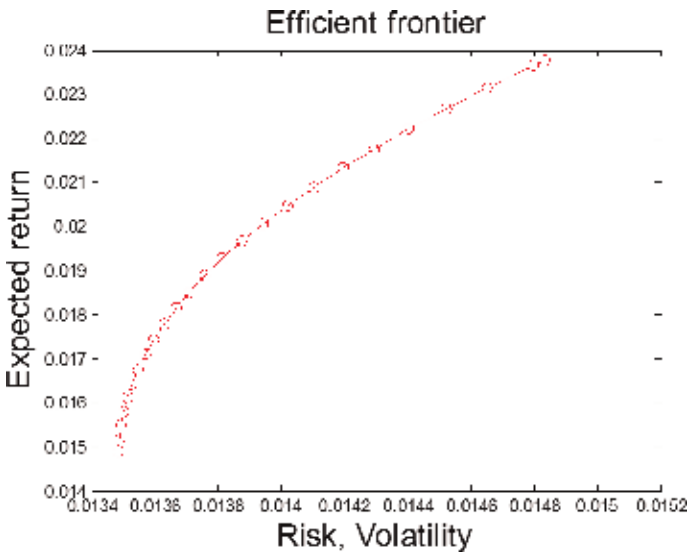

Figure 8.
Graphical presentation of the "efficient frontier" with historical data.

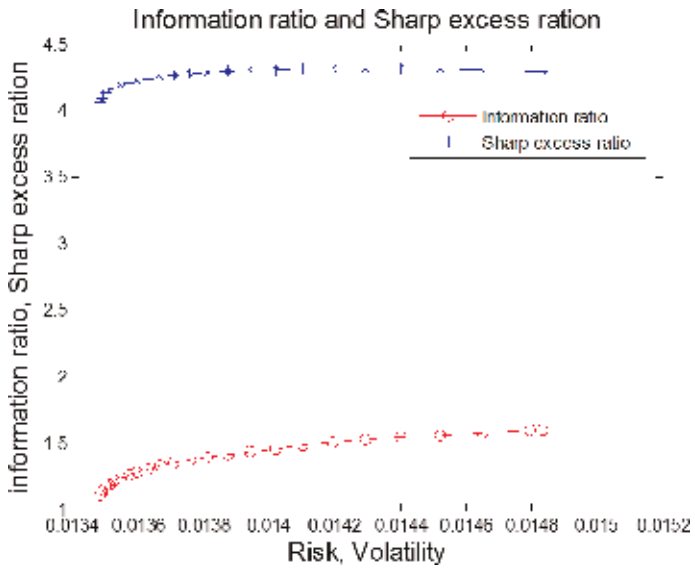

Figure 9.
Graphical presentation of Sharpe excess ratio and information ratio.

LEONIA+ which is abbreviation of Lev (the name of the National currency) Over Night Index Average. This index is used by the mutual funds to take or giving loans for overnight activities on the financial market. This index is recommendation from the Bulgarian National Bank for all financial institution and authorities in Bulgaria dealing in overnight deposits with Bulgarian currency [15]. For this research the risk-free value is negative on monthly basis, $r_f = -0.4$.

9.3.2 Evaluation of the market point

The characteristics of the market point are the mean return E_M and the risk, numerically estimated by the standard deviation σ_M. The market point is found as a tangent one where the CML (Capital Market Line) makes over the "efficient frontier." Additionally, the CML must pass through the riskless point $(0, r_f)$. The CML cannot be presented in analytical way because the "efficient frontier" is not analytically given. The last have been found numerically as a set of points in the plane (*Risk/Return*) from the multiple solutions of portfolio problem (11), given in p. 2. This research makes a quadratic approximation of the "efficient frontier" and finds analytical description of the "approximated efficient frontier." Then with algebraic calculations using the linear equation of the CML and the approximated efficient frontier the tangent point is evaluated. The coordinates of the market point give the mean market return E_M and the market risk σ_M. For these market values the market capitalization weights $\mathbf{w_M}$ are found from the working arrays when problem (11) has been solved in p. 2. The "approximated efficient frontier" is a quadratic curve of the form

$$y = a_2 x + a_1 x + a_0 \tag{48}$$

where $a_2 = -3980.6$; $a_1 = 118.40$; $a_0 = -0.9$, $x = Risk$, $y = Return$.
The numerical values of the market point are:
$E_M = 0.0222$, $\sigma_M^2 = 0.0143$, $\lambda = 4.3462$ (according to (22)).
The graphical presentation of the CML, the "efficient frontier" and its approximation and the market point are given in **Figure 10**.

9.3.3 Evaluation of the implied excess returns Πi, i = 1,...,N.

Using relation (23) the "implied excess returns" Πi, $i = 1,...,N$ are:
$\mathbf{\Pi}^{\mathbf{T}} = [0.0523; -0.0126; 0.0235; 0.0635; 0.0375; 0.0433; 0.0427]$.
Respectively, the "implied returns" is $\mathbf{\Pi}^{*} = \mathbf{\Pi} + r_f$ or.
$\mathbf{\Pi}^{*\mathbf{T}} = [0.0923; 0.0274; 0.0635; 0.1035; 0.0775; 0.0833; 0.0827]$.

9.3.4 Definition of the characteristics of the expert views P and Q

The portfolio parameter, which is used for the estimation of matrices **P** and **Q** is the difference between the implied returns **Π** and the mean assets' historical returns **E**, **(Π–E)**. These values are as follows:
$\mathbf{\Pi}^{*\mathbf{T}} = [0.0923; 0.0274; 0.0635; 0.1035; 0.0775; 0.0833; 0.0827]$;
$\mathbf{E}^{\mathbf{T}} = [-0.0592; -0.0424; 0.0238; -0.0105; -0.1277; -0.1141; -0.1216]$;
$(\mathbf{\Pi}^{*}\mathbf{-E})^{\mathbf{T}} = [0.1115; 0.0298; -0.0003; 0.0741; 0.1652; 0.1575; 0.1643]$.

Because the value of the third component of $(\mathbf{\Pi}^{*}\mathbf{-E})^{\mathbf{T}}$ is less than 0.1% it is assumed to be zero. All differences $(\mathbf{\Pi}^{*}\mathbf{-E})$ have positive sign, which means that the assets are underestimated and their implied returns are higher. Hence, the portfolio manager has to expect an increase of the mean returns of the assets in the portfolio. This case of differences between implied and mean returns defines the usage of relation (39) for the definition of matrices **P** and **Q**. The option (39) is also applied in this simulation work. The calculations have been performed with 7×7 identity matrix $\mathbf{P}$, $\begin{vmatrix} 1 & \dots & 0 \\ \cdots & 1 & \dots \\ 0 & \dots & 1 \end{vmatrix}$ 7×7 and two types of matrices **Q**:

$$\mathbf{Q} = (\mathbf{\Pi}^{*} - \mathbf{E}) \text{ and } \mathbf{Q} = \mathbf{\Pi}^{*}. \tag{49}$$

9.3.5 Evaluation of the BL returns $\boldsymbol{E_{BL}}$ and the BL covariance matrix $\boldsymbol{\Sigma_{BL}}$

The evaluations of the modified mean assets' returns $\mathbf{E_{BL}}$ according to the BL model are done according to relations (43) and (44). The value of the covariance

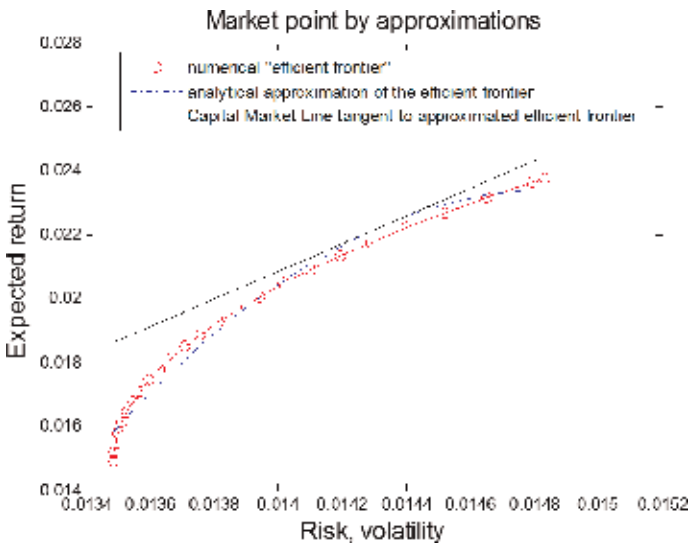

Figure 10.
CML and approximated efficient frontier

matrix of the expert views is assumed to be as the historical covariance $\sum$ but the values of its components are decreased with equal value τ. Thus the covariance matrix of the expert views is $\tau \sum$ where the value of τ must be between 0 and 1. From practical recommendations [7, 16, 17], this research uses $\tau = 0.5$. The BL model evaluations are.

$$\mathbf{E}_{\mathbf{BL}}^{T} = [0.0523, -0.0126; 0.0235; 0.0635; 0.0375; 0.0433; 0.0427]; \tag{50}$$

$$\Sigma_{\mathbf{BL}} = \begin{bmatrix} 0.1588 & 0.0873 & 0.0219 & 0.0416 & 0.0252 & 0.0490 & 0.1675 \\ 0.0873 & 0.0816 & 0.0040 & 0.0199 & 0.0198 & 0.0593 & 0.1130 \\ 0.0219 & 0.0040 & 0.0172 & 0.0272 & 0.0198 & 0.0193 & 0.0163 \\ 0.0416 & 0.0199 & 0.0272 & 0.0566 & 0.0310 & 0.0044 & 0.0398 \\ 0.0252 & 0.0198 & 0.0198 & 0.0310 & 0.0456 & 0.0921 & 0.0681 \\ 0.0490 & 0.0593 & 0.0193 & 0.0044 & 0.0921 & 0.3113 & 0.1696 \\ 0.1675 & 0.1130 & 0.0163 & 0.0398 & 0.0681 & 0.1696 & 0.3424 \end{bmatrix} \tag{51}$$

9.3.6 Solution of portfolio problem with $\boldsymbol{E}_{BL}^{T}$ and $\boldsymbol{\Sigma}_{BL}$

The portfolio problem (11) is repetitively solved by changing $\Psi \in [0, 1]$ with the BL evaluations of the assets' characteristics $\boldsymbol{E}_{BL}^{T}$ and $\boldsymbol{\Sigma}_{\mathbf{BL}}$. The new BL "efficient frontier" is found as a set of numerically evaluated points (100 points). For illustration purposes both "efficient frontiers" with historical data (MV model) and BL data (BL model) are given in **Figure 11**.

9.3.7 Evaluation of the BL weights $\mathbf{w}_{\mathbf{BL}}^{\mathbf{opt}}$

The portfolio which has maximum Sharpe excess ratio is identified. This maximum is found from the numerically evaluated points of the BL "efficient frontier." The needed portfolio parameters are stored in the arrays in MATLAB, during the

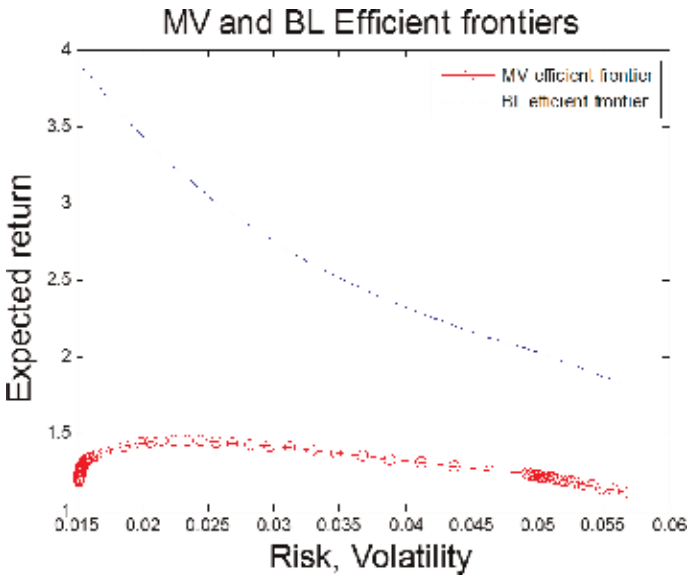

Figure 11.
Efficient frontiers with MV and BL models

sequential solutions of problem (11). The Sharpe excess ratio evaluated from (45) gives:

$$Return(BL) = 0.0201, Risk(BL) = 0.0155, \boldsymbol{w}_{\boldsymbol{BL}}^{\boldsymbol{optT}} = [0;0.0924;0.9076;0;0;0;0]. \tag{52}$$

The difference between $\boldsymbol{w}_{\boldsymbol{BL}}^{\boldsymbol{opt}}$ and $\mathbf{w}^{\mathbf{opt}}$ shows a bit increase of the weight for the second asset (PROFIT) for the BL portfolio.

9.4 Comparison of the MV solution $\mathbf{w}^{\mathbf{opt}}$ and the BL one $\mathbf{w}_{\mathbf{BL}}^{\mathbf{opt}}$

The optimal weights $\boldsymbol{w}_{\boldsymbol{BL}}^{\boldsymbol{opt}}$ and $\mathbf{w}^{\mathbf{opt}}$ are assumed to be implemented as portfolio solutions in the beginning of month of September 2018. At the end of this month we can estimate the actual mean returns of the assets for month of September $\mathbf{E_f}$ and the modified actual covariation matrix $\sum_f$ which is calculated again for 8 months history but from February to September 2018.

- For the case when the MV weights $\mathbf{w}^{\mathbf{opt}}$ are invested the investor results will be

$$Return(MV)_f = \boldsymbol{E}_f^T\ \mathbf{w}^{\mathbf{opt}}, Risk(MV)_f = \mathbf{w}^{\mathbf{optT}} \sum_f \mathbf{w}^{\mathbf{opt}}. \tag{53}$$

- For the case when $\boldsymbol{w}_{\boldsymbol{BL}}^{\boldsymbol{opt}}$ weights are applied the investor results will be

$$Return(BL)_f = \boldsymbol{E}_f^T\ \boldsymbol{w}_{\boldsymbol{BL}}^{\boldsymbol{opt}}, Risk(BL)_f = \boldsymbol{w}_{\boldsymbol{BL}}^{\boldsymbol{optT}} \sum_f \boldsymbol{w}_{\boldsymbol{BL}}^{\boldsymbol{opt}}. \tag{54}$$

Then these portfolio results will be compared in the space $Risk(Return)$. The portfolio point which is situated far on the Nord-West direction of the $Risk(Return)$ space is the preferable portfolio. Such assessment will prove which portfolio model MV or BL gives more benefit and efficiency.

9.5 Multiperiod portfolio optimization

Following **Figure 6** a next portfolio investment with MV and BL models is done by moving the history period 1 month ahead. The portfolio evaluations are done for a history period from February till September 2018. The evaluated weights $\boldsymbol{w}_{\boldsymbol{BL}}^{\boldsymbol{opt}}$ and $\mathbf{w}^{\mathbf{opt}}$ are applied for the month of October. For this case of 8 months historical period and available data for all 12 months of 2018 such multiperiod investment policy will evaluate 4 portfolios using the two models MV and BL. This research did three modifications of the BL model, concerning the evaluation of the matrices **P** and **Q**, related to the views for changing the assets characteristics:

- $\mathbf{P}(\boldsymbol{\alpha})$, weighted procedure, according to relations (33), (35);
- $\mathbf{P}(\boldsymbol{\Pi} - \boldsymbol{E})$, weighted procedure according to relations (35), (36);
- $\mathbf{P}(\boldsymbol{\Pi})$, weighted procedure according to relations (35), (37).

For the cases when all components $(\boldsymbol{\Pi} - \boldsymbol{E})$ or $\boldsymbol{\Pi}$ have same sign, the procedures (32) or (33) are applied. The obtained results are given in **Table 1**.

MV model		**BL model**					
		P(α)		**P($\Pi - E$)**		**P(Π)**	
Return $(MV)_f$	*Risk* $(MV)_f$	*Return* $(BL)_f$	*Risk* $(BL)_f$	*Return* $(BL)_f$	*Risk* $(BL)_f$	*Return* $(BL)_f$	*Risk* $(BL)_f$
0.1080	0.0133	0.1017	0.0132	0.1055	0.0132	0.1122	0.0129
−0.0187	0.0117	−0.0931	0.0120	−0.0632	0.0111	−0.0221	0.0106
−0.4011	0.0282	−0.3861	0.0263	−0.3793	0.0255	−0.4088	0.0292
−0.3525	0.0240	−0.2313	0.0114	−0.1523	0.0080	−0.2028	0.0106
Mean values							
−0.1661	**0.0193**	**−0.1552**	**0.0157**	**−0.1223**	**0.0145**	**−0.1304**	**0.0158**

Table 1.
Results of multi-period portfolio management with MV and BL models.

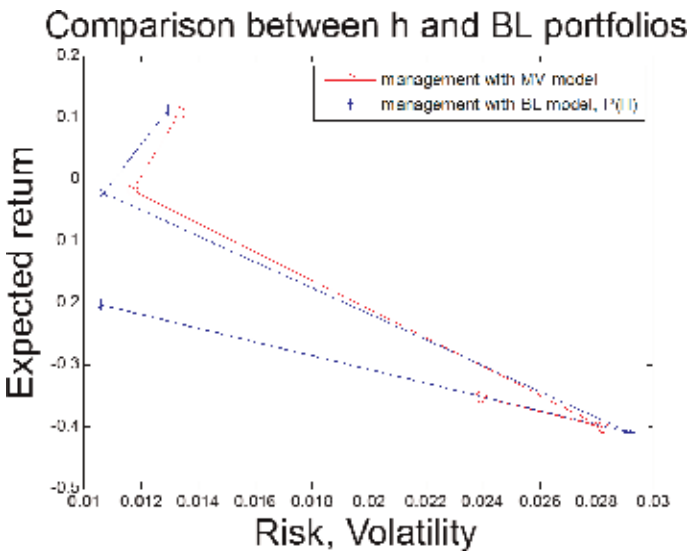

Figure 12.
Comparison of multiperiod MV and BL(P(Π)) portfolio optimization.

The graphical presentation of the comparison of the multiperiod portfolio management between MV and BL with **P(Π)** modification is given in **Figure 12**.

The common results prove that the market situation in 2018 does not allow the mutual funds to achieve positive return. The results are negative but this negative value is less than the riskless return value $r_f = -0.4$. Hence, the portfolio management allows reduction of the losses. Particularly, all three modifications of the BL model give better results in comparison with the classical MV portfolio model. The mean values of the returns with BL model are very close to the returns of the MV model. But the risk values are considerably lower, which means that the probability to be closer to the mean values of BL returns is higher than the case of MV model.

10. Time management considerations for the portfolio investments

This research illustrates that the task of portfolio investment is quite complicated. The meaning of portfolio optimization concerns the definition and solution

of portfolio problem. In both these tasks the time is a prerequisite for successful portfolio investment.

10.1 Time requirements for the stage of definition of the portfolio problem

The content in the paragraph "Portfolio optimization problem" explicitly asserts that the investor has to choose the duration of the historical period. This duration, n is in discrete form. It has to be chosen in a way that can refer to the investment period (T-t_0). Obviously, high number of n will give influence for the slow changes in the market behavior. Respectively, the active portfolio management will not benefit with long duration of the historical period n.

The active management needs to follow the current dynamics of the market. The relations between n and (T-t_0) cannot be derived on theoretical basis. Only practical considerations could be useful. The authors' experience recommends duration of the historical period to be considered between 6 and 8 months. Such history period can be used for multiperiod portfolio management from 1 to 3 months ahead in the future.

An unexpected problem has been met by the authors, concerning the relation between the historical discrete points n and the number N of the assets, included in the portfolio. The two parameters n and N participate both for the evaluation of the covariance matrix $\sum$. This matrix should be in full rank by means that the portfolio problem (11) must generate regular solutions. If the rank of $\sum$ is less than N problem (11) gives unrealistic solutions. To keep $\sum$ with rank N it is needed its components to be evaluated with historical data $n > N$. The practical minimal case is $n + 1 = N$ but before solving the portfolio problem the investor has to check the rank of $\sum$. As practical consideration, if the portfolio contains many assets and N is high, the data from the historical period n have to be also high. For that case one can use not only monthly returns but also weekly average data. Thus, the value of n can increase.

10.2 Time requirements for the solution of the portfolio problem

The solution of the portfolio problem (11) gives unique set of weights, which have to be implemented for the portfolio investment. Because the market behavior changes, reasonable policy is to perform repeatedly definition and solution of the portfolio problem. Potential beneficial strategy can be the multiperiod portfolio management, presented in **Figure 6**. It incorporates the multiperiod management and adopts the portfolio parameters with up to date market data. The relation between the duration of the historical period and the investment period is still an open question. But making additional simulations with 1, 2, 3 or more months (time) ahead the portfolio manager can change his decision on each investment step.

11. Conclusions

This research identifies in explicit way the influence of the time for the definition and solution of portfolio problems. These time requirements are considerably related with the estimation of the parameters of the portfolio problem. Respectively, the time requirements insist the portfolio management to be performed in multiperiod investment.

This research makes an analysis of the development of the portfolio theory. Starting with the Markowitz formalization, the MV portfolio problems are based

only on historical data about mean returns and covariances between the returns. The development of CAPM gives new relations, originated from a new "market" point. The last gives additional information about the values of the parameters of the portfolio problem. Finally, the BL model introduces a new set of points, "implied excess returns," which originate from the market point. As a result, new values for the parameters of the portfolio problem are found. Respectively, the portfolio problem gives weights of the assets, which are not sharp cut, which decreases the risk of the investment.

This research introduces new modifications of the BL model for the part of definition of expert views. Particularly the experts are substituted by additional data, which origins from the dynamical behavior of the assets' returns. Thus, not only mean returns and covariances are taken into consideration, but also the difference between objective parameters as implied and historical mean returns. These modifications allow the portfolio model MV and these based on BL one to be compared on a common basis and to assess their performances. Such comparison cannot be made if subjective experts are used, because their mutual views will be different for the same historical data and with changes the members of the experts.

This research gives also a practical added value with the analysis of the behavior of the market with mutual funds in Bulgaria. This gives additional experience and bases for future comparisons and assessments of the different portfolio models.

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Chapter 10

A Global Method for a Two-Dimensional Cutting Stock Problem in the Manufacturing Industry

Yao-Huei Huang, Hao-Chun Lu, Yun-Cheng Wang, Yu-Fang Chang and Chun-Kai Gao

Abstract

A two-dimensional cutting stock problem (2DCSP) needs to cut a set of given rectangular items from standard-sized rectangular materials with the objective of minimizing the number of materials used. This problem frequently arises in different manufacturing industries such as glass, wood, paper, plastic, etc. However, the current literatures lack a deterministic method for solving the 2DCSP. However, this study proposes a global method to solve the 2DCSP. It aims to reduce the number of binary variables for the proposed model to speed up the solving time and obtain the optimal solution. Our experiments demonstrate that the proposed method is superior to current reference methods for solving the 2DCSP.

Keywords: two-dimensional cutting stock problem (2DCSP), rectangular items, optimal solution, deterministic model

1. Introduction

Two-dimensional cutting stock problem (2DCSP) is a well-known problem in the fields of management science and operations research. The problem frequently arises in the manufacturing processes of different products such as wood, glass, paper, steel, etc. In the 2DCSP, a set of given rectangular items is cut from a set of rectangular materials with the aim of determining the minimum number of materials [1, 2]. These applications include sawing plates from wood stocks [3], reel and sheet cutting at a paper mill [4], cutting plates of thin-film-transistor liquid-crystal display (TFT-LCD) from glass substrate [5, 6], placing devices into a system-on-a-chip circuit [7], and container loading or calculation of containers [8, 9]. Minimizing the number of materials is normally the target in this type of the problem because it does not only reduce the overhead consumption but also enhances environmental protection. The problem in the literatures have been classified as one-dimensional, 1.5-dimensional, and 2DCSPs (Hinxman [10] and Lodi et al. [11]) and suggested two categories of approaches in solving the problems, namely, the heuristic and deterministic approaches (Belov [12], Burke et al. [13], Chen et al. [14], Hopper and Turton [15], Lin [16] and Martello et al. [17]).

Various heuristic approaches have been proposed and discussed in the literatures. The primary advantage of this approach is easier in solving the 2DCSP within an acceptable and economical timeframe [18, 19]. The feasible solution is obtained within a reasonable time, while the optimal solution cannot be guaranteed. Chazelle [20] first proposed a popular heuristic algorithm, called the bottom-left heuristic algorithm. Berkey and Wang [21] proposed a finite best strip heuristic algorithm to improve the original bottom-left method which packs the items directly into the bins with a best-fit policy. On the other hand, Lodi et al. [22] proposed an integrated heuristic approach that initiates the solution by paralleling the edges of the items and bins (i.e., materials) and utilizes a Tabu search [23, 24] to explore the neighborhood and refine the possible solution. In order to enhance the effectiveness of the algorithm used, Boschetti and Mingozzi [25, 26] consider empty bins in turn and fill the bins with items in a sequence defined by the prices attributed to the items and update them iteratively. Likewise, Monaci and Toth [27] initially used Lagrangian-based heuristic to generate a set of covering programming model to obtain a lower bound solution, in which the items cannot be rotated. They applied geometric analytical techniques and Dantzig-Wolfe decomposition to produce various lower bounds of the 2DCSP so that a better solution can be compared and obtained [28–31].

Despite the development of heuristic approaches can obtain possible solution in a reasonable time, however there is a scarcity of literature attempting to ensure the achievement of an optimal solution. Moreover, the distance between one random feasible solution and the actual global optimal solution can be enlarged with an increasing problem size. Only a few studies attempted to develop deterministic approaches for an optimal solution. For example, Chen et al. [32] formed a mathematical model for packing a set of given rectangular items into a rectangular space in which the dimension of the rectangular space is minimized. The packing problem is equal to the cutting problem, and the problem can also be called as an assortment problem. Moreover, Williams [33] formulated a mathematical model considering the increased generalization of 2DCSP, to solve the problem with various sizes of bins. However, Williams' model contains an excessive number of binary variables as indicated by Pisinger and Sigurd [31] who showed that Williams' model has difficulty in solving a standard 2DCSP by their computational experiments. The subsequent studies by Li and Chang [34], Li et al. [35, 36], Hu et al. [37], and Tsai et al. [38] (these approaches are called Li's approach in this study) enhanced Chen's model with reformulation techniques based on reducing binary variables and piecewise linearization technique. The deterministic approaches can guarantee the achievement of global optimization with an acceptable tolerance; however, these approaches are only suitable for the assortment problem (i.e., cutting rectangular items from one material only), while many manufacturing situations require considering minimal number of materials.

Aiming to close the knowledge gap, this study modifies the two programs of the assortment problem proposed by Chen et al. [32] and Li and Chang [34] to be two corresponding deterministic models for the 2DCSP. As an innovative approach, a global approach of the 2DCSP with a logarithmic number of binary variables and extra constraints is proposed and demonstrated.

The remainder of this study is organized as follows: Section 2 discusses the 2DCSP formulations. Section 3 proposes the 2DCSP models with logarithmic number of binary variables and extra constraints. Numerical examples are given in Section 4 to demonstrate the theoretical advances and advantages of the proposed global approach. Section 5 gives the concluding remarks.

2. Problem formulations

Given n small rectangular items, the 2DCSP is to cut all items within large rectangular materials with the objective of minimizing the number of materials used. Denote x and y as the width and the length of the enveloping rectangle. By referring to the method of Chen et al. [32], a mathematical program can be formed with the objective of minimizing the volume (i.e., Min xy) as discussed in Section 2.1. In the 2DCSP, the minimal number of materials can reduce the manufacturing costs. Thus Section 2.2 explains how to reformulate two new 2DCSP programs based on the original model in Section 2.1. Firstly, the terminologies, including decision variables and parameters, are introduced in **Tables 1** and **2**.

2.1 Cutting problem in one material

The cutting problem considering one material is also called the assortment problem, which considers cutting a set of given rectangular items within a rectangular material of minimum area. Avoiding the overlapping of items is the core requirements. Chen et al. [32] and Li and Chang [34] use four binary variables $(a_{i,j}, b_{i,j}, c_{i,j}, d_{i,j})$ and two binary variables $(u_{i,j}, v_{i,j})$, respectively, to handle the non-overlapping conditions, as shown in **Table 3**.

The following assortment program is proposed by Chen et al. [32]:

Original (a)

Min xy

$$s.t.\ x_j + p_j s_j + q_j(1 - s_j) \le x_i + \overline{x}(1 - a_{i,j}) \text{ for } i, j = 1, ..., n \text{ and } i < j, \qquad (1)$$

Parameter	Meaning
n	The number of given rectangular items needed to be cut
m	The number of rectangular materials with the same size
(p_i, q_i)	The width and length of given rectangular item i for $i = 1, ..., n$
$(\overline{x}, \overline{y})$	$\overline{x}$ and $\overline{y}$ are the upper bounds of x and y, respectively. These items also denote the width and length of a given rectangular material

Table 1.
Parameters in the 2DCSP.

Variable	Meaning
(x_i, y_i)	The bottom-left coordinate of rectangular item i
(x, y)	The top-right coordinate of the rectangular material
$(a_{i,j}, b_{i,j}, c_{i,j}, d_{i,j})$	A set of binary variables expressing the non-overlapping conditions for a pair of rectangular items i and rectangular items j for $i < j$, which are defined by Chen et al. [32]
$(u_{i,j}, v_{i,j})$	A pair of binary variables expressing the non-overlapping conditions for a pair of rectangular items i and rectangular items j for $i < j$, which are defined by Li and Chan [34]
s_i	An orientation indicator for a given rectangular item i. $s_i = 1$ if p_i is parallel to the x-axis; otherwise, $s_i = 0$ if p_i is parallel to the y-axis (s_i is a binary variable)
Y	The accumulated length of all materials used.

Table 2.
Decision variables in the 2DCSP.

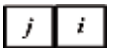
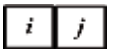
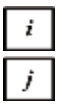
Method		Chen et al. [32]			Li and Chang [34]		Condition
Case	$a_{i,j}$	$b_{i,j}$	$c_{i,j}$	$d_{i,j}$	$u_{i,j}$	$u_{i,j}$	
1	1	0	0	0	0	0	
2	0	1	0	0	1	0	
3	0	0	1	0	0	1	
4	0	0	0	1	1	1	

Table 3.
Four cases of non-overlapping conditions.

$$x_i + p_i s_i + q_i(1 - s_i) \le x_j + \overline{x}(1 - b_{i,j}) \text{ for } i, j = 1, ..., n \text{ and } i < j, \quad (2)$$

$$y_j + q_j s_j + p_j(1 - s_j) \le y_i + \overline{y}(1 - c_{i,j}) \text{ for } i, j = 1, ..., n \text{ and } i < j, \quad (3)$$

$$y_i + q_i s_i + p_i(1 - s_i) \le y_j + \overline{y}(1 - d_{i,j}) \text{ for } i, j = 1, ..., n \text{ and } i < j, \quad (4)$$

$$a_{i,j} + b_{i,j} + c_{i,j} + d_{i,j} = 1 \text{ for } i, j = 1, ..., n \text{ and } i < j, \quad (5)$$

$$x_i + p_i s_i + q_i(1 - s_i) \le x \le \overline{x} \text{ for } i = 1, ..., n, \quad (6)$$

$$y_i + q_i s_i + p_i(1 - s_i) \le y \le \overline{y} \text{ for } i = 1, ..., n, \quad (7)$$

where $a_{i,j}, b_{i,j}, c_{i,j}, d_{i,j}$, and s_i are binary variables; x_i and y_i are nonnegative continuous variables; Constraints (1)–(5) ensure that the rectangular items are non-overlapping, and Constraints (6) and (7) are to cut all of the rectangular items within an enveloping rectangular material $(\overline{x}, \overline{y})$.

Remark 1. Original (a) uses $2n^2 - n$ binary variables $(a_{i,j}, b_{i,j}, c_{i,j}, d_{i,j})$ and $2.5n(n-1) + 2n$ constraints to formulate an assortment problem with n rectangular items.

By referring to Li and Chang [34], an alternative mathematical model can be expressed as follows:

Original (b)

Min xy

s.t. (6) and (7),

$$x_j + p_j s_j + q_j(1 - s_j) \le x_i + \overline{x}(u_{i,j} + v_{i,j}) \text{ for } i, j = 1, ..., n \text{ and } i < j, \quad (8)$$

$$x_i + p_i s_i + q_i(1 - s_i) \le x_j + \overline{x}(1 - u_{i,j} + v_{i,j}) \text{ for } i, j = 1, ..., n \text{ and } i < j, \quad (9)$$

$$y_j + q_j s_j + p_j(1 - s_j) \le y_i + \overline{y}(1 + u_{i,j} - v_{i,j}) \text{ for } i, j = 1, ..., n \text{ and } i < j, \quad (10)$$

$$y_i + q_i s_i + p_i(1 - s_i) \le y_j + \overline{y}(2 - u_{i,j} - v_{i,j}) \text{ for } i, j = 1, ..., n \text{ and } i < j, \quad (11)$$

where $u_{i,j}, v_{i,j}$, and s_i are binary variables; x_i and y_i are nonnegative continuous variables; and Constraints (8)–(11) ensure that the rectangular items are non-overlapping.

Remark 2. Original (b) uses n^2 binary variables $(u_{i,j}, v_{i,j})$ and $2n^2$ constraints to formulate an assortment problem with n rectangular items.

However, these two models are inappropriate for directly solving the general 2DCSP because the objective of the 2DCSP must minimize the number of materials used for cutting all items. By referring to the two models above, two corresponding 2DCSP models are proposed in Section 2.2.

2.2 General deterministic models of 2DCSP

As mentioned above, we need to find out the minimal number of materials used for cutting all items. Original (a) is then reformulated as a general deterministic model of 2DCSP, where cutting n rectangular items from m materials, as shown in P1 (a):

P1 (a)

Min Y

s.t. (1), (2) and (5) in Original (a),

$$y_j + q_j s_j + p_j(1 - s_j) \le y_i + m\bar{y}(1 - c_{i,j}) \text{ for } i, j = 1, ..., n \text{ and } i < j, \tag{12}$$

$$y_i + q_i s_i + p_i(1 - s_i) \le y_j + m\bar{y}(1 - d_{i,j}) \text{ for } i, j = 1, ..., n \text{ and } i < j, \tag{13}$$

$$x_i + p_i s_i + q_i(1 - s_i) \le \bar{x} \text{ for } i = 1, ..., n, \tag{14}$$

$$y_i + q_i s_i + p_i(1 - s_i) \le \sum_{k=1}^{m} k\bar{y} Q_{i,k} \text{ for } i = 1, ..., n, \tag{15}$$

$$y_i \ge \sum_{k=1}^{m} (k-1)\bar{y} Q_{i,k} \text{ for } i = 1, ..., n, \tag{16}$$

$$\sum_{k=1}^{m} Q_{i,k} = 1 \text{ for } i = 1, ..., n, \tag{17}$$

$$y_i + q_i s_i + p_i(1 - s_i) \le Y \text{ for } i = 1, ..., n, \tag{18}$$

where $s_i, a_{i,j}, b_{i,j}, c_{i,j}, d_{i,j}$, and $Q_{i,k}$ are binary variables; x_i, y_i and Y are nonnegative continuous variables; Constraints (1), (2), (5), (12) and (13) ensure that the rectangular items are non-overlapping; Constraints (15)–(17) mean that each rectangular item is fitly cut from one of the m materials; Constraint (18) obtains the accumulated length of materials used; and the objective function minimizes the accumulated length of materials used.

There are nm new binary variables (i.e., $Q_{i,k}$ for $i = 1, 2, ..., n$ and $k = 1, 2, ..., m$) in Constraints (15)–(17) of P1 (a) model. It aims to cut the ith rectangular item from the kth material if $Q_{i,k} = 1$, and Constraint (17) forces any rectangular item to be cut from one of such materials. Supposing that rectangular item i' is cut from the k'th material, then $Q_{i',k'} = 1$ and $Q_{i',k} = 0$ for $k \ne k'$ and $k = 1, 2, ..., m$. Constraints (15)–(17) will force the y-axis position of rectangular item i' cut from the k'th material as shown below:

$$y_{i'} + q_{i'} s_{i'} + p_{i'}(1 - s_{i'}) \le k'\bar{y}, \tag{19}$$

$$(k' - 1)\bar{y} \le y_{i'}. \tag{20}$$

Remark 3. P1 (a) requires $2n^2 - n(1 - m)$ binary variables and $(5n^2 + 3n)/2$ constraints to form a 2DCSP program.

Referring to the Original (b), another corresponding 2DCSP program can be formulated as follows:

P1 (b)

Min Y

s.t. (8), (9), (14)–(18),

$$y_j + q_j s_j + p_j(1 - s_j) \le y_i + m\bar{y}(1 + u_{i,j} - v_{i,j}) \text{ for } i, j = 1, ..., n \text{ and } i < j, \tag{21}$$

$$y_i + q_i s_i + p_i(1 - s_i) \le y_j + m\overline{y}\left(2 - u_{i,j} - v_{i,j}\right) \text{ for } i, j = 1, ..., n \text{ and } i < j, \qquad (22)$$

where $s_i, u_{i,j}, v_{i,j}$, and $Q_{i,k}$ are binary variables and x_i, y_i, and Y are nonnegative continuous variables.

Remark 4. P1 (b) requires $n^2 + nm$ binary variables and $2n(n+1)$ constraints to formulate a 2DCSP program.

Although both P1 (a) and P1 (b) can obtain a minimal number of materials used, there is mainly an issue needed to be addressed. That is, an excessive number of binary variables $Q_{i,k}$ is used to assign rectangular item i into one of the materials; such that the computational load becomes a serious burden as the size of the problem grows.

As indicated by Li et al. [39], reducing the number of binary variables can accelerate the solving speed. Hence, we can roughly estimate the number of materials by the following remark.

Remark 5. The number of materials can be reduced from m to f where $f \le m$ by the following initial calculating:

$$f \cong \lceil \sum_{i=1}^{n} x_i y_i / \overline{x} \times \overline{y} \rceil, \qquad (23)$$

where if f value is not big enough, i.e., in solving P1(a) and P1(b) are infeasible, then we can accumulate f, i.e., $f = f + 1$, until feasible solutions exist.

By referring to Remark 5, the number of binary variables in Constraints (15)–(18) can be reduced from nm to nf where $f \le m$. Moreover, this study proposes a reformulation technique using logarithmic number of binary variables for the P1 (a) and P1 (b) models. The detail of technique is then discussed in Section 3.

3. Logarithmic reformulation technique of 2DCSP

After considering Remark 5, for a 2DCSP with n rectangular items and f materials, the P1 (a) and P1 (b) models will require nf binary variables ($Q_{i,k}$) to cut each rectangular item from one of the materials. The computational efficiency of the P1 (a) and P1 (b) models become a serious burden when an increasing size of the 2DCSP. For any rectangular item i, Constraint (17) ($\sum_{k=1}^{f} Q_{i,k} = 1$) is an SOS1 constraint [40], which is an ordered set of variables where only one variable may be one. An SOS1 constraint model with size f will generally require f binary variables. However, Vielma and Nemhauser [41] use SOS1 constraint with a logarithmic number of binary variables and constraints. This section utilizes the concept of Vielma and Nemhauser [41] and introduces the binary variables $Q_{i,r}$ ($i = 1, ..., n$ and $r = 1, ..., \lceil \log_2 f \rceil$) to replace the original binary variables ($Q_{i,k}$) of the P1 (a) and P1 (b) models. Thus, the number of required binary variables can be reduced from nf to $n\lceil \log_2 f \rceil$. The following remarks and propositions discuss the logarithmic reformulation technique of the 2DCSP.

Remark 6. Let $K = \{1, 2, ..., f = 2^\theta\}$, $\theta = \lceil \log_2 f \rceil$, and $k \in K$ be the injective function for $B : \{1, 2, ..., 2^\theta\} \to \{0, 1\}^\theta$, which can be expressed as follows:

$$B(k) = [w_1, w_2, ..., w_\theta]^T \text{ and } w_r = 1 - \left(\lceil \frac{k}{2^{r-1}} \rceil \% 2 \right) \text{ for } r = 1, ..., \theta. \qquad (24)$$

Proposition 1. Let $K = \{1, ..., f\}$, $\theta = \lceil \log_2 f \rceil$ and $k \in K$; the original SOS1 Constraint in (25) which requires f binary variables (Q_k) can be replaced by the Constraint set (26) and (27):

$$\sum_{k=1}^{f} Q_k = 1 \text{ and } Q_k \in \{0,1\}. \tag{25}$$

The Constraint set (25) and (26) only requires θ binary variables (Q_r), 2θ additional constraints, and f additional continuous variables (λ_k):

$$\sum_{k=1}^{f} \lambda_k = 1, \tag{26}$$

$$\sum_{k \in S^+(r)} \lambda_k = Q_r \text{ for } r = 1, ..., \theta, \tag{27}$$

where

i. $Q_r \in \{0,1\}$.

ii. $B(k)$ is an injective function based on Remark 6 (i.e., $B(k) = [w_1, w_2, ..., w_\theta]^T$ with $w_r \in \{0,1\}$ for $r = 1, ..., \theta$).

iii. $S^+(r) = \{k \in K | \forall B(k) \text{ where } w_r = 1\}$ and $S^-(r) = \{k \in K | \forall B(k) \text{ where } w_r = 0\}$.

Proof: Following Li et al. [39], Constraints (26) and (27) are used to construct the SOS1 property.

Following Proposition 1, we then have Proposition 2 that uses $\lceil \log_2 f \rceil$ binary variables to determine whether rectangular item i could be exactly cut from one of the given materials.

Proposition 2. Let f be the number of materials, $\bar{y}$ the length of material, and y_i the y-axis position of rectangular item i. The original Constraint set (15)–(17) of the P1 (a) and P1 (b) models will be re-expressed by the following linear system, which holds the rectangular item i to be cut from one of the given materials:

$$y_i + q_i s_i + p_i(1 - s_i) \le \sum_{k=1}^{f} k\bar{y}\lambda_{i,k} \text{ for } i = 1, ..., n, \tag{28}$$

$$y_i \ge \sum_{k=1}^{f} (k-1)\bar{y}\lambda_{i,k} \text{ for } i = 1, ..., n, \tag{29}$$

$$\sum_{k=1}^{f} \lambda_{i,k} = 1 \text{ for } i = 1, ..., n, \tag{30}$$

$$\sum_{k \in S^+(r)} \lambda_{i,k} = Q_{i,r} \text{ for } i = 1, ..., n \text{ and } r = 1, ..., \theta = \lceil \log_2 f \rceil, \tag{31}$$

where $S^+(r)$ and $S^-(r)$ are the same as the notations in Proposition 1 and $s_i, Q_{i,r} \in \{0,1\}$.

Proof: According to Proposition 1, the continuous variables $\lambda_{i,k}$ with the Constraint set (30) and (31) have the characteristics of binary variables. Therefore, the Constraint set (28)–(30) is equivalent to the Constraint set (15)–(17).

Two types of 2DCSP models are formulated by utilizing Proposition 2 as the following P2 (a) and P2 (b), respectively:

Items	P1(a)	P1(b)	P2(a)	P2(b)
Concept of non-overlapping	Chen et al. [32]	Li and Chang [34]	Chen et al. [32]	Li and Chang [34]
Constraints for assigning rectangular items into materials	$\sum_{k=1}^{f} Q_{i,k} = 1$	$\sum_{k=1}^{f} Q_{i,k} = 1$	Proposition 2	Proposition 2
No. of binary variables	$2n^2 - n(1-f)$	$n^2 + nf$	$n(2n+\theta-1)$	$n(n+\theta)$
No. of continuous variables	$2n+1$	$2n+1$	$2n+nf+1$	$2n+nf+1$
No. of constraints	$(5n^2+5n)/2$	$2n^2+3n$	$n(5n+10)+4\theta$	$n(2n+2\theta+3)$
where $\theta = \lceil \log_2 f \rceil$				

Table 4.
Comparison of the four ways of expressing the 2DCSP.

P2 (a)

Min Y

s.t. (1), (2), (5), (12)–(14), (18) and (28)–(31),

where $Y, x_i, y_i, \lambda_{i,k} \geq 0$ and $a_{i,j}, b_{i,j}, c_{i,j}, d_{i,j}, s_i, Q_{i,r} \in \{0,1\}$ for $i, j = 1, ..., n, i < j$, $k = 1, ..., f$, and $r = 1, 2, ... \lceil \log_2 f \rceil$.

Remark 7. P2 (a) requires $n\left(2n + \lceil \log_2 f \rceil - 1\right)$ binary variables and $5n^2 + 10n + \lceil \log_2 f \rceil$ constraints to express a 2DCSP model.

P2 (b)

Min Y

s.t.(8), (9), (14), (18), (28)–(31),

where $Y, x_i, y_i, \lambda_{i,k} \geq 0$ and $s_i, u_{i,j}, v_{i,j}, Q_{i,r} \in \{0,1\}$ for $i, j = 1, ..., n, i < j, k = 1, ..., f$ and $r = 1, ..., \lceil \log_2 f \rceil$.

Remark 8. P2 (b) requires $n\left(n + \lceil \log_2 f \rceil\right)$ binary variables and $n\left(2n + 2\lceil \log_2 f \rceil + 3\right)$ constraints to express another 2DCSP model.

Table 4 shows a comparison of the four ways of expressing the 2DCSP, and it clearly lists the number of binary variables, auxiliary continuous variables, and constraints.

4. Numerical examples

There are two examples modified from Tsai et al. [38]. The detail sizes of rectangular items and materials are listed in **Table 5**. We implement a Java program, which embedded an optimization package GUROBI (2011) as an MIP solver

Problem	Size of material	Qty. of items	f	Size of items (p_i, q_i)
1	(40, 69)	8	2	(25, 20), (16, 20), (15, 20), (14, 20), (20, 18), (15, 17), (30, 16), (30, 14)
2	(25, 150)	12	2	(32, 24), (26, 20), (25, 20), (24, 20), (40, 18), (35, 17), (20, 16), (18, 16), (38, 15), (50, 15), (18, 4), (25, 5)

Table 5.
Sizes of rectangular items and materials.

Items		P1 (a)	P1 (b)	P2 (a)	P2 (b)
Problem 2 Y = 83	No. of 0–1 variables	136	80	128	72
	No. of cont. variables	17	17	33	33
	No. of constraints	180	152	404	168
	Iterations	621,821	686,982	263,296	293,432
	Nodes	176,776	211,564	70,154	111,173
	Solving time	18.8	18.0	7.5	9.1
Problem 2 Objective = 293	No. of 0–1 variables	300	168	288	156
	No. of cont. variables	25	25	49	49
	No. of constraints	390	324	844	348
	Iterations	31,166,357	1,017,922	1,114,911	805,136
	Nodes	9,766,654	244,444	266,672	229,701
	Solving time	856.5	24.5	34.9	19.4

Table 6.
Experiment results of two problems.

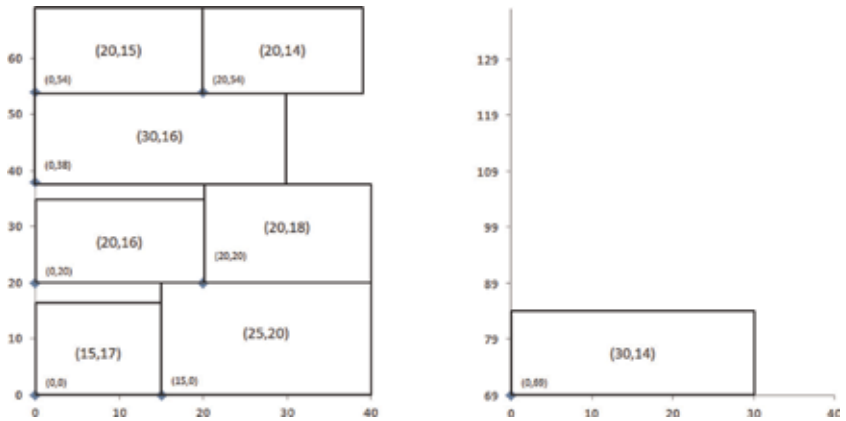


Figure 1.
Visualization result of Example 1.

for solving the two examples with the four proposed models (P1 (a), P1 (b), P2 (a), P2 (b)). The experimental tests were run on a PC equipped with an Intel® Core™ 2 Duo CPU, 4GB RAM, and 32 bit Windows 7 operating system.

The two problems with the number of materials firstly estimated to be 2 (i.e., $f = 2$) are solved by using the four models including P1(a), P1(b), P2(a), and P2 (b). **Table 6** shows the experiment results of two problems. Both of **Figures 1** and **2** depict the visualization solutions. In solving four models, we obtain the same objective values of (83) and (293) in Problem 1 and Problem 2, respectively. The results clearly indicate that solving P2(a) and P2(b) is much more computationally efficient than that of P1(a) and P1(b). By observing the four models, we know that both P2(a) and P2(b) use proposed approach to reduce the numbers of binary variables. The results demonstrate that the adoption of a smaller number of binary variables can enhance the solving efficiency in solving 2DCSP.

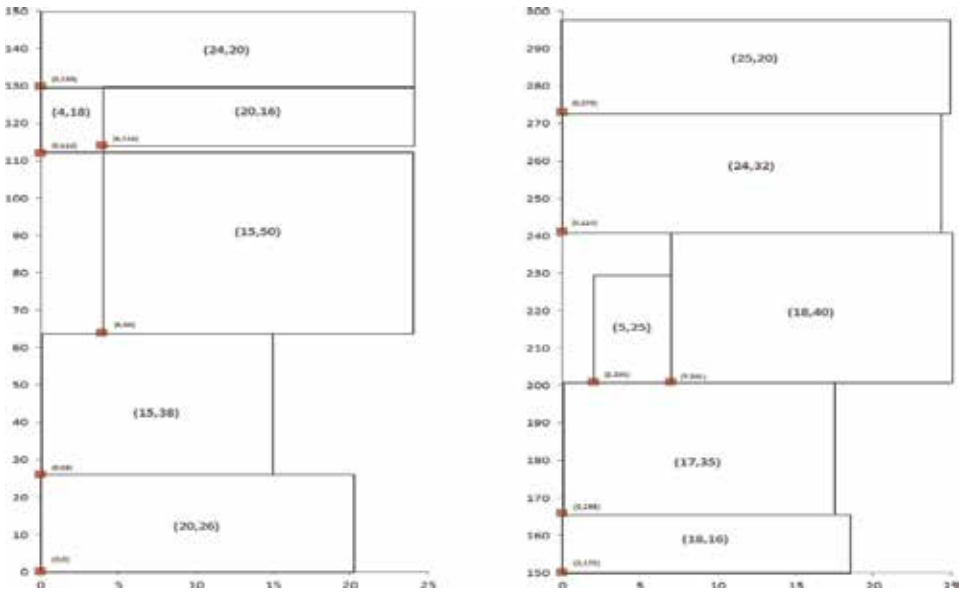


Figure 2.
Visualization result of Example 2.

5. Conclusions

This study develops a logarithmic reformulation technique for reducing the required binary variables of the mixed integer program for two-dimensional cutting stock problem in the manufacturing industry. A reformulated logarithmic technique in the deterministic method reduces the number of binary variables to speed up the solving time. The deterministic methods are guaranteed to find a global optimal solution, but the computational complexity grows rapidly by increasing the number of variables and constraints. Future studies are suggested to enhance the computational efficiency for globally solving large-scale 2DCSP, such as column generation, cloud computing and meta-heuristic algorithms.

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Chapter 11

Selection of Food Items for Diet Problem Using a Multi-objective Approach under Uncertainty

Saman Hassanzadeh Amin, Samantha Mulligan-Gow and Guoqing Zhang

Abstract

It is a problem that concerns us all: what should we eat on a day-to-day basis to meet our health goals? Scientists have been utilizing mathematical programming to answer this question. Through the use of operations research techniques, it is possible to find a list of foods that, in a certain quantity, can provide all nutrient recommendations in a day. In this research, a multi-objective programming model is provided to determine the selected food items for a diet problem. Two solution approaches are developed to solve this problem including weighted-sums and ε-constraint methods. Two sources of uncertainty have been considered in the model. To handle these sources, a scenario-based approach is utilized. The application of this model is shown using a case study in Canada. Using the proposed model and the solution approaches, the best food items can be selected and purchased to minimize the total cost and maximize health.

Keywords: food optimization, diet, nutrition, multi-objective programming, uncertainty

1. Introduction

It is common knowledge that diet affects general health in extraordinary ways. What is less clear is what specific diet results in the best health. Some diets restrict the quantity of carbohydrates or fats, others require particular percentages of the three macronutrients (carbohydrates, fats, and protein), some depend solely on liquids, and the list continues [1–5]. There are unlimited amounts of unique diets being used today by people all over the world, especially since countless health trends have become the new normal. One thing that can be agreed upon is the recommended dietary allowances (RDA), given by the federal government of Canada, which presents the quantity of vitamins and nutrients needed to meet requirements. So it is important to determine the combination of the seemingly infinite food items that reaches nutrient goals in the most efficient manner.

The diet problem was first introduced by Stigler [6] as a way to determine the minimum cost of feeding an adult for a year. Many models have since explored diet optimization with the objectives of reaching recommended nutrient levels while keeping the diets similar to actual intakes, decreasing environmental impact, or satisfying taste. There are numerous models that can be used to create unique diets

based on the main target criteria. These models include linear and nonlinear, multi-objective, goal-oriented, integer, and mixed-integer programming. Each yields specific results due to the mathematical basis.

2. Literature review

In this section, some related papers are discussed, classified on the subject of the model's goal. Most research of the diet problem is centered on at least one of the following targets: cost of diet, similarity of diet, environmental sustainability of diet, prevention of health implications by diet, and taste/satisfaction of diet.

2.1 Cost of diet

The first diet problem [6] focused on minimizing the cost of food. The author showed that to feed one man for a year can cost as little as $39.93 (1939 prices). Certainly, lowering the grocery bill is a desire for all and this type of objective is quite common to this day. One paper discusses whether it is too expensive to follow a healthy diet, comparing 2012 and 1980 costs [7]. Stigler's problem was reinvented with updated costs and nutritional information in 1999 [8] and taste of diet was included in the cost minimization by Smith [9].

In recent years, further papers focused on more specific problem statements and how they are affected by expense. In Mozambique, the affordability of a nutritious meal plan was studied and fortified foods were assessed with the hopes of creating more economic value [10]. Specific diets have also been studied to determine whether they can be accomplished in a cost-effective manner [11]. To attempt a solution of high-cost food, James David Ward studied urban agriculture and how it could reduce grocery expenses [12].

2.2 Sustainability of diet

Considering that livestock production is a major contributor to greenhouse gas emissions, worldwide [13], the question of nutritional sustainability has been asked and answered. Multi-objective linear programming was used to formulate three unique diets that minimized cost, environmental indicators (H_2O use, amount of land to regenerate the resources, and CO_2 emissions), and the integration of the two [13]. Another study was completed in which the optimal diet was to be as similar to the general, observed diet [14]. This chapter noted that a sustainable diet reduces greenhouse gas emissions by 27% [14]. Mathematical programming was also used to study which food sources contributed least to environmental footprints such as land use, carbon and nitrogen footprints [15]. Barre et al. [16] found diets by using – on the reduction percentage of environmental impacts being at least 30%. It was concluded that all diets required a decrease in meat consumption to meet the sustainability factors [16]. The cost of feeding cattle was found to increase (by as much as 48.5%) in a hypothetical scenario where there was either a tax on greenhouse gas emissions or a constraint on methane emissions applied [17].

2.3 Disease prevention of diet

It is commonly known that what you eat affects your health. Studies have been conducted to explain how diets can reduce your risk of certain health risks and concerns. Observed diets and those recommended by the World Cancer Fund and the American Institute of Cancer Research were compared by Masset et al. [18].

Furthermore, obesity and its relation to dietary intake has been a frequent topic of interest. Silva et al. [19] presented the possibility of a diet that constricts amount of calories by increasing the quantity of proteins eaten in a day, which will then create the opportunity for weight loss.

2.4 Similarity of diet

In many papers, one of the objectives (usually secondary) is to minimize the difference between the proposed diet and the current, observed diet of a group of people being studied [16, 20–23]. This is done for many reasons: to ensure palatability, ease of acceptance, and culturally appropriate solutions. This focus is often the backbone of the programming calculation as it guarantees a certain level of logic and reality.

In **Table 1**, related papers are organized by which mathematical programming approach was utilized. Linear programming (LP) is used for optimizing (maximizing or minimizing) a linear function of many variables [24], while nonlinear programming (NLP) does the same when there is(are) one or more nonlinear functions in the problem [25, 26]. For computing problems with multiple objectives, goal programming (GP) is often used [27]. This technique is popular in recent diet studies due to its potential ability to achieve a more realistic food balance [28]. Linear programming has been seen in **Table 1** as the most commonly used technique for diet problems, including a paper done to disavow goal programming [29].

Publication	LP	NLP	GP	MOP	Un	Final Diet	Nutrients	Model Only
[9]	✓					✓		
[32]	✓					✓		
[33]	✓					✓		
[34]				✓		✓		
[8]	✓					✓	✓	
[20]								
[21]	✓							
[10]	✓		✓			✓	✓	
[11]	✓					✓	✓	
[18]	✓							✓
[35]	✓					✓	✓	
[22]				✓	✓			✓
[10]	✓					✓		
[17]	✓							
[15]	✓		✓				✓	
[7]	✓		✓					✓
[13]			✓					
[23]	✓					✓		
[12]	✓							
[13]	✓			✓				
[14]	✓					✓		✓
[19]				✓		✓	✓	
[16]	✓	✓						
Our paper	✓			✓	✓	✓		

Goal Programming (GP); Linear Programming (LP); Multi-Objective Programming (MOP); Non-Linear Programming (NLP); Uncertainty (Un).

Table 1.
Review of some related papers and their operations research techniques [32–34].

Multi-objective programming (MOP) is used when there are multiple, competing objectives that result in more than one optimal solution [30]. With uncertain environments, fuzzy set theory (FST) and some specific techniques can be applied so that qualitative statements can be described numerically without losing precision [31].

Included in **Table 1** is the format of the results in each respective paper. Some papers explicitly create day-to-day diets, including exact foods and their quantities. We call them "Final Diet." Other papers note the nutrients that their proposed model offers if created into a diet. These are called "Nutrients" in **Table 1**. Other papers only present the model that is used to create a diet without stating which foods should be chosen. In these papers, no specific food intake is specified, rather only the math is presented.

2.5 Research gaps

There are some gaps in the literature of diet problems. There are a few papers in the literature that have considered multiple objectives in diet problems. Among them, most publications have focused on two objectives. Therefore, the research gap can be filled by considering more than two objectives. The other point is related to the availability of data. In recent years, companies have been forces to provide nutritional information for the packages and products. Therefore, a lot of useful information is available that is new and valuable in this field. Case studies can be conducted based on the available information. The other gap in the literature is about the uncertainty of the parameters in diet problems. Most of the papers in this area have ignored uncertain parameters and their effects on the results.

2.6 Research contributions

The main research contributions of this paper are defined in this section.

- A novel optimization model is provided to determine personal food selection.
- Multiple objectives are considered in the mathematical model. To our knowledge, these objectives have not been considered simultaneously in the other papers in the literature.
- The mathematical formulation is solved by two solution approaches including weighted-sums and ε-constraint approaches. As a result, the efficient solutions are obtained.
- Uncertainty in the parameters is considered using an effective scenario-based solution approach. Different combinations of the scenarios are analyzed in this paper.
- The application of the model is shown using real data and a case study in Canada.

3. Problem statement

As discussed previously, the optimization of diets is a continuously important problem since we all eat every day. What is more, the food costs money and affects our health and well-being. Some diseases related to obesity (e.g., cardiovascular and

diabetes) have significant impacts in Canada. Some factors of diets such as sugars, sodium, and fat play important roles on health of people. A study done by Hajizadeh et al. [35] found that body mass index, an indicator of obesity, is negatively related to household income (and fruit and vegetable consumption). Families across Canada suffer from food poverty: the inability to purchase healthy, nutritious food for their loved ones [36]. There are people who have to make the difficult decision to either pay rent, or buy groceries. These people should be able to know that what money they put toward food is being used in the most efficient way possible. On the other hand, if food can be used to combat major health concerns within our population, this information should be taken advantage of. Obesity is an extensive issue in all regions of Canada and the major contributor is nutrition [35].

The government of Canada provides health and nutrition information online. The federal government has also created legislation that ensures all food items show a nutrition facts table on the packaging. This information covers facts on recommended macronutrients and micronutrients. Carbohydrates give the body energy and are separated into three categories: starch, fiber, and sugars [36]. Fat is a macronutrient that also provides energy to the body as well as helps digest essential vitamins. Fats are categorized into trans, saturated, and unsaturated but only trans and saturated are needed on nutrition facts tables as they are the fats that increase blood cholesterol level [36].

Cholesterol is a type of fat that is produced by the body but can also be consumed through food. High levels of cholesterol can increase risk of developing heart disease. Only animal-based foods contain cholesterol. Protein is the third macronutrient which helps tissues and muscles build recover from strain and as well as provide energy [36]. Sodium is a nutrient that is prevalent in our society due to our use of salt to preserve food, which raises blood pressure, increasing the risk of stroke, heart and kidney diseases. Calcium is a mineral found in our bones but can also be eaten in order to strengthen our bones and help our muscles work [36]. Another mineral, iron, helps produce red blood cells and helps carry oxygen through the body. Some important vitamins the government emphasizes are vitamins A and C [36]. Vitamin A maintains healthy skin and normal bone growth. Vitamin C facilitates the absorption of iron, is an antioxidant, and helps heal wounds [36].

Another resource from the Government of Canada is the recommended number of food guide servings per day [37]. They have created a table that presents the number of servings needed of each food group for all ages and genders of the Canadian population. The four food groups are: vegetables and fruit (VG), grain products (GP), milk and alternatives (MA), and meat and alternatives (ME). The ages of population categories are split into 2–3, 4–8, 9–12, 14–18, 19–50, and 51 and over [37].

In this problem, selected food items should be determined (to be purchased) according to some constraints and goals. There are four goals in this diet problem based on the available information for foods in Canada. They allow the cost of the food to be minimized while decreasing the trans/saturated fats and sugar, and maximizing the amount of fiber. This combination of objectives aims to limit nutrients that are harmful to the human body, as noted above. The diet will be based on the consumption of the chosen foods for 1-month period. Since nutrition guidelines vary based on age, the chosen population group for this study is 51 and older. This group was chosen due to the aging population of Canada.

Figure 1 shows an example of nutrition facts table. In addition, examples of four food groups (vegetables and fruit (VF), grain products (GP), milk and alternatives (MA), meat and alternatives (EA)) are illustrated in **Figure 2**.

Nutrition Facts

Per 9 crackers (23 g)

Amount			% Daily Value
Calories 90			
Fat 4.5 g			**7** %
Saturated 2.5 g + Trans 0 g			**13** %
Cholesterol 0 mg			
Sodium 280 mg			**12** %
Carbohydrate 12 g			**4** %
Fibre 1 g			**4** %
Sugars 0 g			
Protein 3 g			
Vitamin A	0 %	Vitamin C	0 %
Calcium	2 %	Iron	8 %

Figure 1.
An example of nutrition facts table [38].

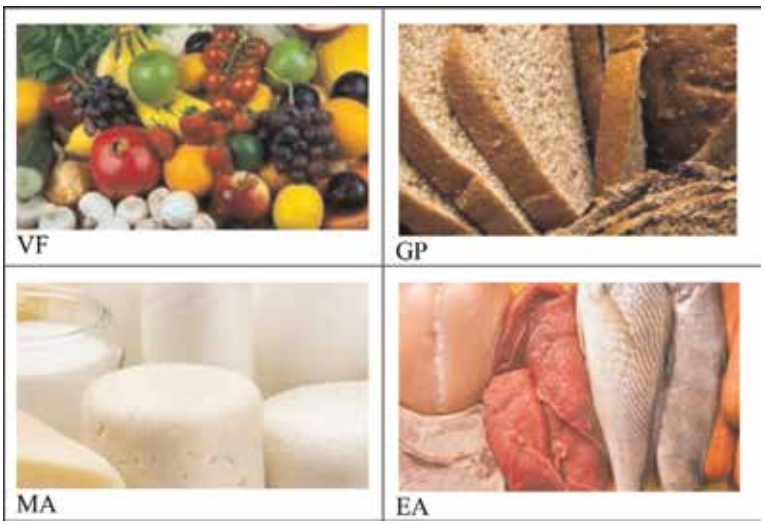

Figure 2.
Examples of four food groups (vegetables and fruit (VF), grain products (GP), milk and alternatives (MA), meat and alternatives (EA)).

4. Optimization model

In this section, a multi-objective programming formulation is proposed to determine the numbers of the foods that should be consumed. The definitions of sets, parameters, and decision variables are provided in this section.

Sets

i = Type of food (1, 2, ..., I).
h = Food group (1, 2, ..., H).

t = Period (1, 2, ..., T).
j = Vitamin (1, 2, ..., J).

Parameters

a_{ih} = Size of food i in food group h.
A_{iht} = Cost of food i in food group h and period t.
B_t = Minimum total calories in period t.
C_{ih} = Calories of food i (in each unit) in food group h.
D_t = Maximum total calories in period t.
E_{jt} = Minimum total vitamin j in period t.
F_{jih} = Vitamin j in food i (in each unit) and food group h.
G_{jt} = Maximum total vitamin j in period t.
K_{ih} = Saturated and trans fats of food i (in each unit) in food group h.
L_{ih} = Sugar of food i (in each unit) in food group h.
M_{ih} = Fiber of food i (in each unit) in food group h.
O_t = Minimum total cholesterol in period t.
P_{ih} = Cholesterol of food i (in each unit) in food group h.
Q_t = Maximum total cholesterol in period t.
R_t = Minimum total sodium in period t.
S_{ih} = Sodium of food i (in each unit) in food group h.
V_t = Maximum total sodium in period t.
X_t = Minimum total protein in period t.
Y_{ih} = Protein of food i (in each unit) in food group h.
Z_t = Maximum total protein in period t.
β_t = Minimum total calcium in period t.
λ_{ih} = Calcium of food i (in each unit) in food group h.
α_t = Maximum total calcium in period t.
ρ_t = Minimum total iron in period t.
γ_{ih} = Iron of food i (in each unit) in food group h.
σ_t = Maximum total iron in period t.
ψ_{ht} = Amount of food guide servings per month in food group h in period t.

Decision Variables

N_{iht} = Number of food i in food group h and period t.

$$\text{Min } z_1 = \sum_t \sum_h \sum_i A_{iht} N_{iht} \tag{1}$$

$$\text{Min } z_2 = \sum_t \sum_h \sum_i a_{ih} K_{ih} N_{iht} \tag{2}$$

$$\text{Min } z_3 = \sum_t \sum_h \sum_i a_{ih} L_{ih} N_{iht} \tag{3}$$

$$\text{Max } z_4 = \sum_t \sum_h \sum_i a_{ih} M_{ih} N_{iht} \tag{4}$$

s.t.

$$B_t \le \sum_h \sum_i a_{ih} C_{ih} N_{iht} \le D_t \qquad \forall t \tag{5}$$

$$E_{jt} \le \sum_h \sum_i a_{ih} F_{jih} N_{iht} \le G_{jt} \qquad \forall j, t \tag{6}$$

$$O_t \le \sum_h \sum_i a_{ih} P_{ih} N_{iht} \le Q_t \qquad \forall t \qquad (7)$$

$$R_t \le \sum_h \sum_i a_{ih} S_{ih} N_{iht} \le V_t \qquad \forall t \qquad (8)$$

$$X_t \le \sum_h \sum_i a_{ih} Y_{ih} N_{iht} \le Z_t \qquad \forall t \qquad (9)$$

$$\beta_t \le \sum_h \sum_i a_{ih} \lambda_{ih} N_{iht} \le \alpha_t \qquad \forall t \qquad (10)$$

$$\rho_t \le \sum_h \sum_i a_{ih} \gamma_{ih} N_{iht} \le \sigma_t \qquad \forall t \qquad (11)$$

$$\sum_i a_{ih} N_{iht} = \psi_{ht} \qquad \forall h, t \qquad (12)$$

$$N_{iht} \ge 0 \qquad \forall i, h, t \qquad (13)$$

The total cost of the foods is minimized in the first objective function. The second objective minimizes saturated and trans fats in the foods. In addition, the third objective minimizes the sugar of the foods. Besides, the fourth objective function maximizes the fiber of the foods.

Constraint (5) is related to the minimum and the maximum required calories in the foods. Constraint (6) is about the vitamins in the foods. In addition, constraints (7)–(11) are about the minimum and the maximum values of cholesterol, sodium, protein, calcium, and iron in the diet, respectively. Constraint (12) considers the recommended amount of food guide servings. Finally, the last constraint ensures that the variables are nonnegative.

5. Solution approach

In this section, a solution approach counting weighted-sums method and ε-constraint method is described. The main goal is to convert the multi-objective model to a single objective one.

5.1 Weighted-sums method

In this technique, a weight is assigned to each objective function. Then, the objective functions are combined to build a single objective function [39–45]. Suppose that the weight of objective function w is W_w. Thus, W_1, W_2, W_3, and W_4 should be determined in this problem. The summation of the weights is one. The weights represent the importance of the objectives for the decision-makers. The proposed optimization model is converted to the following optimization formulation using the weighted-sums method.

$$Miz \; z_5 = W_1 z_1 + W_2 z_2 + W_3 z_3 - W_4 z_4 \qquad (14)$$

$$s.t. \quad \sum_w W_w = 1 \qquad (15)$$

Constraints (1)–(15).

5.2 ε-constraint method

In ε-constraint technique, the most prominent objective among others is chosen as the primary objective function. Other objective functions are considered as constraints of the optimization model [46–50]. The first objective function is the most important one in this model. Therefore, it is selected as the main objective function. Three constraints are added to the mathematical model [constraints (17)–(19)]. It is noticeable that the signs of the inequalities are related to the types of the objective functions (minimization or maximization).

$$Miz \ \ z_6 = z_1 \tag{16}$$

$$s.t. \quad z_2 \le \varepsilon_2 \tag{17}$$

$$z_3 \le \varepsilon_3 \tag{18}$$

$$z_4 \ge \varepsilon_4 \tag{19}$$

Constrains (5)–(13)

6. Results of the case study

Four types of foods are considered in four food groups including vegetables and fruit, grain products, milk and alternatives, and meat and alternatives. The recommended number and amount of food guided servings in a month are provided in **Table 2**. This table is based on the information in Food-guide-basics, 2018. We focus on 51+ year-old females in this case. The last column of the table shows 50% of the required amount of food. It is supposed that the other 50% nutrition is supplied by other sources. Two periods (months) are considered in this case study. Two types of vitamins including vitamin A and vitamin C are taken into account because information about them is provided in nutrition facts tables of the products in Canada. Mentioning the values of other vitamins in the tables is optional for Canadian food producers. The other data of the case are provided in Appendix A.

In this research, the General Algebraic Modeling System (GAMS) software is employed to write the codes and find the solutions. First, different weights are devoted to the objective functions and the problem is solved. Each solution of the multi-objective model is called efficient solution. Efficient solutions cannot be improved without scarifying other objective functions [46, 51–56]. The results have been collected in **Table 3**. As it can be seen, the weights are assigned between 0 and 1. The efficient solutions are presented to the decision-makers. The second part of

Food group	Examples of one food guide serving	Number of food servings	Amount of food servings	50% of the amount
Vegetables and fruit (VF)	125 mL (½ cup) fresh, frozen or canned vegetable or fruit or 100% juice	210	26,250 ml	13,125 ml
Grain products (GP)	1 slice (35 g) bread or ½ bagel (45 g)	180	6,300 g	3,150 g
Milk and alternatives (MA)	250 mL (1 cup) milk or fortified soy beverage	90	22,500 mg	11,250 mg
Meat and alternatives (EA)	75 g (2 ½ oz.)/125 mL (½ cup) cooked fish, shellfish, poultry or lean meat	60	4,500 g	2,250 g

Table 2.
Recommended number and amount of food guided servings in a month for 51+ year-old females.

a) Weighted-sums method				
(w_1, w_2, w_3, w_4)	z_1	z_2	z_3	z_4
(0.7, 0.1, 0.1, 0.1)	147.197	372.000	3,957.000	588.000
(0.25, 0.25, 0.25, 0.25)	288.572	228.000	3,642.000	588.000
(0.1, 0.2, 0.5, 0.2)	297.812	181.059	3,464.118	148.235
(0.9, 0.025, 0.025, 0.05)	106.997	372.000	4,587.000	588.000
b) ε-constraint method				
$(\varepsilon_2, \varepsilon_3, \varepsilon_4)$	z_1	z_2	z_3	z_4
(1,820, 34,900, 586)	98.436	835.500	4,587.000	588.000

Table 3.
The efficient solutions.

Table 3 includes the results of ε-constraint method. The main objective function is about the cost objective. Based on the information in **Table 3**, more efficient solutions have been obtained in weighted-sums method. Consequently, this method is selected to solve the mathematical model.

One of the efficient solutions in **Table 3** has been obtained by considering equal weights (w_1 = 0.25, w_2 = 0.25, w_3 = 0.25, and w_4 = 0.25). The values of the decision variables related to this solution are as follows: $N_{1.3.1}$ = 11.250, $N_{1.3.2}$ = 11.250, $N_{2.2.1}$ = 4.667, $N_{2.2.2}$ = 4.667, $N_{3.4.1}$ = 3.775, $N_{3.4.2}$ = 3.775, $N_{4.1.1}$ = 7.500, and $N_{4.1.2}$ = 7.500. In other words, Food 1 in Group 3 in Periods 1 and 2, Food 2 in Group 2 in Periods 1 and 2, Food 3 in Group 4 in Periods 1 and 2, and Food 4 in Group 1 in Periods 1 and 2 should be purchased to have optimal solution.

7. The optimization model under uncertainty

In reality, several parameters are uncertain. In this section, the effects of uncertainty in two parameters including cost of foods and amount of food guide servings per month are examined in the mathematical model. These two parameters are very important factors of food items. Suppose that u represents a scenario among U scenarios. The decision variables (nonnegative variables in this case) are written based on each scenario [39]. A_{ihtu} is defined as cost of food i in food group h and period t in scenario u. It is noticeable that the costs of foods in different stores are usually different. Furthermore, Ψ_{htu} represents the amount of food guide servings per month in food group h in period t in Scenario u. m_u is introduced as the probability related to Scenario u. The new optimization model under uncertainty is written as follows:

$$\text{Min } z_1 = \sum_u \sum_t \sum_h \sum_i m_u A_{ihtu} N_{ihtu} \tag{20}$$

$$\text{Min } z_2 = \sum_u \sum_t \sum_h \sum_i m_u a_{ih} K_{ih} N_{ihtu} \tag{21}$$

$$\text{Min } z_3 = \sum_u \sum_t \sum_h \sum_i m_u a_{ih} L_{ih} N_{ihtu} \tag{22}$$

$$\text{Max } z_4 = \sum_u \sum_t \sum_h \sum_i m_u a_{ih} M_{ih} N_{ihtu} \tag{23}$$

s.t.

$$B_t \le \sum_h \sum_i a_{ih} C_{ih} N_{ihtu} \le D_t \qquad \forall t, u \qquad (24)$$

$$E_{jt} \le \sum_h \sum_i a_{ih} F_{jih} N_{ihtu} \le G_{jt} \qquad \forall j, t, u \qquad (25)$$

$$O_t \le \sum_h \sum_i a_{ih} P_{ih} N_{ihtu} \le Q_t \qquad \forall t, u \qquad (26)$$

$$R_t \le \sum_h \sum_i a_{ih} S_{ih} N_{ihtu} \le V_t \qquad \forall t, u \qquad (27)$$

$$X_t \le \sum_h \sum_i a_{ih} Y_{ih} N_{ihtu} \le Z_t \qquad \forall t, u \qquad (28)$$

$$\beta_t \le \sum_h \sum_i a_{ih} \lambda_{ih} N_{ihtu} \le \alpha_t \qquad \forall t, u \qquad (29)$$

$$\rho_t \le \sum_h \sum_i a_{ih} \gamma_{ih} N_{ihtu} \le \sigma_t \qquad \forall t, u \qquad (30)$$

$$\sum_i a_{ih} N_{ihtu} = \psi_{htu} \qquad \forall h, t, u \qquad (31)$$

$$N_{ihtu} \ge 0 \qquad \forall i, h, t, u \qquad (32)$$

It is supposed that the values of the two sources of uncertainty can increase, decrease, or remain same. Therefore, three situations exist for each source of uncertainty. The combination of the two sources of uncertainty produces nine

Scenario	Cost of food	Amount of food servings	Probability
1	$1.05A_{iht}$	$1.05\ \Psi_{ht}$	0.04
2	$1.05A_{iht}$	Ψ_{ht}	0.16
3	$1.05A_{iht}$	$0.95\ \Psi_{ht}$	0.04
4	A_{iht}	$1.05\ \Psi_{ht}$	0.16
5	A_{iht}	Ψ_{ht}	0.2
6	A_{iht}	$0.95\ \Psi_{ht}$	0.16
7	$0.95A_{iht}$	$1.05\ \Psi_{ht}$	0.04
8	$0.95A_{iht}$	Ψ_{ht}	0.16
9	$0.95A_{iht}$	$0.95\ \Psi_{ht}$	0.04

Table 4.
Nine scenarios in the diet problem.

	u	1	2	3	4	5	6	7	8	9
i	*h.t*									
1	3.1	11.812	11.250	10.687	11.812	11.250	10.687	11.812	11.250	10.687
1	3.2	11.812	11.250	10.687	11.812	11.250	10.687	11.812	11.250	10.687
2	2.1	4.899	4.667	4.433	4.899	4.667	4.433	4.899	4.667	4.433
2	2.2	4.899	4.667	4.433	4.899	4.667	4.433	4.899	4.667	4.433
3	4.1	3.963	3.775	3.763	3.963	3.775	3.763	3.775	3.775	3.763
3	4.2	3.963	3.775	3.763	3.963	3.775	3.763	3.775	3.775	3.763
4	1.1	7.875	7.500	7.125	7.875	7.500	7.125	7.875	7.500	7.125
4	1.2	7.875	7.500	7.125	7.875	7.500	7.125	7.875	7.500	7.125

Table 5.
The values of the decision variables (N_{ihtu}) under uncertainty.

scenarios. Based on the historical data, 5% change in the values of each source of uncertainty is examined. The basic scenario is Scenario 5. A summary of different scenarios in this problem is provided in **Table 4**.

The new model under uncertainty is solved by GAMS, and the values of the decision variables are calculated. There are 365 equations and 4,149 nonzero elements. **Table 5** includes the results. For instance, $N_{1.3.1.1}$ = 11.812. The results of Scenario 5 are the numbers that were calculated in the deterministic multi-objective model in the previous section. The maximum deviations are observed in scenarios 1, 3, 7, and 9.

8. Conclusions

Diet problem has been formulated in the form of optimization models in the literature. The main goal of the models is to minimize the total cost of the foods. In this chapter, a unique optimization model has been developed based on a case study in Canada. Four proposed objectives consist of minimizing the total cost, saturated and trans fats, and sugar; and maximizing the fiber of the foods. The data of this problem have been gathered based on the information in the official website of the government of Canada. The recommended number of food guide servings and the nutrition information are available in that website. In addition, nutrition facts tables are good sources of the core nutrients in the foods. They are mandatory for most of the foods in Canada. The proposed multi-objective model has been solved by two approaches containing weighted-sums and ε-constraint solution approaches. Then, the efficient solutions have been provided in two tables.

The effects of uncertainty in two parameters of the mathematical model have been investigated by a scenario-based solution approach. To this aim, nine scenarios for two sources of uncertainty (cost of foods and amount of food guide servings per month) have been investigated. Furthermore, the results have been analyzed. The proposed multi-objective model under uncertainty can be applied in real cases, and determine the food items accurately.

There are several opportunities to extend this research. We focused on a case in Canada. The proposed mathematical model can be extended based on the other cases in other countries such as European countries. Another future opportunity for research is related to the uncertainty in the problem. We concentrated on two sources of uncertainty. It is interesting to investigate the impacts of more sources of uncertainty at the same time. For the case of four uncertain sources, 3*3*3*3 = 81 scenarios should be considered. Therefore, computational time is an important factor for several sources of uncertainty.

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Appendix A

Based on the information in [57], the maximum total calories in 1 month (D_t) is estimated as 2100 * 30 = 63,000 (for females over 51). The minimum is 0.

Based on some studies, no more than 300 * 30 = 9000 milligrams (mg) of cholesterol for each month is recommended [58].

Based on the information in [36], the maximum total sodium in 1 month (V_t) is estimated as 2300 * 30 = 69,000 mg (for people over 51). The minimum is considered 0.

The maximum amount of vitamin A for 1 month is considered 1000 * 30 = 30,000 RE (retinol equivalents). In addition, the maximum value of vitamin

a_{ih}	1 (ml)	2 (g)	3 (ml)	4 (g)
1	1,750	675	1,000	1,224
2	1,750	675	1,000	750
3	1,750	675	1,000	596
4	1,750	400	1,000	537

Table A1.
Sizes of the foods.

A_{iht}	1	2
1.1	4.27	4.27
1.2	2.99	2.99
1.3	2.97	2.97
1.4	2.97	2.97
2.1	1.59	1.59
2.2	2	2
2.3	2.89	2.89
2.4	2.47	2.47
3.1	2.58	2.58
3.2	2.47	2.47
3.3	2	2
3.4	2.58	2.58
4.1	12.24	12.24
4.2	9	9
4.3	12.47	12.47
4.4	7.17	7.17

Table A2.
Costs of the foods ($).

C_{ih}	1	2	3	4
1	110/250	230/85	110/250	270/100
2	130/250	180/75	160/250	220/100
3	130/250	220/79	130/250	100/100
4	120/250	110/43	130/250	160/100

Table A3.
Calories of the foods (in each unit).

F_{jih}	1	2	3	4
1.1	0/250	0/85	100/250	0/100
1.2	0/250	0/75	100/250	0/100
1.3	0/250	0/79	100/250	0/100
1.4	0/250	0/43	100/250	20/100
2.1	1000/250	0/85	0/250	0/100
2.2	1000/250	0/75	0/250	0/100
2.3	1000/250	0/79	0/250	0/100
2.4	1100/250	0/43	0/250	0/100

Table A4.
Vitamins of the foods (in each unit), j = 1 (Vitamin A), j = 2 (Vitamin C).

K_{ih}	1	2	3	4
1	0/250	0.5/85	1.5/250	10.5/100
2	0/250	1/75	1.5/250	7/100
3	0/250	1/79	3.1/250	0.2/100
4	0/250	0.4/43	3.1/250	3/100

Table A5.
Fats of the foods (in each unit).

L_{ih}	1	2	3	4
1	25/250	1/85	12/250	0/100
2	31/250	3/75	26/250	0/100
3	28/250	2/79	12/250	0/100
4	22/250	2/43	12/250	0/100

Table A6.
Sugar of the foods (in each unit).

M_{ih}	1	2	3	4
1	0/250	2/85	0/250	0/100
2	0/250	7/75	0/250	0/100
3	0/250	2/79	0/250	0/100
4	0/250	1/43	0/250	0/100

Table A7.
Fiber of the foods (in each unit).

P_{ih}	1	2	3	4
1	0/250	0/85	10/250	70/100
2	0/250	0/75	10/250	65/100
3	0/250	0/79	20/250	60/100
4	0/250	0/43	20/250	75/100

Table A8.
Cholesterol of the foods (in each unit).

S_{ih}	1	2	3	4
1	15/250	480/85	120/250	55/100
2	20/250	300/75	170/250	60/100
3	10/250	420/79	120/250	50/100
4	0/250	230/43	120/250	80/100

Table A9.
Sodium of the foods (in each unit).

Y_{ih}	1	2	3	4
1	0.4/250	9/85	9/250	18/100
2	1/250	8/75	9/250	19/100
3	1/250	8/79	9/250	25/100
4	2/250	4/43	9/250	18/100

Table A10.
Protein of the foods (in each unit).

λ_{ih}	1	2	3	4
1	22/250	66/85	33/250	0/100
2	0/250	88/75	33/250	0/100
3	22/250	66/79	33/250	0/100
4	0/250	22/43	33/250	22/100

Table A11.
Calcium of the foods (in each unit).

γ_{ih}	1	2	3	4
1	0/250	2.8/85	0/250	2.1/100
2	0/250	1.4/75	0.28/250	2.1/100
3	0.28/250	2.8/79	0/250	1.12/100
4	0/250	1.4/43	0/250	1.12/100

Table A12.
Iron of the foods (in each unit).

C for 1 month is considered a big number. Furthermore, the maximum total calcium is assumed 1100 * 30 = 33,000 mg for each month. The maximum amount of iron is supposed 14 * 30 = 420 mg for 1 month. These values have been calculated according to the information in Percent-daily-value, 2018. The maximum total protein is considered as a big number because no daily-value has been mentioned for this element in [58, 59]. **Tables A1** to **A12** include other data of the problem.

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Chapter 12

Contribution of Professional Pedagogy to Decision-Making

Franco Blezza

Abstract

The aim is to offer a contribution to the problem of decision-making in the world of the higher intellectual professions, considering the pedagogy as a paradigmatic profession in the social, caring, and helping field. Pedagogy is an ancient science and profession, like medicine and jurisprudence, as it is known. The professional practice, in the social field as in the health and in other fields, consists in reconnecting the complex phenomenology of each singular particular case to a more limited number of general cases, theories, or disciplinary casuistries. It is a question of making a diagnosis, in a broad sense of the term. For this procedure, both the positive inductivist approach, from many facts to the generalization, and the idealistic and deductive approach, from general a priori ideas to the particular, are obsolete. We then examine the pragmatistic concept of abduction and, more generally, the contributions of the most up-to-date methodology, just as it is applied in the practice of professionals.

Keywords: professional pedagogy, methodology, abduction, clinical method, Sozialpädagogik, social professions

> *Il mio maestro era veramente molto acuto.*
> *"Ma quali conclusioni traete da questa scoperta?" chiesi allora.*
> *"Nessuna," mi rispose "solo delle premesse."*
>
> *My teacher was really very intelligent.*
> *"But what conclusions do you draw from this discovery?" I asked then.*
> *"None," he replied me, "just some premises."*
>
> *(Umberto Eco, 1980)*

1. Aim

Pedagogy is a fully fledged science in the wide field of the *human- sozial- geistes- Wwrtschafts- Wissenschaften* or human- social- intellectual economics (sciences). A fundamental methodology is common to all these sciences: a beginning by problem posing and attempting solutions, subject to the rules of logical coherence and factual control; otherwise they cannot accurately call themselves sciences/Wissenschaften.

As such, it brings its contribution to other social sciences, particularly the problems of application of decision science in business and management. This is, from a general point of view, the fundamental aim of the present chapter.

Methodological considerations will broadly demonstrate their necessity and essence, as indeed was to be expected and is perfectly logical.

2. A profession and a science current with an ancient history: perhaps they can help us

Although the term seems to have appeared at the end of the fifteenth century, pedagogy as a science and a profession has over 2500 years of history, and this claim has a meaningful sense as many of the conceptual and operational tools and many technical terms date back to those remote origins, as well as subsequent developments.

Among the Greek-classical conceptualities of the ante litteram pedagogy, it will be enough to mention some of the most famous ones: ὁ διάλογος (the dialogue) in its two phases ἡ ειρωνεία; (irony) and ἡ μαιευτικὴ τέχνη (the art of the midwife); γνῶθι σεαυτόν nosce te ipsum (let know yourself) and condemnation of ‘ὕβρις, the superb and arrogant violation of this character, tools and warning of the latter’s evident momentum; πολιτέια (politics in the city-state), classic Logic and ‘ρητορεία (rhetorics) and all that pertains to political life, the art of public speaking, of obtaining consent, of constructing well-made sentences, ἡ ἐπιστήμη and οἱ λόγοι, two different ways of speaking about sciences and fields of study. Other examples of specific interest in our theme will bring us back to that historical period in their utmost importance, as we shall see.

But they are just some particularly emerging examples. Much of the Greek-class philosophy, including the described examples, can be summarized on the basis of the colossal *scientific culture* of that people: a knowing that it aroused our admiration, but that it was never intended for the application, even though it included electricity, magnetism, heat transformation in mechanical energy, and much more knowledge that would revolutionize human life in different periods, with particular regard to the last two to three centuries.

To understand today’s professional pedagogy [1, 2], it is necessary to carefully consider the historical and cultural turning point of fundamental importance that came with the end of the proper modern era (sixteenth, twelfth, and eighteenth centuries, anticipating the beginning of some decades) with the Enlightenment, the bourgeois revolutions, the end of the modern or absolute state, the seizure of power by the bourgeoisie, and the Industrial Revolution and the related enormous changes and accelerated processes.

It was a turning point of fundamental and easily understandable importance for education, rapidly consolidating an educational system that has held up until 50 years ago but also for relationalities, society, the human psyche, and man in general.

In fact, in the nineteenth century, the Sozialpädagogik [3–5][1,2] was born; skittles like sociology, psychology, psychoanalysis, and many other disciplines that would have founded the corresponding social professions in the following century, responding to an increasingly strong, obvious, specific social demand, were born.

3. Method issues

From the teaching of Wilhelm Windelband (1848–1915) until today, the distinction between the sciences and between knowledges, between the various ways of using human creativity, must be traced not to the subject of study but to the method of study and professional application, also of professional application. Medicine, surgery, psychology, anthropology, and pedagogy study the same man, but with essentially different methods and professional applications.

[1] See also the abundant and significant production of social pedagogy of Émile Durkheim, widely accessible in public domain as for the work we’ll mention.

[2] The complexive synthesis on Sozialpädagogik is in Ref. [5].

Generally speaking, the method of pedagogy, which identifies it and distinguishes it from other sciences and professions, is a composite method. Pedagogy is a field for collecting and incorporating different inputs, for integration, and for addressing educational purposes that are not the aims of the original sciences.

The methodology of pedagogy is articulated with continuity between two opposite and mutually exclusive polarities:

- The operational statistical methodology.
- The situational case study (casuistry) methodology.

The first methodological polarity, a search for measurable data in large populations to be treated with statistical methods, is widely present in the quantitative studies and researches of the social sciences, including an important part of pedagogy; in Italy we speak about *pedagogia sperimentale*. The components of the sample population can be correctly called "individuals." We will not take away from this methodology in this chapter.

In the particular field of the scholastic pedagogy, the most relevant institutional pedagogy and in certain aspects non-secondary of Sozialpädagogik, a situational casuistic methodology has long been followed and for decades on this basis progressively increasing, and more essential elements of operational statistical method have been inserted and integrated.

In this chapter we will deal with the second polarity, which besides all is the canonical methodological choice for pedagogical counseling, interlocution, dialog (Socratic διάλογος but without ἀλήθεια), and more generally for the personal provision of the aid's relationship specifically pedagogical.

It is the most suitable for the treatment of personal problems, of couples, family, parenting, and of single persons in social situations, including school and work.

This second choice of method currently takes the name of "clinical" method. In the use of this adjective, and of the corresponding noun, we can also recognize a meaning of etymological type. In classical Greek, κλινικός was an adjective referring to the intervention on the couch (κλίνε) where the patient was; that is to say, an intervention properly in situation, an intervention in which the professional enters, correctly and strictly, in the context, in the environmental contingency, of the recipient; and this is consistent with the way in which the professional practice of the medical doctor is intended to refer to the patient's illness or disease, as is immediately evident. There is no substantivation: today's "clinic" may correspond to ἡ κλινιχή τέχνε.

We should also remember the increasing use of the Anglo-American term clinic, to indicate a sports or musical session, for example, with an athlete, an artist, and an example of particular value, in which the great personage of human activity enters in the context of a team or a complex or a band or other human societies, to bring his own example in the very particular case in which the clinic takes place. And this is an exceptionally effective way of proceeding as education and Bildung, which generally requires limited time and efforts.

In this methodological approach, for the interlocutor, the Latin term persona is used, the actor's mask which allows to recognize some characters and which was also used figuratively. The proponent of this term (in Greek πρόσοπον) which was to become the technical term for the social sciences was Johannes Damascenus (from Damascus, 675–749).

In a reciprocal way with respect to the statistical procedure, in the clinical method, every single subject is unrepeatable and must be considered with all its peculiarities. Doctors often say that they treat sick people and not diseases. A pedagogist could say that he cares for men who have complaints and not human problems.

The question, at this point, concerns general cases: it is understood that there is neither science nor higher intellectual profession without general laws and theories and general cases: so for a medical doctor (the diseases), as for a pedagogist (the casuistries of general cases), as for an architect (the construction science), and so on. How does one go back from particular cases to general cases?

The solution to the question lies in the human mediation of the qualified professional and with his experience, and in a little-known conceptuality, abduction (abduction), called also retro-ductio (retro-duction). Here is also the substantial contribution that pedagogy can bring to the decision-making process, as previously intended in this chapter.

The professional pedagogy, as in this particular regard as in all professional practice, involves the use of old 'απαγωγή known by Aristotle (384–322 BC), used as a figure of speech in particular in the field of philosophy, logic and legal or juridical, approachable to reductio ad absurdum of Zeno from Elea (489–430 BC). This is used to justify the falsity of a statement underlining the absurdity of the consequences of its application.

The whole theoretical framework of reference for the profession pedagogy refers to the classic Pragmatism [6, 14, 15][3] or to a Neopragmatism current perspective.[4] The[5] concept of abduction was formulated by Charles S. Peirce (1839–1914) [14–17], as inference and not as an argument or a demonstration; it represents an alternative to induction and deduction, which provides an opportunity and a chance that we would call "corroboration" in accordance with the concept of the critical rationalism by Popper [19], with some similarity to the concept of "educated guess," about which we'll have to discuss later too.

4. The decision process in the pedagogical interlocution context: the abduction

In substance, and taking the topic of this contribution into account, we can describe synthetically the abduction as follows:

Rule	the general case A presents (or can present) the B_1, B_1, B_2, ... B_n, ... phenomenology
Data	the evidences B_1, B_2, ... B_n, ... of a particular case repeat aspects that can be considered professionally experienced to include reference into the A general case. and no other reasonable hypothesis explains these evidences as well
Clinical diagnosis: ...	the case we are studying, with the B_1, B_2, ... B_n evidences, constitutes a particular case of the general case A

Pay attention: the abduction is not a valid syllogism; it concerns a possible example of a general case or of a rule, whose actual pertinence to this general case or this rule is mediated by the professional or expert assumptions.

[3] Among the rich production of John Dewey we exemplify [8–10]. All these works are public dominium in the Web.

[4] We have been dealing with pedagogical Neopragmatismum since the 1990s, see [11, 12]. It is a research that continues through the developments of Pedagogy as a social profession.

[5] A good comprehensive treatise in Italian language is [13].

Someone speaks of gambling and of guessing, and instead it is the maximum exaltation of professionalism and, ultimately, of human mediation, of the anthropological principle.

It is suitable to increase our knowledge, to advance new hypotheses, and make predictions, which can find their substance in the past experiences, particularly thanks to some professional skills. But it is also the operative way of reasoning to be more subject to the risk of error. It, like the induction, doesn't contain its logical validity in itself; therefore it must be assessed through empirical tests, the previous mentioned *future experience*, following a fundamental thought (or principle) of the classical Pragmatism.

Abduction with diagnosis and choice of the general case is an important type of decision; if it is expressed, the translation of the previous table in terms of decision-making is immediate and clearly evident. It is essential in any case the mediation of the professional with his experience and his competence, which, more generally, is a reference to the value of the anthropological principle; reality is knowable, diagnosable, and decidable because there is man.

Given that factories of certainty and finality do not exist and cannot exist in human affairs, we observe that this is certainly a risk, but an inevitable risk, calculated and not arbitrary. The essential is the professional meditation, which is the human factor.

Knowledge	the general decision A is indicated for the phenomenology $B_1, B_2, \ldots B_n, \ldots$
Data	the evidences $B_1, B_2, \ldots B_n, \ldots$! of a particular case repeat aspects that can be considered professionally experienced to include reference into the A general case, and no other reasonable hypothesis explains these evidences as well
Clinical decision	in the case we are studying, the $B_1, B_2, \ldots B_n, \ldots$ evidences, constitutes a particular case of A

5. Decision-making, *Logik der Forschung*, professional pedagogy, open society, coexistence, and civil and democratic society

We can understand from the pedagogical professional approach that we are following the problem of decision-making, having given the essential importance to methodology, that there is a huge common domain for the natural sciences and for the humanities, both being absolutely analogous in method.

These are speeches that still face heavy resistance in contexts like the Italian one, where for a long time philosophy has imposed a tyrannical power, claiming to judge, devaluate, upset, and hierarchize other knowledges.

In the background, we come to identify the closed dualism between positivism and idealism. It is a nineteenth-century philosophical railway that cannot be resolved, but with respect to which it is necessary to place oneself decidedly and unconditionally outside.

It is particularly suitable for our purposes what has been done since the nineteenth century by the American Pragmatism, while the Positivism-Idealism dualism was European; and, in the twentieth century, from Epistemology and in particular

from Karl R. Popper (1902–1994) who built his "Logik del Forschung" precisely starting from the critique of Logical Neopositivismum and any form of cognitive inductivism.

Logic induction is not just an obsolete theory, but also it does not exist. This, since it is not possible from a number how much high of positive data, how much it can be desired, to infer actually the universal quantifier "always", "for every A of a certain domain". We must recall that the logical form of scientific laws is indeed a universal implication in a domain, i.e. "for every A in a certain domain, if A then B", Well, we cannot generalize even if we have observed or detected many Bn referring to A and without exception.

But there is not even an inductive decision making process: the experiences and facts, always provided they are numerous and consistent, are rather a requirement that the decision maker, the diagnostician, the pedagogist, the designer, the teacher must possess as a professional experience, but this abduction, the professional decision, remains only "corroborated", possible and valid until proven otherwise. The decision is a hypothesis built by man to try to solve human problems; the answers to the questions "what do you do when you have raised a problem" and "what do you do when you have to make a decision" are not "you solve it" and "you take it" but "you make an attempt of decision or solution"; a well-founded example of possible decision and solution is devised on the basis of one's own professionalism and experience, without ever being able to be certain.

At this point, there is often an answer that exemplifies dual reasoning, the simplest and most trivial one, that of younger children, that of people not at the forefront of civilization, and also that of all digital tools, which are notoriously stupid and yet have the advantage of speed and huge data processing.

Among those who emphasize the nonexistence of the inductive method, it is indeed easy to find someone whose reasoning skills are limited to dualism, which replies by proposing the use of the deductive method, as if it were the only alternative available. If we cannot proceed inductively, can we proceed deductively? Finally, if abduction is not a tautology, the modus ponens is an immediately intuitable tautology, and it is quite obvious: "if A, and A implies B, then B."

The fundamental argument is that in human affairs, that is, in everything we are dealing with in this chapter, we have no way of establishing the truth of an A which is its own, and the deductive method, however appealing it may be, has no applicability.

We can explain it more clearly: the truth of the deductions has as a necessary condition the a priori condition of the premises. We can proceed "as if" the premises were true, and as long as the deductions work, we can also benefit. But A may be false as it is believed to be true, and we should be fully aware of it if we make decisions by deduction.

In Italy exists a τόπος *la matematica non è un'opinione*, translated as more or less "mathematics is not an opinion." It is absolute dogmatism, or trust, in the deductive and axiomatic method even among those who ignore what is the axiomatic of numbers or of sets theory and perhaps have a vague idea of a single axiomatic geometry, that is, that Euclidean one. The scientific ignorance, a serious responsibility of the philosophical neo-idealist tyranny in Italy mentioned above, also leads to this.

And yet, any nonintuitive but axiomatic mathematical theory is true as long as this or that system of axioms is assumed to be true: Euclidean geometry in particular had a critical point in the last of its five axioms, and indeed replacing it with alternative axioms created various families of "non-Euclidean" geometries. We could also exemplify with logic or set theory; the negative conclusion remains: it is not true that mathematics is not an opinion.

Two and a half millennia after Socrates and after so much classical, Latin, and medieval philosophies, we can affirm that we do not only need any αλιεια, in

human things such as natural and social sciences, or technique, but also philosophy, literature, and figurative arts.

Which takes the place of so many unthinkable absolutisms is the idea of a continuous research, without end or τέλος, with a continuous position of problems—questions—alternatives—decision-making moments and so on, the practice of human creativity to face them with products that are always fallible both in terms of internal consistency or logic and in terms of empirical testing, what Pragmatists called "the future experience."

The result is the image of an open society, which values experience to the extent that it is part of a very specific professional competence practiced and applied in the interests of all. Nothing is true, everything is questionable. Human history, neither the macrostoria nor the mycristorias of each of us, doesn't have and cannot have a direction; there is no progress if not local and partial; rather history, in all senses, has a verse, that of increasing entropy that of the arrow of time, that of cultural evolution, and that for which one cannot retrace in the opposite direction what one has already traveled. And it is not even possible to stop.

Let us take a look at a historical background already made, after the transformations at the end of the eighteenth century that constituted a transition from an historical epoch (the modern era) to the following that still does not have its own historiographically consolidated name. Well, in 1814/1815 Der Wiener Kongress represented an illusion and a pathetic operation that would have tended to make the hands of history go back or at least stop the evolution of new ideas. It is well seen: the illusion would have lasted a few decades.

Be careful, we talk about "evolution" and not about "progress"; the Latin etymology is illuminating. The term "progress" derives from the Latin *progredior*, that is, to go forward: it is a matter of believing that humanity gives rise to a history that is like a linear proceeding with a prevalence of improvements. We rather use the term "evolution," from *e*—from and *volveo*—I turn away, just in the sense that there is no direction and in the sense that there is no turning back.

6. Karl R. Popper: *Logik der Forschung* and open society

Popper's (1902–1994) first proposal concerned epistemology [20]. This proposal of philosophy of science, which he himself preferred to call Logik of Forschung just as from the title of his fundamental work. The "scientific" booklet was added only with the English edition of its fundamental work [20]. In the middle there where the Second World War and the first postwar period with the Cold War.

His vision of science is known as critical rationalism, or fallibilism, although the first to speak of fallibility was Charles S. Peirce (1839–1914) [18], the scholar of logic among the founders of Pragmatism.

His proposal in the political field [21, 22], the open society theory, was known later, even if in Italy it was known previously.

In order for a society can be defined strictly "open," the fundamental and unavoidable condition is not who should govern, but that government practice is controlled by the sovereign people: controlled in itinere, with the social tools of today's information, which suggest the pedagogical importance of the public speaking in the ancient Greece and, in imperial Rome, Marcus Fabius Quintilianus (35–96) and *Institutio oratoria* (70–90 about); and above all by the time the decision returns to the same sovereign people, who can confirm the ruler or revoke it and replace it with another, without this handing over involves any problem or any violent and bloody implication.

In summary, we derive the teaching that decision-making must go hand in hand with general and intersubjective controllability, without privileged controllers being possible or even conceivable.

7. The scientific contribution of Umberto eco: a semiologist novelist

Umberto Eco (1932–2016) is internationally known to the general public first of all as a writer, as a novelist. But he is even better known among the experts as a semiologist, as a scientist of signs, from the fundamental *Opera aperta* [23]. The title's locution indicates a work that includes several readings, which allows multiple interpretations, and in the most important part of his university career, he completed in the faculties of architecture (of Florence and Milan).

Umberto Eco wrote in his most famous narrative work (a novel) *Il nome della rosa* (Bompiani, Milan (1980)), discussing of solving a mystery which for us is a very general way of understanding the diagnosis, the formulation of a scientific law, the decision-making, and the hypothesis of a solution in a single phrase of a problem.

The narrator is the elderly monk Adso von Melk, who tells an extremely involving story of when he was a young novice, a student of the expert and critic William of Baskerville, Franciscan monk on the occasion among the Benedictines.

The whole book focuses on a complex of mysteries and deaths, so it allows us to extend our methodological analogy to detection, which also involves a complex of decisions, in particular on the causes and the colas of events.

William tries to explain to Adso in simple terms the methodology to be followed: "*risolvere un mistero non è la stessa cosa che dedurre da principi primi.*
E non equivale neppure a raccogliere tanti dati particolari per poi inferirne una legge generale. Significa piuttosto trovarsi di fronte a uno, o due, o tre dati particolari che apparentemente non hanno nulla in comune, e cercare di immaginare se possano essere tanti casi di una legge generale che non conosci ancora, e che forse non è mai stata enunciata."[6]

The discourse has a complex articulation opposed to the deduction from the first philosophical principles. They are assumed, precisely, as if they were unquestionably true for theological reasons and for this reason susceptible of deduction that produces certainties.

William is cautious, hypothetical, inspired by a genuine benefit of the doubt: "Onestamente, io non so se le ragioni che ha trovato siano quelle buone, né ho mai controllato [...] la ricerca delle leggi esplicative, nei fatti naturali, procede in modo tortuoso. Di fronte ad alcuni fatti inspiegabili tu devi provare a immaginare molte leggi generali, di cui non vedi ancora la connessione coi fatti di cui ti occupi: e di colpo, nella connessione improvvisa di un risultato, un caso e una legge, ti si profila un ragionamento che ti pare più convincente degli altri. Provi ad applicarlo a tutti i casi simili, a usarlo per trarne previsioni, e scopri che avevi indovinato. Ma sino alla fine non saprai mai quali predicati introdurre nel tuo ragionamento e quali lasciar cadere. E così faccio ora io. Allineo tanti elementi sconnessi e fingo delle ipotesi. Ma ne devo fingere molte, e numerose sono quelle così assurde che mi vergognerei di dirtele. [...] Vinsi, ma avrei anche potuto perdere. Gli altri mi hanno creduto saggio perché ho vinto, ma non conoscevano i molti casi in cui sono stato stolto perché ho perso [...] Ora, sui casi dell'abbazia, ho molte belle ipotesi, ma non c'è nessun fatto evidente che mi permetta di dire quale sia la migliore. E allora, per non apparire

[6] "*solving a mystery is not the same as deducting from first principles. Nor does it amount simply to collecting a number of particular data from which to infer a general law. It means, rather, facing one or two or three particulars data apparently with nothing in common, and traying to imagine whether they could represent so many instances of a general law you don't yet know, and which perhaps has never been proposed.*" [24].

sciocco dopo, rinuncio ad apparire astuto ora. Lasciami ancora pensare, sino a domani, almeno."[7]

In fact, it is a novel for its developments. The anticipation of the *Hypotheses non fingo* formula by Isaac Newton (1642–1727) in a novel set at the beginning of the fourteenth century would be excellent, but in the English translation in our opinion is not put in proper evidence.

The pupil and novice Adso, narrator of the novel in old age, reports his reflections: "*Capii in quel momento quale fosse il modo di ragionare del mio maestro, e mi parve assai difforme da quello del filosofo che ragiona sui principi primi, così che il suo intelletto assume quasi i modi dell'intelletto divino. Capii che, quando non aveva una risposta, Guglielmo se ne proponeva molte e diversissime tra loro. Rimasi perplesso*.

> *"E voi," dissi con infantile impertinenza, "non commettete mai errori?"*
>
> *"Spesso" rispose, "Ma invece di concepirne uno solo ne immagino molti, così non divento schiavo di nessuno."*
>
> *Ebbi l'impressione che Guglielmo non fosse affatto interessato alla verità, che altro non è che l'adeguazione tra la cosa e l'intelletto. Egli invece si divertiva a immaginare quanti più possibili fosse possibile.*
>
> *In quel momento, lo confesso, disperai del mio maestro e mi sorpresi a pensare: "Meno male che è arrivata l'inquisizione." Parteggiai per la sete di verità."*[8]

The young Adso, perhaps even as an old man, seeks the truth by describing it with the philosophical phrase *Adaequatio rei et intellectus* which was expressed a few years before the story told by Thomas Aquinas (1225–1274) based on previous sentences of Avicenna (980–1037) and before that by Isaac Israeli ben Solomon,

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[7] "*Honestly, I do not know whether his conclusions are the right ones [...]. I was trying to tell you that the search for explicative laws in natural facts proceeds in a tortuous fashion. In the face of some inexplicable facts you must try to imagine many general laws, whose connection with your facts escapes you. Then suddenly, in the unexpected connection of a result, a specific situation, and one of those laws, you perceive a line of reasoning that seems more convincing than the others. You try applying it to all similar cases, to use it for making predictions, and you discover that your intuition was right. But until you reach the end you will never know which predicates to introduce into your reasoning and which to omit. And this is what I am doing now. I line up so many disjointed elements and I venture some hypotheses. I have to venture many, and many of them are so absurd that I would be ashamed to tell them to you. [...] Now, for the events of the abbey I have many fine hypotheses, but there is no evident fact that allows me to say which is best. So, rather than appear foolish afterward, I renounce seeming clever now. Let me think no more, until tomorrow at least.*" [24].

[8] *I understood at that moment my master's method of reasoning, and it seemed to me quite alien to that of the philosopher, who reasons by first principles, so that his intellect almost assumes the ways of the divine intellect. I understood that, when he didn't have an answer, William proposed many to himself, very different one from another. I remained puzzled.*

> *"But then ..." I venture to remark, "you are still far from the solution. ..."*
> *"I am very close to one," William said, "but I don't know which."*
> *"Therefore you don't have a single answer to your questions?" [...]*
> *I had the impression that William was not at all interested in the truth, which is nothing but the adjustment between the thing and the intellect. On the contrary, he amused himself by imagining how many possibilities were possible.*
> *At that moment, I confess, I despaired of my master and caught myself thinking, "Good thing the inquisitor has come. Was on the side of that thirst for truth", [25].*

(855–955) which referred to the correspondence between reality and its linguistic and conceptual representation.

The indicated methodology is the way through which to carry out this passage: this is the meaning of the Greek-classical locution μέθοδος (μετά through, in search of, in the direction of; and *ό*δός, road, itinerary).

Abduction, or retro-duction, is neither positivistic and empiricist inductivism nor idealism with the postulations of some a priori truth.

It is significant that the inspiring master and philosopher of the protagonist, Brother William of Baskerville, acute inquiring and investigator, is Roger Bacon, Doctor Mirabilis (1214– about 1294), also a Franciscan friar, an empiricist thinker, and precursor of the science of the modern age.

8. No progress, no direction in history, and no increase in verisimilitude in scientific research, in society, and in decision-making

The renunciation of speaking of truth in human affairs, such as those in this chapter, has left the conditions for a very particular conception of progress, at least in the Popper of fundamental works, and for about 50 years.

In a science devoid of truth and always falsifiable, it was believed to identify a criterion of progress in verisimilitude, in the sense that a theory was to be considered progressive with respect to the previous one in that it was able to explain the same phenomenology and explained it further. In extreme synthesis, one would never have truth, but a little more truth, or an approach to the truth, or a greater similarity to some image of truth.

But it was Popper [26–29] who admitted his mistake to the very brief expiry of the knowledge of the now well-known theorem of Pavel Tichý[9,10] [32].

All this is equally true for decision-making. The overall pragmatist methodological framework from the nineteenth century and then epistemological and neopragmatist in the twentieth century has kept its function perfectly and to this day has no alternative.

In fact, one should easily guess that it makes no sense to talk about approaching the truth or bringing about verisimilitude, where truth has also been renounced as a conceptual tool, and in any case the renunciation remains, at most the truth can become an ideal trend, which could therefore not even exist.

A little more complex is understanding the substance of Pavel Tichý's message: more or less in a theory that cannot be said to be true, one cannot add truth without thereby adding falsehood, and vice versa one cannot remove falsehood without thereby even take away the truth. It is less difficult to guess than to formalize. Are we willing to take this into account in decision-making?

Among the epistemologists/philosophers of science/logics of research and also among the historians of Popperian matrix, an orientation was expressed for a vision of science on a journey through a particular type of utilitarianism; the evolution of science is progressive as it allows ever greater applications and benefits for man and mankind. This shifts the problem to utility criteria: there are achievements of science that improve some aspects of life and make it worse than others or that improve life for some and not for others, and so on.

For a philosopher, even a philosopher of science, it is certainly a heavy withdrawal to resort to instrumentalism where science was affirmed as a form of

[9] On Popper's definition of verisimilitude [30].

[10] Verisimilitude redefined [31].

essential knowledge; it is not so for pedagogy, so much so that Dewey's pedagogical theory, which is the most substantial part of pedagogical Pragmatism, was called instrumentalism. For us pedagogists the only essence is the man: all the rest, starting with education and pedagogy, are tools for man and humanity.

From a narrow epistemological point of view, it should be added that rather than talking about truth in any way in the research process, we should talk about reality or the phenomenology of reality. Perhaps to some extent, the scientific research in its historical evolutionary course is approaching: the phenomenology of the real, its prediction, its understanding, and an interaction that can be more functional to humanity. But it is not even said that this is so. This is just another hypothesis; if we prefer it is a meta-hypothesis.

9. The person and the clinical eye

In decision-making, as in pedagogy, the concept of the person avoids this complex of difficulties, confusion, and lack of solutions and answers. It is all the more clear that pedagogical help lends itself to the person, even for his being part of a couple, a family, a partnership, a service, and any social aggregation, and if we speak of "helping the family" or "helping a sports team," we use a synecdoche, a rhetorical figure consisting in talking about a part talking about the whole. We still deal with a social subject, part of the society in its instances, precisely the person always.

The discourse on decision-making can be different, sometimes concerning the person and sometimes not: think of the example of a sports team, which is much more than the sum of the people (players), or of a professional team. However, the sports team or the professional team builds up to common aims and objectives, that is to say to common personal expressions; the decision will be taken by the most expert, the manager, the coach, and so on, for abduction, starting right from the people making up the group and taking into account exactly how much of the group the team allows to realize: over-personal, but essentially personal in nature. The person, unlike the individual of a statistical sample, has his own values, his own sense of life, his own interpersonal communication network, and his own political essence. The decision is constructed precisely considering, in addition to the individuals, these expressions as they become common in the constitution and in the functioning of the group.

On the other hand, having said that empirical induction does not exist and that decision-making abduction is based on the data and evidence that the expert gathers in the group members, it is understood that this survey cannot be general but selective, highly selective and guided by the observer's competence. It is a matter of generalizing and also of the decision-making discourse that the concept of "clinical eye" should not be considered reduced to the only category of surgeons or similar professions. At the base of a good decision of the trainer, the coach, the manager, and the team leader (etc.) is his clinical eye on the evidence of the components to be detected and reworked, an essential part of his professionalism.

Also in other sectors, not only in medicine surgery and in professional pedagogy, the clinical eye is a reasoning eye, and that is the essential premise for the maturation of experience, part of professionalism and leadership.

Who decides can also give the impression of seeking the decision within himself, and in some respects it is so. But an essential premise is a lot of experience on the evidence in the decision field and on the situation in which the decision is required, which must presuppose the clinical eye in the decision-maker.

There is a further reflection to be made between the consequences of Tichý's theorem and the decision by anyone with responsibility for a group, a social reality, a team, an *équipe*, a department, an association, and so on. Stripped of the pretense of having some truth or of being able to conquer it or even approach it, and carefully considering the conceptuality of the person and of the clinical eye, we see that acting on the person is not and should not be considered a limitation as it does not treat his subjects as individuals or elements. This is what gives meaning to his professionalism in the clinical eye, and that fully (or more possible) enhances the group of people being something more and different than the sum of the characters of the individuals of a sample.

Deciding on people is more consequential and different than deciding on individuals.

10. Decisions that cannot admit explicit systematic doubt and must deny fallibility

In summary, from the professional pedagogy comes an indication that crosses the natural sciences, the human and social sciences if and as they are sciences such as the latter and the first, civil and democratic coexistence, and other sectors of the humanities. The decision, sometimes a solution to a problem, sometimes a law or scientific theory or an idiographic description, is always and in any case a hypothesis created by man in an attempt to solve human problems, subject to the laws of logical coherence and above all of fallibility. The systematic doubt should never be lacking; the knowledge involved cannot be considered "strong knowledge," but on the contrary it is weak knowledge, indeed very weak, which owes precisely to their weakness, their ability to evolve and their transferability from one person to another one.

We have seen various implications of this vision, not without mentioning possible misunderstandings deriving from the legacy of the philosophical nineteenth century, of European philosophy polarized between positivism and idealism. This is all the more evident when we consider the professional aspects of these human and cultural sciences, as well as of course of the natural sciences.

All this does not detract from the human need, which is anything but infrequent, to come up with well-defined decisions that leave no room for doubt, which bring with them certainty and decision-making. Among the *théories pratiques*, Durkheim exemplified medicine, politics, strategy [33], and even, scattered in his works, other sciences, techniques, and human professions.

Well, can a surgeon decide for an operation that presents certain risks or not to carry out an operation that presents other certain risks, simultaneously with all those reserves of hypotheticality, doubt, fallibility, and the others that we have illustrated up to here? Can a military commander give the order to attack or retreat with similar clarifications? Could a politician do it in the performance of his duties? In this case we might also think that it should be done more frequently and with more conviction than it actually is, but the problem is that a decision that must be made without any methodological superstructure imposes itself, in politics, almost always. What about the designer of a civil artifact that must rule on its security and on the manufacturer of a drug that must guarantee that the benefits of the administration, given certain conditions and observed certain warnings, are preferable to non-intake? Even the judge, who is a man who professionally sentences about other men on human problems, and who can impose penalties that in some countries reach the death penalty even in our own time, pronounces "beyond every reasonable doubt," when the only reasonable reality of doubt and its irrepressibility anyway?

Without going into the specifics of each of these and the other innumerable examples that we could bring, it is clear that we are dealing always with decisions consisting of hypotheses created by man, fallible and questionable, about which we always and in any case doubt. The suppression, or suspension, of these and all the other warnings, which for those who have a minimum scientific culture are purely formal and will never be substantial in any case, can indicate the need to corroborate the decision-hypothesis in the most humanly way as possible, performing cross-checks, involving different points of view and skills, and bringing together different human, scientific, social, and political positions as such. We can try to reduce the risk of error to the minimum, as much as humanly and socially possible: but infallibility will never be possible in any human thing.

Anymore, the reflections and considerations that we could make on this subject are many, and so far we have remained to the exemplification. But the problem of the need for certainties, around decisions which, being hypotheses and human creations, cannot but be fallible, is in substance unsolved.

11. Toward some conclusions

Ending the chapter, we understand how and why it is not possible to operate some form of "conclusion," since our whole discussion is centered on an institutionally open and unlimited discourse, without end or ἔλος, in continuous evolution (and not in progress!). It is always a questionable discourse on a social level and on a level political in a broad sense, the heritage of everyone as it is transmissible intersubjectively like any theory, law and scientific evidence and as it is not personal opinions, ideologies, faiths, philosophical theories, and so on, listing what is not it has been the subject of our discussion if not "to complementary."

Curiously, in the Italian language the adjective *discutibile* (questionable) has a fundamentally negative use, tending to devalue what it is applied to. Instead, we will understand that questionability is an invaluable value of a pedagogical discourse, and human in general, as it brings openness, evolution, culture, sociality, and much of what man needs, even or before all in terms of decisions.

Then there is everything that is not considered questionable, but it can only be the object of a personal adhesion. Indeed, as the contemporary Pedagogy warns us, we must stigmatize any attempt to enslave other human persons to, or under, beliefs considered infallible, certain, definitive, dogmatic, ideological. They are all behaviors humanly incongruous. Often such attempts are cloaked in disguise, making one believe that the imposition of an ideology is made "for the good" of the recipient, or of a social class, or of the whole society. This is not the case, and no one must fall into the trap of discussing the goal: man is never a tool to extrinsic ends; he will always be only a purpose in itself.

As such, each human person has every right to make his own decisions or to assume from those who believe the decisions he needs, facing fallibility, doubt, uncertainty, and the limits of human creativity, but also the openness, evolution, the possibility to correct oneself, and so on.

This, in essence, is the lesson of professional pedagogy for just under two centuries. We do not educate despite our limitations but precisely because we have limits and tend to go further, as a sort of personal ethics. Our limits, recognized for such and made the basis of the educational act and pedagogical professional practice, are the highest expression of our love for man and for humanity and of our dedication to those entrusted to our education and our professional pedagogical intervention.

12. Possible overall conclusions

Empirical induction does not exist, as Karl Popper imply demonstrated by placing this critique as the foundation of his *Logik der Forschung*.

The logical deduction is a correct and tautological procedure, but it poses the problem of validating the system of premises, with the current risk of an infinite regression, and also poses the problems of what logic applies, of how inferences are operated.

For the decision in every field, for the medical-surgical diagnosis or for the pedagogical diagnosis, for the proposal and development of laws and theories in nomothetic sciences (both natural sciences and human, social, and culture sciences), and for any human act of choice and determination, even in the economic world and in the world of the work or of business, an alternative exists in Western culture, an alternative which has its roots in classical Greece and which had its strict formalization in the nineteenth century at the Pragmatism of Charles S. Peirce.

These are acts of practice of human creativity in an attempt to resolve certain human problems, in which the passage is from the particular to the general, from evidences or data to the general case, and is operated by the necessary mediation of the qualified, trained professional and expert; logically it is not a tautology, i.e., a true formula, fallibility characterizes the decision as in any case the scientific and technical research, and any human act. The name of this procedure is abductio or retroductio.

The discourse, among other things, centered on the necessary human mediation and on the irrepressibility of the expert man's intervention in confronting impersonal procedures such as both empirical induction and logical deduction, constitutes a way of putting the right emphasis on the anthropological principle.

Nach diesem Sinn, and in the context we have outlined, we can well conclude with the Sophist Protagoras from Abdera (ca. 490-420 BC): "Πάντων χρημάτων μέτρον εστίν άνθρωπος, των μεν όντων ως έστιν, των δε μη όντων ως ουκ έστινπάντων χρημάτων μέτρον *ἐστὶν ἄνθρωπος, τόν μὲν ὄντων ὡς ἔστιν*, τόν δὲ *οὐκ ὄντων ὡς οὐκ ἔστιν*".[11]

[11] Man is the measure of all things, of those that are as they are and of those that are not because they are not.

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Chapter 13

A Query Matching Approach for Object Relational Databases Over Semantic Cache

Hafiz Muhammad Faisal, Muhammad Ali Tariq, Atta-ur-Rahman, Anas Alghamdi and Nawaf Alowain

Abstract

The acceptance of object relational database has grown in recent years; however, their response time is a big concern. Especially, when large data are retrieved frequently on such databases from diverse servers, response time becomes alarming. Different techniques have been investigated to reduce the response time, and cache is among such techniques. Cache has three variants, namely tuple cache, page cache, and semantic cache. Semantic cache is more efficient compared to others due to capability to store already processed data with its semantics. A semantic cache stores data computed on demand rather than retrieved from the server. Several approaches proposed on relational databases over semantic caching but response time on relational database is unsatisfactory. Hence, we proposed object relational databases over semantic cache. It is a novelty because semantic cache is mature for evaluation of relational databases but not for object relational databases. In this research, the implementation of query matching on object relational database with semantic caching along with object query is investigated to reduce the response time. Then, a case study is conducted on an object relational database model, and an object (relational database) query with semantic segment is applied. Results depict significant improvement in query response time.

Keywords: semantic cache, query matching, probe query, remainder query, object relational query

1. Introduction

Data size increased day by day, due to large data response time is going slow. In this regard, according to [1], relational databases can be used due to their better response time. Its idea is based on distributed database, which is helpful to reduce the data load and make access easy. In several scenarios, it occurs that structure must be continuously modified in multiple respects due to change in data types [2]. A relation in database is made up of several relations corresponding to relational database schema. The objective of a relational database design is to create a set of relation schema that allows user to store information and to retrieve information easily [2]. Relational database is structured in table, fields, and records. Relational database also delivers relational operator to manipulate the information kept in the

database tables [3]. Most RDBMS use SQL as database query language. The relational data base model is an extensively used data model, and a huge majority of existing database systems are based on the relational model [2]. Dr. E.F. Codd, a mathematician and research scientist at IBM, designed the relational model. Although most of the current RDBMS are not aligned to the Codd's model, yet it is considered as RDBMS [4]. Mitigating data redundancy and enhancing data integrity are two design principles of Codd's model [5]. The relational model also defines several logical operations that could be performed over the data. The relational data model has established itself as the main data model for commercial data processing applications [4]. Its achievement in this area has led to its applications outside data processing in systems for computer aided design and other environments [6]. Various issues in efficiency arise in RDBMS such as lack of handling the advanced data type, a restricted set of built-in types that use only numbers and strings. Also, certain types of relationships between database objects are hard to represent in the relational database model [7]. The RDBMS is pretty good in handling most information problems. But for new type of data type's problems, RDBMS technology could be superior upon. So, to attain the deficiency of RDBMS, we move on to ORDBMS [3]. To conform to the SQL standards, relational database model is reconsidered by ORDBMS; however, the object relational data model is a new definition altogether [7]. Object oriented languages like Java and C# can be integrated to ORDBMS, pertaining to their class, method, and objects features that are useful for the programmers for better integration. Moreover, ORDBMS schemas have additional features compared to its earlier counterpart [8]. ORDBMS model supports the object oriented features like abstraction, polymorphism, inheritance, etc. [9]. Like RDBMS, ORDBMSs rely on SQL queries and declarative approach for accessing and manipulating data rather than a procedural approach [10]. Occasionally, a mismatch in the programming language structure (procedural, declarative, or functional) and ORDBMS engine may occur at the time of database connectivity and access, which may results in performance issues. In a architectural point of view, ORDBMS is different than OODBMS that use a distributed approach while the former uses a centralized approach [8]. Nevertheless, this issue can be resolved by replicating ORDBMS over several machines. The further significant outcome of the technology is that it makes it possible to build information systems to address data management problems that are usually considered to be too challenging. In terms of interoperability, ORDBMS has two benefits. First is compatibility with the existing RDBMS components and second an object oriented access for the users and programmers. Similarly, storage and access mechanism, query processing, and optimization are the significant challenges in employing ORDBMS [7]. One of the efficient ways to mature a very large database is to distribute it between various server nodes [11]. Now ORDBMS is going to convert into the semantic caching and query result is more efficient in the semantic cache. Semantic cache is used to response the query in part such as Probe and Remainder [1]. Some part of query is answered from the cache and some is from the server [4]. ORDMBS is used in this technique in an intelligent way to answer the query result [8]. Different methodologies are easily making on semantic cache, and different definition of semantic cache content is used. Semantic cache content is {Rs, As, Ps, Cs}. Result is accessed according to the cache content, and a complete set of cache part is known as cache [1]. Suppose a user gives a query SELECT student id, name FROM student WHERE age < 28. In this query, Student ID and Name are answered from Probe part (saved in cache) but for Name, where clause it will be accessed by the remainder part (server result). So, it will consume more time if query is complex and more result is accessed from server [1]. For that ORDBMS is mainly focused on sematic caching but query optimizing technique is used, and this technique is going to be improved

by Query Matching part of query optimizing. For more understanding, we take the help from the problem statement.

- Query matching technique on ORDBMS is hard to implement.
- Query retrieving is time consuming.
- Query matching approach is unsatisfied on complex data.

The objective of this research is to overcome the said issues. In this regard, semantic cache query matching technique is proposed to extract useful contents from the cache to improve query response time. Then, query matching is investigated for object relational query on complex data by exploiting the semantic cache, and results of object query and relational database query are compared. In this section we take discussion for our proposed approach for query matching on object relational database query over semantic cache. Query matching approach is satisfying the query result with the object relational semantic content. Our projected approach being employed is on semantic cache architecture with object query and with the below concept. Firstly, the query is accessed on the complex structure and data set, so object relational query is used with row reference to access the query [7]. Secondly, the relation in database is retrieved with the object query but in the form of object [10]. The query is into the part by using query semantic content of QS, QF, and QS and result is retrieved according to adaptive region of semantics segments [1]. The study is mainly focused to indicate various advantages of semantic caching and then the simple workloads where the indication also includes the low overheads, decreased amount of network traffic, physical layout of database that is insensitive, and additionally a source to minimize and answer the queries without the participation of server [4]. In addition, handling the complexity of the workloads and depth coding for queries is left for quick processing query at server. By manifesting the semantic caching works on object database with usage of complex workloads, we would investigate the wide variety of applications particularly in an environment that is network constrained [12]. Semantic cache plays an important role in fetching results. Semantic cache is divided into two main parts. One part that is answered with the help of cache is the Probe query and the second part that is answered from server is the Remainder query. Query when passed to on a Query algorithm is decomposed into various parts depending upon the data required. Before passing query to algorithm, first check whether the current data is available in cache or not; if it is, then fetching data from the server. If some of data are available in local cache, then decompose query in such a way that data not available in cache should only be fetched from semantic cache [1]. To increase the power of semantic cache, we use the object relational model that made the query on complex structure as efficient [7]. ORDBMSs deliver the lowest access time for development and for greatest performance combination when using objects because they stored objects on disk and have the translucent program integration with object programming languages [5]. Performance is boosted by storing objects directly on disk which excludes impedance mismatch. Development period are reduced because there is no need to program the caching for the application programs and there is only one model to develop [10].

In this approach, we mainly focus on the object relational query matching on complex data and structures which have many tuples to increase the complexity of query matching and they are time consuming. In this research, we proposed the approach ORDBMSs in semantic cache that reduce the cost and use less time for result; we easily increase the trust of database user by using his model. Data latency

and workload can easily be distributed and handled. Rest of the chapter is organized as follows: Section 2 contains review of literature and related work in the field. Section 3 contains proposed work and results are obtained in Section 4, while Section 5 concludes the chapter.

2. Review of literature

In this section, a comprehensive survey of cache is presented. In Sections 2.1–2.3, the concept and work of semantic cache on query is discussed. Sections 2.4 and 2.5 are dedicated to databases, while the related work is given in Section 2.6.

2.1 Cache

It comprises of small-sized type of volatile memory like the memory of computer that is useful in terms of providing high speed data while having an easy access to the processor and storage to install programs, applications, and data that are frequently used by the computer. It is considered to have memory that is fastest and is placed on the motherboard directly connected to the processor or Random Access Memory. Cache that has pronunciation as "cash" neither "catch" nor "cashay," saves information that is recently used for it to have accessibility later. A PC memory with short access time utilized for capacity of every now and again or as of late utilized directions or information called likewise reserve memory [11]. PCs consolidate a few unique kinds of storing with a specific end goal to run more productively, in this manner enhancing execution. There are few of the caches that comprise of browser cache, disk cache, memory cache, and processor cache [13].

2.1.1 Browser cache

The webpage data by default are found in the browser cache. For instance, when the webpage is being visited, the browser might cache the HTML, images, and any CSS or JavaScript files that are being referred by the page. When the website is accessed by different pages and of utilization similar pictures, CSS, or JavaScript, your program will not need to redownload the records. Rather, the program can basically stack and store them on a local hard drive from the cache [4].

2.1.2 Memory cache

During the time of a running application, there is a chance that is cache of data in system memory or Random Access Memory. The example is if there is a video project you are working on, the video clips and audio tracks from the hard drive into Random Access Memory may get loaded on the video editor, since this can reduce the delay while importing the files and editing them and RAM has easier accessibility than hard drive [4].

2.1.3 Disk cache

The HDDs and SSDs present have a small amount of Random Access Memory that fulfills the need of disk cache. The typical disk cache of 1 TB has 32 megabytes, while a 2 TB hard drive may have a 64 MB cache. Therefore, the little measure of Random Access Memory can have a major effect in the execution of drive. The example is of when an envelope is opened with a substantial number of records, the

referring of documents might be naturally spared. The list of files is loaded instantly despite taking some time to appear when the folder is opened [11].

2.1.4 Processor cache

They are smaller in size as compared to disk cache. The reason is of the processor cache that has some tiny blocks of data that are basically instructions that are used frequently and can be accessed by the CPU quickly. Present day processors frequently contain a L1 reserve that is appropriate by the processor and a L2 store that is marginally further away. The L1 reserve is the littlest (around 64 KB), while the L2 store might associate with 2 MB in measure. Some top of the line processors even incorporate a L3 store that is bigger than the cache L2. The data might get moved to the level that is low to access it faster when the processor tries to access data from a level that is higher in caches [4]. The caching done in background will not get noticed. However, browser cache is the only cache that can be controlled. There is choice to view the settings of cache and change the size of browser and even empty it if there is a need [11].

2.2 Cache levels

Following are different cache levels and their details.

2.2.1 L1 cache

L1 (Level 1 cache) is a memory bank built into the CPU chip. Also known as the "primary cache," the cache that has the fastest memory is L1 in computer and is closer to processor.

2.2.2 L2 cache

L2 (Level 2 cache) has a memory bank that is made inside the CPU with a package present inside the component or is built on motherboard. The L2 cache feeds the L1 cache, which feeds the processor. The L1 memory is better than L2; basically L2 is slower than L1.

Figure 1 illustrates the working of cache on database—to access the data with the help of cache and improve the answer time of query.

2.3 Semantic cache

This works for the caches query result. And the elements that are present in the semantic cache are known as the regions or segments [14]. This term semantic caching is derived from the semantics of SQL queries that work for systematically handling the information of cache and building conclusions of the availability or unavailability of query results in the cache [12].

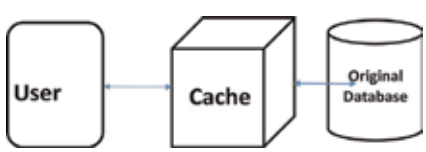

Figure 1.
Cache working.

The performance of the client-server systems is improved by the caching at local clients. The novel caching scheme being introduced is hence called the semantic caching. The transformation of the semantic storing can enhance the efficacy of XML inquiry that is prepared in the Web condition [9]. Semantic storing increases reserved information with a semantic depiction of the information.

These semantic depictions can be utilized to enhance execution time for comparable inquiries by recovering little information from reserve and issuing a leftover portion question for the rest. Benefits of semantic reserving include low network overhead, independence of physical format of the database, decreased system activity, and the capacity to answer a few inquiries without reaching the server. For workloads that are less complex, there is a need to maintain efficacy of the query processing by cautious coding of queries that are remainder at the server. For workloads that are very complex, using very complex workloads, there is a display of semantic caching that works better in a variety of applications specifically in the environments that were constrained [9].

2.3.1 Semantic cache scenarios

Semantic cache answers the query in different scenario's which are described below [15] in **Figures 2–5**, respectively. The scenarios are, namely

- full answer;
- partial answer; and
- no answer.

Example:

The semantic data are being extracted from the query while there is addition to this semantic data that will be used for more matching and the cache [16]. This high-power semantic fragment reserve is versatile, which means that, as and when the client is entering the inquiry for which the appropriate response is to be discovered, the applicable characteristics of the database will be populated in the store. The part of the cache that is semantic basically the highlights and the content which is refined just add quality in boosting the performance in a manner that is convincing and exuberant [14].

In case of the semantic cache, the semantics stored on the cache are compared to the input user query and subject to availability of data, the decision is taken. It is carried out by two processes known as splitting that involves division of query based on its clauses and rejecting if a certain clause is missing, e.g., WHERE

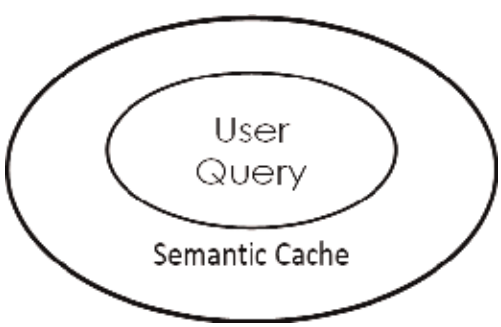

Figure 2.
Semantic cache full answer.

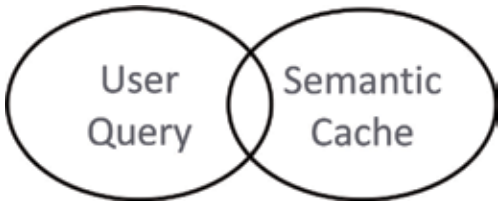

Figure 3.
Semantic cache partial answer.

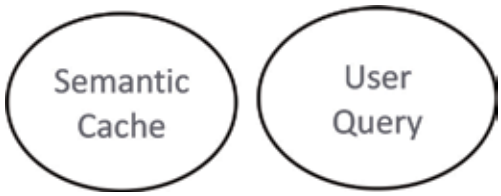

Figure 4.
Semantic cache no answer.

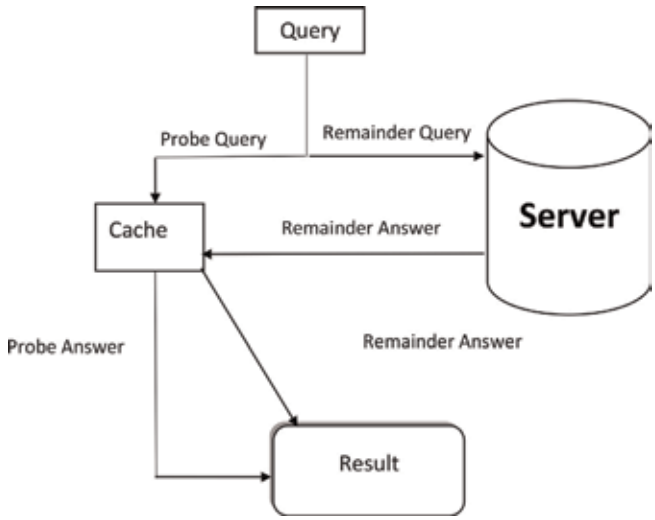

Figure 5.
Semantic cache working.

and so on [1]. The queries that are matched (overlapped) either fully or partially are answered locally by the semantic cache. Query processing and cache management are the main critical aspects of semantic cache, yet it performs way better than simple data (page, tuple) cache. Semantic caching provides the significance workload reduction in distributed systems, especially in mobile computing as well as improves the performance. However, the performance is purely based on the efficiency of its subprocesses like query trimming, indexing, etc. [1].

2.4 Relational database

A relational database is a category of database. It uses an arrangement that lets us to recognize and access data in relation to additional part of data in the database. Often, data in a relational database are organized into tables [5]. A relational

database management system (RDBMS) is a program that allows you to create, update, and administer a relational database [17]. Most relational database management systems use the SQL language to access the database. In RDBMS, the data are stored in the form of relations (tables) in a row-column architecture. It is comprised of records (rows) that are uniquely identified by a key attribute. There are several ways to access the stored data without manipulating the database relations as such [5].

Example:

In this example, a case study is used to understand the relational database and query is conducted on data model to understand working (**Tables 1** and **2**).

A query is conducted "Query: - Select Account=6 From Main account, Employee table" and for answer of query, every record is checked which is time consuming.

2.5 Object relational database

Object relational query processing is needed to speed up queries over object relational databases. We are here to define a couple of features mentioned in to characterize an ORDBMS. These structures are desired to model real-world problems in a method that is instinctive and easy for the developer and proposals noble performance for the application (**Figure 6**).

In this example, the query is answered directly by object which saves the time, and query efficiency is increased.

2.6 Related work

In [9], authors proposed an XML-based system "XPERANTO" for data representation and the access is duly retrieved from a native database for

Account no	First name	Last name	Amount
1	John	Doe	277$
2	Clay	Russell	586$
3	Albert	Luke	321$
4	Christina	Jorge	448$
5	Tim	Joe	520$
6	Dany	Clark	459$

Table 1.
Main account.

Account no	Emp-ID	Title	Branch
1	BW-123	Flipper	California
2	CA-448	Cashier	L.A.
3	DG-456	Manager	Washington
4	FA-114	Washer	London
5	DC-587	Doctor	Canada
6	HG-894	Plumber	England

Table 2.
Employee account.

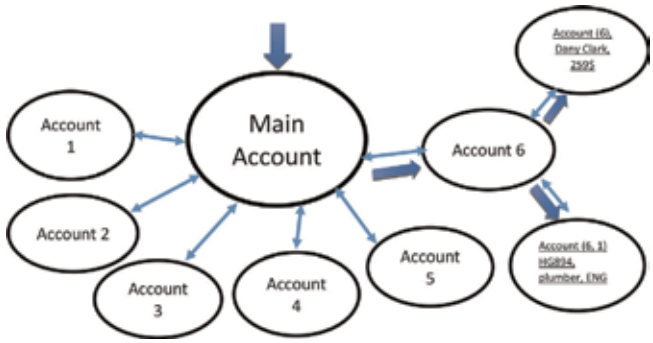

Figure 6.
ORDBMS working.

better accessibility. The system works as a middleware between XML and native database.

In [18], authors proposed a digital library and archiving system for educational institutes. The system takes advantage of ORDMS concept and builds a top layer XML object. These objects are kept in a library that can be accessed by client side QueryX engine duly executed by IBM domino server.

In [19], authors proposed a query optimization technique for RDF data stored in triplet format. The main idea was optimization of the SPARQL query based on the storage type, that is, adjacency list or matrix. It was concluded that the performance depends on the nature of data whether it is dense or sparse.

In [20], authors investigated the TYPE constraint for sake of query optimization in the context of frequent pattern mining. The idea behind this research was the data type that plays an important role in semantic association that increases the likelihood of its access.

Brown [10] presented the ORDBMS technique and investigated its properties related to flexible data access, functional improvement, enhanced efficiency, and organizational integration.

Author in [5] presents the object relational mapping (ORM) approach. The ORM refers to better data and transaction handling on a database using an object oriented approach. The investigation was conducted on a Java-based open source system "Hibernate," which is currently added to Microsoft model for .Net Systems.

In September 2007 [21], the Object Database Technology Working Group of the Object Management Group (OMG) issued a white paper that introduced the concept of an "object calculus" for ODBMSs that is analogous to "relational calculus" in RDBMSs.

In [22], the authors proposed the research of cache moves around in the scalability of new data-intensive environments and applications, and the trade-offs that are highly determined by the characteristics of these applications. Early work on information storing, for instance, concentrated on protest situated database frameworks supporting applications, for example, CAD/CAM; these frameworks had the coupling between the customers and server which took into consideration sharing of individual tuples or entire plate pages. The procedures utilized in examinations have been named physical reserving strategies.

In [23], the authors present the query-based services that do not entirely give out the physical layout of database; furthermore, customers have no power over the internals or interfaces; even application servers have just the data in the inquiries. Regarding the reserving models, the administrations should consequently be dealt with as self-sufficient inheritance frameworks even though they may dwell in best in class business database frameworks. In this condition, physical reserving

strategies are basically no longer pertinent as there is assumption coupling between client and server.

In [24], authors present the Object Relational Query Processing approach for optimizing the queries over ORDBMS. The approach was originally inspired by the object oriented paradigm.

In [25], authors present the idea of a three-level caching for efficient query processing in large Web search engines where a huge number of interactive data queries are posed in small fraction of time. Due to the volume of data access, semantic caching was a plus in efficiently handling data for sake of improving response time and reducing Web traffic. To keep up with this immense workload, large search engines employ clusters of hundreds or thousands of machines, and several techniques such as caching, index compression, and index and query pruning are used to improve scalability. Each level equips the higher level for better accessibility and locality [26].

3. Research methodology

In this section, the proposed model of the work is explained in Section 3.1. Then notation table that is used to understand the model in Section 3.2 and algorithm on query matching in Section 3.3 are discussed, and then a case study is conducted in Section 3.4.

3.1 Proposed model

Figure 7 is used to describe the proposed model, that is, the object relational query as example. Suppose we have a query Select Selection department, Section Marks, Grade From Enrollment Where Student S.Name='Clay' And Section Department='CSCI'.

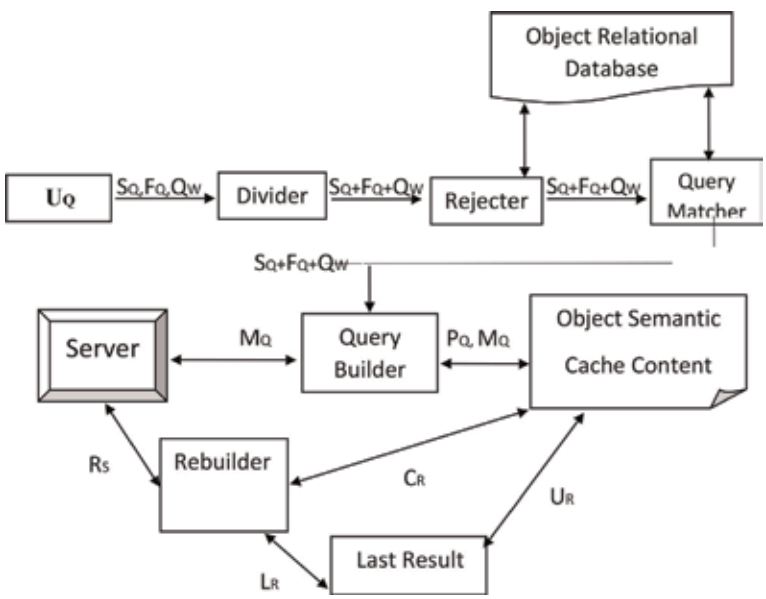

Figure 7.
Proposed model.

Notation	Details
SC	Cache segment
UQ	User query
SQ	***Select*** part of query
FQ	***From*** part of query
WQ	***Where*** part of query
MQ	Modify query
RQ	Remainder query
PQ	Probe query
PA	Predicate attribute
AS	Attribute of segment
PS	Predicate of segment
RS	Relation of segment
CS	Content of segment
AK	Key attribute of segment
SA	Same attributes
RS	Result from server
DA	Difference attribute
LR	Last result
CR	Server result
QR	Query result

Table 3.
Notation table.

All the notations used are enlisted in **Table 3**.

3.2 Proposed algorithms

Algorithm 1:-	The pseudo code of proposed algorithm to match the query
Purpose:-	To enhance the query matching approach on the ORDBMS over semantic cache
Input:-	User query, Semantic cache
Output:-	Result of User Query (Probe Query and Remainder Query)
PROCESSING:-	Get the query from user and go to query splitter
STEP 1:-	DIVIDE _QUERY (**UQ**)
STEP 2:-	Rejecter: - CHECK _REJECTIONS(**SQ**+ **FQ**+ **PA**)
STEP 3:-	IF (Reject= False) I. **SA**, **DA**:= MATCH _ SELECT_CLAUSE (**SQ**) a. IF (**DA** != Empty) b. **RQ**1 = π **DA**σ**PQ** (QR) II. Else rq1= Null

	III. IF (**SA** != Empty) a. IF (! (QPA ⊆ **SP**)) **MQ** = GEN_AMEND_QUERY() b. ELSE **MQ** = Null IV. IF (QP ==>SP) a. PQ:=π**S**AσPS (CS) b. RQ2: Null V. ELSE (QP ^ SP) is Satisfiable PQ : πSAσPS (CS) VI. ELSE IF (QP ^ SP) is Unsatisfiable Pq: Null Rq2 = πCA σSP (QR) a. ELSE b. PQ:= Null c. RQ2:= Null d. LR: = PQ + RQ + RQ2
STEP 4:	ELSE Query Is Incorrect

Algorithm 2	**DIVIDE _UQ()**
Input	**UQ** (Query from user)
Output	**SQ, WQ, FA**
Procedure	**SQ:** - SELECT CLAUSE **WQ:**- WHERE CLAUSE **FA:-** FROM CLAUSE Return:- SQ, WQ, FA

Algorithm 3	CHECK _REJECTIONS(**SQ, FQ, PA**)
Input	**UQ** (User Query)
Output	**SQ, FQ, PA**
Procedure	I. If all attributes of **SQ** present in schema II. If relation of **FQ** present in schema III. 5 IV. If **PA** is present in schema Return false Else return true V. Else return true VI. Else return true

3.3 Case study

Following schema is taken as a case study to demonstrate the proposed approach. In this regard, following object relational database query is posed. UQ2: "Select (selection) Section, Department, Marks, Grade From Enrollment Where Student S.Name='Clay' And Section Department='CSCI'".

UNIVERSITY							
STUDENT				**ENROLLMENT**			
S.Name	S.ID	Age	Gender	Section	Department	Marks	Grade

Enrollment		**Student**	
S. no	**Cache segment**	**S. no**	**Cache segment**
C1	S.ID	C14	Section
C2	S.name	C15	Department
C3	Gender	C16	Marks
C4	Age	C17	Grade
C5	S.ID, S.name	C18	Section, department
C6	S.ID, gender	C19	Section, marks
C7	S.ID, age	C20	Section, grade
C8	S.ID, S.name, gender	C21	Section, department, marks
C9	S.ID, S.name, age	C22	Section, department, grade
C10	S.ID, gender, age	C23	Department, marks
C11	S.name, gender	C24	Department, grade
C12	S.name, age	C25	Marks, grade
C13	Gender, age	C26	Grade, marks

Table 4.
Cache segments on relation.

For the above given case study of university, there are 26 possible cache segments of the enrollment and student relation. In other words, we can say that 13 are made against the enrollment relation and 13 for the student as in given **Table 4** according to given formula $2^n - 1$ [1].

4. Results and discussion

The discussion on the case study in Section 4.1 and the comparison on the case study in Section 4.2 are conducted.

4.1 Discussion

In the example, there are 30 possible enquiries that make separate segments. But in ORDBMS, the reference is used toward accessing the query result and the reference is added on the row [7]. The given two object oriented user query on possible segments are as follows:

UQ1:- ***Select*** Section department, Section Grade, **F*rom*** Student **W*here*** Student S. Name='Bursch' And Student Age='21'.

UQ2:- ***Select*** Selection department, Section Marks, Grade **F*rom*** Enrollment **W*here*** Student S. Name='Clay' And Section Department='CSCI'

As from above Object queries, UQ1 is rejected as initial state from query rejecter SQ is not coordinated with attributes of Student relation. Now let us assume from UQ2 over projected architecture as with respect to cache segment of Object relational query from **Table 4**. Query split function splits the query into segment with reference as below:

SQ: -{Selection department, Section Marks, Grade}
WQ: -{Enrollment, Student}
FA :-{Student S. Name='Clay' and Section Department='CSCI'}

Rejecter receives these three {SQ, WQ, FQ} and passes it to decider after checking the validity. Then, the decider checks the availability of required attributes by applying the proposed approach.

Here, for simplification, we assume that there exist two segments S12 and S16, for enrollment and student. So, the SA and DA will be composed as follows:

SA = {Department,Marks}

DA = {Grade}

After combining difference and common attribute, query will generate and send the following remainder query to the server.

RQ= Select Grade From Enrollment Where Section Department='CSCI

Common attributes with WQ and FQ will be sent to LQG, whereas probe and remainder queries will be produced by LQG based on similarity with segment on cache [14]. Note that here SQ will be equal to SA. So, probe and remainder queries are given below:

PQ= Select Selection department, Section Marks, From (CS)

RQ= Select Grade from Enrollment Where Section Department='CSCI.

Here, modify query (MQ) is null because PS $\subseteq$ SQ. This process of takeout probe and remainder query will be continued with entirely of segments that are visited or remainder queries become null. Query generator sends all the probe queries to the cache content and final remainder query to the server to retrieve data.

As a final point, rebuilder obtains CR from cache and RS joined to build LR and the semantics in the cache will be updated accordingly.

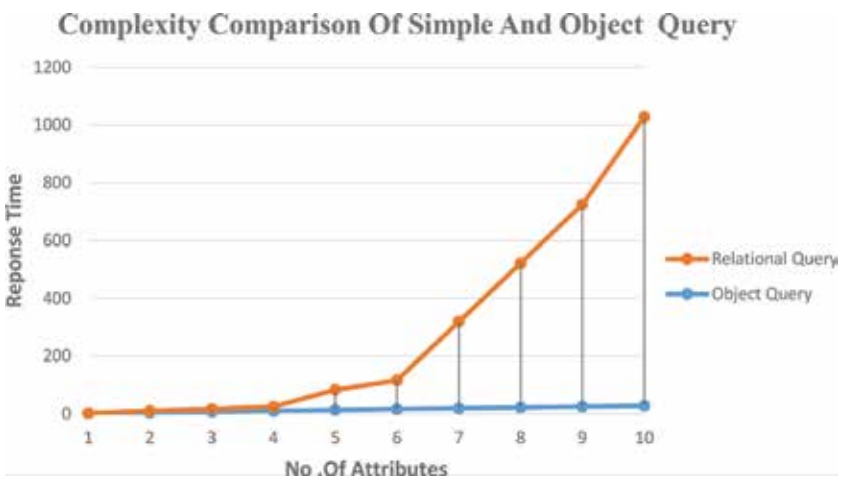

Figure 8.
Complexity comparison.

4.2 Complexity comparison

This section provides comparison between previous work on RDBMS with semantic cache and proposed query matching scheme on ORDBMS with semantic cache [7]. We have used workload parameter, such as response time, no of attribute more detail is given with the help of **Figure 8** present the response time through number of attributes. Comeback time is purely calculated on the bases of complexity expression use as previous (n vs. 2^n-1).

In **Figure 8**, the comparison result is displayed, which is used to show difference between relational query on relational data model with semantic cache and object relational database query with sematic cache, and response time is getting better on object relational query and object relational database can have ability to answer the complex data type. The retrieve time of query on ORDBMS is better and efficient; the query matching approach has improved the working procedure of the object relational query.

5. Conclusion

In this proposal, we talked about the significance of ORDBMS query for associations and organizations. We featured our approaches for outlining model and approach algorithm. Additionally, we talked about contextual analyses of executing RDBMS in online store situations and their methodologies of the implementation.

This exploration, in current stage, centers on outlining and available information which will help for the most part in basic leadership process that is identified with the advertising. We found that the greater part of works in this field have been given diverse ways to deal with the choice of perspectives to appear considering query upkeep cost and time consuming.

The investigations demonstrate that the proposed model can be incorporated with the existing models since it limits the arrangement of perspectives before appearance process.

In this research, we proposed an efficient scheme to reduce the query execution cost by making the query matching process swift. Moreover, in this era, every organization required the records in short time in the presence of big data, data lake, Teradata, etc. On the other hand, the organizations do not want to change their current systems due to the reasons like data losses, delays, and other cost-related issues. To avoid these issues, proposed advanced level query matcher can be a good alternate.

To fix this issue, we present a technique for Query Matcher and semantic cache process over object relational database. We use object query on relational database.

Now we provide solution for decision-makers or user of traditional database that can enhance speed and cost and optimize query matching. We can manage large queries on data set with matching approach and save these results dynamically in semantic cache which updated on run time. Rather accessing the whole large data set from object relational database we pull data from Semantic cache where similar queries answer before that reduce time and system delay. This will increase the confidence of database users.

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