COMPARISON OF THE METHODS AND A MODEL FOR THE EVALUATION OF THE READINESS IN IMPLEMENTING BUSINESS INTELLIGENCE PROJECTS: A HYBRID APPROACH

PhD thesis

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Debrecen, 2017.

Hereby I declare that I prepared this thesis within the program of Debrecen University, Doctoral Council of Natural Sciences, Doctoral School of Informatics in order to obtain a PhD Degree in Natural Sciences at Debrecen University.

The results published in the thesis are not reported in any other PhD theses.

Debrecen, 2017. 03. 30.

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Hereby I confirm that Mr. Vahid Farrokhi candidate conducted his studies with my supervision within the Industrial and Scientific Applications of Informatics Doctoral Program of the Doctoral School of Informatics between 2011 and 2014. The independent studies and research work of the candidate significantly contributed to the results published in the thesis.

I also declare that the results published in the thesis are not reported in any other theses.

I support the acceptance of the thesis.

Debrecen, 2017 03. 30.

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Doctoral Thesis in order to obtain a Ph.D. degree in the field of Informatics

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Date of the defense of the thesis:……………………….. 20..

Acknowledgment

Firstly, I would like to express my sincere gratitude to my supervisor Prof. Laszlo Pokoradi for his tremendous mentoring and the continuous support of my Ph.D study and related research. His guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better advisor and mentor for my Ph.D study. I also would like to appreciate Prof. János Sztrik and my thesis committee members for their insightful comments and encouragement.

Last but not the least, I would like to express my special appreciation and thanks to my beloved wife Farnaz Homauni who support me and also my children Mahdis and Ali for their patience. The time belonged to them but spent in this way. Also, I thank my mother and my brothers for supporting me spiritually throughout my study.

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Abstract

In recent years, Business Intelligence (BI) systems have consistently been rated as one of the highest priorities of Information Systems (IS) and of business leaders. BI allows firms to apply information to support their processes and decisions by combining its capabilities in both organizational and technical issues. A significant portion of companies' IT budgets is being spent on BI and related technologies. In spite of these investments, the risk of failure in implementing is high and only 24% of BI implementations are identified as being very successful. Hence, the evaluation of BI readiness is vital because it serves two important goals. First, it reveals gap areas where a company is not ready to proceed with its BI efforts, so by identifying BI readiness gaps, wasting time and resources can be avoided. Second, the evaluation points out what we need to close the gaps and implement BI with a high possibility of success.

This dissertation presents an overview of BI and the necessities for the evaluation of the readiness, and a comparative analysis of the evaluation methods and identifying and ranking the right methods which can be applied in building a model to assess the readiness of organizations. There are many Multiple Criteria Decision Making (MCDM) methods and other further methods which can be applied for building a model of evaluation but each of them has its own advantages and disadvantages. By combining and integrating these methods with each other and also with various other methods, we can avoid the disadvantages and improve the model of evaluation. We also examine the MCDM methods in the other unrelated area to show their applicability in order to confirm the validity of our approach in applying these methods for the comparison of the techniques and methods. In addition, we provide important and critical success factors and classify them into two main categories; organizational and technical. Finally, we show the process of building the hybrid model by using Interpretive Structural Modeling (ISM) and Graph Theory and Matrix Approach (GTMA) and examine it in a real company as a case study.

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List of Acronyms

ACO	Ant Colony Optimization
AHF	Analytical Hierarchy Framework
AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
BA	Business Analytics
BI	Business Intelligence
BIIAR	Business Intelligence Index of Assess Readiness
BPM	Business Process Modeling
BSC	Balance Scorecard
CEP	Complex Event Processing
CM	Characteristic Matrix
CR	Consistency Ratio
CRM	Customer Relationship Management
CSF	Critical Success Factors
DSS	Decision Support Systems
ERP	Enterprise Resource Planning
ETL	Extraction, Transformation and Loading
FNIS	Fuzzy Negative Ideal Solution
FPIS	Fuzzy Positive Ideal Solution
GA	Genetic Algorithm
GTMA	Graph Theory and Matrix Approach
ISM	Interpretive Structural Modeling
KMS	Knowledge Management Systems
KPI	Key Performance Indicators
MADM	Multiple Attribute Decision Making
MCDM	Multiple Criteria Decision Making

OLAP	OnLine Analytical Processing
OLTP	OnLine Transaction Processing
RDBMS	Relational Database Management Systems
RGMM	Row Geometric Mean Method
RIM	Relative Importance Matrix
ROI	Return On Investment
SA	Simulated Annealing
SME	Small and Medium Enterprises
SSIM	Structural Self Interaction Matrix
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
VCM	Variable Characteristic Matrix
VPF	Variable Permanent Function

Chapter 1

Introduction

1.1 Motivation and Overview

Nowadays, the importance and the power of information for every organization in surviving and competing is obvious. In today's highly competitive world, the quality and timeliness of business information for an organization is not just a choice between profit and loss; it may be a question of survival or bankruptcy [1]. The rapid development of information and communication technologies, which has been recorded in recent years, has caused an increase in the amounts of data in companies annually by 40-50% [2]. The business needs to know what is happening right now, faster, in order to determine and influence what should happen next time [3]. Companies spend billions of dollars annually on the implementation and maintenance of Information Systems (IS) [4]. Estimates are that IS expenses constitute the largest portion of organizational expenditures [5, 6]. Given the size of these expenditures, companies expect to gain benefits commensurate with the money being spent. Unfortunately recent figures estimated that nearly half of IS project did not result in the anticipated benefits [6]. So it is important to know how companies can get a benefit and a suitable return on their investments.

Previous information systems like maintaining accounting ledgers or processing financial transactions were applied to automate manual processes. The main aims of these kinds of systems are to improve efficiency and effectiveness of processes in order to save costs and increase revenues. Traditional enterprises may normally face issues such as the overflow of data, the lack of information, the lack of knowledge and insufficiency of reports [7]. Top managers usually make and take decisions based on their experiences which lead to more risk of decision failure and reduce the value of the decision. As worldwide competition is maturating, past decision-making modes can no longer satisfy the requirements of enterprises for decision efficiency and benefits; enterprises must make good use of electronic tools to quickly extract useful information from huge volume of data by providing the skills of fast decision-making [8]. The socio-economic reality of contemporary organizations has made them face some necessity to look for instruments that would facilitate effective acquiring, processing and analyzing vast amounts of data that come from different and dispersed sources and that would serve as some basis for discovering new knowledge [9]. In recent years, there have been many software packages which can provide a set of complete solutions for the operation and management processes of organizations. Nowadays, the individual-system approach applied to decision-support such as Decision Support Systems (DSS) has been substituted by a new environmental approach [10]. With the potential to gain competitive advantage when making important decisions, it is vital to integrate decision support into the environment of their enterprise and work systems. BI can be embedded in these enterprise systems to obtain this competitive advantage [11, 12]. The past few years have imposed the reconfiguration of the place and role of business data and information in companies' development strategy and concepts as data, big data, data governance, data visualization, business intelligence, business analytics, have become intrinsic terms of the support activities for decision making [13]. BI systems provide benefits by supporting analytical processes that provide recommendations for changing products or processes in ways that improve their competitiveness or operational efficiency [14]. But we should consider that the advent of computing and internet technologies have facilitated collection of a large volume of heterogeneous data from multiple sources on an ongoing basis posing new challenges and opportunities for BI [15]. More recently emerging BI-related trends such as Business Analytics (BA) and management of ‘Big Data’ have contributed to the sustained growth of the BI software market [16]. And practitioners design and implement BI as umbrella concept create a decision-support environment for management in enterprise systems [17]. Figure 1.1 illustrates this concept within an organization.

However, the effects of the implementation of electronization tools vary that the probability of failure is higher than that of the success [18]. Therefore, the ability to implement and support BI projects depends on the readiness of companies.

Farrokhi and Suhaimi in their article address the importance of information and its flow in companies and developed a model based on Business Process Modeling (BPM) [F1]. Business intelligence technology enables managers and experts of companies to make right decisions. It should be emphasized that nowadays BI systems include one of the largest and fastest growing areas of IT expenditure in companies and if BI project fails, stakeholders of companies will lose a lot of money. To reduce costs of BI implementation and to prevent BI projects from failure, we need to evaluate the readiness of these companies from two aspects: Organizational and Technical.

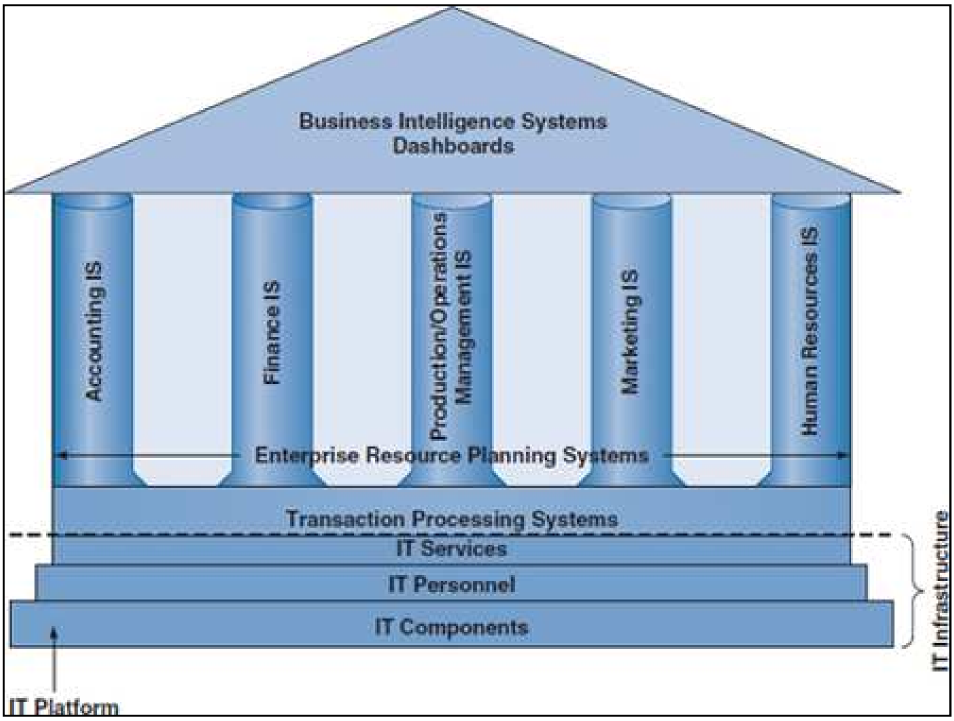

Figure 1.1: BI systems position in an organization (Source: [19])

1.2 Approach and Contributions

The contributions of this work are to develop a model for evaluating the readiness of firms in their way to implement BI systems via a hybrid approach. Building a right hybrid model which can help organizations in deciding further steps of BI project process before launching the project is our main subject in this dissertation.

Our approach to the efficient evaluation of firms is based on experts' opinions who know BI projects and the methods very well. The main goal is to introduce key factors in implementing BI projects and to show how related mathematical methods and techniques can be applied for modeling in order to solve the problem of assessment. The approach to the evaluation of the readiness of a firm is to determine the key factors from different aspects. This can help managers and other stakeholders to focus on critical success factors which is a well known concept in the investigation of every project.

The contributions made by this research are the following:

1. We describe the necessities for building a model to evaluate BI projects via a comprehensive literature review. The review shows the need for investigating and determining BI readiness factors and their associated contextual elements that influence the implementation of BI systems in companies and also there is a demand to develop a model for the assessment of BI readiness in companies. We published this state of the art survey in [F2, F3] and discussed considering them. Citations of our survey in a number of publications including Elsevier [20] and others (more than twenty) have motivated the further investigations in this realm.
2. We depict an overview of BI and its means in theory and practice. We describe the components of a BI in architectural form for better understanding of those people who want to work on BI subject as an academic or practitioner. Basically, for BI information and its components to be user-friendly, it needs to be expressed in a way that makes it understandable to people doing their study. One of the best ways is to describe in architectural form. Hence, we have tried to describe the components of the conventional and of the new-generation architectures. In our published study [F4], we presented the architectures in detail.
3. We provide a better understanding of the important and critical success factors via conducting a survey and comprehensive study

of the critical factors in the evaluation phase of the readiness by classifying the factors into two main categories; organizational and technical. We published this study in [F5]. It is obvious that each category has its own characteristics. A brief description of each factor is discussed. For both academics and practitioners concerned with BI systems, one of the most important issues is to identify the factors which are vital for the successful implementation of BI projects. Hence, we offer a broad summary of the most common and impact factors which can influence the implementation of BI projects. It is vital to determine these factors, particularly for managers of those companies that are involved in implementing BI projects and face the challenge of evaluating the readiness of their organizations before launching the project in pre-implementation stage.

4. We identify the right evaluation methods for building a model to assess the readiness of organizations in implementing BI projects. Therefore, this dissertation offers a summary of the most common evaluation methods which can be used to build the model. It is invaluable to compare these methods, especially in the areas where they lead to similar conclusions. The objective of this investigation is to provide a better understanding of the current similarities and differences of these methods and to compare them based on their features and suggest a suitable method for building a model to evaluate the readiness of firms in implementing BI projects. The proposed method is published in [F6] which can assist us in the evaluation. We built a model in order to compare the methods by using Analytic Hierarchy Process (AHP) method.

5. Our further aim is to show the applicability of AHP and AHP-Fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods in building a model to compare techniques and methods in an the other unrelated area of BI subject. We use the methods in ranking the techniques which can solve reactive scheduling problems in the operating room. It confirms the validity of our approach in applying these methods for the comparison of the techniques and methods for the evaluation of the readiness of firms. We published a study in [F7] and another is submitted to a well-known journal [F8] and under revision. This work was the part of a PhD study at the Université de Lorraine (France) as a scholarship opportunity which helps us in the research.
6. We also build the proposed model based on combination of Interpretive Structural Modeling (ISM) and Graph Theory and Matrix Approach (GTMA) on the factors to earn an indicator for evaluating the organization's readiness for implementing a BI project. It is to provide a method to evaluate the key factors for the successful implementation of BI projects and to determine the organization’s index of assess readiness before the implementation of BI projects. We applied this method in an organization and determined the organization's readiness before the implementation of BI and found it to be very effective. The study is submitted in a famous Hungarian journal [F11] and under revision.

These contributions are presented in the following chapters of this thesis. A brief summary of these chapters is provided in the next section.

1.3 Organization of Thesis

In this section, we summarize the content of the remaining chapters of the thesis which are described briefly as follows:

Chapter 2 provides an introduction to BI. It is necessary to have an overview of BI as a main information system in our study which usually works as an umbrella over other information systems in an organization. BI's components have been shown from architectural perspective in both forms of conventional and new-generation BI architectures.

Chapter 3 discusses the necessities for the evaluation of the readiness and considerable subjects to BI success, BI readiness and the need for building a readiness assessment model.

Chapter 4 introduces those methods and techniques which are applicable in evaluating the state of preparedness of an organization for implementing a BI project. We provide a review of the methods, classify them and we also make a framework to compare readiness evaluations and ranking the methods. It is one of the most important advantages of our approach in this thesis.

Chapter 5 describes the application of AHP and AHP-Fuzzy TOPSIS methods in order to show their usability in building a model to compare techniques and methods in the other unrelated area of BI. They are applied in ranking the solution techniques of reactive scheduling problems in operating room. In fact, this chapter is to confirm the validity of our approach in applying these methods for the comparison of techniques and methods.

Chapter 6 expresses our proposed hybrid approach and model. We present the critical organizational and technical factors as well as our hybrid approach in identifying the key factors for implementing BI projects. We apply the Interpretive Structural Modeling (ISM), Graph Theory and Matrix Approach (GTMA) to derive a measure to check the readiness of a sample organization before implementing BI. BI Index of Assess Readiness (BIIAR) is obtained to show the readiness.

Chapter 7 summarizes the whole thesis and provides a conclusion to the researchers by giving directions for future works.

Chapter 2

2.1 An overview of Business Intelligence

Nowadays, there are many diversities and complexities in the environment organizations operate in and in today's world with rapid technological changes and dynamic and unpredictable business environment; BI solutions can assist the managers in decision making processes. The interest in this subject has increased significantly when the opinions began to appear indicating that BI systems are an important component of a modern enterprise's information infrastructure, as they contribute to its success and competitiveness [21]. In the Information Era, agility is the gold standard. Facing uncertain futures in a complex, dynamic, and challenging environment, organizations around the world are transforming themselves, becoming more information-enabled and network-centric and BI’s role to assist a decision making process not only is essential for all organization but also has a vital role among necessitates of correct reaction to rapid environmental changes and rivals measures [22]. The IS literature has long emphasized the positive impact of information provided by BI systems on decision-making, particularly when organizations operate in highly competitive environments [23]. A successful implementation of BI project enables experts and managers of companies to make and take better decisions.

The ability of a business to make use of the data that is available to it is sometimes termed Business Intelligence or BI. The term was first popularized by Luhn in 1958 who used it to describe the abstracting, encoding and archiving of internal documents and their dissemination using 'data-processing machines'. Later, BI as a grand, umbrella term, was introduced by Howard Drenser of the Gartner Group, in 1989, to describe a set of concepts and methods to improve business decision making by using fact-based, computerized support systems. The first scientific definition by Ghoshal and Kim referred to BI as a management philosophy and tool that helps organizations to manage and refine business information for the purpose of making effective decisions. The goal of BI systems [3] is to capture (data, information, knowledge) and to respond to business events and needs better, more informed, and faster, as decisions. BI was considered to be an instrument of analysis, providing automated decision making about business conditions, sales, customer demand, product preference and so on [24]. The Data Warehousing Institute, a provider of education and training in data warehouse and BI industry defines business intelligence as: The processes, technologies, and tools needed to turn data into information, information into knowledge, and knowledge into plans that drive profitable business action. Business intelligence encompasses data warehousing, business analytic tools, and content/knowledge management. Business intelligence has been defined as "business information and business analyses within the context of key business processes that lead to decisions and actions and that result in improved business performance" [25]. Another definition is "a set of processes and technologies that transform raw, meaningless data into useful and actionable information" [26]. It utilizes a substantial amount of collected data during the daily operational processes, and transforms the data into information and knowledge to avoid the supposition and ignorance of the enterprises [27]. Golfarelli at al. argue that BI is the process that transforms data into information and then into knowledge [28]. It is the process of gathering high-quality and meaningful information about the subject matter being researched that will help the individual(s) to analyze the information, draw conclusions or make assumptions [29]. Stackowiak et al. opine that BI is the process of taking large amounts of data, analyzing that data, and presenting a high-level set of reports that condense the essence of that data into the basis of business actions, enabling management to make fundamental daily business decisions [30]. Zeng et al. have put forth that BI is "The process of collection, treatment and diffusion of information that has an objective, the reduction of uncertainty in the making of all strategic decisions [31]. Ranjan [32] considers BI as the conscious methodical transformation of data from any and all data sources into new forms to provide information that is business-driven and results-oriented. Eckerson [33] understood that BI must be able to provide the following tools: production reporting, end-user query and reporting, OnLine Analytical Processing (OLAP), dashboard/screen tools, data mining tools, and planning and modeling tools. It uses huge-database (data-warehouse) analysis, and mathematical, statistical and artificial intelligence, as well as data mining and OLAP. BI includes a set of concepts, methods and processes to improve business decisions, using information from multiple sources and applying past experience to develop an exact understanding of business dynamics [34]. It has emerged as a concept for analyzing collected data with the purpose to help decision making units get a better comprehensive knowledge of an organization's operations, and thereby make better business decisions [1]. A BI system is a data-driven DSS that primarily supports the querying of a historical database and the production of periodic summary reports [35]. It can be presented as an architecture, tool, technology or system that gathers and stores data, analyzes it using analytical tools, facilities reporting, querying and delivers information and/or knowledge that ultimately allows organizations to improve decision making [36-43].

Lönnqvist and Pirttimäki [44] stated that term, BI, can be used when referring to the following concepts:

1. Related information and knowledge of an organization, which describe the business environment, the organization itself, the conditions of the market, customers and competitors and economic issues;
2. Systemic and systematic processes by which organizations obtain, analyse and distribute the information for making decisions about business operations.

BI allows firms to apply information for supporting their processes and decisions by combining its capabilities in both organizational and technical issues. Put another way, "business intelligence allows people at all levels of an organization to access, interact with, and analyze data to manage the business, improve performance, discover opportunities, and operate efficiently" [45]. Contemporary BI and analytics technology have promoted data-driven management, where decision makers rely heavily on analytical tools and data at their fingertips to guide their work [46]. Problems and a huge amount of data of enterprises are input into data mining systems for data analysis so that decision makers can obtain useful information promptly to make correct judgment; that is, in regard to enterprise operating contents, abilities of fast understanding and deducing are provided, and thus enhancing the quality of decision-making and improving performance and expediting processing speed [47]. From a technical perspective, BI systems offer an integrated set of tools, technologies and software products that are used to collect heterogenic data from dispersed sources in order to integrate and analyse data to make it commonly available [9].

In some research, BI is concerned with the integration and consolidation of raw data into key performance indicators (KPIs). KPIs represent an essential basis for business decisions in the context of process execution. Therefore, operational processes provide the context for data analysis, information interpretation, and the appropriate action to be taken [48]. Ghazanfari et al. [49] believe that BI is the process through which organizations take advantage of virtual and digital technology to collect, manage, and analyze structural or non-structural data. As a data-centric approach to BI, data acquisition is becoming easier to acquire and large data warehouses with 10–100s of terabytes of relational database management systems (RDBMS) are becoming increasingly common due to the popularity of interactive, web-based databases [50].

Therefore, BI covers a wide range of tools and broad scope, and among the commonly mentioned important applications are data warehouse, data mining, OLAP, DSS, Balance Scorecard (BSC), etc [7]. The demands for a range of capabilities to satisfy a diverse set of user needs have enforced BI software companies to develop better and more suitable BI applications. This concept is shown in Figure 2.1.

BI involves several distinct areas and technologies that converge in the common goal of having access to data in order to help businesses by facilitating knowledge and supporting better management decisions [51].

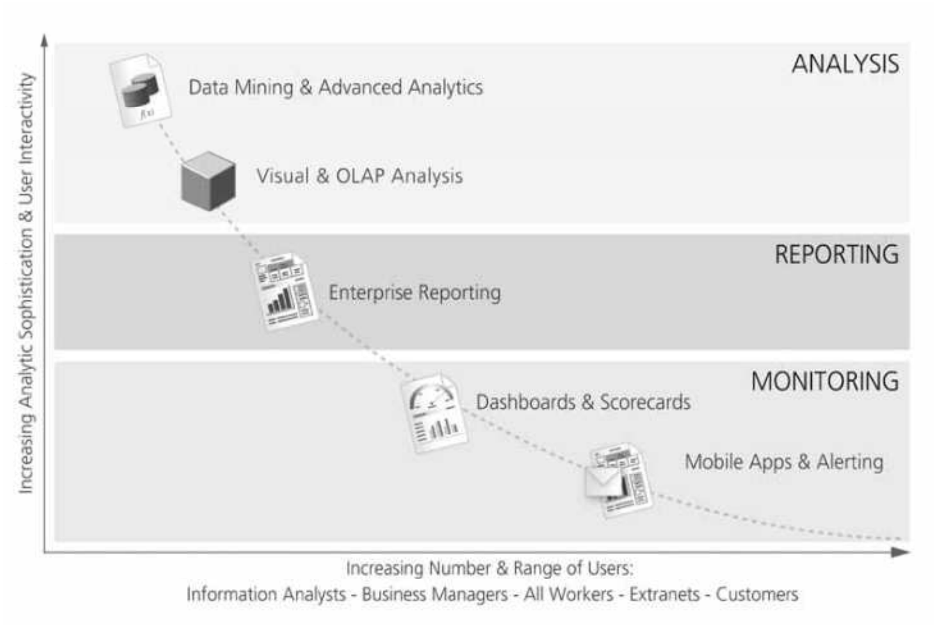

Figure 2.1: The capabilities of BI applications (Source: [52])

Besides the above mentioned BI can refer to a set of methods, processes, architectures and technologies that can process and transform collected datasets into meaningful and useful information for business purposes, and often used in business-critical servers, applications and services [53]. However, in the overall view, there are two important issues. First, the core of BI is the gathering, analysis and distribution of information. Second, the objective of BI is to support the strategic decision-making process [24]. By strategic decisions, it means decisions related to the implementation and evaluation of organizational vision, mission, goals and objectives with medium to long-term impact on the organization, as opposed to operational decisions, which are day-to-day in nature and more related to execution [54]. In a new definition, BI includes a range of areas such as competitor intelligence, customer intelligence, market

intelligence, product intelligence, strategic intelligence, technological intelligence and business counterintelligence [55].
After having the reviewed the literature we came to the conclusion that we define BI as a solution which should be considered in both managerial and technical approaches in order to assist experts and all levels of managers in decision making and taking processes [F11].

2.2 Architecture of Business Intelligence

Architecture of BI has an important role in implementing BI projects and it is a framework for organizing the data, information management and technology components that are used to build business intelligence systems for reporting and data analytics [56]. A well planned architecture needs to be in place for content integration, modeling/mapping and presentation [57]. In this section, at first, we express the conventional architecture of BI and its components and then we describe new-generation architecture of BI.

2.2.1 Conventional architecture of Business Intelligence

Basically, the conventional architecture has seven major components: source data in form of OnLine Transaction Processing (OLTP) and structured data; data integration; data warehousing; query and reporting; KPIs; BI software engine and Meta data management. Figure 2.2 depicts this concept.

As we observe in Figure 2.2, data extract, transform and load into data warehouse by ETL process from OLTPs and structured data files for integrating data and making data warehouse. Then data cubes are defined to prepare query and reporting. OLAP users need to analyze facts aggregated at multiple levels of abstraction. The basic query that aggregates base facts at a granularity given by a list of categories, one per dimension, is called a cube view.

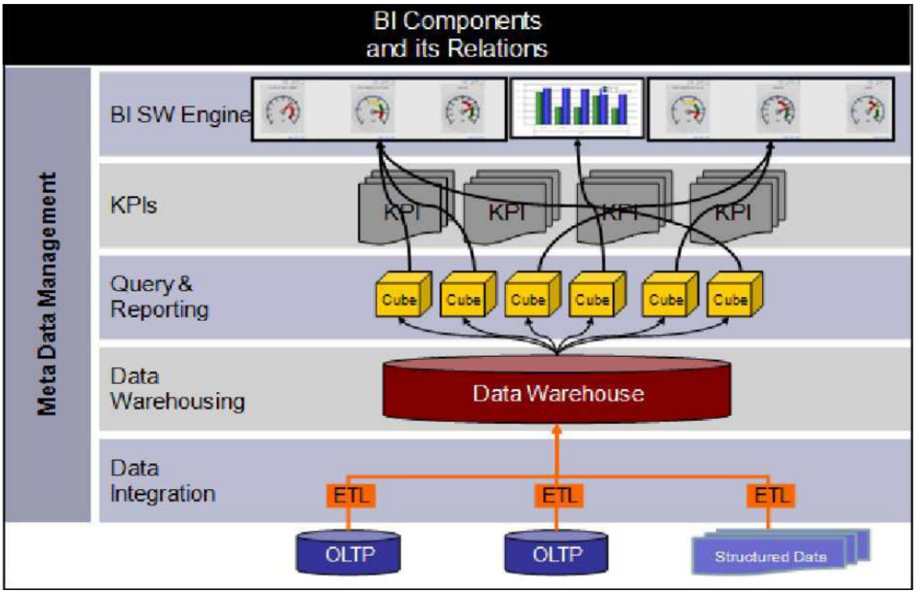

Figure 2.2: Conventional architecture of BI (Source: [F9])

A data cube is the set of all possible cube views defined over a list of dimensions, a base table, and aggregated measures [58]. Based on data cubes, we can prepare analytical reports and dashboards by BI software engine, which is built on KPIs. As we know, Meta data is “data about data” and generally means information about the data objects, whether generated by system, application, or people. Meta data management is the activities associated with ensuring that Meta data is properly created, stored, and controlled so that inconsistencies and redundancies are removed.

Another conventional architecture which has been depicted by Chaudhuri et al. shows a typical architecture for supporting BI within an enterprise and focus on technology. This architecture is shown in Figure 2.3.

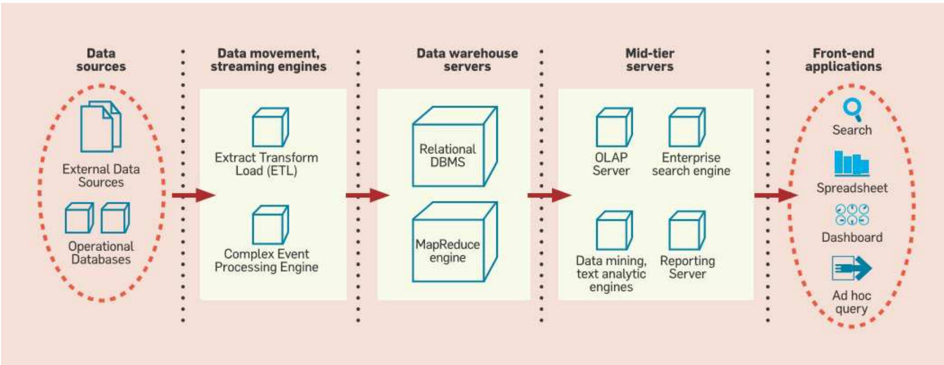

Figure 2.3: BI architecture (Source: [59])

For better understanding, it seems that two components of the above figure need to be addressed because previously we have not explained them and also they are not very popular with end users. These components are "Complex Event Processing Engine" and "MapReduce engine". To define the first term, we should know first what Event Processing is and secondly what Complex Event Processing is (CEP). Event Processing is a method of tracking and analyzing (processing) streams of information (data) about things that happen (events), and deriving a conclusion from them [60]. Complex Event Processing, or CEP, is event processing that combines data from multiple sources to infer events or patterns that suggest more complicated circumstances [61]. The goal of complex event processing is to identify meaningful events (such as opportunities or threats) and respond to them as quickly as possible [62]. Therefore, CEP engine can be considered as a dedicated service to handle requests from client application for managing a system.

Traditional MapReduce engines, following the original design of Google's engines, employ dynamic routing for data shuffling, an algorithm where intermediate data is stored temporarily on the nodes executing map tasks and subsequently fetched on demand by the nodes executing reduce tasks. Of course, an alternative approach recently is to use static routing, in which a predetermined configuration dictates where to process and store each data partition [63].

2.2.2 New-Generation architecture of Business Intelligence

A new-generation architecture of BI was introduced by W. Eckerson to show that the new-generation BI architecture is more analytical, giving power users greater options to access and mix corporate data with their own data via various types of analytical sandboxes [33]. It also brings unstructured and semi-structured data fully into the mix using Hadoop and nonrelational databases. This architecture is illustrated in Figure 2.4.

The top half of the figures on the next page indicates that the classic top-down architecture which data warehouse delivers interactive reports and dashboards to casual users and the bottom half represents a bottom-up analytical architecture with analytical sandboxes and new type of data sources. New terms with less popularity which are used in this architecture are analytical sandboxes and Hadoop.

Analytical sandboxes are created as a separate analytic environment to respond the needs of power users for answering unanticipated questions and issues. Analytic sandboxes are proving to be a key tactic in liberating business analysts to explore data while preventing the proliferation of spreadmarts and renegade data marts [64].

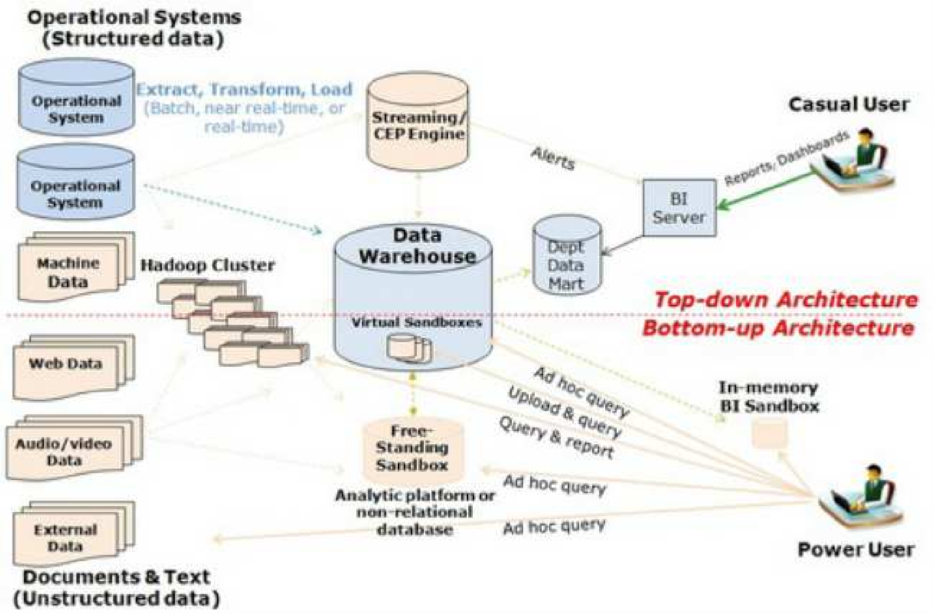

Figure 2.4: The new-generation BI architecture (Source: [65])

The illustration depicts three kinds of sandboxes which include: Virtual sandbox, Free-standing sandbox and In-memory BI sandbox. In fact, a virtual sandbox is a set of tables inside a data warehouse which enables analysts to upload data into the sandbox and combine it with data from the data warehouse in order to permit them to go to one place to do all their analyses. A free-standing sandbox is often used to offload complex, ad hoc queries from a data warehouse as a separate database server and give business analysts their own space. Most times, analysts like those sandboxes which let them connect to virtually any data source and do the activities such as: model data, apply filters, and visually interact with the data without IT intervention. These kinds of sandboxes are called in-memory BI sandboxes.

Hadoop is an open-source framework for distributed computing, written in Java and developed by the Apache Foundation and inspired by Google's MapReduce. On one hand Hadoop is being used by many companies such as Facebook and Yahoo in order to analyze large-scale data tasks and on the other hand being easily adapted for use with any kind of hardware ranging from a single computer to large data center [F10]. In previous page's figure, actually, Hadoop is a staging sandbox which is a staging area for a data warehouse that contains raw, non-integrated data from multiple source systems in large volumes of unstructured data.

2.3 Summary of chapter

In this chapter an attempt has been made to depict an overview of BI and its components from architectural perspective. Conventional architecture of BI represents a tried-and-true mechanism for delivering strategic-level insight and decision support. However, it is not designed to address the needs of power users for answering unanticipated questions and issues. The new-generation BI architecture gives the opportunity to power users to access and mix corporate data with their own data via various sandboxes. Therefore, we have made an effort to describe components of the architectures for better understanding which helps us to investigate and determine BI readiness factors and their associated contextual elements that influence the implementation of BI systems in companies.

Chapter 3

Necessities for the evaluation of readiness

In recent years Business Intelligence systems have consistently been rated as one of the highest priorities of IS and business leaders [26, 66, 67]. Winning companies, such as Continental Airlines, have seen investments in BI generate an increase in revenue and produce cost savings equivalent to a 1,000% return on investment (ROI) [68]. A significant portion of several companies' IT budgets are being spent on business intelligence and related technology. Estimates of the amount spent on BI in 2006 range from $14 to $20 Billion, with growth estimates of from 10% to 11% per year for the foreseeable future [45, 69]. A Gartner Executive Program survey, as shown in Figure 3.1, conducted in 2008 across 1,500 organizations in Western Europe found that BI is the top technology priority for CIOs.

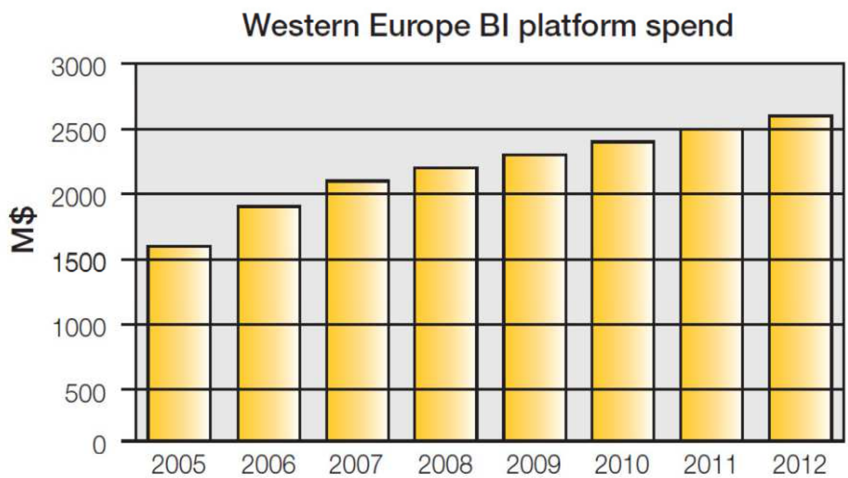

Figure 3.1: BI Spend Prediction (Source: [70])

In spite of these investments only 24% of BI implementations were identified as being very successful in a recent survey of companies using BI systems [45]. Losing companies have spent more resources than their competitors with a smaller ROI, all while watching their market share and customer base continuously shrink [71]. The complexity of business intelligence – data warehouse systems is very high so it is better to consider from the beginning various foreseen aspects that could impact the overall cost and increase the initial investment of the project. But even with good analysis there still remain a large number of variables to be considered [72]. The companies which are investing heavily in BI must expect to achieve benefits from their investments. How can some organizations achieve these benefits while others do not? What are the differences between companies which gain benefits from BI implementation and those that lose their money? Unfortunately, while much has been written about how to effectively implement and use business intelligence technology [25, 45, 73, 74], research on BI and specifically detailing how an organization can achieve benefits from BI is sparse [75].

3.1 Business Intelligence Success

The stakes are high for organizations to develop successful BI implementations [76]. A successfully implemented BI project plays an important role in understanding business status, measuring organization performance, improving relationship with stakeholders and making profitable opportunities. If we want to research how BI is considered successful first we have to be able to define what we mean by success. BI is a category of information systems and it is better that we begin to clarify how success is measured for IS in general. Many IS researchers have tried to evaluate success [77, 78]. Early work focused on multiple criteria including "profitability, application to major problems of the organization, quality of decisions or performance, user satisfaction and wide-spread use". The appropriate success measure depended upon the perspective of those evaluating success or the nature of the problem being addressed [79].

While multiple criteria measures are useful in IS success, many of those criteria are difficult to measure. As a result, much of the work on IS success has focused on system use as a proxy for success. In other words, it is advised that capability of system usage is an important clue for its success. Usage of an information system means that the system can be accepted by users, and users' work-related needs can be met and the objective at the initial implementation can be achieved. Still it was recognized that a better measure of IS success would probably be some weighted average of the criteria. So the advantages of an information system differ and they depend on the type of system being implemented and its stakeholders. This subject guides us that success measures for the research is necessary to be based on BI specific characteristics. BI systems are implemented to provide analytical capability to offer recommendations to improve operational or strategic processes or product characteristics [25, 45]. The value of BI for business is predominantly expressed in the fact that such systems cast some light on information that may serve as the basis for carrying out fundamental changes in a particular enterprise, i.e. establishing new co-operation, acquiring new customers, creating new markets, offering products to customers [80-82]. This means that when a BI system is used it is not enough to say it is successful but also recommendations and advices need to be used as important factors. Thus the achievement of organizational benefits must be considered to be appropriate measure of BI success.

3.2 Business Intelligence Readiness

BI readiness means that the essential prerequisites for BI success are in place. BI readiness assessments are used at the front end of BI projects to determine the degree to which a given company is prepared to make the changes that are necessary to capture the full business value of BI [25]. The BI Readiness Assessment is a series of tasks that analyzes several key areas across an organization to evaluate how prepared an organization is to begin short term tactical deployment of Business Intelligence solutions and mature it practice over the long term [83]. The evaluation of BI readiness is vital because it serves two important goals. First, it shows gaps areas where a company is not ready to proceed with its BI efforts. Thus by identifying BI readiness gaps, we can avoid wasting time and resources. Second, the evaluation reveals what we need to close the gaps and implement BI with a high probability of success.

3.3 Necessities for building a model

The bottom line in any evaluation program is to find problems and demonstrate that the system under evaluation satisfies the requirements. It is unfortunate that, in many cases, the evaluating program is actually aimed at showing that the BI system, as implemented, runs as it is requested by the users. That is, the evaluations are aimed at showing that the BI project does not fail, rather than that it fulfills its requirements.

There are a few books that discuss exactly BI readiness. Williams and Williams (2007) identified seven factors defining "business intelligence readiness" as being:

i. Strategic Alignment;
ii. Continuous Process Improvement Culture;
iii. Culture Around Use of Information and Analytics;
iv. BI Portfolio Management;
v. Decision Process Engineering Culture;
vi. BI & DW Technical Readiness;
vii. Business/IT Partnership [25].

The authors suggest that an organization can only gain the benefits of BI, if it has these readiness factors. Davenport and Harris in their book "Competing on Analytics," [73] focused on the impact of BI systems on organizations. They identified something that is called analytical capability, which was their concept of the ability of an organization to use BI and one that consists of organizational acumen and technology factors [73]. They suggest that an organization need to have capability in both organizational and technical factors. But they provide a high level view of these factors without discussing them in detail.

Jourdan et al. have collected, synthesized, and analyzed 167 articles on a variety of topics closely related to business intelligence published from 1997 to 2006 in ten leading Information Systems journals [76]. Based on their research, there are only 35 articles in BI implementation category which are issued in a variety of BI contexts including data warehousing, data mining, Customer Relationship Management (CRM), Enterprise

Resource Planning (ERP), Knowledge Management Systems (KMS), and eBusiness projects.

Research in information systems generally focuses on either developing theories that explain related phenomena or on verifying existing theories [84]. Analysis of the research strategies (in BI Research) over the ten year period from 1997 to 2006 illustrates that Formal Theory/Literature Review, Field Study-Primary Data, Field Study-Secondary Data, and Sample Survey are represented in almost every year of the time frame [76]. These four strategies are exploratory in nature and indicate the beginnings of a body of research [85]. BI research covers diverse subjects ranging from practical applications of neural networks [86], to end-user satisfaction [87], to the use of clustering as a business strategy to gain a competitive advantage.

Based on the journals and the books mentioned above and previous sections, there is not any research on the evaluation of BI readiness in companies. So we need to:

i. investigate and determine BI readiness factors and their associated contextual elements that influence implementation of BI systems in companies;
ii. develop a model for the evaluation of BI readiness in companies.

3.4 Summary of Chapter

Our aim in this chapter is to show the necessities for building a model to evaluate the readiness of companies in implementing BI project. It was shown that in today’s highly competitive world, BI usage is vital and no business organization can deny the benefit of BI. BI technologies are applied by profit and non-profit firms and business users became increasingly proactive. A successful BI project is an important issue for both researchers and practitioners; however, not many studies have been done on BI readiness. Although some guidelines for implementation exist, few have been subjected to model building in evaluating the readiness.

Chapter 4

The evaluation methods for the readiness

In the previous chapter, it is clarified that assessing the readiness is a requisite for a successful BI project. Therefore, it should be determined which evaluation method is the most suitable. It is best to start with the concept of evaluation. Evaluation can be defined as a systematic review and assessment of the benefits, quality, and value of a program or activity, or organization as a whole. In the evaluation process, an important choice must be made, that is, which evaluation method should be used. Based on Clarke [88], methods are used to reveal the existence of, to identify the 'value', significance or extent of, or represent semantic relationships between one or more concepts identified in a model from which statements can be made. Hence, evaluation methods are various procedures, schemes, algorithms, etc. which can be applied in the systemic review and assessment. Pohl et al. [89] inferred that very often, the quality of the results is dependent not only on the analytical expertise of the company but also on the method of evaluation itself.

If an available method is chosen arbitrarily, it may result in misleading or even wrong conclusions. To avoid this problem, it is necessary to develop a formal procedure for the selection of the readiness evaluation method for a specific readiness decision problem. There are typically multiple conflicting criteria that need to be evaluated in this kind of decision. Therefore, we face a multiple-criteria evaluation problem. These problems consist of a finite number of alternatives (readiness evaluation methods) which are known explicitly in the beginning of the solution process. Each alternative (method) is represented by its relation in multiple criteria. The methods (alternatives) are to be sorted and classified and a good alternative (method) with regard to tradeoff should be found between criteria. MCDM methods are a well-known approach to solving these problems. So, we applied one of the famous methods of MCDM which is called AHP. In this chapter, we present a framework by using AHP for the comparative analysis of readiness evaluation methods. Its purpose is to help the authors gain insight into the strengths and weaknesses of the various categories of readiness evaluation methods in order to apply for building a model to evaluate the readiness of those companies which want to implement BI projects.

4.1 Review and classification of the evaluation methods

Methods for readiness evaluation may be broadly classified into three main categories, namely probabilistic method, Multiple Criteria Decision Making (MCDM) methods and hybrid methods, as shown in Figure 4.1.

The probabilistic approach is one of the most popular methods [90]. Probability deals with the analysis of likelihoods of outcomes from experiments or trials, whose outcomes are not known or cannot be known in advance [91]. The probabilistic method is an important and remarkable technique/way to prove the existence of combinational objects with specified properties. Matoušek et al. [92] opines that based on probability theory but, surprisingly, it can be used to prove theorems that have nothing to do with probability. Mitzenmacher et al. [93] express that the basic principle of the probabilistic method is simple, but its application to specific problems often involves sophisticated combinatorial arguments. In [94], the partial least squares method was used to analyse and modell the readiness of the organization.

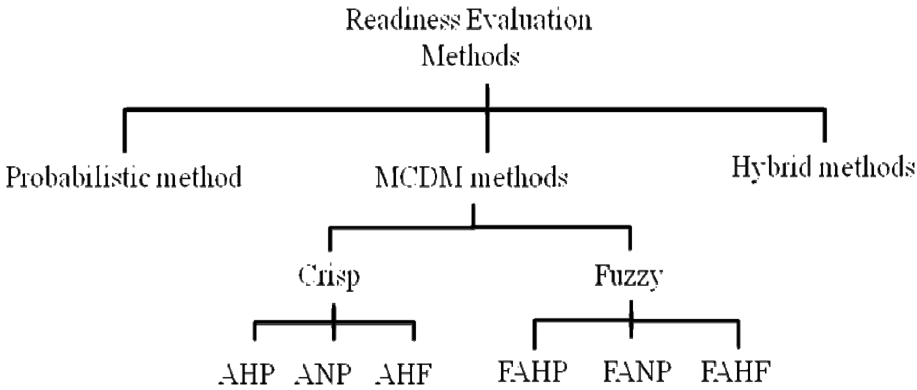

Figure 4.1: Classification of readiness evaluation methods

Toloie-Eshlaghz and Homayonfar [95] infer the development of MCDM methods has been motivated not only by a variety of real-life problems requiring the consideration of multiple criteria, but also by practitioners' desire to propose enhanced decision making techniques using recent advancements in mathematical optimization, scientific computing, and computer technology. The impact that the MCDM paradigm makes on business, engineering, and science is being reflected in the large number of articles with MCDM-type studies and analyses which are presented at professional meetings in various disciplines by Wiecek et al. [96]. MCDM can be defined as disciplines aimed to study methods and procedures by which concern about multiple conflicting criteria to help and support decision makers and takers. A literature review from 1999 to 2009 on MCDM methodologies and applications is done by Toloie-Eshlaghz and Homayonfar [95], and based on its context, we categorized these methods by regarding to their fuzzy and crisp nature and their applications into the readiness evaluation area.

Ishizaka and Labib [97] express that the analytic hierarchy process (AHP) is a MCDM method to help decision-makers when facing a complex problem with multiple conflicting and subjective criteria (e.g. location or investment selection, projects ranking, etc.). The AHP forms a problem into a hierarchy and the criteria and the relevant factors are decomposed hierarchically for a better understanding of the situation. The levels typically include the overall goal at the top, which is followed by the criteria contributing to the goal, sub-criteria (if any), and finally the alternatives at the lowest level. A series of pairwise comparisons at each level of the hierarchy are performed to produce local weights. Then a set of global weights or priorities for the alternatives are produced by combining these local weights and using an additive value model. Based on the computed global weights, the alternatives may be ranked.

Saaty [98] who is the developer of the ANP method says that the Analytic Network Process (ANP) is a generalization of the AHP, by considering the dependence between the elements of the hierarchy. Many decision problems involve the interaction and dependence of higher-level elements in a hierarchy with lower level-elements. Therefore, they cannot be structured hierarchically and for this reason, ANP is represented by a network, rather than a hierarchy. Figure 4.2 exhibits a hierarchy and a network and compares them.

The Analytical Hierarchy Framework (AHF) was established by Wang and Lin [99] to help small and medium enterprises (SMEs) to predict implementation success as well as identify the actions necessary before implementing B2B e-commerce to increase e-commerce initiative feasibility. This method considers only *n-1* judgments whereas the traditional analytic hierarchy approach (that is AHP or FAHP) uses *n(n-1)/2* judgments in a preference matrix with attributes or alternatives. The creators of this approach believe that the application of the proposed approach is clearly faster and more efficient than the conventional analytic hierarchy methodologies.

Mofarrah [100] opines that the MCDM methods are based on crisps values and the main limitations of these techniques are that they cannot handle the vagueness and uncertainty in the decision-maker's judgment. This limitation has led to the fuzzy based approach.

Liu et al. [101] understood that the complexity and dynamics of real-world engineering, financial and economical problems require advanced and sophisticated methods and tools to build hybrid risk assessment tools which can deal more powerfully with issues like fast-learning, uncertainty, online adaptability, knowledge capability and hierarchical solution etc. There are a wide range of hybrid methods that have been developed but we mean those hybrid methods which combine probabilistic method with the MCDM methods. The hybrid methods take advantage of the "rich" information provided by probability distributions, while retaining the multiple decision criteria and multiple decision alternatives character of MCDM methods as well as the conservative character of fuzzy calculus.

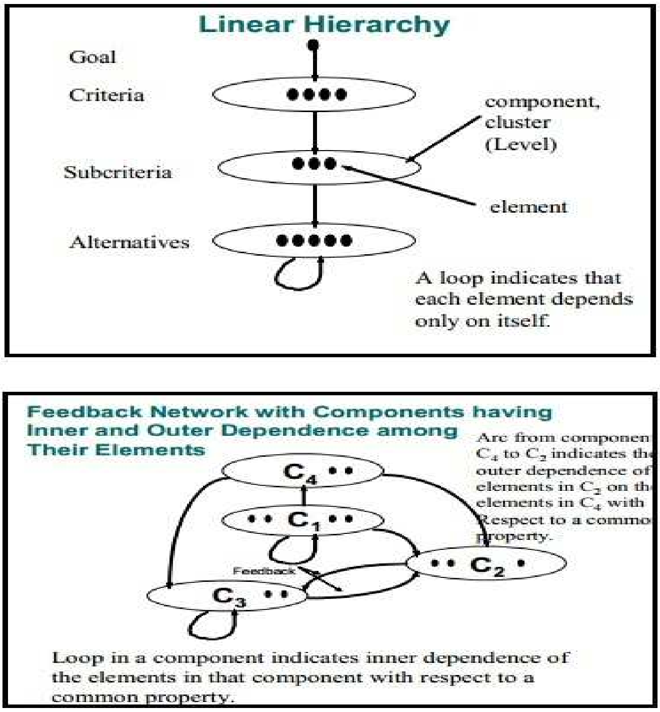

Figure 4.2: How a Hierarchy Compares to a Network (Source: [102])

Another hybrid method which has been attended by the experts includes the authors and categorized in this category is a combination of Interpretive Structural Modeling (ISM) and Graph Theory and Matrix Approach (GTMA). Finally, this hybrid approach is chosen by the authors in this dissertation and it is addressed completely throughout the next chapter.

4.2 Framework for comparing readiness evaluation methods

We adopt the AHP method as a framework for comparative analysis of readiness evaluation methods. Some reasons for our selection are the following:

- Application of AHP in ranking the methods

- It is simple and easy to use
- Structuring and organizing the complexity, measurement and synthesis of ranking the methods.
- It is almost universal adoption.
- It has proved in producing results that agree with perceptions and expectations.

The AHP can be applied in a wide variety of practical settings to model complex decision problems. One of its major strengths is its ability to compare and rank decision alternatives based on both qualitative and quantitative factors [89]. Concerning these abilities, we apply this method for a comparative analysis of the evaluation method. As mentioned in the previous section, AHP has the advantage of permitting a hierarchical structure of the criteria.

The first step in building framework is to structure the hierarchy. This step is important, since a different structure may lead to a different final ranking [97]. Figure 4.3 depicts the AHP hierarchy for our comparative analysis of the evaluation methods. We intend to perform a comparative study of the eight methods identified in the previous section and are enumerated at Level 4 of the hierarchy in Figure 4.3. At the highest level, we define the goal which is the identification of the ideal or best evaluation method for readiness evaluation. Level 2 lists eight major criteria or factors which are essential in determining the effectiveness of readiness evaluation methods.

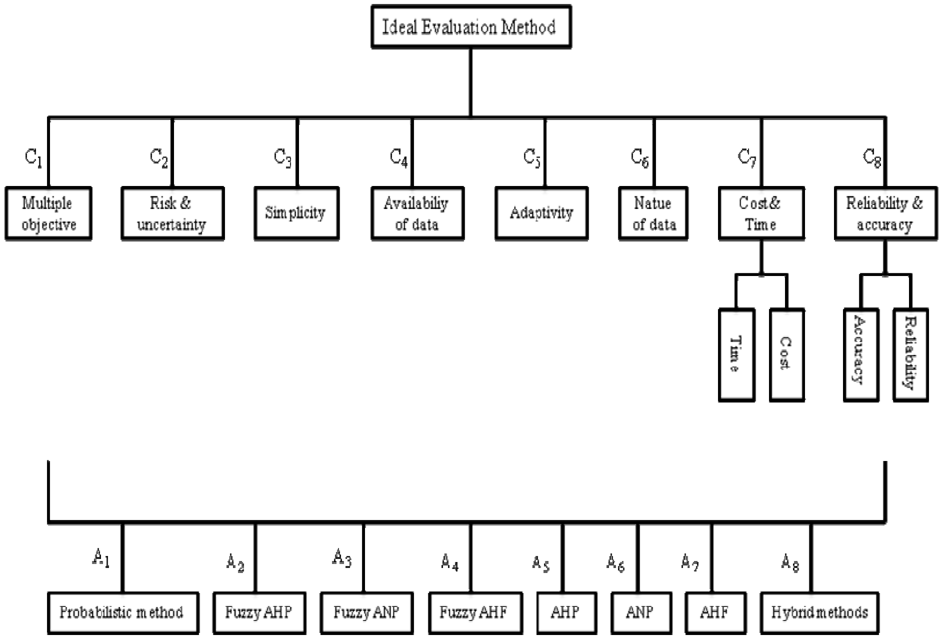

Figure 4.3: Hierarchy for the comparative analysis of the readiness evaluation methods- based on AHP method

4.3 Comparison of the readiness evaluation methods

In this step, the experts include seven specialists (three BI project managers, two BI experts and two BI academicians) who shall compare the criteria at Level 2 with respect to the overall goal at top level by assessing the importance of each criterion in relation to the choice of evaluation methods. Following the AHP methodology, the experts performed pairwise comparison to obtain the relative importance of the factors. Based on the actual characteristic of the methods, whenever possible, the weights are determined. Otherwise, the experts provided their best judgments based on their experiences in using methods. It should be noted that the exact result of the study could be different if different people with different backgrounds and experiences did the pairwise comparisons.

Table 4.1 shows the pairwise comparison matrix for the eight Level 2 criteria with respect to the goal. This analysis indicated that the criterion 'Multiple objective' has the highest weight of 26%, followed by criteria 'Reliability and Accuracy' and 'Risk and Uncertainty' which have weights of 19% and 18%. This prioritization is consistent with the very nature of real-world readiness evaluations and is usually multiple objective and a company typically has more than one objective in an evaluation program. The quality of being reliable and accurate is a necessity for every evaluation method. Also, the readiness evaluation methods usually incorporate risk and uncertainty in analysis.

Table 4.1: Pairwise comparison of criteria with respect to the goal

	Element	Comment		Weights
1	Multiple objective	The ability to deal with multiple objectives		26%
2	Risk & Uncertainty	The ability to incorporate R&U		18%
3	Simplicity	Easy to understand and operate		9%
4	Data availability	Obtaining data should be easy		10%
5	Adaptivity	To adapt knowledge of different DMs		7%
6	Nature of data	One form of data may be preferred		7%
7	Cost & Time	Monetary expenses' & 'Time required'		4%
8	Reliability & Accuracy	The quilty of being reliable & accurate		19%
	Eigenvalue	lambda	8.798	
	Consistency Ratio	CR	8.1%	

Matrix	Multiple objective	Risk & Uncertainty	Simplicity	Data availability	Adaptivity	Nature of data	Cost & Time	Reliability & Accuracy	normalized principal Eigenvector
Multiple objective	1	1	3	3	4	5	6	2	25.5%
Risk & Uncertainty	1	1	2	2	3	4	6	1/3	18.0%
Simplicity	1/3	1/2	1	1	2	3	4	1/3	9.1%
Data availability	1/3	1/2	1	1	1	2	2	1	9.9%
Adaptivity	1/4	1/3	½	1	1	2	3	1/2	7.2%
Nature of data	1/5	1/4	1/3	1/2	1/2	1	2	1	6.6%
Cost & Time	1/6	1/6	¼	1/2	1/3	1/2	1	1/2	4.2%
Reliability & Accuracy	1/2	3	3	1	2	1	2	1	19.5%

Based on the normalized weights, Figure 4.4 depicts a graphical plot of the weight as a bar chart.

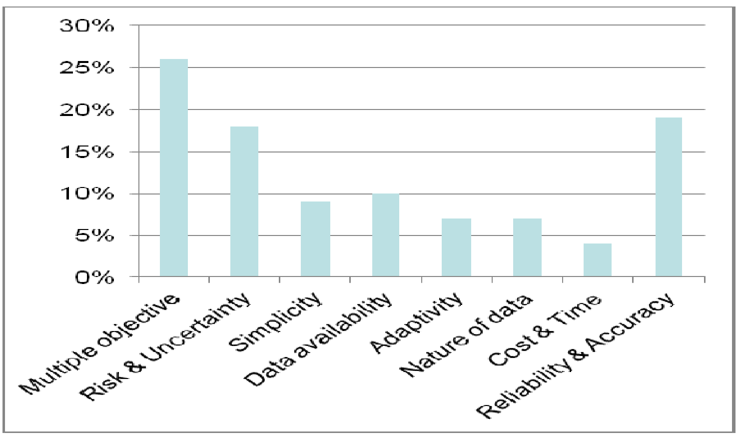

Figure 4.4: The normalized weights for the eight criteria.

Now, we are proceeding down the hierarchy and perform pairwise comparisons on the alternative methods with respect to each criterion at Level 2 except the 'Cost and Time' and 'Reliability and Accuracy' which have two Level-3 sub-criteria. The alternatives are also likewise pairwise compared with respect the four Level-3 criteria.

Table 4.2 depicts a summary of the normalized relative weights for the eight evaluation methods with respect to the eight Level-2 criteria. In the last two columns of the table, we also indicated the overall weights for the eight readiness evaluation methods and their ranks, respectively. Also, Figure 4.5 in the form of a bar chart shows a graphical comparison of the overall weights.

The analysis on the next page depicts that the hybrid methods have the highest weight of 0.211, and with large gap, we have the probabilistic method in the second rank with a weight of 0.124, and it is closely followed by the AHP with a weight of 0.122. The rest of the readiness evaluation methods in decreasing importance have approximately equal weights which means there is not any meaningful difference among them.

Accordingly, the criteria proposed by the experts as mentioned in the first paragraph of this section as well as the subjective judgments made by them, this comparative study depicts that the hybrid methods are the most favorable methods for building the evaluation models.

Table 4.2: The overall results of the comparative study

	CRITERIA									
	Multiple objective	Risk & Uncertainty	Simplicity	Availability of data	Adaptivity	Nature of data	Cost & Time	Reliability & Accuracy		
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8		
METHODS	0.255	0.180	0.091	0.099	0.072	0.066	0.042	0.195	Priority	Rank
Probabilistic	0.055	0.096	0.330	0.242	0.033	0.090	0.164	0.120	0.124	2
AHP	0.087	0.055	0.196	0.242	0.050	0.153	0.240	0.123	0.122	3
ANP	0.087	0.055	0.118	0.133	0.073	0.146	0.173	0.127	0.103	8
AHF	0.142	0.055	0.087	0.087	0.100	0.128	0.096	0.133	0.108	6
FAHP	0.087	0.153	0.110	0.125	0.079	0.170	0.117	0.081	0.110	5
FANP	0.087	0.153	0.070	0.079	0.168	0.170	0.095	0.081	0.107	7
FAHF	0.157	0.153	0.050	0.053	0.163	0.087	0.058	0.091	0.115	4
Hybrid	0.297	0.280	0.039	0.039	0.333	0.058	0.058	0.245	0.211	1

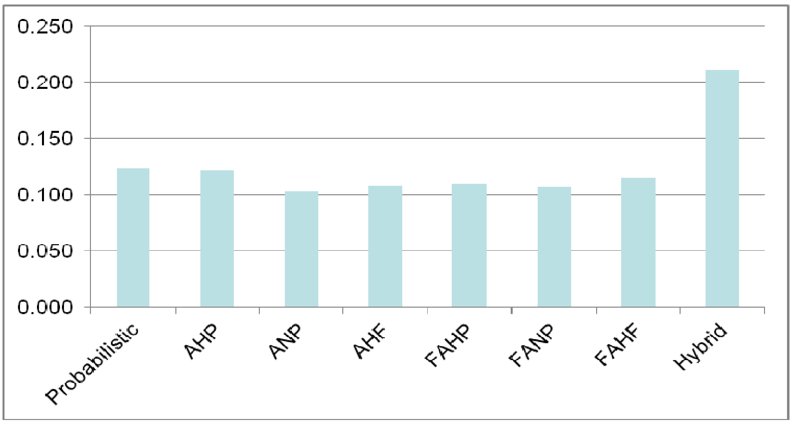

Figure 4.5: Overall weights for the eight readiness evaluation methods

Chapter 5

AHP and AHP-Fuzzy TOPSIS methods for the comparison

In this chapter, we want to show the applicability of AHP and AHP-Fuzzy TOPSIS methods in building a model to compare techniques and methods in the other unrelated area of BI in order to prove correctness of our way in comparing the techniques. It is studied and investigated as a part of the PhD program at the Université de Lorraine (scholarship opportunity-France) which enriched our research. The methods are applied in ranking the techniques that can solve reactive scheduling problem in operating rooms.

This chapter proposes to give an overview of reactive scheduling problem in opearting rooms and also it is to provide a comparative analysis of the techniques which can solve this problem. Operating room planning and scheduling in hospitals is becoming increasingly important and the real scheduling problems are very seldom static. Hence, an attempt has been made to depict reactive scheduling in this field.

Reactive scheduling is a way to respond to disruptions of operating room includes room (machine) disruption and patient (job) disruption. The changes like surgery disruptions and delays in the schedule on the day of surgery forces the use of reactive scheduling. In fact, reactive scheduling method modifies the predetermined initial surgery schedule when this schedule cannot satisfy the given constraints.

Identifying the right technique for solving a reactive scheduling problem in operating rooms is an area of considerable interest to both academics and practitioners. Therefore, the authors tried to offer a broad summary of the most common techniques which can be used to solve the problem and conduct a comparative analysis of the techniques. We adopted the Analytic Hierarchy Process (AHP) method and AHP-Fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) as the frameworks for our comparative analysis of reactive scheduling techniques. These methods enable us to compare and rank the alternatives based on both qualitative and quantitative factors.

5.1 Introduction

In today's health services to patients in hospitals, the managers of hospitals have to reduce costs and expenses and improve financial assets with increasing satisfaction of patients. Within a health care organization, managers of different functions jointly organize the health care delivery with the objective to provide high quality care using the limited resources that are available [103]. A hospital's largest cost (approximately 40%) and revenue center is the operating room and around 67% of hospital revenues are generated by surgeries [104]. Also it is one of the most expensive resources of any hospital [105] and the demand for greater efficiency in the use of resources and the performance of each surgical suite is a necessity [106]. The operating room involves directly and indirectly with many other hospital departments, hence, it has a major impact on the performance of the hospital as a whole [107]. Managing a surgical suite is complicated because it involves many levels of decision making that affect or is affected by surgery scheduling systems [108]. These challenges express the necessity for planning and scheduling operating room departments to improve efficiency and effectiveness of hospitals and offer a high quality of care to patients.

Józefowska [109] describes the scheduling problem as a collection of parameters that specify jobs and resources together with optimal criterion. The principal task of scheduling is the temporal assignments of a set of activities to a set of resources subject to a set of constraints [110]. Mainly operating room scheduling includes two kinds of objectives. One is maximizing the number of operation of patients, in which the list of planned patients are mapped into an operating schedule while covers patient priority and available resources for a particular operation considering at the same time the accomplished total time of care [111]. Inefficient scheduling of the operating room may result in longer waiting time and consequently worsen the patient's disease, while an effective scheduling can increase the reputation and performance of both government as well as private hospitals [112]. Since poor operating room scheduling impresses some other areas within the healthcare organization, it must be carefully considered and coordinated [113]. Another objective is to minimize the costs associated with operating rooms such as staffing cost, known as overtime cost, which is greater than that of regular working hours [114].

The main problem of regular or predictive scheduling is that the actual events in the operating room can be significantly different from the schedule. Unpredictable real-time occurrences in the operating rooms may change the predetermined initial schedule and consequently convert a feasible schedule to an infeasible one. In most real-world environments, scheduling is a continuous reactive process where the presence of a variety of unexpected disturbances is usually unavoidable, imposing revision and modification of pre-established schedules frequently [115].

The reactive scheduling is an approach for solving this problem in the real-environment of operating rooms.

It is critically important for both academics and practitioners like hospital managers and consultants to select a suitable technique for solving a reactive scheduling problem in the operating rooms. Hence, we have tried to provide a comprehensive summary of the most common techniques to solve reactive scheduling. Another purpose of this section is to present the similarities and differences between these techniques accurately and to conduct a comparative analysis of the methods by classifying them into distinct categories. The current section compares different techniques based on their features and proposes a novel solution for solving reactive scheduling problems in the operating rooms. The rest of the section is organized as follows: a brief introduction to the reactive scheduling problem is presented in section two. Section three describes the mathematical model of the reactive scheduling problem. Section four explains the available approaches and classifies them into distinct groups. A general framework for the comparative evaluation of the solution techniques is proposed in section five. The experimental results of the evaluation are demonstrated in section six. Finally, section seven concludes the section and presents a prospective of the problem.

5.2 The reactive scheduling problem

Any scheduling system includes two essential phases: schedule generation and revisions. The first phase acts as a predictive mechanism in which the planned start and completion times of operations of the jobs are specified. The second phase is the reactive part of the system which monitors the execution of the schedule and deals with unexpected events

[116]. Reactive scheduling is the process of revising a certain schedule in real time since the occurrence of unexpected events during the execution of the schedule is inevitable [117]. In summary, a robust reactive scheduling system attempts to aggressively modify the predictive schedule and does not deliberately offer any safety substructures against future disturbances due to the sole responsibility of the proactive scheduling routine against future disturbances [118]. Actually, the reactive scheduling procedure is activated only when unexpected events or disturbances occur during the operating process [119]. Figure 5.1 demonstrates a reactive scheduling scheme in contrast to classical scheduling which acts as a guideline more than a practical tool.

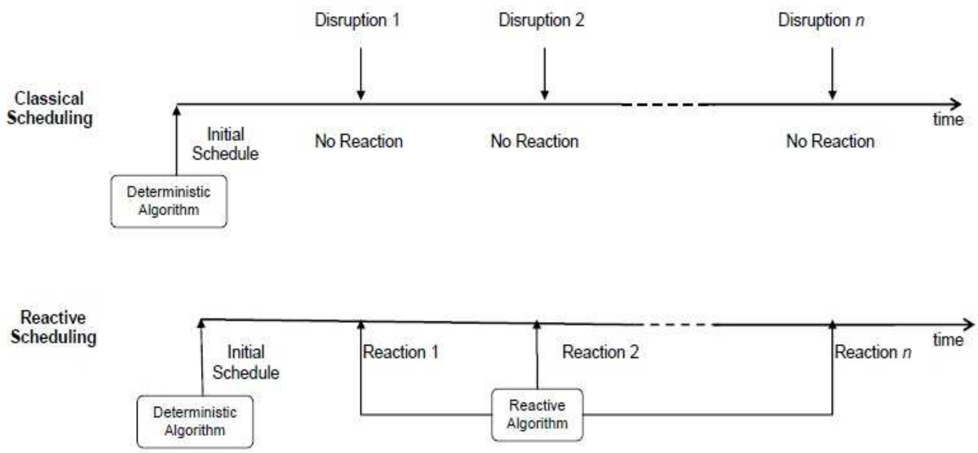

Figure 5.1: Reactive Scheduling vs. classical Scheduling [120]

Reactive scheduling for operating rooms is a single machine scheduling problem which patients are the jobs should be assigned to the operating rooms (machines) with limited capacity [121]. That is, the list of selected patients is pre-scheduled and whenever emergency patients arrive randomly on the day of surgery, the patient list is updated. Additionally, actual lasting time of surgeries may differ from the period of time assigned for them and there may be issues with patient punctuality [122]. Consequently, it is necessary to recheck and update systematically the patient schedule list.

Actually, in the single operating room scheduling problem, the objective is to allocate start times for a certain number of surgeries in order to schedule a particular operating room on a given day. The variability in surgery durations causes waiting and wasting time between surgeries which will be impacted by the choice of start times and it is possible some extra time is needed at the end of the day. Figure 5.2 displays the situations when these conditions occur in an operating room.

Regarding the problem in manufacturing systems [119], the reactive scheduling process in operating rooms can be described using the following terms:

- Job (Patient): J_i $(i=1,2,\ldots,m)$. Patients are the persons who should be operated in an operating room.
- Resource: R_j $(j=1,2,\ldots,n)$. Resources are elements which are used in operating processes of patients. Surgeons, anesthesiologists, nurses, technicians and equipment are typical examples of resources.
- Operation: O_{ij}. Operations are surgery activities which are carried out to operate the patients by the resources. A surgical process is an example of the operation. By default, each resource performs one operation on each patient and there is no priority constraint of operations. The information of each operation are processing time pt_{ij}, starting time st_{ij} and finishing time ft_{ij}. The patient J_i and the resource R_j preset the processing time pt_{ij} of the operation O_{ij} while the starting

time st_{ij} and the finishing time ft_{ij} are specified in the operating room scheduling problem.

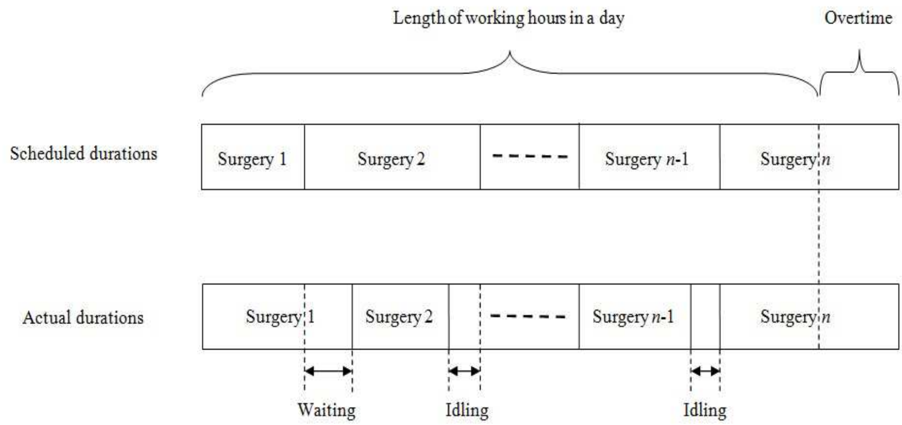

Figure 5.2: Single operating room problem (Adapted [123])

Surgical operation schedules are constructed via the following three activities. They are,

1. Choosing appropriate resources to perform operations for patients and designation of their sequences, known as operating sequences, for each patient.

2. Determination of appropriate loading sequences of the patients on the resources.

3. Computing the starting time and/or finishing time of each operation accomplished by the resources.

The reactive scheduling process can improve a postponed operating schedule without interrupting the progress of the operating process. The entire reactive scheduling process in the operating rooms is demonstrated in Figure 5.3. When delay information is sent from the operating system at the time T_1, due to the increase in makespan by the unexpected delays, predetermined operating schedule does not satisfy the given constraint on the make-span and consequently the process is activated. *dt* is the computational time required for generating new possible operating schedule which yields (T_1+dt) and after this moment, the schedules can be adapted through the process. If the newly generated operating schedule is better than the existing schedule, it will apply to the operating system. Otherwise, if the modified operating schedule is not able to satisfy the constraint, the reactive scheduling process will be activated continuously until new operating schedule can satisfy the given constraint on the makespan or until all the operations have already started.

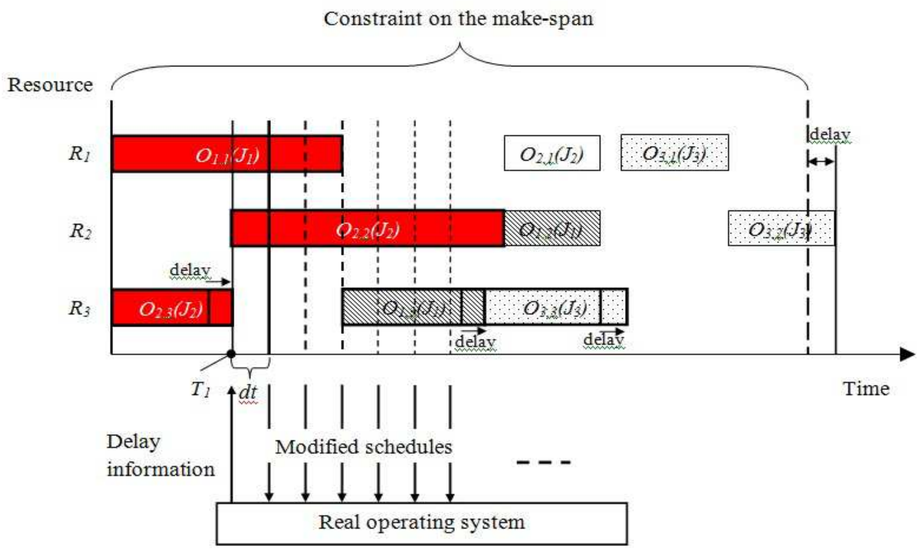

Figure 5.3: Whole reactive scheduling process (Modified [119])

Actually, reactive scheduling models are provided by academics and practitioners, offering a solution to operating rooms' disruptions which occur because of the operating room unavailability and patients' unbalanced surgery time. Hence, in order to avoid the disruptions, selecting the right approaches and techniques for creating these models are very important.

5.3 Mathematical Model

As mentioned before, the reactive scheduling of an operation room can be modeled as a single machine scheduling problem. In this optimization problem, some constraints and calculations should be considered as follows:

- Without considering whether or not patients are treated, for each patient a unique position should be assigned.
- In surgery time calculation, rather than the sum of expected duration (d_i) and standard derivation (s_i), a slack time for each patient is added. Generally, the time is considered as a lognormal random variable with μ_i and σ_i as its mean and standard derivation respectively. These parameters are calculated using previous historical data.

$$d_i = e^{\mu_i + \frac{\sigma_i^2}{2}} \tag{5.1}$$

$$s_i^2 = \left(e^{\sigma_i^2} - 1\right) e^{2\mu_i + \sigma_i^2} \tag{5.2}$$

In this case, the total surgeries time for all patients in the sequence is computed as follows:

$$U = \left(\frac{M^2}{\sqrt{V + M^2}}\right) e^{\sqrt{\ln\left(\frac{V+M^2}{M^2}\right)}} \quad (5.3)$$

Where M and V are the sum expected and variance of all surgeries duration and are calculated as follows:

$$M = \sum_{i=1}^{I} e^{\mu_i \sqrt{e^{\sigma_i^2}}} \quad (5.4)$$

$$V = \sum_{i=1}^{I} (e^{\sigma_i^2} - 1) e^{2\mu_i + \sigma_i^2} \quad (5.5)$$

The sum of means (M_{O_j}), variance (V_{O_j}) and the accomplishment time of the surgeries in sequence 1 to j be calculated as follows:

$$M_{O_j} = \sum_{k=1}^{j} \sum_{i=1}^{I} X_{i,j} e^{\mu_i \sqrt{e^{\sigma_i^2}}} \quad (5.6)$$

$$V_{O_j} = \sum_{i=1}^{I} \sum_{k=1}^{j} X_{i,j} \left(e^{\sigma_i^2} - 1\right) e^{2\mu_i + \sigma_i^2} \quad (5.7)$$

$$t_j = \left(\frac{M_{O_j}^2}{\sqrt{V_{O_j} + M_{O_j}^2}}\right) e^{\sqrt{ln\left(\frac{V_{O_j} + M_{O_j}^2}{M_{O_j}^2}\right)}} \quad (5.8)$$

Where $X_{i,j}$ is a binary variable and the equation intends to calculate it. Let i and j be the patient identifier and the index in patient sequence respectively, then $X_{i,j}$ is defined as follows:

$$X_{i,j} = \begin{cases} 1 & patient\ i\ assigned\ to\ position\ j \\ 0 & Otherwise \end{cases} \quad (5.9)$$

And the surgery duration of a patient in position j is calculated as follows:

$$D_j = t_j - t_{j-1} \tag{5.10}$$

In a real world online, a good solution technique for reactive scheduling of operating room should be able to consider elective and non-elective patients. Also, the solution must optimize the weighted number of expected surgeries. Formally, by considering the notations demonstrated in Table 5.1, the problem can be modeled as follows:

Table 5.1: Description of notations used in the modeling of the problem

C	Remaining capacity in the operating room
P_i	Penalty of patient i, if not treated
U	The sum of the surgeries durations of all patients in the schedule sequence
Z_j	Consider the present patient arrangement. If the patient in position j is tardy then: $Z_j = 0$, otherwise $Z_j = 1$.

$$Maximize \left\{ \sum_{i=1}^{I} \sum_{j=1}^{J} P_i X_{i,j} Z_j \right\} \tag{5.11}$$

$$Subject\ to: \sum_{j=1}^{J} X_{i,j} = 1, \quad \forall i$$

$$\sum_{i=1}^{I} X_{i,j} = 1, \quad \forall j$$

$$t_j - C \leq U(1 - Z_j)$$

$$X_{i,j} = 0 \; or \; 1, \forall \; i, j$$

$$Z_j = 0 \; or \; 1, \forall \; j$$

Now, the problem can be solved by the techniques.

5.4 Review and classification of the solution techniques

The solution techniques for reactive scheduling problems may be broadly classified into ten main categories, namely: heuristics, meta-heuristics, branch and bound algorithm technique, integer programming, knowledge-based systems, fuzzy logic, neural networks, Petri nets, multi-agent systems, and hybrid techniques. Figure 5.4 displays these main categories with their sub-categories.

The term heuristic is defined by Foulds as a method which, on the basis of experience or judgment, seems likely to yield a reasonable solution to a problem but which cannot be guaranteed to produce the mathematically optimal solution. In general, heuristics provide a powerful trade-off between descriptive models, such as simulation and queuing models, and perspective (optimization) models for problems that are very computationally challenging and they do not necessarily provide an optimal solution and it is often difficult to develop good bounds on their performance [123]. The most common heuristic is to instantiate the most constrained variable to its least constraining value [124].

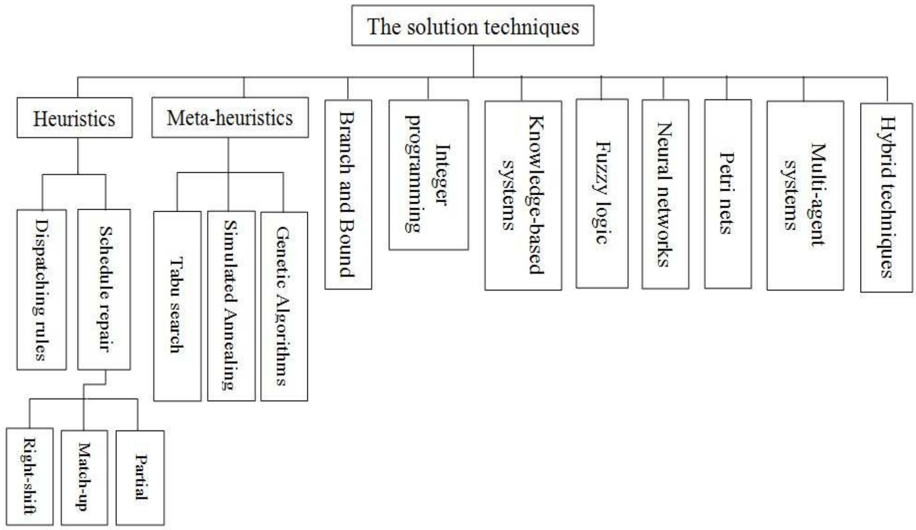

Figure 5.4: Classification of the solution techniques

A dispatching rule is a rule that prioritizes all the jobs that are awaiting for processing on a machine and whenever a machine has been freed, a dispatching rule inspects the waiting jobs and selects the job with the highest priority [125]. Dispatching rules are quick, usually intuitive, and easy to implement and also they have played a significant role in completely reactive scheduling [115]. But application of these techniques should be concerned with their disadvantages like limited use in practice and finding unpredictably bad solutions.

Schedule repair is a procedure to modify the original predictive schedule to accommodate sudden disruptions (internal or external) in the job shop. As it is shown in Figure 5.4, the most common schedule repair heuristics are: right-shift schedule repair, match-up schedule repair, and partial schedule repair. The right-shift heuristic technique shifts all of the remaining jobs (altogether) in the time horizon so that the disruption length is accommodated but the sequence of jobs remains unchanged.

Match-up schedule repair technique could generate a match-up schedule, where at some point in the future, the new schedule and the original one become the same/converge and partial schedule repair reschedules only operations in failure [115].

A meta-heuristic is a higher level heuristic procedure designed to guide other methods or processes towards achieving reasonable solutions to difficult combinatorial mathematical optimization problems. In fact, meta-heuristics are high level heuristics which guide local search heuristics to escape from local optima [126] and are based on the idea of searching neighbourhoods.

The basic principle of tabu search is to pursue local search whenever it encounters a local optimum by allowing non-improving moves; cycling back to previously visited solutions is prevented by the use of memories, called tabu lists, that record the recent history of the search, a key idea that can be linked to artificial intelligence concepts [127].

Origination of simulated annealing (SA) is from metallurgy. Annealing is the metallurgical process of heating up a solid and then cooling slowly until it crystallizes [128]. By analogy with this physical process, the fundamental idea is to allow moves resulting in solutions of worse quality than the current solution (uphill moves) in order to escape from local minima [129].

Genetic algorithms (GA) are inspired by Darwin’s theory about evolution. To solve a problem, a GA generates a set of solutions (population) and each of these solutions is evaluated by a fitness function. Then, some of the best solutions cause to create new solutions which make evolution in the solutions and the search space. This process works iteratively until some condition (e.g. number of populations or improvement of the best solution) is occurred. One important difference between GA and SA and tabu search is the iteration step. In GA, a number of different schedules are generated at each iterative step and carried over to the next step. But in SA and tabu search only a single schedule is carried over from one iteration to the next. Hence SA and tabu search may be regarded as special cases of genetic algorithms with a population size that is equal to 1 [125]. In [130], the authors focused on the problem, under open scheduling strategy. They utilize multiple resources constraints and propose an Ant Colony Optimization (ACO) approach to solve it. Their results of assessments demonstrate that the ACO outperforms in makespan, overtime and balanced resource utilization.

A branch and bound algorithm searches the entire space of candidate solutions, with one extra trick: It throws out large parts of the search space by using previous estimates on the quantity being optimized [131]. The basic concept underlying the branch and bound technique is to divide and conquer. Since the original large problem is hard to solve directly, it is divided (branched) into smaller sub-problems until these sub-problems can be conquered [132]. The branching is done by partitioning the feasible solutions into smaller and smaller subsets and the conquering (fathoming) is done partially by (i) giving a bound for the best solution in the subset; (ii) discarding the subset if the bound indicates that it can't contain an optimal solution. In [133], the authors have proposed a bi-objective model for the operating room scheduling problem. The objectives are the relative cost of the operating room and the approval of patients. They have used a Lagrangian relaxation approach to solve it. Besides, a branch and bound algorithm has been developed to solve the dual problems.

Integer programming is a form of mathematical programming which is an optimization technique for finding the minimum (or maximum) of a function comprised of a set of decision variables and the values of the decision variables must satisfy a set of restrictions, or constraints, and all of decision variables are restricted to be integer-valued [134]. In fact, an integer program is basically a linear program in which the variables are required to be integer and it can formulate many scheduling problems. In [135], a method proposed utilizes the power of integer programming without the need for creating scenarios. Various layers of robustness are assessed and the robust solutions are compared with the deterministic ones based on the number of operated and tardy patients, the operating room utilization rate and the number of cancelled patients. In [136], the operating room planning problem is presented as an integer program. The authors design a logic-based Benders' methods to solve it.

Knowledge-based systems focus on capturing the expertise or the experience of the expert in a specific domain and an inference mechanism is used to derive conclusions or recommendations regarding the corrective action to undertake [115]. To support the decision makers, knowledge based systems are right tools, as they consist of a theoretical framework and common sense knowledge [137].

Fuzzy sets theory has been successfully applied in treating different sources of uncertainty in scheduling problems, particularly when intuition and judgment play an important role [138]. An algorithmic reaction on the reactive level of problem solving based on sophisticated combinational considerations is generally not possible because of prohibitive computing times; therefore, the competence of human problem solvers in reaching quality, real-time decisions is extremely important and the application of fuzzy logic allows to present the vague, qualitative view of the human scheduler most conveniently [139].

A neural network is just a collection of units connected together; the properties of the network are determined by its topology and the properties of the “neurons” [140]. Neural network is sometimes referred to as artificial neural network or neural computing. Aleksander and Morton in their book “An Introduction to Neural Computing”, define neural computing as: “Neural computing is the study of networks of adaptable nodes which, through a process of learning from task examples, store experimental knowledge and make it available for use”.

A Petri net may be identified as a particular kind of bipartite directed graph populated by three types of objects which are places, transitions, and directed arcs connecting places to transitions and vice versa [141]. As we know, a schedule is an allocation of resources to tasks over time. Hence, Petri net is changed to time Petri net by adding time concept for describing the temporal behaviour of the system such as durations and delays. In this way, we have to map concepts such as tasks, resources and precedence onto places and transitions. In [142], a stochastic programming model is utilized to model the nature of operating room scheduling in Chinese big city hospitals. They have been developed some mathematical methods to solve the problem as optimal as possible.

There is substantial evidence that multi-agent systems are one of the most promising approaches to building complex, robust and cost-effective next-generation scheduling systems because of their autonomous, distributed and dynamic nature, and robustness against failures [143-145]. O'Hare and Jennings define multi-agent system as a network of problem solvers that work together to solve problems that are beyond their individual capabilities. In a multi-agent scheduling problem each agent is responsible for a set of jobs and has his own objective function [125]. In fact, an agent is a computer system that is capable of independent (autonomous) action on behalf of its user or owner and a multi-agent system is one that consists of a number of agents, which interact with one-another [146].

Some researchers [147-150] believe that with hybrid techniques and combining artificial intelligence techniques, we can derive better scheduling systems. Future research on job shop scheduling may focus on the development of hybrid techniques incorporating two or more of these techniques in a single framework that can be adapted easily to any given job shop instance [125]. The reason for creating a hybrid scheduling system is to combine various intelligent techniques, to integrate these techniques with conventional computing systems in order to overcome the limitations of individual techniques and to obtain technique enhancement, the multiplicity of application tasks and the realization of multifunctionality.

5.5 Application of AHP in ranking the solution techniques

For a comparative analysis of the solution techniques of reactive scheduling problems in operating rooms, we adopt the analytic hierarchy process (AHP) method as a framework. AHP is a Multiple Criteria Decision Making (MCDM) method helping decision-makers facing a complex problem with multiple conflicting and subjective criteria [97]. AHP has a wide range of applications in modeling complex decision problems [F6]. One of the AHP advantages is its ability to compare and rank decision alternatives based on both qualitative and quantitative factors [151]. Regarding these abilities and those we mentioned in section 4.2, we apply this method for a comparative analysis of the solution techniques.

The AHP forms a problem into a hierarchy and the criteria and the relevant factors are decomposed hierarchically for a better understanding of the situation. The levels typically include the overall goal at the top, which is followed by the criteria contributing to the goal, sub-criteria (if any), and finally the alternatives at the lowest level. A series of pairwise comparisons at each level of the hierarchy are performed to produce local weights. Then a set of global weights or priorities for the alternatives are produced by combining these local weights and using an additive value model. Based on the computed global weights, the alternatives may be ranked.

5.5.1 Framework for comparing the solution techniques

The initial and most important step for creating a framework is to construct a hierarchy. It is obvious that a different hierarchical structure may result a different final ranking. Figure 5 illustrates the AHP hierarchy for our comparative analysis of the solution methods. We will perform a comparative study of the ten previously introduced techniques that have been listed at level 3 of the hierarchy in Figure 5.5. At the highest level, we specify the goal which is the identification of the ideal or best solution technique for solving reactive scheduling problems in operating rooms. Level 2 enumerates eight major and essential criteria for determining the effectiveness of solution techniques.

To clarify the criteria, we briefly explain each criterion in the following.

Reactivity (C1): This criterion refers to the technique's ability of adapting and reacting properly to the disturbances (operating room disruption and patient disruption) in the online environment by delaying, rescheduling or adding additional surgeries according to the available operating time capacity.

Performance (C2): This criterion is related to the processing time of technique. That means techniques which require less processing time are better.

Monetary expenses (C3): Techniques that are inexpensive and need a short execution time are more preferred.

Simplicity (C4): Regarding this criterion, a good solution technique should be easy to understand and operate. Also the interpretation of results should be simple and convenient.

Bi-purpose (C5): A bi-purpose technique is capable of solving both of the elective and non-elective surgeries' scheduling problems.

Uncertainty (C6): It shows the ability of a technique to involve uncertainty in the analysis.

Reliability (C7): This criterion refers to ability of an approach to solve the problems under stated conditions for a certain period of time.

Accuracy (C8): It presents the precision of a technique to resolve a problem.

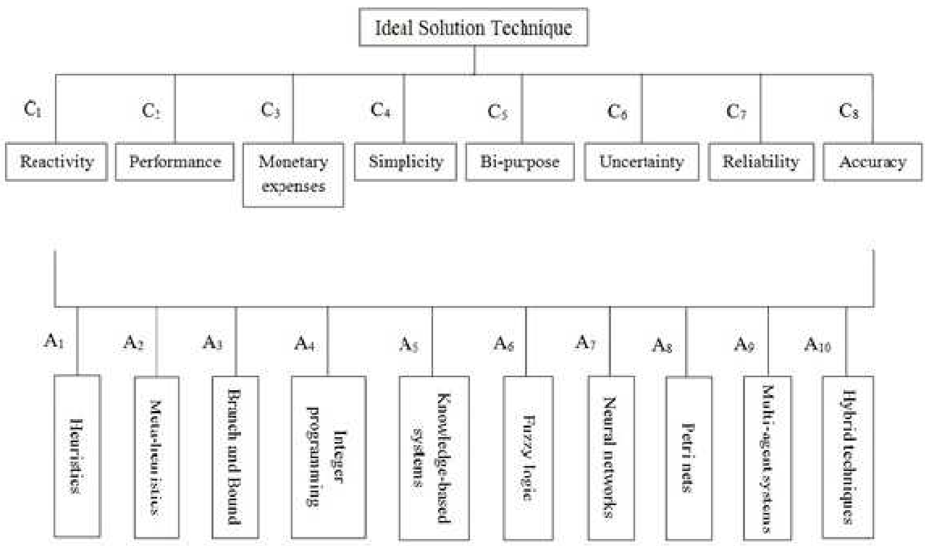

Figure 5.5: Hierarchy for the comparative analysis of the solution techniques- based on AHP method

5.5.2 Comparing the solution techniques

At the beginning of this section, we evaluated the importance of the aforementioned criteria within their relevance to the solution techniques. Our aim is to compare the criteria concerning the ideal solution technique as our overall goal located at the highest level. Based on the AHP methodology and specifications of techniques, pairwise comparisons have been performed and the weights have been determined by specialists of scheduling and the related techniques (six academicians who have focused on scheduling problems in operating rooms). The specialists individually judged their best upon their experiences in applying the techniques. It is evident that the results of the study could not exactly be the same when the pairwise comparisons are accomplished by different experts [F6]. Table 5.2 displays the pairwise comparison matrix for the eight criteria with respect to the ideal solution technique for solving reactive scheduling problems in operating rooms.

Table 5.2: Pairwise comparison of criteria with respect to the goal

	Element	Comment		Weights
1	Reactivity	Capability of adapting and reacting		19%
2	Performance	The process time		18%
3	Monetary expenses	Inexpensive and quick implementation		7%
4	Simplicity	Easy to understand and operate		5%
5	Bi-purpose	Solving both elective and non-elective		17%
6	Uncertainty	Incorporate uncertainty in the analysis		11%
7	Reliability	Solving problem under stated conditions		13%
8	Accuracy	Solving a problem with precision		11%
	Eigenvalue	lambda	8.367	
	Consistency Ratio	CR	3.7%	

Matrix	Reactivity	Performance	Monetary expenses	Simplicity	Bi-purpose	Uncertainty	Reliability	Accuracy	normalized principal Eigenvector
Reactivity	1	1 4/9	3 7/9	6	1	1 3/5	1 1/4	1 4/9	19.3%
Performance	2/3	1	2 5/8	6 1/4	1 1/4	1	1 4/5	2	18.1%
Monetary expenses	1/4	3/8	1	3/5	3/8	1 1/7	1/2	4/5	6.7%
Simplicity	1/6	1/6	1 2/3	1	1/3	4/5	1/2	½	5.0%
Bi-purpose	1	4/5	2 5/8	3 1/9	1	2	1 3/5	1 1/7	16.8%
Uncertainty	5/8	1	7/8	1 1/4	1/2	1	5/9	1	10.5%
Reliability	4/5	5/9	2	2	5/8	1 4/5	1	1 1/4	12.7%
Accuracy	2/3	1/2	1 1/4	2 1/6	7/8	1	4/5	1	11.0%

The results demonstrate that the ‘Reactivity’ criterion has the highest weight of 19%, followed by criteria ‘Performance’ and ‘Bi-purpose’ which have weights of 18% and 17%, respectively. This prioritization is consistent with the nature of real-world reactive scheduling problems in operating rooms since online reaction and performance and supporting both of elective and non-elective patients are essential capabilities for every technique in solving the real problems. Reliability is a necessity for each and every solution technique. Moreover, not only the solution techniques must be accurate with high precision but also, they must be able to incorporate with risk and uncertainty in analysis.

Figure 5.6 displays a graphical plot of the normalized weights as a bar chart.

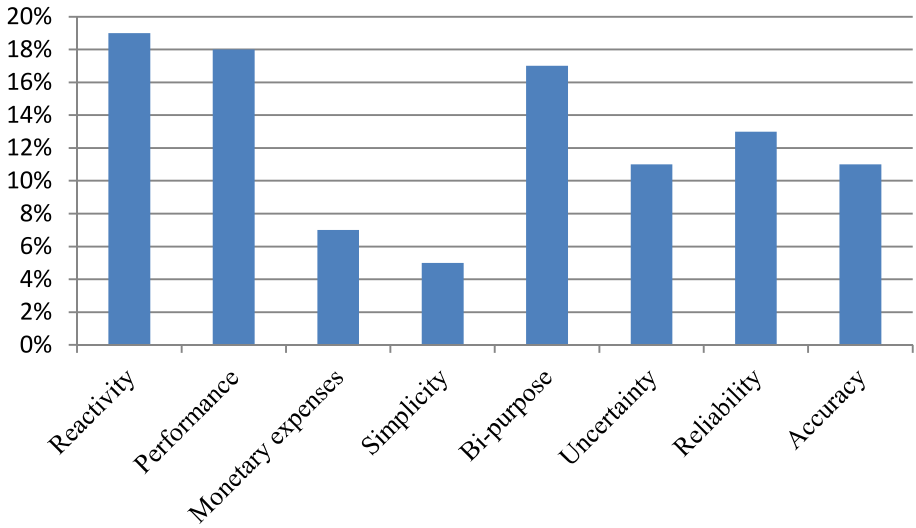

Figure 5.6: The normalized weights for the eight criteria

In the following, we should accomplish pairwise comparisons on the alternative techniques with respect to each criterion at level two in continuing and proceeding down the hierarchy. We should notify one of specialists (Prof. Dr. Imed Kacem- Université de Lorraine) who is a well known expert in solving scheduling problems of operating rooms, has weight two in our calculation. It means that his input is weighted twice the input of all other experts when comparing the alternative techniques. Also, the consistency ratio (CR) for all pairwise comparisons is lower than 0.1 and the consensus indicator which is based on the row geometric mean method (RGMM) results of all inputs using Shannon alpha and beta entropy is around 90% which means that there is very good consensus between the experts. BPMSG AHP Excel template [152] is used to facilitate ease in computation. Table 5.3 depicts a summary of the normalized relative weights for the ten solution techniques with respect to the eight Level-2 criteria. In the last two columns of the table, we also indicated the overall weights for the ten solution techniques and their ranks, respectively. Also, Figure 5.7 in the form of a bar chart shows a graphical comparison of the overall weights.

Table 5.3: The overall results of the comparative study

	CRITERIA									
	React.	Perf.	MonEx	Simp.	Bi-Pur.	Uncert.	Relia.	Accu.		
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8		
TECHNIQ.	0.193	0.181	0.067	0.050	0.168	0.105	0.127	0.110	Pri.	Rnk
Heuristics	0.2212	0.0605	0.2979	0.2788	0.0840	0.0541	0.0686	0.0816	0.125	4
Meta-heuristics	0.0998	0.0631	0.1182	0.1311	0.0923	0.0584	0.0654	0.0743	0.083	5
Branch and Bound	0.0809	0.3108	0.0745	0.0637	0.2755	0.3483	0.3511	0.2836	0.238	1
Integer program.	0.0441	0.2472	0.0822	0.0700	0.2379	0.2498	0.2432	0.2589	0.188	2
Know. systems	0.0876	0.0465	0.0741	0.0615	0.0367	0.0402	0.0339	0.0428	0.053	7
Fuzzy logic	0.1059	0.0384	0.0619	0.0471	0.0473	0.0391	0.0341	0.0434	0.055	6
Neural networks	0.0540	0.0407	0.0615	0.0737	0.0449	0.0391	0.0341	0.0457	0.047	9
Petri nets	0.0249	0.0204	0.0513	0.1075	0.0237	0.0203	0.0177	0.0230	0.028	10
Multi-agent systems	0.0740	0.0346	0.1016	0.0895	0.0471	0.0320	0.0300	0.0408	0.051	8
Hybrid techniques	0.2076	0.1378	0.0767	0.0770	0.1104	0.1188	0.1218	0.1059	0.132	3

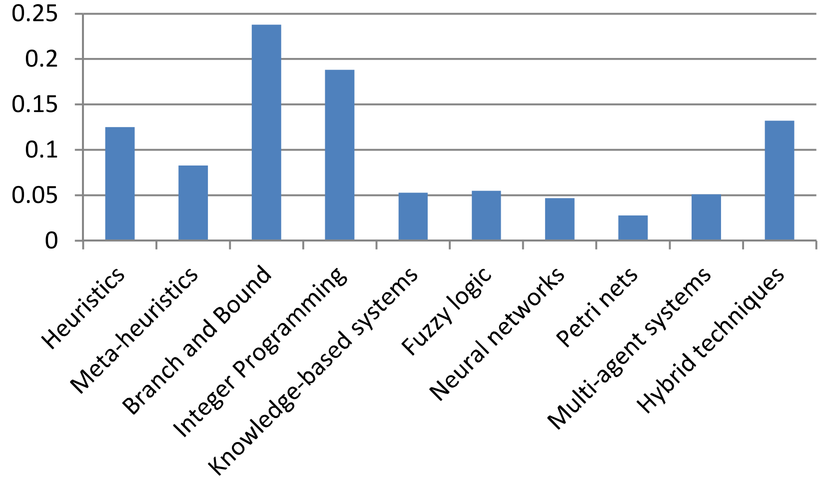

Figure 5.7: Overall weights for the ten solution techniques

The above analysis depicts that the branch and bound technique has the highest weight of 0.238, and we have the integer programming technique in the second rank with a weight of 0.188, and the hybrid techniques with a weight of 0.132 are in the third rank, and it is closely followed by the heuristics with a weight of 0.125. The rest of the solution techniques in decreasing importance are meta-heuristics with a weight of 0.083 and four techniques (fuzzy logic, knowledge-based systems, multi-agent systems, and neural networks) have approximately equal weights which mean there is not any meaningful difference among them and finally, the Petri nets with a weight of 0.028 is in last rank.

5.6 Application of AHP-Fuzzy TOPSIS in ranking the techniques

For ranking the solution techniques of reactive scheduling problems in operating rooms, we adopt AHP and fuzzy TOPSIS methods as our framework. These methods are the famous methods among Multiple Criteria Decision Making (MCDM) methods with capability in comparing and ranking the alternatives based on both qualitative and quantitative factors with vagueness data. AHP is a MCDM method helping decision-makers facing a complex problem with multiple conflicting and subjective criteria [97]. Application of the AHP in modeling complex decision problems is obvious in wide related issues [153]. One of its major strengths is its ability to compare and rank decision alternatives based on both qualitative and quantitative factors [151]. On the other hand, TOPSIS as a classical method in solving multiple attribute decision making (MADM) problems, is based on the idea that the chosen alternative should have the shortest distance from the positive ideal solution, and, on the other side, the farthest distance from the negative ideal solution [154]. It is obvious that many concepts, variables and systems in decision making process are imprecision and vagueness. Therefore, many decisions are made in uncertain conditions. Applying fuzzy theory is a good approach in this field. Concerning these abilities, we apply this hybrid method for ranking the solution techniques.

Based on AHP method, the main steps in determining weights of the criteria are:

1. Define clearly main objective
2. Form structure of the criteria and the solution techniques
3. Make pairwise comparison of the criteria
4. Calculate weightings and consistency ratio
5. Evaluate the criteria according weightings

AHP method is based on the solution of an Eigenvalue problem. The extracted results from pairwise comparisons are formed as a matrix and the first normalized Eigenvector of the matrix represents the weightings. Also, the consistency ratio is determined by the Eigenvalue.

Steps 1 and 2 are the same with the AHP method and described in sub-section 5.5.1.

5.6.1 Comparing and ranking the solution techniques

At this stage, the importance of each criterion from level two of the hierarchy in Figure 5.5 must be evaluated within its relation to the solution techniques to compare the criteria concerning the ideal solution technique as our overall goal which is located at top level. Based on the AHP methodology and specifications of techniques, pairwise comparisons are accomplished and the weights are determined by the experts. Contrary to the above result the experts (four academicians who have focused on the subject) judged their best upon experiences in applying the techniques. In addition, another input was entered by a specialist in scheduling and the related techniques. It is obvious that the result of the study could not be same exactly when the pairwise comparisons are done by different experts [F6]. Table 5.4 shows the pairwise comparison matrix for the eight level 2 criteria with respect to the ideal solution technique for solving reactive scheduling problem in operating rooms.

The next page's analysis indicated that criterion 'Reactivity' has the highest weight of 19.3%, followed by criteria 'Performance' and 'Bi-purpose' which have weights of 18.1% and 16.8%. This prioritization is consistent with the very nature of real-world reactive scheduling problems in operating rooms because online reaction and performance and supporting both elective and non-elective patients are core capabilities for every technique in solving the real problems. The quality of being reliable is a necessity for each and every solution technique. Not only must the solutions techniques be accurate with high precision but also, they must be able to incorporate with risk and uncertainty in analysis.

Table 5.4: Pairwise comparison of criteria with respect to the ideal solution technique

Element		**Comment**	**Weights**
1	Reactivity	Capability of adapting and reacting	**19.3%**
2	Performance	The process time	**18.1%**
3	Monetary expenses	Inexpensive and quick implementation	**6.7%**
4	Simplicity	Easy to understand and operate	**5.0%**
5	Bi-purpose	Solving both elective and non-elective	**16.8%**
6	Uncertainty	Incorporate uncertainty in the analysis	**10.5%**
7	Reliability	Solving problem under stated conditions	**12.7%**
8	Accuracy	Solving a problem with precision	**11.0%**
Eigenvalue		Lambda	**8.367**
Consistency Ratio		CR	**3.7%**

Based on the normalized weights, Figure 5.8 depicts a graphical plot of the weight as a bar chart.

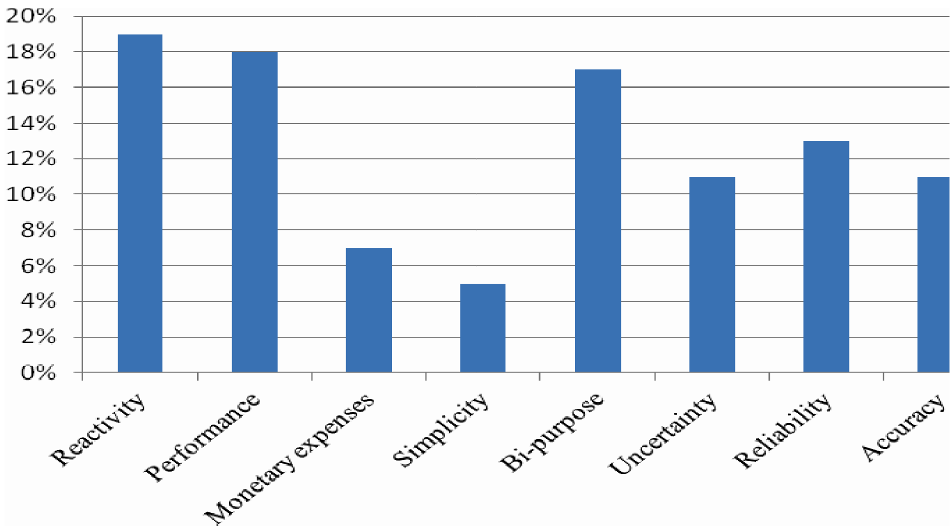

Figure 5.8: The normalized weights for the eight criteria

At this stage, we input data (weights of criteria) into Fuzzy TOPSIS method with determining the type of each criterion, i.e., positive and negative. In fact, the extracted weights from AHP are included in fuzzy TOPSIS computations and the solution technique priorities are determined. We followed the next basic steps in Fuzzy TOPSIS method:

1. The linguistic rating values for the solution techniques with respect to the criteria are chosen.
2. Aggregate fuzzy ratings (based on triangular fuzzy numbers) for the techniques are calculated.
3. The fuzzy decision matrix and the normalized fuzzy decision matrix are constructed.
4. The weighted normalized matrix is formed.

5. The fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) are identified.
6. The distance of each technique from FPIS and FNIS is calculated.
7. The closeness coefficient of each technique is calculated.
8. The techniques by comparing the closeness coefficient are ranked.

Now, we accomplish decision making matrix which is filled with linguistic variables. As Prof. Lotfi A. Zadeh expresses, a linguistic variable is a variable whose values are expressed in linguistic terms and this concept is very useful to describe situations that are too complex or not well defined in conventional quantitative expressions. These variables can be described by triangular fuzzy numbers which are given in Table 5.5 and shown in Figure 5.9.

Table 5.5: Fuzzy scale for prioritizing the techniques

Linguistic Variables	**Triangular Fuzzy Numbers**
High (H)	(8,9,10)
Medium High (MH)	(5,7,9)
Medium (M)	(3,5,7)
Medium Low (ML)	(2,3,5)
Low (L)	(1,2,3)

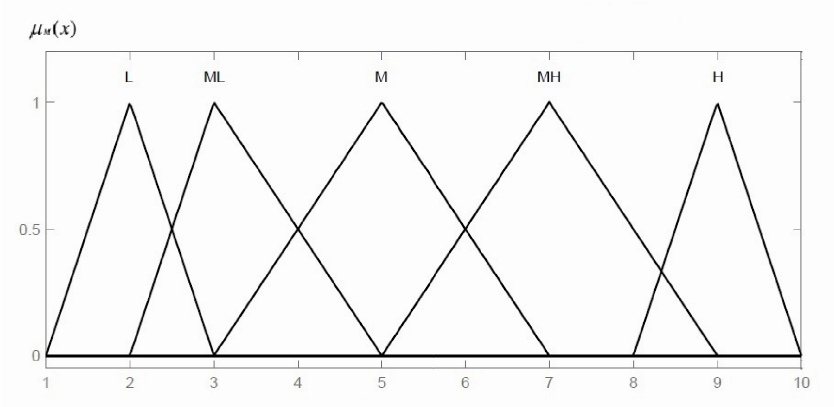

Figure 5.9: Linguistic values for showing degree of priorities

The experts used the above linguistic rating variables to evaluate the rating of the techniques with respect to each criterion. Finally, a closeness coefficient for each technique was defined to determine the ranking order of all techniques. The higher value of closeness coefficient indicates that a technique is closer to the positive ideal point and farther from the negative ideal point.

Table 5.6 depicts the ten solution techniques and their ranks. Also, Figure 5.10 in the form of a bar chart shows a graphical comparison of the overall priorities.

Table 5.6: Final ranking of the techniques

Rank	**Technique**	**Coefficient**
1	Branch and bound	0.6743
2	Integer programming	0.5665
3	Hybrid techniques	0.4520
4	Heuristics	0.3459
5	Meta-heuristics	0.2652
6	Fuzzy logic	0.2302
7	Knowledge-based systems	0.1967
8	Multi-agent systems	0.1834
9	Neural networks	0.1765
9	Petri nets	0.1765

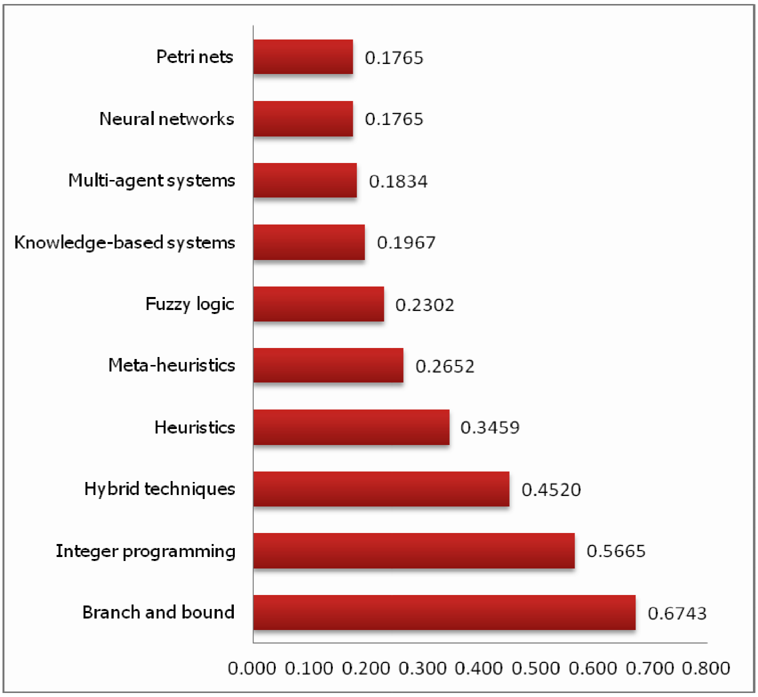

Figure 5.10: The comparison of the ten solution techniques

The above analysis depicts that the branch and bound technique has the highest coefficient of 0.6743, and we have integer programming technique in the second rank with a coefficient of 0.5665, and the hybrid techniques with a coefficient of 0.4520 are in the third rank, and it is followed by the heuristics with a coefficient of 0.3459. The rest of the solution techniques in decreasing importance are meta-heuristics with a coefficient of 0.2652 and is closely followed by the fuzzy logic with a coefficient 0.2302 and finally, the four techniques (knowledge-based systems, multi-agent systems, neural networks, and petri nets) have approximately equal weights which mean there is not any meaningful difference among them. Of course, the subjective judgment, selection and preferences of different experts can be influential of the results. In other words, if we chose another group of experts, we would not have exactly the same, above results.

5.7 Conclusions and prospective

In this chapter an attempt has been made to depict an overview of the reactive scheduling problem in operating rooms and also to select the right solution technique which is an important step in solving this problem, the authors provide a comparative analysis of the techniques. In responding to disruptions of operating rooms include room and patient disruptions, reactive scheduling can be a good way to modify the changes of predetermined initial surgery schedule.

Although many solution techniques have been developed for solving scheduling problems, there are a few techniques applicable for solving the reactive scheduling problem in operating rooms. Application of different techniques may lead to different results and hence different schedules. Therefore the choice of appropriate solution techniques would be a necessity to both academics and practitioners like hospital managers and consultants.

Regarding the proposed criteria as well as the subjective judgments made by the experts and a specialist in scheduling and the related techniques, the comparison results illustrates that the branch and bound method is the most appropriate technique for solving the reactive scheduling problems. This chapter has provided a framework for the comparative study and selection of the right technique based on the AHP method and AHP-Fuzzy TOPSIS which in this case is the AHP method applied to get weights of the criteria, while fuzzy TOPSIS is utilized to rank the solution techniques.

Of course, the ranking of these techniques with the use of other MCDM methods and also related methods which can be applied in this area can be a prospective research study for those scholars and practitioners who want to concentrate more on the solution techniques. Furthermore, testing these techniques as an experimental research in some hospitals for confirming the experts' opinions about the ranking is another interesting subject for future work.

Chapter 6

Proposed hybrid approach and model

As we mentioned in chapter 4, the hybrid approach is the most appropriate way and the hybrid methods are the most suitable methods in building an evaluation model for assessing the readiness of an organization before implementing a BI project. Rajesh Attri et. al in [155] provided a survey on Interpretive Structural Modeling (ISM) and says it is a suitable method to identify relationships between specific items that define a problem and Rao in [156] indicated that Graph Theory and Matrix Approach (GTMA) is a good method for the modeling of systems, network analysis, functional representation, conceptual modeling, diagnosis, etc. According to the results of [155] and [156], the combination of ISM and GTMA are considered in this dissertation for assessing the organization's readiness. Overall, the main contribution of this chapter is the usage of the ISM method to depict the relationship between the involved key factors in a successful implementation of BI projects. Then by using the Graph Theory and Matrix Approach (GTMA) an indicator is obtained to evaluate the organization's readiness before implementing BI projects.

6.1 The critical organizational and technical factors

For both academics and practitioners concerned with BI systems, one important issue is to identify the factors which are vital for the successful implementation of BI projects. Hence, this section offers a broad summary of the most common and impact factors which can be influential when implementing BI projects. We believe it is valuable to determine these factors, particularly for managers of those companies that are involved in implementing BI projects and face the need to evaluate readiness of their organizations before launching the project in pre-implementation stage.

The objective of this section is to provide a better understanding of the important and critical success factors and it is to conduct a survey and comprehensive study of the critical factors in the evaluation phase of the readiness by classifying the factors into two main categories; organizational and technical. It is obvious that each category has its own characteristics and a brief description of each factor is discussed.

To be successful in implementing a BI project and to gain the associated benefits, we need to identify the factors which contribute to the success. These factors must receive careful attention by top managers and BI project managers of those companies that are evaluating the readiness of their organizations. These prerequisites can be grouped into organizational factors and technical factors for better understanding and concentrating. Most authors often name these factors as Critical Success Factors (CSF). CSFs are a set of conditions, characteristics and variables that are defined in all fields and, if managed carefully, lead to organizational success. The CSFs can help to ensure the success of BI implementation in an arbitrary organization. Every BI project includes multiple stages and each stage has its characteristic with specific activities. The main aim is to find and categorized CSFs in the setting-up stage of implementing a BI project by related literature review. This way, the authors with assisting an experienced BI project manager provide their best judgments based on their studies and experiences in determining and categorizing CSFs.

The study of critical organizational and technical factors helps us to extract the core activities that are essential for successfuly implementing a BI project. These critical success factors as Rockart defined are “the limited number of areas in which results, if they are satisfactory, will ensure successful competitive performance for the organization”. In fact, they are the few key areas where “things must go right” for the company to be successful in implementing its BI project. In our literature review, as we mentioned previously, we categorized these factors as organizational and technical factors for the better understanding and focusing. Of course, the nature of these factors has also led us to this categorization. To apply a BI system, an organization needs to have capability in both organizational and technical factors.

Based on related studies in the literature [157-167], the organizational factors which influence a BI project success are: management support, decision-making structure, management style, managerial IT knowledge, goal alignment, and resources allocation, user participation, balanced and skilled project team, and an agile project management. The related and critical technical factors are: system quality, information quality, reliable back-end system, metadata management, technical framework, and agile methodology. Table 6.1 provides a summary of these factors. Of course, the names of factors are selected based on their similarities in concepts and definitions.

Similarity of implementing BI projects with other infrastructural projects like Enterprise Resource Planning (ERP) projects implementation shows that these kinds of projects need to consider many aspects of the project before deployment. Implementing a BI system is not a simple activity entailing merely the purchase of a combination of software and hardware; rather, it is a complex undertaking requiring appropriate infrastructure and resources over a lengthy period [165], [168].

Table 6.1: Critical organizational and technical factors for successful BI implementation

	Critical Success Factor	Description
Organizational	Management support (CF1)	The managers of organization involve and participate in the activities of BI project.
	Organizational culture (CF2)	A corporate culture which emphasizes on the value of sharing common goals over individual pursuits and the value of trust between partners, employees, managers and corporations.
	Decision-making structure (CF3)	The type of control or delegation of decision-making authority throughout the organization and the extent of participation by organizational members in decision-making pertaining to BI.
	Goal alignment (CF4)	The linking together of the business goals and the BI goals.
	Managerial IT knowledge (CF5)	Knowledge and experience of senior management about IT.
	Management style (CF6)	The way in which management tends to influence, coordinate, and direct people's activities towards a group's objectives.
	Resource allocation (CF7)	Allocating adequate resources of money, people, and time.
	User participation (CF8)	Involving and participating user in BI development process.
	Balanced and skilled project team (CF9)	The composition and skills of a BI team have a major influence on the success of the systems implementation.
	Agile project (CF10) management	Managing team members work together in the most effective manner possible.

Technical	System quality (CF11)	The performance characteristics of the BI system itself, which includes ease-of-use, functionality, reliability, flexibility, integration, and response time.
	Information quality (CF12)	It refers to accuracy, timeliness, completeness, relevance, consistency, and usefulness of information generated by the system.
	Reliable back-end system (CF13)	It is critical to ensure that the updating of data works well for the extraction, transformation and loading (ETL).
	Metadata management (CF14)	It is an end-to-end process for creating, enhancing and maintain meta-data repository and associated processes.
	Technical framework (CF15)	It must be business-driven, scalable and flexible framework.
	Agile methodology (CF16)	The purpose of agile BI is to get the development done faster, and react more quickly to changing business requirements.

Good performance of the CSFs requires that their elements (or constituents) be known so that management can formulate appropriate policies and strategies to ensure that the elements are constantly and carefully being managed and monitored [169].

It is generally believed that the organizational factors are more important than the technical factors, and identifying these factors can help us to find the organizational strengths and weaknesses of the company with regard to implementation of BI. Burton et al. [170] pointed out that organizational dynamics are the most significant challenge to the success of business intelligence initiatives and implementations. The results from the recent survey show clearly that non-technical factors were the hardest to solve and indicate that these CSFs play a dominant role in BI initiatives' success in large enterprises [171]. In the organizational factors, management support has been widely acknowledged as the most important factor in implementing a BI project. Managers must consider and fund the BI project as a top priority and take an active role in leading the change by being involved in every step of the BI implementation.

In spite technical factors having second role, they must completely be concerned as without these elements, implementing a BI project is impossible and the lack of each element can lead to the failure of the project. It is assumed that the main tasks to be faced by BI systems include intelligent exploration, integration, aggregation, and a multidimensional analysis of data originating from various information resources [172]. System and information quality are the most important factors among the technical factors because each BI system needs to integrate right data and information from various source systems. Hence, having a system approach for BI project managers is a necessity and they should make a balance between organizational and technical factors.

An important step in the pre-implementation stage of a BI project is to identify critical factors which influence the success of the project. First, in this section an attempt has been made to depict, based on the literature survey, vital and critical factors in both organizational and technical aspects, impact of which on the success were determined. We believe that both the organizational and technical dimensions are important and they should be concerned together and interact with each other leading to BI success. It can be useable to assist managers who are decision makers in implementing BI projects by optimizing their scarce resources on these CSFs and as a consequence concentrate their commitment to monitor, control and support only these factors. In the next sections, we apply these CSFs in building our model.

6.2 The hybrid approach

In chapter 4, we examined the assessment of the methods of evaluation of the readiness for implementing business intelligence. We divided the existing methods into three categories: probabilistic method, Multi Criteria Decision Making (MCDM) methods (such as fuzzy AHP, fuzzy ANP, fuzzy AHF, AHP, ANP and AHF) and hybrid methods. Then, we compared all these methods through AHP. The results demonstrated that the hybrid methods are the best option to build an evaluation model.

As mentioned in previous chapters, BI projects are naturally with a high failure rate, so the identification of CSF of these projects can play an important and valuable role in the successful implementation of the system and the reduction of the failure rate. In [165], Yeoh and Koronios say if BI shareholders gain understanding of CSF, they can optimize their resources and efforts by focusing on critical factors that contribute to the successful implementation of the system. Farrokhi and Pokorádi [F5] believed that these factors should be carefully considered by senior managers and BI project managers of companies that are evaluating the readiness of their organizations.

6.3 Mathematical background

In this section the concepts of ISM and GTMA methods are presented. These concepts are utilized in the research process and works done.

6.3.1 ISM Method

ISM is an appropriate technique to analyze the impact of an element to other elements. This methodology investigates respectively and complex relationships directions between elements of the system. In other words, the means by which, the system can overcome the complexity of the elements [173]. In this study, we need to determine the relationship between factors in the successful implementation of BI and convert them to a graph for further analysis. In this case, ISM comes to help. The implementation of ISM in accordance to [155] includes the following steps:

6.3.1.1 Structural Self Interaction Matrix (SSIM)

Primarily with utilizing the suggestions of experts from industry and academia, the relationships between components are defined. Four symbols are used to determine the relationship between two factors (i and j):

V: means factor i leads to factor j (factor i will influence factor j).

A: means factor j leads to factor i (factor i will be influenced by factor j).

X: for both direction relations (factors i and j will influence each other).

O: for no relation between the factors.

6.3.1.2 Reachability Matrix

To get the reachability matrix, the symbols of the SSIM matrix must be converted to zero and one. The reachability matrix is calculated according to the following rules:

I. If the (i,j) cell in the SSIM is V, then the (i,j) cell in the reachability matrix becomes 1 and the (j,i) cell becomes 0.

II. If the (i,j) cell in the SSIM is A, then the (i,j) cell in the matrix becomes 0 and the (j,i) cell becomes 1.

III. If the (i,j) cell in the SSIM is X, then the (i,j) cell in the matrix becomes 1 and the (j,i) cell also becomes 1.

IV. If the (i,j) cell in the SSIM is O, then the (i,j) cell in the matrix becomes 0 and the (j,i) cell also becomes 0.

After obtaining primary reachability matrix, the transmissibility property must be checked. This means that if (i,j) = 1 and (j,k) = 1, then (i,k) = 1.

6.3.1.3 Level Partitions

The Reachability set for a factor is a collection which includes the factor itself and the factors that can be reached through this factor and Antecedent set is a collection that includes the factors which can be reached through this factor and factor itself.

For level partitioning, we first determine the Reachability set and the Antecedent set from the Reachability Matrix for any factor. After determining the Reachability set and the Antecedent set, similar elements in both sets of any factor is detected (named Similar set). In the first iteration, the factor with the same elements in the Reachability set and the Similar set are placed on the first level. Then this factor is removed from consideration and this iteration is repeated to show factors of the second level. This process is continued until the levels of all factors are defined.

6.3.1.4 Diagraph

According to the levels of each factor and the final Reachability Matrix, the initial model of ISM, with regard to the transmissibility is drawn. Then, the final version of ISM is computed by removing the transmissibility of nodes. This graph shows the relationships between the different factors. High-level factors are placed on top of the graph and low-level factors at the bottom of the graph. Then we replace the node contents with factors to obtain ISM model.

6.3.2 Graph Theory and Matrix Approach

A graph $G = [N,L,f]$ is a 3-tuple consisting of a set of nodes N, a set of links L, and a mapping function $f : L \rightarrow N \times N$ which maps links into pairs of nodes. Nodes directly connected by a link are called adjacent nodes [174]. When the node-pair order does not matter in linking the node pair, G is an undirected graph. In an undirected graph, $p_i \sim p_j$ is equivalent to $p_j \sim p_i$, But in direct graph, a link defined by the node pair $(p_i; p_j)$ is not the same as a link defined by node pair $(p_j; p_i)$. In fact, both links may exist in a directed graph [16]. Adjacency matrix **A** shows the number of links directly connecting node i to node j. This number is stored at row i, column j of the matrix [174].

In this sub-section, we transform the ISM diagraph to a matrix and by analyzing it; we will obtain an index to assess the readiness of the organization for the successful implementation of BI. The routine for applying GTMA to the matrix is as follows:

First, the Relative Importance Matrix (RIM), **B** from ISM digraph is defined. **B** is a binary matrix (b_{ij}), where b_{ij} represents the relative importance between factor *i* and *j* such that [175]:

$$\boldsymbol{B} = \begin{cases} b_{ij} = 1 & \textit{if the } i^{th} \textit{ factor is more important than the } \\ & j^{th} \textit{ factor for a given machining operation.} \\ \\ b_{ij} = 0 & \textit{otherwise} \end{cases} \qquad (6.1)$$

In other words, RIM is similar to the adjacency matrix in graph theory. In this matrix, all diagonal elements have a value of 0 and non-diagonal elements have value either 0 or 1. So in this matrix only relative importance among the factors is considered, and the measures of the factors are not considered. To incorporate this, another matrix, called Characteristic Matrix (CM), is defined:

$$\mathbf{C} = [\,\mathbf{AI} - \mathbf{B}] \qquad (\mathbf{6.2})$$

where **I** is an identity matrix, and **A** is a variable representing the measure of the factors. All diagonal elements of **C** are considered equal which means the measures of all factors are equal. But it is not true in the real world. In this formula, the relative importance of one factor to the second factor (b_{ij}) can adopt values greater than zero or one [173]. For solving this problem, another matrix (**D**) called Variable Characteristic Matrix (VCM), is developed:

$$\mathbf{D} = [\mathbf{E} - \mathbf{F}] \qquad (\mathbf{6.3})$$

In this equation, **E** is a diagonal matrix with diagonal elements e_i, which indicates the presence or size of factor *i*. If a factor is excellent, then it is assigned a maximum value. Also, for a very low significant factor, it is assigned a minimum value [175]. **F** is a matrix of which the off-diagonal elements are represented as $f_{i,j}$, instead of 1, wherever the i^{th} factor has more relative importance than the j^{th} factor.

Due to the positive and negative values in matrix **D**, when calculating the matrix determinant, there may be a number of statements in the determinant formula of calculation that become zero and we lose some of the information. So the Variable Permanent Function (VPF) is defined instead of determinant. This function is derived from a new matrix called the Permanent Matrix [175]:

$$\mathbf{H} = [\mathbf{E} + \mathbf{F}] \qquad (\mathbf{6.4})$$

The Permanent function (Leibniz's formula) is as follows:

$$Per(H) = \sum_{\pi \in \prod_n} a_{1\pi(1)} a_{2\pi(2)} \dots a_{n\pi(n)} \qquad (6.5)$$

Where

$$\prod_n = \{\pi | \pi \text{ } is \text{ } permutation \text{ } of \text{ } \{1,2,\dots,n\}\} \qquad (6.6)$$

Permanent function is a standard matrix function that is used in combinatorial mathematics [175].

The index to assess readiness of an organization for the successful implementation of BI is achieved by using the Permanent matrix, from the following equation:

BIIAR*[1] *= the numerical value of the Permanent matrix of factors.

The time complexity of this formula is O(N*N!) and is not appropriate in cases where N is high. Therefore, we utilized the optimized algorithm from H. J. Ryser (1963) which has higher execution speed (O($N^2 2^N$)). This formula is as follows:

$$per(A) = \sum_{t=0}^{n-1} (-1)^t \sum_{x \in \tau_{n-t}} r_1(X) r_2(X) \dots r_n(X) \quad (6.7)$$

where

$$\tau_k = \{X \epsilon R^{n \times k} \mid X \text{ consists of columns of } A\} \quad (6.8)$$

and

$$r_i(X) = \text{sum of row } i \text{ of matrix } X \quad (6.9)$$

We adapted above the algorithm and wrote it in C# and all calculations were done.

6.4 Works done

In this chapter, we achieved an index for evaluating the readiness of the organization to implement BI by combining ISM and GTMA methods and taking into account the views of experts in the field BI. Our research design is provided in Figure 6.1.

As can be seen in Figure 6.1, we studied different literature and detected the critical factors that are involved in the successful implementation of

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[1] **B**usiness **I**ntelligence **I**ndex of **A**ssess **R**eadiness

BI. We used the technical and organizational factors for the successful implementation of BI that were presented and listed in Table 6.1.

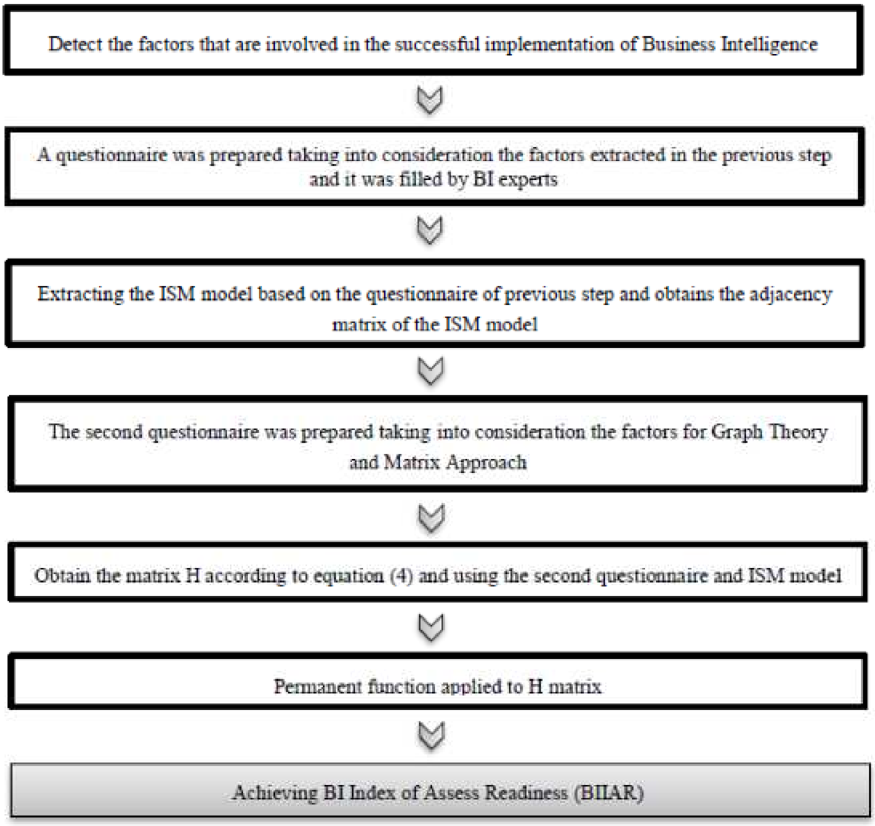

Figure 6.1: The block diagram of the proposed method

The two series of questionnaires were prepared according to these CSFs. The first questionnaire (Appendix A) was related to the ISM and the second one (Appendix B) is for GTMA. To check the reliability and validity of the questionnaires, we calculated Cronbach's alpha, which was 0.885 and also experts confirmed the accuracy of the questionnaires.

Then questionnaires were completed by several specialists (five experts plus two academicians) in BI field. Relations between factors were extracted by applying ISM method and according to the experts' answers of the first questionnaire. In Table 6.2 the final Reachability Matrix and in Table 6.3, the Factor Levels resulted from the ISM method have been brought.

Table 6.2: Final Reachability Matrix for Sample Organization

CF→	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
CF1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CF2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CF3	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
CF4	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
CF5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CF6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CF7	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
CF8	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1
CF9	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
CF10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CF11	1	1	1	1	0	1	0	1	0	1	1	1	1	1	1	1
CF12	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	1
CF13	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	1
CF14	1	0	1	1	0	0	1	1	0	0	1	1	1	1	1	1
CF15	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1
CF16	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1

Table 6.3: Factor levels

Le vel	Factors
1	CF1, CF3, CF4, CF8, CF11, CF12, CF13,CF14,CF15,CF16
2	CF2, CF6, CF7, CF9, CF10
3	CF5

According to these two tables, the Interpretive Structural Model is achieved. This model is an input for GTMA. As the graph of ISM in our study was large and complex, we brought only the adjacency matrix of this model in Table 6.4.

To apply GTMA, first we obtain the adjacency matrix of the ISM model. Then to create matrix **H** (equation 6.4), we form matrixes **E** and **F** by using the adjacency matrix of ISM model and the results of the second questionnaire. **E** is a diagonal matrix with diagonal elements e_i, which indicates the importance of factors. The importance of factors was derived from the questionnaires completed by professionals. **F** is a matrix which non-diagonal elements show the importance of one factor to another factor instead of 1 value in the adjacency matrix of ISM model. These values are derived from the second questionnaire too. Given the matrixes **E** and **F**, the matrix **H** is obtained according to Equation 6.4.

Finally, permanent function applied to H matrix and BIIAR is obtained. This index shows the readiness of organization to implement BI.

Table 6.4: Adjacency Matrix of ISM Model for Sample Organization

CF→	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CF1	9	4	0	5	0	4	4	4	2	3	3	2	0	2	3	0
CF2	4	8	3	2	0	3	0	4	3	2	0	0	0	0	0	0
CF3	3	0	7	2	0	0	3	2	3	4	2	3	0	0	3	3
CF4	4	3	4	8	0	0	0	3	0	2	0	0	0	0	0	0
CF5	4	0	0	0	7	3	3	0	3	2	3	4	3	3	0	2
CF6	0	2	3	2	3	7	2	3	3	4	3	3	0	0	0	3
CF7	0	3	0	4	0	0	9	3	0	3	4	4	4	3	2	0
CF8	0	0	0	2	0	0	0	8	3	0	5	4	0	3	0	0
CF9	4	4	5	0	0	0	4	5	8	3	4	3	3	3	4	4
CF10	0	4	4	3	0	5	4	4	5	6	3	3	3	2	3	4
CF11	0	3	0	0	0	0	0	3	0	0	7	4	4	0	5	4
CF12	4	5	4	3	0	0	0	0	0	0	4	8	0	0	2	0
CF13	4	0	3	2	0	0	0	2	0	0	3	2	7	3	4	0
CF14	3	0	4	0	0	0	0	0	0	0	3	5	4	6	0	0
CF15	4	0	3	0	0	0	0	0	0	0	2	0	5	3	8	4
CF16	4	3	4	0	0	0	3	4	0	4	3	2	2	0	3	6

6.5 Conclusion of chapter

Before the implementation of BI, the readiness of the organization must be evaluated to minimize the waste of costs and resources. In this study, we examined a utility organization with about 1,000 employees, which covers two provinces and has the task of electricity transmission. POPEANGĂ and LUNGU [176] believe that the utilities industry is an environment where decisions are time sensitive and so focusing on BI for utilities can be important for this industry.

We applied the Interpretive Structural Modeling (ISM), Graph Theory and Matrix Approach (GTMA) to derive a measure to check the readiness of the sample organization before implementing BI. The research design is provided in Figure 6.1.

The adjacency matrix of ISM model was illustrated in Table 6.4 and shows the relationship between factors. GTMA applied to the ISM model and BI Index of Assess Readiness (BIIAR) was obtained to show the Readiness of the organization before implementing BI. The result of GTMA which applied to sample organization in this research is as follows:

$$\text{BIIAR} = 21.35\times10^{17}$$

To interpret the sample company's readiness, we have to calculate the best and the worst conditions of the readiness. In the best condition of the readiness which can be ideal for the company, it is when all quantities of the final matrix are equal with 9 which the output of algorithm will be 3.87770e+28. If the resulted number is closer to this number, we can conclude that the company's condition of readiness is more desirable.

The worst condition is when all quantities of the final matrix are equal with 1 which the output of algorithm will be 2.0923e+13. Therefore, if the resulted number is closer to this number, it shows that the company's condition of the readiness is more undesirable.

As we mentioned, the sample company's BIIAR is equal with 2.1350e+18 which is close to the worst condition. So, this company is not ready to implement BI project.

Chapter 7

Conclusion and Future Works

In the usual manner, we summarize the main contributions of this dissertation and highlight future orientations to expand this work.

7.1 Summary

Previously, decisions were made by senior management in organizations and were based solely on personal experience, leading to increased risk in decision making. Nowadays, however, most companies are moving towards Business Intelligence (BI) systems. It is estimated that technology budgets dedicated to Business Intelligence in 2006, increased from $ 14 to $ 20 billion. Experiments have shown that the probability of failure in BI projects is high and evaluation before the start of implementation is important, because if the company is not assessed, the implementation of BI projects can cause waste of time and resources and the company will not achieve the expected profit.

The thesis has achieved its goals, building the models for comparative analysis the methods and techniques which are applicable in the related and unrelated areas of BI and also building a model for evaluation of the readiness for implementing BI projects via a hybrid approach.

The most important scientific contributions of the doctoral thesis are:

1. This dissertation has shown the necessities for building a model to evaluate BI projects via a comprehensive literature review. We expressed the necessity of investigation and determination of BI readiness factors and their related items which have an effect on

the implementation of BI systems in companies and also a need to build a model in assessing BI readiness [F2];[F3].

2. An overview of BI and it's components in form of architecture has been depicted. Basically, for better understanding BI and its component, we need to address it in a way which is useful to the people. One of the best ways for expressing is architectural form. Hence, we used this way and demonstrated the architectures and described components of the conventional and the new-generation architectures as well [F4].
3. A series of technical and organizational key factors for the successful implementation of BI have been proposed in various literatures. These key factors are evaluation ones for an organization [F5].
4. Determining the right method for developing a model to evaluate the readiness of organizations in implementing BI projects is done by offering a summary of the most common evaluation methods and comparing the methods based on their features and suggesting a suitable method. We built a model for this comparison by using AHP method [F6].
5. For showing the applicability of AHP and AHP-Fuzzy TOPSIS methods in the other unrelated area, they are applied in ranking the techniques for solving reactive scheduling problem in operating room. It confirms the validity of our approach in applying these methods for comparison of the techniques and methods to the evaluation [F7];[F8].
6. We provide a method to evaluate the key factors for the successful implementation of BI projects and to determine the organization's

index of assess readiness before the implementation of BI projects. We apply a combination of Interpretive Structural Modeling (ISM) and Graph Theory and Matrix Approach (GTMA) on the factors to earn an indicator for the evaluation of the organization's readiness for implementing a BI project. We applied this method in an organization and determined the organization's readiness before the implementation of BI and found it to be very effective [F11].

7.2 Suggestions for Future Works

Our suggestions for future works which can be related to this study are: comparing the appropriate methods and techniques with other suitable MCDM methods to choose the best method for building a model and compare the results of the various ways. Ranking of the CSFs with the use of other methods including MCDM methods can be interesting to both academicians and practitioners.

As we know, the algorithm will produce different results according to any society's culture and economy. Our suggestion is to implement the proposed algorithm in an organization that has implemented BI successfully. Then the BIIAR rate can be obtained for that organization will be a standard for other organizations in that society. Also, we can use the average from the BIIARs of several successful organizations as a measure to obtain more accurate standard.

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Appendix A

In this study with the title "A model for evaluation of the readiness in implementing BI projects: A hybrid approach; Interpretive Structural Modeling, Graph Theory and Matrix Approach", we need your opinion as an expert in the field of Business Intelligence. In addition, the answers will be preserved for integrity.

Based on previous research that has been done to identify criteria for successful implementation of Business Intelligence, critical success factors were identified. These factors listed in table 1.

Table 1: Important organizational and technical factors for successful implementation of Business Intelligence

Critical Success Factor	Description
Management support (Organizational) [C1]	The managers of organization involve and participate in the activities of BI project.
Organizational culture (Organizational) [C2]	A corporate culture which emphasizes on the value of sharing common goals over individual pursuits and the value of trust between partners, employees, managers and corporations.
Decision-making structure (Organizational) [C3]	The type of control or delegation of decision-making authority throughout the organization and the extent of participation by organizational members in decision-making pertaining to BI.
Goal alignment (Organizational) [C4]	The linking together of the business goals and the BI goals.
Managerial IT knowledge(Organizational) [C5]	Knowledge and experience of senior management about IT.
Management style (Organizational) [C6]	The way in which management tends to influence, coordinate, and direct people’s activities towards a group’s objectives.

Resource allocation (Organizational) [C7]	Allocating adequate resources of money, people, and time.
User participation (Organizational) [C8]	Involving and participating user in BI development process.
Balanced and skilled project team (Organizational) [C9]	The composition and skills of a BI team have a major influence on the success of the systems implementation.
Agile project management (Organizational) [C10]	Managing team members work together in the most effective manner possible.
System quality (Technical) [C11]	The performance characteristics of the BI system itself, which includes ease-of-use, functionality, reliability, flexibility, integration, and response time.
Information quality (Technical) [C12]	It refers to accuracy, timeliness, completeness, relevance, consistency, and usefulness of information generated by the system.
Reliable back-end system (Technical) [C13]	It is critical to ensure that the updating of data works well for the extraction, transformation and loading (ETL).
Metadata management (Technical) [C14]	It is an end-to-end process for creating, enhancing and maintain meta-data repository and associated processes.
Technical framework (Technical) [C15]	It must be business-driven, scalable and flexible framework.
Agile methodology (Technical) [C16]	The purpose of agile BI is to get the development done faster, and react more quickly to changing business requirements.

The relationship between factors should specify, and for this purpose the symptoms listed in table 2 were used.

Table 2: Defined signs used in ISM

Signs	Definition
V	To show one-sided relationship(factor i affected into factor j)
A	To show one-sided relationship(factor j affected into factor i)
X	To illustrate the bilateral relationship(factors i and j have an impact on each other)
O	To show a lack of relationship (there is no relationship between the factors).

We will try to specify relationship between factors by the ISM approach so on this basis, the diagram of relationship between criteria is drawn and then the relational model of each criterion is obtained. ISM is an effective method to analyze the impact of factors on each other. For this purpose, Tables 3-1, 3-2 and 3-3 must complete by the above symptoms. For example, in table 3-1 if factor C4 have one-side effect to factor C5, we enter at the intersection of row four and column five V. It is obvious that any white cells are indicative of a question and its answer shows the relationship between the two components.

Table 3-1: The relationship between factors

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
C1								
C2								
C3								
C4								
C5								
C6								
C7								
C8								

Table 3-2: The relationship between factors

	C9	C10	C11	C12	C13	C14	C15	C16
C1								
C2								
C3								
C4								
C5								
C6								
C7								
C8								

Table 3-3: The relationship between factors

	C9	C10	C11	C12	C13	C14	C15	C16
C9								
C10								
C11								
C12								
C13								
C14								
C15								
C16								

Appendix B

((Related to convert model obtained from ISM method to matrix in the sample organization and obtain the organization final indicator))

In continuing the research, a Regional Electricity Company has been considered as an example to quantify the obtained relationships (matrix approach). The assumption is that the final indicator demonstrates the ability of organization in successful implementation of Business Intelligence. To achieve the final indicator, we need numerical values of all successful implementation factors of Business Intelligence and relationships between them.

For this purpose the values of table 1 is used (scale of 1 to 9) to determine the size or existence of components in the organization (Diagonal elements in Table 3-1, 3-2, 3-3 and 3-4). This means that if a component is in an excellent condition in organization, also the value attributed to related home of this component will be higher. For example, if the state of component C4 is in the middle in organization, in the house crosses of the fourth row and fourth column of the table, we will enter number 5.

Also the values of table 2 (scale of 1 to 5) will be used to determine the size of dependence between the components in organization (Non-diagonal elements of tables 3-1, 3-2, 3-3 and 3-4). For example, if the dependence value of C3 to C4 is strong, we enter in the third row and fourth column of table (3-1) number 4.

Table 1 – The value defined to determine the factors affecting successful implementation of Business Intelligence in the organization

Qualitative scale factors in the successful implementation of Business Intelligence	**The value allocated to factors**
Super low	1
Very low	2
Low	3
Below Average	4
Average	5
Above average	6
Much	7
Too much	8
Extraordinary	9

Table 2. Value defined to determine the size of dependencies between the components in organization

Component dependence qualitative scale	**Value allocated**
very strong	5
strong	4
Average	3
weak	2
Very weak	1

Table (3-1) - The relationship between factors

	C1	C2	C3	C4	C5	C6	C7	C8
C1								
C2								
C3								
C4								
C5								
C6								
C7								
C8								

Table (3-2) - The relationship between factors

	C9	C10	C11	C12	C13	C14	C15	C16
C1								
C2								
C3								
C4								
C5								
C6								
C7								
C8								

Table (3-3) - The relationship between factors

	C1	C2	C3	C4	C5	C6	C7	C8
C9								
C10								
C11								
C12								
C13								
C14								
C15								
C16								

Table (3-4) - The relationship between factors

	C9	C10	C11	C12	C13	C14	C15	C16
C9								
C10								
C11								
C12								
C13								
C14								
C15								
C16								