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A New Approach Based on Business Intelligence and Bayesian Network for Analysis of Corporate Accounting Systems

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Abstract:

Due to the inherent complexity and increasing competition, today's business environment requires new approaches to organizing and managing. One of the new approaches is business intelligence, which is the most critical technology to help manage and deliver smart services, especially business reporting. Business intelligence enables firms to manage their business efficiently to meet the needs of businesses at different macro, middle, and even operations levels. In this paper, while investigating the feasibility of implementing business intelligence in firms, designing business intelligence to report and present new services is discussed. In order to demonstrate the capabilities of this type of intelligence, an approach based on the concept of Bayesian network in the application layer of business intelligence is presented. This approach is implemented for one of the companies governed by the Iranian Industrial Development and Renovation Organization, and the effects of important accounting and financial variables on the firm goals are investigated.

Keywords: Business Intelligence; Business Networks; Decision Support System; Business.

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1. Introduction

Today, the field of business and production, due to the expansion of the supply and competition environment, requires serious revisions at the level of management and the provision of new services (Olivia , 2009; Sharda *et al.* , 2020). Managing a business with a multitude of production, support, and supply mechanisms in the manufacturers, suppliers, and vendors' sectors is a serious challenge. As a branch of information technology, business intelligence has been able to open its place in such systems today. This intelligence allows managers to report in real-time by efficiently managing and organizing the mass of business environment data. In addition to real-time reporting, providing applications such as decision support systems, expert systems, business analysts, executive information systems, etc., enables business stakeholders to solve many of their management challenges efficiently and cost-effectively through these systems. Accordingly, the data are extracted from different data sources after performing data cleaning and preparation operations and three steps (extraction, transportation, and load) and then enter the analytical database. In the analytical database, different dimensions of data and data structure are specified. The data extracted from the analytical database is analyzed using online analytical processing and data mining operations. The results of this step will be sent for reporting.

In this paper, to provide a decision support system and report on various firm situations, the Bayesian network and dashboard reporting tool were used. The rest of this paper is structured as follows: In the second section, theoretical foundations and research background are reviewed. The third section is devoted to research methodology. The fourth section describes the scope of the research and the statistical population. The fifth section is dedicated to the obtained results, and finally, in the sixth section, a summary and conclusion are presented.

2. Theoretical foundations and review of research background

Due to the increasing benefits of business intelligence in many systems, this technique has been used well. In a research (You , 2010) studied the knowledge management approach to real-time business intelligence. This study showed that since traditional business intelligence cannot fully meet the dynamic market's needs, organizations seek real-time business intelligence to solve the problems ahead. However, due to the lack of effective use of real-time business intelligence to help the organization gain a competitive advantage, analytics, and operational delays are considered a major challenge. This paper addresses these shortcomings in organizations by proposing a new model that proposes the application of knowledge management in the data mining process to reduce data, analysis, and delays the practice of real-time business intelligence. In this model, knowledge development through data mining is proposed and adds knowledge management to data mining for real-time business intelligence. This model can effectively meet dynamic market requirements and reduce data, analysis, and delay in organization's real-time business intelligence operation through initial testing. According to the research findings, to maximize the organization's profit in a competitive environment, although the proposed model has some advantages in the dynamic transformation of latent knowledge and tacit knowledge for knowledge management, it needs to be further studied.

In his research, Klein examined business intelligence's role in knowledge management (Colin , 2005). He claimed that every organization must have vital information for the analysis and create innovations. Also, it should maintain this information and improve the quality of information. These innovations provide businesses with capabilities such as cost savings, increased productivity, and reduced time delay. Such organizations should also provide accurate information to managers and employees quickly and help them make decisions. Since the solutions provided by knowledge management have less growth than business intelligence and also do not take into account mental factors, business intelligence tools should be used and considered as an integral part of knowledge management. It helps to determine the influential factors in decision making and to achieve goals. Employees and managers can use the data in the data warehouse and make decisions based on a solid foundation of facts. However, since there is only part of the information in this section and does not include tacit knowledge in employees' minds, knowledge architecture was used as a data warehouse model. It facilitates, retrieves and shares knowledge in the organization, and improves the role of business intelligence in promoting knowledge and improving the performance of companies.

Another study examined the use of knowledge sharing to collaborate on business intelligence (Yang and Wang , 2009). IT services need to change to respond to dynamic changes in the environment. Change in management is considered as one of the most important tasks in IT service management. This research shows that research in IT management uses techniques that are very limited or only perform data collection and integration. In their research, he proposed a collaborative management system based on knowledge sharing for IT service management that aims to bridge the gap between expert knowledge and management systems. An example of an IT service management collaboration pattern by application of expert knowledge and experience to improve quality management and reduce costs is the analysis of the effectiveness of business in changing the infrastructure for IT service management. They concluded that business intelligence collaboration based on knowledge sharing had provided some potential in a dynamic market environment, such as priority-based user management, management experience, and knowledge reuse. This research claimed that business effectiveness analysis on infrastructure change has aspects that need to be addressed. These aspects include how to get help from the knowledge, how to resolve the conflict between current knowledge, and apply heritage knowledge. They need to be examined in more detail, including problem determination, retrieval, financial management, etc., in the future.

In a study, Oyo and Peng examined the knowledge and process based on decision support in the business intelligence system (Ou and Peng , 2006). In this study, a framework to facilitate the reuse process model was presented as a combination of Rule-Based Reasoning (RBR) and Case-Based Reasoning (CBR) that can overcome the limitations of these two methods, and provide satisfactory results. In this context, the business intelligence system's knowledge management strategy is central to accumulating information in business intelligence and software, and it uses customer relationship management.

In another study, several researchers examined the effect of knowledge management systems on business intelligence optimization (Hanandeh *et al.* , 2012). This study showed that an optimization is a key approach for organizational systems, and knowledge management is an innovative management tool that enables them to reap the benefits of a new approach to development. Business intelligence can also create more value for the customer by creating knowledge with the customer. Their research goal is to investigate the effect of knowledge management systems on optimizing business intelligence using the measurement of complex systems, which raises questions to illustrate this point. The answers to these questions are shown in the framework of Figure 1. This study suggested that knowledge management can be integrated into key optimization indicators and other optimal measurement methods.

In another study entitled "a Prototype System for Data Warehouse Training and Data Mining" (Dimokas *et al.* , 2008), a design and development of a data warehouse solution was presented that facilitates a more accurate analysis of data. The proposed system is an integrated platform for data analysis. Data analysis is obtained from online analysis operations. In addition, a complete statistical analysis with a set of data mining techniques and advanced statistical tests, models, and methods that are suitable for performing tasks are provided.

In another research, Tomingas *et al.* (2016) proposed a method to integrate business semantics and ontology learning based on data structures and schemas

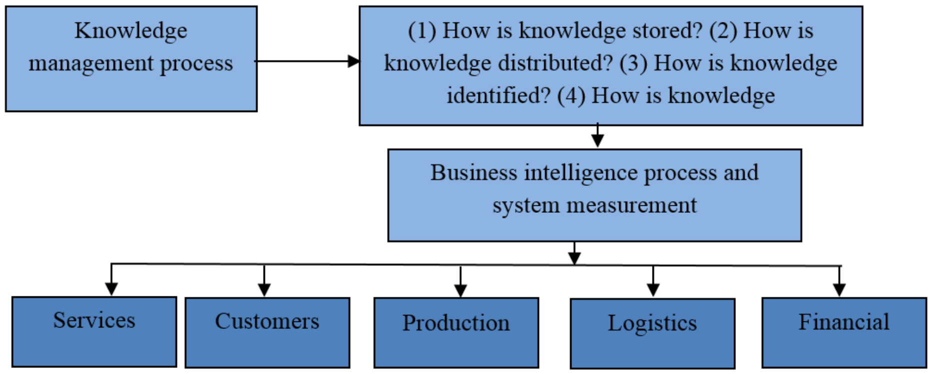

Figure 1: Optimization of business intelligence using knowledge management (Hanandeh *et al.* , 2012)

with a combination of query semantics derived from dependency diagrams. This method is based on semantic techniques, calculating the probable weight and estimating the effect of data on the data display, and calculating these estimates' dependency graph. In addition, this method uses business ontology for technology-related assets to provide management meanings and perspectives for manpower planning as well as machinery to address various planning, automation, and decision support problems. In this research, the data processing performance and integration of business ontology through several real data sets were evaluated and analyzed.

Another research (Gomes *et al.* , 2022) reviewed the literature to identify using artificial techniques on reproducibility and extensions in business. They applied their search string in the Scopus and Web of Science databases and discovered 21 relevant papers pertaining. In these papers, they identified methods that automated tasks and helped analysts make assertive decisions when designing, extending, or reengineering business processes. The authors applied diverse AI techniques, such as K-means, Bayesian networks, and swarm intelligence. Their analysis provides statistics about the techniques and problems being tackled and points to possible future directions.

2.1 Business intelligence

Business intelligence is a set of technologies and processes that collect, store, analyze organizational data, and the results are used for organizational reporting and decision making. A business intelligence system analyzes business data and makes accurate and intelligent decisions through Online Analysis Processing operations. According to Rodavlio, business intelligence is a set of theories, methods, processes, architectures, and technologies that turn raw data into useful and meaningful information for business processes (Olivia , 2009). Operations used in business intelligence systems include: online analytical processing operations, data warehouse processing as analytical database, data mining; extraction, transportation, and load; dashboard reporting, and score card.

2.2 The role of business intelligence in business systems

Business systems have played an important role in improving business activities and promoting the level of supervision. Despite the advantages of these systems, there are many problems facing researchers in this field. There are problems such as measuring and evaluating the efficiency of activities as well as the difficulty of obtaining the effect of business activity related to business sub-sectors due to the high volume of input data. In order to improve the level of management activities, it is necessary to record, analyze and control a large amount of data. The use of relational databases to store business information is restricted to a limited amount of information. In fact, the data extent of a relational database is about a few megabytes to a few gigabytes. In contast, in an analytical database, it is about a few gigabytes to a few terabytes. Therefore, using an analytical database, one of the architectures used in the business intelligence system, has significant effects on efficient control and business management. On the other hand, the lack of tools to evaluate and measure the effect on business activities, leads to the lack of effective evaluation of management decisions' effectiveness. Therefore, using analytical tools, and reporting dashboard, and score card in this area helps a lot in the structure and management plan. Preparing real-time reports is one of the most important reasons for implementing business intelligence in such systems. Preparing real-time reports using the dashboard reporting tool will provide an efficient picture of the business environment, identify and correct negative trends, and make decisions about improving the executive plan. Therefore, monitoring and analyzing micro-activities' performance requires using business intelligence technologies such as analytical databases, online analytical processing, and real-time reporting.

3. Research methodology

One of the business intelligence capabilities is that it supports a large volume of real-time reporting with an efficient organization. Figure 2 shows the business decision support system architecture based on business intelligence. In this architecture, business intelligence operations are a key part of the business decision support system. This architecture consists of three layers, the data layer, the business intelligence layer, and the application layer. In the data layer, data related to each subdivision's performance in the business management system, such as production volume, sales volume, and other factors, are extracted and stored in a data warehouse. Then the main operation of business intelligence begins to analyze the extracted data. In this step, the data in the data warehouse is extracted using a triple process (extraction, transformation, and loading of data), and data cleaning and preparation operations are performed on them. After this step, the data enters the analytical database. Then, online analytical processing, data mining, dashboard reporting, and decision-making are performed on the data. Finally, after performing the previous steps, the data enters the application layer to infer the business situation. In this layer, the business environment analysis program is presented by identifying the effective factors for making efficient decisions to increase profits. In general, the purpose of designing this architecture is to demonstrate the effects of business intelligence on the business decision support system. Using business intelligence technologies, the business model unique to each sector is extracted and can be used to decide about each business's future status.

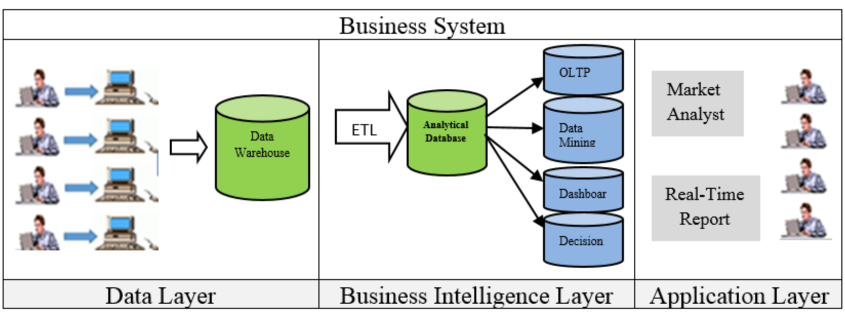

Figure 2: Business intelligence based business decision support system architecture

3.1 ETL Process in the business decision support system

One of the most important steps in cleaning and preparing data in a business intelligence system is the three-step process of extracting, transportation, and load data. This step is performed before entering the data into the analytical database. The data related to the activities of the sub-sectors, which include: production volume, sales volume, technological risk level, taxes, and operating costs, are extracted from the relational database, and the operations of cleaning, preparation, transportation, and load are performed on the data. This step is done to resolve inconsistencies, errors in the input data and to transport and prepare raw data for analysis. After this step, the data is ready to enter the analytical database, and business analysis operations are performed.

3.2 Analytical database in business decision support system

An analytical database is a centralized data warehouse whose input data is generated from operational databases and other data sources. It is a good platform for data analysis and organizational decision making. One of the most important applications of analytical databases is data preparation for online analytical processing. One of the problems that business management systems face is the problem of analyzing, storing, and controlling large volumes of information obtained from different sectors. With the help of an analytical database, various dimensions of the business profit increase program can be considered. To implement this system of business decision support, the Bayesian network was used, which is presented below.

3.3 Bayesian networks and business management

Due to the uncertainty and high speed of events in today's competitive environment, the use of Bayesian networks in management systems has been considered (Durante *et al.* , 2017; Wang *et al.* , 2018, 2011). Networks are a suitable and expressive structure for modeling uncertainty. Here, the foundations of these networks and the method of inference in them are examined.

The Bayesian network is an undirected graph in which nodes represent "concepts", and edges show a cause-and-effect relationship between nodes (Pauwels and Calders , 2020). This graph can be used to calculate the probability of performing each of the sub-sectors or to calculate the probability of different business profit situations.

Bayesian reasoning provides a probability-based method for inference. This method is based on the assumption that the values under study follow a probability distribution. Optimal decisions can be made by reasoning on these probabilities and the observed data. Because this method provides a quantitative solution for weighting the evidence that supports the various hypotheses, it is very important in machine learning. Bayesian reasoning provides a direct way to work with probabilities for learning algorithms, as well as a framework for analyzing the performance of algorithms that do not deal directly with probabilities.

3.4 Bayes' theorem

Many problems seek to find the best hypothesis in the space of hypotheses H, with available training data D. One way to express the best hypothesis is to identify the most probable hypothesis, having data D with basic knowledge of the prior probabilities of hypotheses H. The Bayes theorem provides a direct method for calculating these probabilities.

To define the Bayes theorem, it is first necessary to provide the necessary notation. The symbol $P(h)$ indicates the initial probability that (h) is assumed to be true before we have the training data. $P(h)$ is generally called a priori probability and indicates any prior knowledge about the chance of (h) being true. Suppose there is no basic knowledge of the assumptions. In that case, the same probability can be assigned to the entire space of the assumption H. Similarly, $P(D)$ is used to express the prior probability that data D is observed. In other words, the probability of observing D provided there is no knowledge of the validity of the assumptions. $P(D|h)$ is also used to express the probability of D in a space where the assumption of h is true. Machine learning follows $P(h|D)$, i.e., the probability of assumption h is true provided that the training data D are observed. The expression $P(h|D)$ is the posterior probability h because it shows the confidence of h after observing the data D.

Bayes theorem is the main cornerstone of Bayesian learning, because it provides a method for calculating the posterior probability $P(h|D)$ from the prior probability $P(h)$ along with $P(D)$ and $P(D|h)$ as in Equation (3.1).

$$P(h|D) = \frac{P(D|h)P(h)}{P(D)} \tag{3.1}$$

As expected, $P(h|D)$ can be observed to increase with increasing $P(h)$ as well as $P(D|h)$. Likewise, it seems reasonable that $P(h|D)$ decreases with increasing $P(D)$. Because the probability of $P(D)$ increases which is independent of h, there will be less evidence in D to support h.

In many learning scenarios, the learner considers a set of hypotheses H and is interested in finding the $h \in H$ hypothesis that is most probable (or at least one of the most probable hypotheses if there are several). Any hypothesis with this property is called the Maximum a Posteriori (MAP). The MAP hypothesis can be determined using the Bayes theorem to calculate the probability of each candidate. More precisely, hypothetical h_{MAP} is as follows in Equation (3.2):

$$\begin{aligned} h_{MAP} &= \arg\max_{h \in H} P(h|D) = \arg\max_{h \in H} \frac{P(D|h)P(h)}{P(D)} \\ &= \arg\max_{h \in H} P(D|h)P(h) \end{aligned} \tag{3.2}$$

In the final step, $P(D)$ is omitted, because its calculation is independent of h

and is always constant. In some cases, it is assumed that all assumptions $h \in H$ have the same probability of occurrence (i.e., $\forall hi, hj \in H; P(hi) = P(hj)$). In this case, another simplification can be done in relation (3.2). In other words, the hypothesis that provides the Maximum Likelihood $P(D|h)$ can be considered as Equation (3.3).

$$h_{ML} = \arg\max_{h \in H} P(D|h) \tag{3.3}$$

In this research, we use data D as training examples for an objective function and H as a set of possible objective functions.

3.5 Bayesian simple classification

An efficient Bayesian learning method is the simple Bayesian learning method, commonly called the Bayesian simple classification method. In some contexts, it has been shown that its efficiency is comparable to the efficiency of methods such as neural networks and decision trees (Durante *et al.* , 2017). This section introduces the simple Bayesian classification method.

The simple Bayesian classification applies to problems in which each instance of x is selected by a set of attribute values and the objective function $f(x)$ from a set such as V. A set of training and output data of the objective function or class to which the new sample belongs is desired. The Bayesian method for classifying a new sample is to identify the most probable classification of the VMAP objective value by having the attribute values $\langle a_1, a_2, \ldots, a_n \rangle$ that describe the new sample as Equation (3.4).

$$v_{MAP} = \arg\max_{v_j \in V} P(v_j | a_1, a_2, \ldots, a_n) \tag{3.4}$$

Using Bayes theorem, Equation (3.4) can be rewritten as Equation (3.5):

$$\begin{aligned} v_{MAP} &= \arg\max_{v_j \in V} \frac{P(a_1, a_2, \ldots, a_n | v_j) P(v_j)}{P(a_1, a_2, \ldots, a_n)} \\ &= \arg\max_{v_j \in V} P(a_1, a_2, \ldots, a_n | v_j) P(v_j) \end{aligned} \tag{3.5}$$

Now, using the training data, two expressions of Equation (3.5) are estimated. Calculating v_j from educational data is easy, given how much v_j is repeated in the data. However, calculating different terms $P(a_1, a_2, \ldots, a_n | v_j)$ requires that a considerable amount of educational data be available. Here, the number of these terms is equal to the number of possible instances multiplied by the number of values of the objective function. Therefore, each sample must be observed several times to obtain a proper estimate.

The bayesian simple classification method is based on the simplification assumption that attribute values have conditional independence by having objective function values from each other. In other words, this assumption implies that provided that the output of the objective function is observed, the probability of observing the properties $a_1, a_2, \ldots, a_n$ is equal to multiplying the probabilities of each property separately. If we substitute this condition for Equation (3.5), the simple Bayesian classification method results in Equation (3.6).

$$v_{NB} = \arg\max_{v_j \in V} P(v_j) \prod_i P(a_i|v_j) \tag{3.6}$$

Where, v_{NB} is the output of simple Bayesian classification for the objective function. The number of terms $P(a_i|v_j)$ to be calculated in this method is equal to the number of properties multiplied by the number of output classes for the objective function. This value is much less than the number of terms of $P(a_1, a_2, \ldots, a_n|v_j)$. Therefore, simple Bayesian learning tries to estimate different values of $P(v_j)$ and $P(a_i|v_j)$ using their repetition rate in the training data. This set of estimates corresponds to the hypothesis. This assumption is then considered to classify new samples using Equation (3.5). Whenever the independent assumption of the conditionally simple Bayesian classification method is satisfied, the simple Bayesian class will be equivalent to the MAP class.

4. Research area and the statistical population

Providing a decision support system for the business environment requires careful modeling of this system. To model the business environment, one must first determine the parameters that affect the increase in profit, decrease, and stabilization of a selected business management plan's profit.

Our case study is a real enterprise of companies under the auspices of the Industrial Development & Renovation Organization of Iran, which operates in the casting and rolling industries. Due to the company's financial figures' confidentiality, we refuse to use its name, but other information about this company is provided in (Rashidi , 2014). The equations necessary to create a pattern and relationships between variables are described in a study and book published by (Rashidi , 2018, 2017).

In order to be able to model this problem using Bayesian networks, three steps must be performed (Wang *et al.* , 2018): (a) Extract a set of relevant parameters along with their values (b) Form a network structure in the form of an acyclic graph with nodes of variables. (C) Determine a conditional probability distribution of CPD for each of the network variables.

In the first step, the company's financial and accounting equations in the sources (Rashidi , 2018, 2017) were examined. Figure 3 shows how to calculate the variables related to the profit and loss account. According to this figure and currency and technological constraints, the amount of production and the amount of sales, and the cost of goods sold are determined. The difference between sales and cost of goods sold is determined as the gross profit (loss). The operating expenses are then estimated, and net operating profit is deducted from gross profit (loss), net profit before tax, and net tax is deducted from net profit (loss).

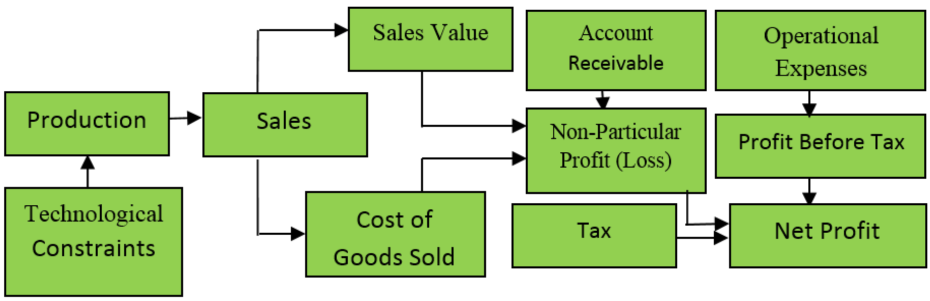

Figure 3: Chart of calculations of profit and loss statement variables for the firm

Table 1 illustrates the effective parameters of this firm, including 11 parameters in which the notations are shown, along with a brief description of these parameters.

Table 1: The effective parameters in the accounting and financial model of the firm

Variable	Description
AR	Account Receivable
ProductAmount	Production Amounts
Techrest	Technological Restriction
SaleAmount	Sales Amount
SalesValue	Sales Value
CGS	Cost of Goods Sold
NNP	Non-Particular Profit (Loss)
Tax	Tax
OE	Operational Expenses
PBT	Profit (Loss) Before Tax
NP	Net Profit (Loss)

In the second step, the Bayesian network structure is formed with the help of an acyclic graph. In this graph's formation, the direction of the edge between two nodes related to two variables is determined, to affect one variable on another variable. For example, accounts receivable (AR) variables affect the ProductAmount variable. In the same way, the amount of production will affect the amount of sales (SaleAmount).

In the third step, the CPD values for the Bayesian network variables are specified. Table 2 shows an example of a CPD related to sales amount. Based on this table, the sales amount has three values with specified probabilities.

To train the Bayesian network, the findings of results (Rashidi , 2017) were used. In that research, using the obtained model, planning for the 6-year horizon with respect to a set of specific exogenous variables was done for the target firm.

5. Research results

In this paper, SamIam version 3 was used to model the decision support system based on business intelligence and Bayesian network and to implement the model in the three steps presented in Section 4 of this paper. Figure 4 shows a section of the Bayesian network designed with this tool for the target firm. As a data set, the source (Rashidi , 2017) was used. All values of CPDs are determined based on this source according to the opinion of experts and field operations on this data set. The results of the direct and indirect effects of variables on each other are shown in Figure 5.

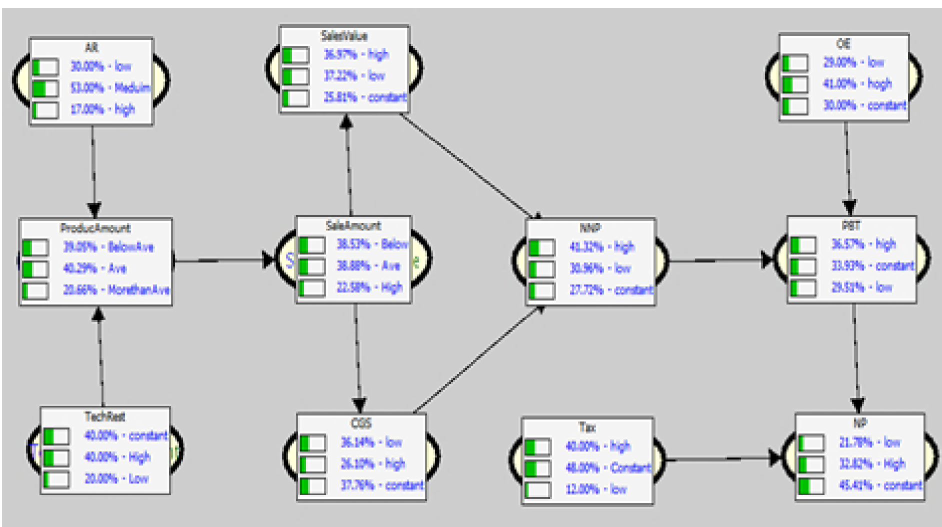

Figure 4: A section of the Bayesian network designed with the SamIam tool to plan the enterprise

According to the results obtained in Figure 5, the following observations can be concluded in the future decision of the firm:

- **Observation-1:** As shown in Figure 5 (A), based on the experiments done, the PBT and NNP have the highest impacts on the increase of the net profit (NP), with the values 1.63 and 0.8, respectively.

- **Observation-2:** In examining the factors, which influence the reduction of the profits (NP), we will have variables somewhat similar to before, but with different effects, according to Figure 5 (B). In this study, PBT with an effect of 1.66 and taxes with an effect of 1.19 has the highest rate.

- **Observation-3:** Figure 5 (C) shows the effect of factors in stabilizing the NNP interest rate. As can be seen, PBT with an effect of 0.9 and the tax with an effect of 0.54 show the highest effects.

- **Observation-4:** According to Figure 5 (D), the production (with a rate of 0.44) and sales amounts (with a rate of 0.23) were identified as the most effective factors in the case of fixing technology capacities on profits. It seems that the greater the effectiveness of the production than the sales for the firm is due to the stability of the unit price of goods sold.

- **Observation-5:** According to Figure 5 (E), the production and sales amounts, with different impact rates, are the most influential factors in increasing the technology capacity on profit. Of course, the degree of effectiveness of production is more effective in the case of increasing constraints. The difference between these two factors (by 0.4) is due to the severe negative impact of technology constraints on the production.

- **Observation-6:** Similarly, according to Figure 5 (F), the production and sales amounts with different impact rates are the most influential factors in reducing technology constraints on profits. The effectiveness of these two factors in reducing the capacities is less than that of these two factors in increasing technology capacities.

- **Observation-7:** The ineffectiveness of the variables TAX, OE, and AR (zero-impact) for profit in all three cases (including stabilization, increase, and decrease of technology capacities) seems quite reasonable.

6. Summary and conclusions

Business intelligence was proposed as an applied technique for managing business activities. This paper deals with the issue of business decision support systems based on business intelligence. To analyze a business, a model of business activity and its effective parameters must be designed. In this paper, a Bayesian network-based approach to business modeling is presented, and this approach is implemented for one of the companies under the auspices of the Industrial Development and Renovation Organization of Iran. In this implementation, SamIam version 3 of the Bayesian network was used. First, the firm's parameters affecting the business plan were extracted, and then the structure of the business network was formed by drawing an acyclic and directional graph. By reviewing the data related to the company, variables, and CPDs were quantified and analyzed. Using this research, the impact of various factories on this desired business can be easily identified. Also, using the proposed approach, the interactions of variables on each other can be studied and the best conditions for the firm can be determined.

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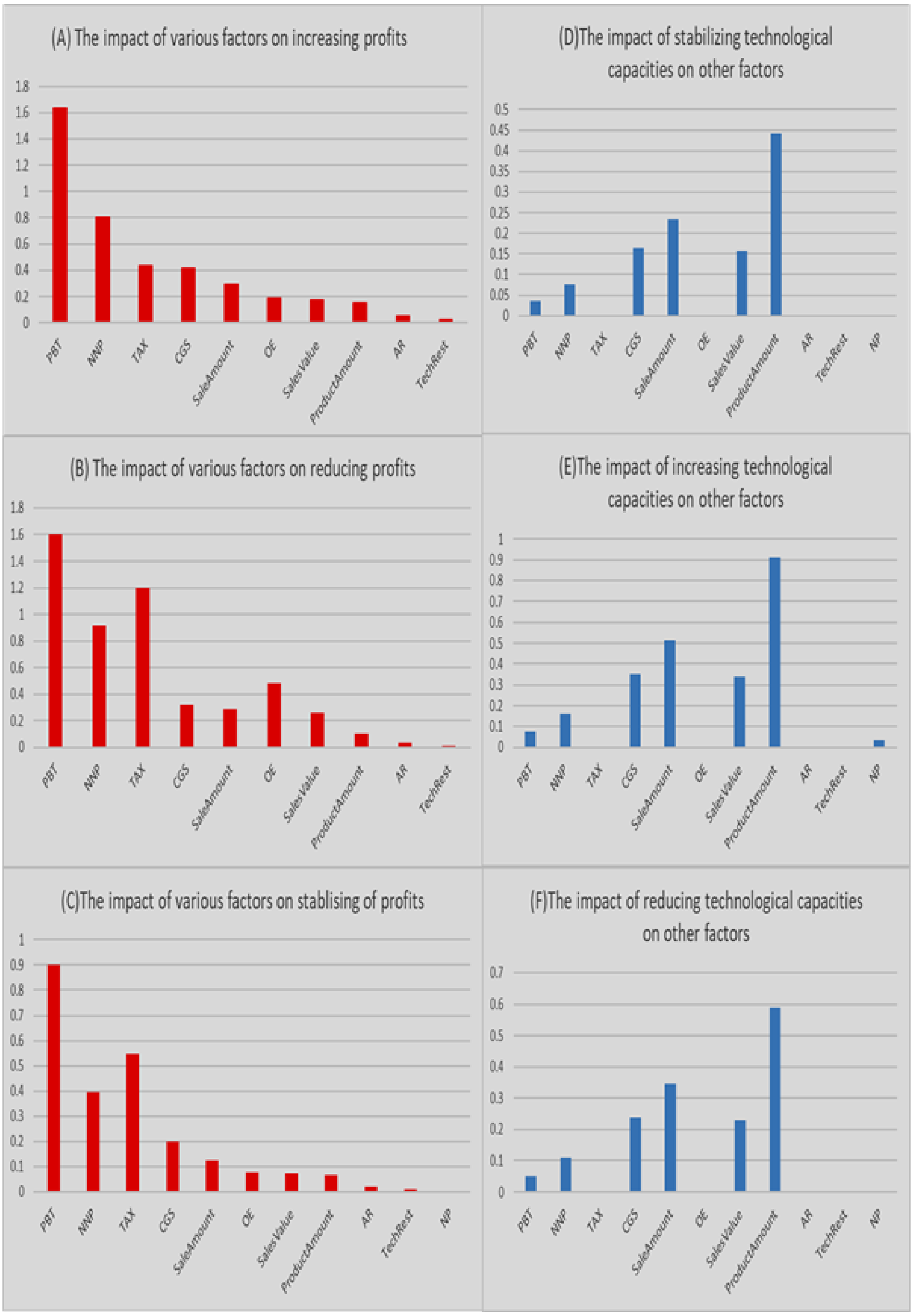

Figure 5: Analytical results obtained from the study of the degree of direct and indirect effect of variables on each other