Journal of Industrial and Systems Engineering
Vol. 12, No. 4, pp. 107 - 135
Autumn (November) 2019

A new framework for dynamic sustainability balanced scorecard in order to strategic decision making in a turbulent environment

S.Y. Shariat [1], M. Zandieh [1*], M. Rabieh [1], M. Tootooni [2]

[1] *Department of Industrial Management, Management and Accounting Faculty, Shahid Beheshti University, G.C., Tehran, Iran*
[2] *Department of Industrial Engineering, Iran University of Science and Technology, Tehran, Iran*

yasser.shariat@gmail.com, m_zandieh@sbu.ac.ir, m_rabieh@sbu.ac.ir, jotan2002@gmail.com

Abstract

The purpose of this paper is to develop a new framework for strategic decision making in a turbulent environment via a dynamic sustainability balanced scorecard (BSC). Environmental factors are selected by fuzzy TOPSIS method and added to a dynamic model of BSC for a company. The decision-making model is proposed in three main scenarios: Optimistic (economic growth scenario), Realistic (average long term economic situation) and Pessimistic (continuity of current sanctions situation scenario) and two internal policies: Production maximization is the first internal policy and Productivity maximization is the second internal policy.

The model is separately simulated in each scenario and policy, with the dynamic BSC model and every main aspect of the organization is analyzed with the majority of profit-making and its sustainability. The results show that a different policy is preferred in each scenario, which can help strategic managers for the decision-making process in uncertain and turbulent environments. Due to the increasing complexity of organizations in the competitive environment, it is necessary to propose performance evaluation models. The Balanced Scorecard (BSC) model is one of the most commonly used models for enterprise performance assessment that can be significantly adapted to environmental conditions. This research is novel because the environmental factors are added to a dynamic model of BSC for a company that has been encompassed with a turbulent economic, political and social environment within last years.

Keywords: Decision making, environmental management, measurement, sustainability, system dynamics.

1- Introduction

Iran, historically known as a crossover of incidents, is a country in the central middle east region. Even though these incidents are mainly political, the effects of their frequent incidence are transmitted to other aspects, economy being a major instance of such fields. As a result of this turbulent-oriented and super-dynamic economic environment, maintaining the business trajectory within the desired path and achieving its anticipated strategic goals are extraordinary challenges senior executives and strategic planners in Iran face.

Many models have been introduced in recent decades to facilitate planning, executing, and evaluating strategic decisions in the organizations. Each proposed method is applicable to a certain situation, and numerous elements are important to true managerial tools such as company conditions,

*Corresponding author
ISSN: 1735-8272, Copyright c 2020 JISE. All rights reserved

nature of the industry, micro and macro environments, and other related factors. The Balanced Scorecard (BSC) method is a well-known tool for companies specially to conduct performance evaluation, and is mostly used by manufacturing companies in Iran. However, this method has some limitations, as are discussed recently in detail in many papers. For instance, cause and effect relations as well as the link between perspectives are not specified in real circumstances, while the significance of time between growth and financial perspective is somewhat ignored in the relations. Hence, critics argue that the BSC model is static and misses dynamicity, and it ignores the importance of the environment, especially in turbulent situations that may lead to drastic changes in not only the companies but also as grand as the industry.

What is proposed in the following research, and is its novelty, is a system to assist decision makers in coping with the environmental uncertainties of the company. The dynamic sustainability of BSC model is developed in this study to enable results analysis for different policies in each external scenario and to improve strategic decisions. Furthermore, implementation of the proposed model is discussed for an Iranian leading company in the Tire Industry, and the results and conclusions are provided in the final section.

2- Literature review

2-1- Sustainability Balanced Scorecard (SBSC)

The Balanced Scorecard (BSC) method was first introduced in an article in Harvard Business Review by Kaplan and Norton (1992) to develop a business performance evaluation system. This approach is a comprehensive evaluation model that integrates physical and intangible assets, and develops a relationship among different criteria (Rabbani et al., 2015; Zhao and Li, 2015; Kaplan and Norton, 1996). The innovation of the BSC technique, as a corporation performance evaluation system, is formulating a hierarchical system of strategic objectives according to four main perspectives: financials, customer, internal process, and learning and growth. Non-financial parameters and financial indicators were also considered in this technique. Some instances of the studies conducted recently with the BSC approach are Agrawal et al. (2016), Rabbani et al. (2015), Zhao and Li (2015), Hoque (2014), and Hsu et al. (2011). Kang et al. (2015) used SBSC model to evaluate the importance of Corporate Social Responsibility (CSR) to performance of family-owned hotels. The fifth perspective of CSR added to traditional BSC and results showed that CSR had a significant effect on performance of hotels.

Moreover, Hoque (2014) reviewed the status of research on balanced scorecard, highlighted its gaps, and outlined some ideas for further research. However, the BSC technique ignores environmental, social, and sustainable aspects And hence, the SBSC was proposed by Figge et al. (2002) as a derivation of the traditional BSC which provides meaningful instruments for sustainability management and overcomes the conventional BSC deficiencies in social, environmental, and sustainable management systems (Zhao and Li, 2015). Lu et al. (2018) proposed a hybrid MCDM and SBSC model to establish sustainable evaluation in three international airports. They employed DEMATEL and VIKOR to estimate the key influences in relation to sustainability, and presented a SBSC model for airport performance evaluation system. Vanegas et al. (2018) used methodological procedures for product development and sustainability and studied the effects of sustainability aspects to product development process which could be considered as one of main parts of internal process perspective of BSC model and analyzed this at different industries in Brazil. Nikolaou and Tsalias (2013) developed a new SBSC scoring framework based on global indicators to evaluate performance of the Greek companies.

In addition, Nicoletti Junior, De Oliveira, and Helleno (2018) proposed a sustainability evaluation system based on a correlation matrix between the dimensions of the Triple Bottom Line (TBL) concept and the SBSC. Furthermore, Agrawal, Singh, and Murtaza (2016) developed a decision making framework in a reverse logistics system based on the SBSC model and implemented this framework in a mobile manufacturing firm. Figure 1 demonstrates a typical structure of the SBSC method. As can be seen, the corporate sustainability is promoted by integrating economic, social, and environmental dimensions into the business strategy (Rabbani et al., 2015).

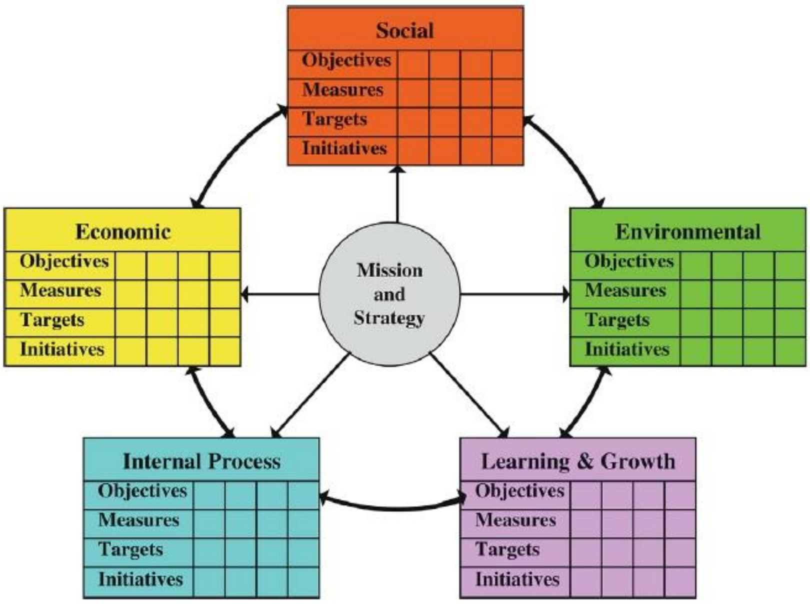


Fig. 1. Structure of SBSC technique adopted from Rabbani et al., (2015)

2-2- A brief review of system dynamics (SD)

The System Dynamics (SD) approach is a holistic method utilized to resolve real-time problems. This is an effective modern operational research methodology for analyzing and discussing complex issues. The SD modeling is often the ground layer of a systemic thinking approach (Sekhar Pedamallu et al., 2012). The principles of SD was initially introduced in Forrester (1961), according to which a system structure decides its behavior. However, his greatest contribution was the Stock and Flow Language that enabled the creation of virtual worlds, and controlled experimental laboratories to enhance learning (Tang and Rehme, 2017). Therefore, it is important to understand the behavior of a system, its information flow, and control policies.

SD combines the necessary theory and methods to analyze the behavior of complex systems and understand the system behavior variations over time. This approach is interested in particular in dynamics affected by a combination of flows, delays, and feedback loops (Ozcan-Deniz and Zhu, 2016). SD has a broad area of applications in the fields such as social science, economy systems, engineering, public policy management, energy and environment policy, and dynamic decision making (Sterman, 2000). As the literature review indicates, the SD can potentially detect indirect and often counter-intuitive relations (Tang and Rehme, 2017).

The modeling procedure in SD includes defining the problem, formulating the hypothesis, developing the simulation model, testing the model, and designing policy and assessment criteria. There are three basic elements in SD models used to model the flow of work and resources, namely stock elements (state variables), flow elements, and auxiliary variables and constants. These elements enable simulating the variations over time as well as the information feedback. This stocking and flowing structure of the systems are realized in order to create an SD simulation model in the form of a Stock and Flow Diagram (SFD) (Ozcan-Deniz and Zhu, 2016, De Salles et al., 2016).

To elaborate, a typical SD model structure contains:

- Project features representing the development tasks as they flow through a project.
- A rework cycle illustrating the repetitive development tasks flow in the time frame.
- Project control feedback loops employed to monitor the project performance.
- Side effects such as ripple and knock-on resulting from activities taken to complete the gap between project performance and the goals (Ozcan-Deniz and Zhu, 2016).

Various applications of SD are discussed in the literature, such as the investigation of renewable certificates policy in Swedish electricity industry (Tang and Rehme, in press), construction project management (Ozcan-Deniz and Zhu, 2016), SD applications in electricity industry (Ahmad et al., 2016), effects of climate change risks on the economic performance of the firms(Nikolaou et al., 2015), modeling of a production and inventory system for re-manufacturing (Poles, 2013), and academic performance of the international students in Turkey (Sekhar Pedamallu et al., 2012).

2-3- Dynamic Balanced Scorecard

As discussed in previous sections, BSC method has been one of the most successful management concepts in recent years and is now the leading approach utilized for enterprise performance measurement and management in private, public, and non-profit organizations (Zhang and Gao, 2008). Moreover, some problems arising from the gap between measures and objectives were eliminated by Kaplan and Norton (2004) using strategy maps. However, there are still some problems evident in this approach. Specifically, some researchers criticize the BSC approach for its weakness in determining the interrelationships between measures. Such limitations can lead to difficulties for organizations in implementing this method, as noted in the following (Khakbaz and Hajiheydari, 2015):

- The relationships between the objectives are not clear, while the aims rely on the developer
- The causality between the objectives are not properly described by the BSC
- The causal connections between the objects do not conform to the strategy maps
- BSC is a static model that does not consider time factors. Hence, by dismissing the time delays between the measures, the decision making process of the organization suffer numerous complexities
- BSC requires dynamics. However, it does not correctly considers the effect of the dynamics existing within a system.

To overcome the shortcomings mentioned above, the dynamic BSC approach was developed with regards to SD approach, which has a lower limit compared to the traditional BSC, thus facilitating the development of a strategic management system. Some achievable advantages resulting from the DBSC deployment include the ability to select achievable, rational, and objective-based goals, scenario planning, change management, policy analysis, and demonstrating the time delays between organizational objectives (Khakbaz and Hajiheydari, 2015; Barnabè and Busco, 2012). Barnabè and Busco (2012) addressed the important issues for the contribution of SD methodology in designing and implementing the BSC as follows:

- Clarifying the concept of causality in BSCs to visualize causal linkages and their polarities through utilizing specific mapping tools
- Providing a better representation of the system structure
- Applying the concept of the feedback loop and combining key performance indicators and factors with “key success loops”
- Relying on mechanisms employed for rigorous testing and validation of assumptions, relationships, parameter choices, and strategy development
- Answering the “what if” questions as well as performing policy analysis and scenario testing
- Sustaining individual and organizational learning and supporting improvements in mental models (Sterman, 2000, Bianchi and Montemaggiore, 2008).

In recent years, the number of researches that addressed the combination of SD and the BSC has been increasing significantly. For instance, Khakbaz and Hajiheydari (2015) proposed an integrated framework to integrate BSC with the SD approach and applied their approach to an Iranian public transportation company. Moreover, Zhang (2012) provided an overview on the literature related to the combination of SD and the BSC. Over the last decade, several companies, governmental organizations, and consulting firms have utilized SD to address critical issues and decisions. A number of examples and applications include service industry (Zhang and Gao, 2008), capital employed (Nielsen and Nielsen, 2008), service-based business (Barnabe, 2011), public transportation (Khakbaz and Hajiheydari, 2015), and service quality management. Supino et al.

(2019) developed the DBSC model to support decision making process and evaluating alternative scenarios. They enhanced the proposed DBSC model with statistics to forecast the trends of the main indicators which could affect the Scenarios and also the main internal policies of the company.

2-4- Environmental uncertainty

Uncertainty is a key factor for strategic decision makers who aim to sustain the competitiveness of their respective firm over time. Uncertainty can be found in interactions among natural, economic, and social systems (Koul et al., 2016). The concept of the uncertainty is defined as: "the absence of knowledge, a situation of inadequate information that manifests as inexactness, unreliability or border with ignorance, and any departure from the unachievable state of complete determinism" (Funtowicz and Ravetz, 1990, Walker et al., 2003). Uncertainty arises when managers cannot accurately predict the future events or do not feel confident about recognizing the main variations in their business (Vecchiato, 2012). Moreover, any new information may lead to uncertainty. Nature (i.e. inadequacy of knowledge), location, and the level of uncertainty (from deterministic uncertainty to the lack of knowledge) are listed as other major characteristics of uncertainty.

Various approaches to resolve uncertainty have emerged in order to manage complex uncertainties, including those proposed by Koul et al. (2016), Wieteska, (2015), Vecchiato, (2012), Chai and Ngai (in press), and Ghosh and Olsen (2009). The literature highlights the strength of SD in managing uncertainty via providing comprehensive sensitivity analysis, validation and confidence building tests, formal scenarios analysis, cross-impact matrices, and direct automated non-linear experiments. A list of the reviewed literature along with the summary of their findings on SD modeling for uncertainty, as well as different approaches and policy types for various levels of uncertainty are discussed in detail in Koul et al. (2016).

Sustainability is not merely a manner of the system or the goal to be achieved. Rather, it is a process that occurs over time. Therefore, SD simulation could very well be a suitable tool, along with sustainability, to evaluate the firm's performance and assist managers in improving their decisions, especially in turbulent environments. This combination analyzes different scenarios and internal policies and thus, strategic managers are enabled to make more conscious decisions regarding the consequences of their decisions.

3- Methods and procedures

Analytical dynamic system approach is the best approach to combine with the strategic plan. This approach enables logical detection of the causal relationships on routine activities in a company. To perform such detection, variables regarded in the strategic plan are generally used for the dynamic model. Moreover, to provide a better understanding of the dynamic nature of the subject, intermediate and auxiliary variables are employed as well.

The activities carried out and the processes are under rigorous supervision based on the strategic plan viewpoint. Then, the problem is presented to the company's experts and decision makers to be used in model design and development. At the time being, the company was suffering from a lack of precise realization of the dynamics present in the strategic plan nature. In addition, the managers were interested in observing the effects of policies imposed on the growth and learning layers of the strategic plan, when there was a delay in consequences layer.

Barez Industrial Group, a leading company in the tire industry in Iran, has played a key role in its domestic market as well as its international market in the Middle East. However, as discussed earlier, there has been a turbulence in its environment throughout the recent years, which affected mainly its market and its financial condition. To elaborate, the questions the managers need to answer are the following:

- How should the market demand be managed?
- How to determine the best level of production for all economic situations?
- How much time and cost should be spent on Research and Development and new products?
- How to make the best feasible decisions to increase profit?

The procedure flowchart of this research is demonstrated in figure 2. Once the problem was defined, the company's SBSC model is developed initially to add the key external factors to the existing BSC model. To do that, Fuzzy TOPSIS method is employed to select external factors for the SBSC model. Then, the system concept model is developed in meetings with the experts (including middle and top level managers of the company), and the causal loop diagram is drafted to visualize the interrelation of the model variables. Next, the dynamic SBSC model for the company is finalized via formulating the mathematical equations according to historical data and expert opinions. Finally, three main scenarios are developed based on the macroeconomic situations, two major policies are proposed, and the behavior of the main variables for each combination of scenarios and policies are analyzed.

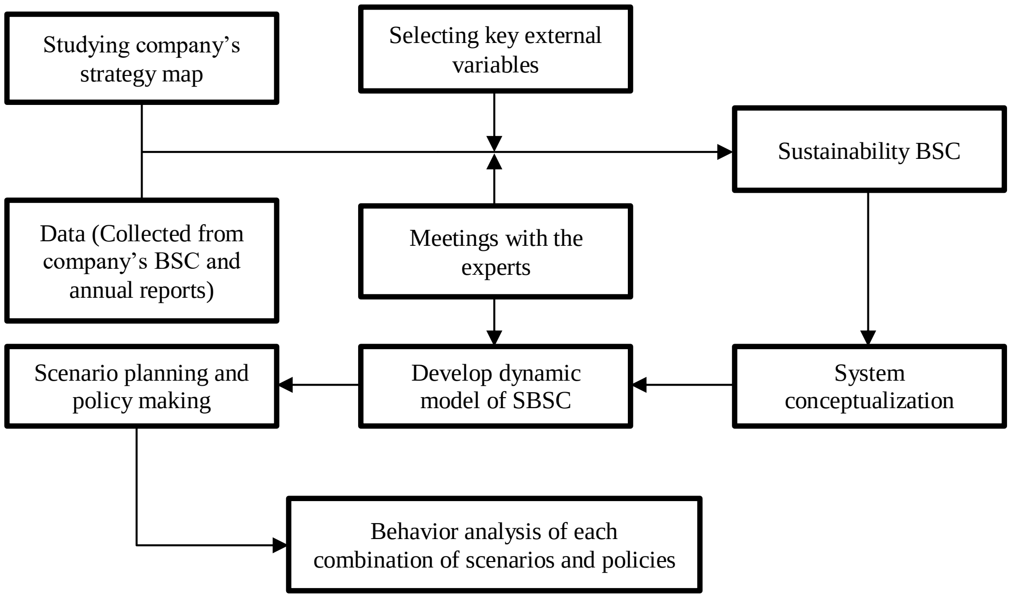


Fig.2. Research procedure

3-1- Proposed dynamic SBSC model

To overcome the points mentioned in the previous section, once the causal relationships were provided, the stock and flow model is produced. In this dynamic model, all notable organization variables are analyzed and combined alongside the environmental variables affecting the organization. It is worth mentioning that the traditional BSC platform is utilized to design the simulation model.

The first step was selecting key external factors that influence the performance of the company. As discussed earlier, sustainability consists of three dimensions, namely economic, social, and environmental. As for the case of the current research, the main factors were defined for each dimension. Then, the Fuzzy TOPSIS method was used to rank and select the proposed model according to the experts in the industry.

The decision matrix is shown in table 1:

Table 1. Decision matrix

criteria / alternatives	financial perspective	customer perspective	internal business processes perspective	learning & growth perspective
inflation	8	6	5	4
currency exchange rate	7	5	4	3
raw material price	7	7	3	2
Iran economic growth	6	8	3	3
middle east economic growth	5	4	2	2
car production	6	6	2	3
tire label	3	4	1	2
CO2 emissions	2	3	2	1
product waste	4	5	3	3
unemployment rate	2	3	1	2
population growth rate	3	2	1	1

The weights defined for all criteria are presented in table 2:

Table 2. Weight of each criterion

criteria	financial perspective	customer perspective	internal business processes perspective	learning & growth perspective
Weight	0.25	0.25	0.25	0.25

The normalized fuzzy decision matrix is developed as shown in table 3.

Table 3. Normalized fuzzy decision matrix

criteria / alternatives	financial perspective	customer Perspective	internal business processes perspective	learning & growth perspective
inflation	0.461112334	0.352941176	0.5488213	0.478091444
currency exchange rate	0.403473292	0.294117647	0.43905704	0.358568583
raw material price	0.403473292	0.411764706	0.32929278	0.239045722
Iran economic growth	0.345834251	0.470588235	0.32929278	0.358568583
middle east economic growth	0.288195209	0.235294118	0.21952852	0.239045722
car production	0.345834251	0.352941176	0.21952852	0.358568583
tire label	0.172917125	0.235294118	0.10976426	0.239045722
CO2 emissions	0.115278084	0.176470588	0.21952852	0.119522861
product waste	0.230556167	0.294117647	0.32929278	0.358568583
unemployment rate	0.115278084	0.176470588	0.10976426	0.239045722
population growth rate	0.172917125	0.117647059	0.10976426	0.119522861

The distance from each alternative to the Fuzzy Positive Ideal Solution (FPIS) is shown in table 4.

Table 4. Distance from each alternative to the FPIS

alternatives	Di+
inflation	0.029411765
currency exchange rate	0.061643144
raw material price	0.083710101
Iran economic growth	0.068814752
middle east economic growth	0.125209885
car production	0.096775938
tire Label	0.155791074
CO2 emissions	0.166416586
Product waste	0.095778553
unemployment rate	0.168823218
population growth rate	0.181825202

The distance from each alternative to the Fuzzy Negative Ideal Solution (FNIS) is shown in table 5:

Table 5. Distance from each alternative to the FNIS

alternatives	Di-
inflation	0.176122678
currency exchange rate	0.132234389
raw material price	0.120426366
Iran economic growth	0.133008282
middle east economic growth	0.06617924
car production	0.105389313
tire label	0.044334527
CO2 emissions	0.031133182
product waste	0.096749203
unemployment rate	0.033303455
population growth rate	0.01440976

Next, the closeness coefficient for each alternative is calculated to the ideal solution (table 6).

Table 6. Closeness to the ideal solution

alternatives	closeness to the ideal solution
inflation	0.856901041
currency exchange rate	0.682051124
raw material price	0.589930687
Iran economic growth	0.6590342
middle east economic growth	0.345783702
car production	0.521302808
tire label	0.221533509
CO2 emissions	0.157596652
product waste	0.502520805
unemployment rate	0.164765266
population growth rate	0.073431158

Finally, the six external factors with closeness coefficients more than 0.5 were chosen for the sustainability balanced scorecard model. In table 7, the final ranking of the external factors are presented:

Table 7. Final ranking

alternatives	rank
inflation	**1**
currency exchange rate	**2**
Iran economic growth	**3**
raw material price	**4**
car production	**5**
product waste	**6**
middle east economic growth	7
tire label	8
unemployment rate	9
CO2 emissions	10
population growth rate	11

All factors involved in the final model can be classified into three classes: internal factors, near external factors (the factors that belong to the micro-environment), and external factors (the factors that belong to the macro-environment). On the other hand, the main model framework is the company's strategy map. Therefore, another factors classification is based on the BSC model of the firm. Table 8 shows the classification of the main factors based on internal/external origins and based on the BSC strategy map of the case.

Table 8. Factors classification

factors / **BSC perspective**	**internal**	**near external**	**external**
financial perspective	• profit • revenue • total cost • employee Salary	• advertisement investment	• raw material price • inflation rate • currency exchange rate
customer perspective	• customer satisfaction • advertisement policy	• market share • perceived value • image • word of mouth	• total market capacity • demand • car production
internal business processes perspective	• production • productivity • order plan for raw material • inventory	• raw material delay time	• waste product
learning & growth perspective	• work force • training policy		

It is evident that in the process of designing the model, the reciprocating process maintained from the problem introduction to the final phase. Even the casual model produced was under constant supervision and modification.

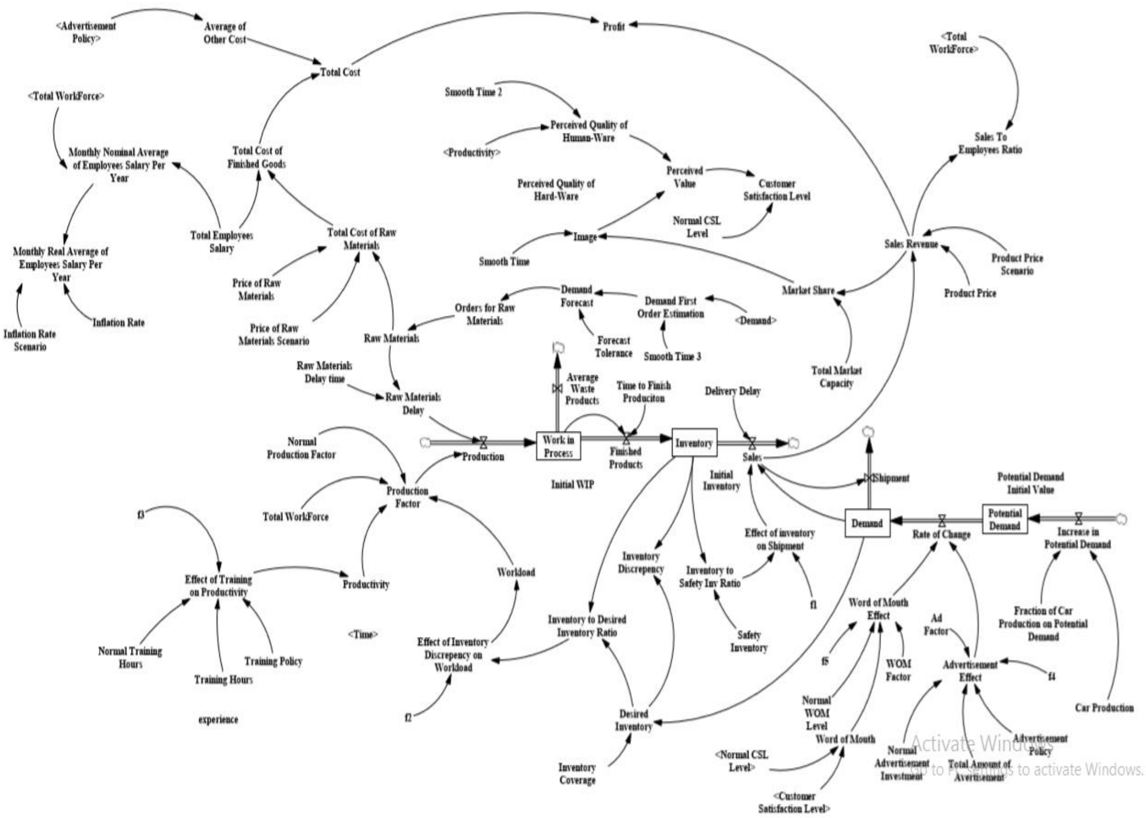


Fig.3 Stock and flow diagram of Barez industrial group

The stock and flow model development is described in figure 3. In all records, the expenditures are in million IR Rials.

The model can be divided in three sections, namely demand, production, and profit. To elaborate:

1- The demand input variable is the result of advertisement and WOM impacts on the potential demand. The potential demand is in turn affected by the number of automobiles manufactured. In addition, the shipment output is equal to the number of sales leaving the repository.

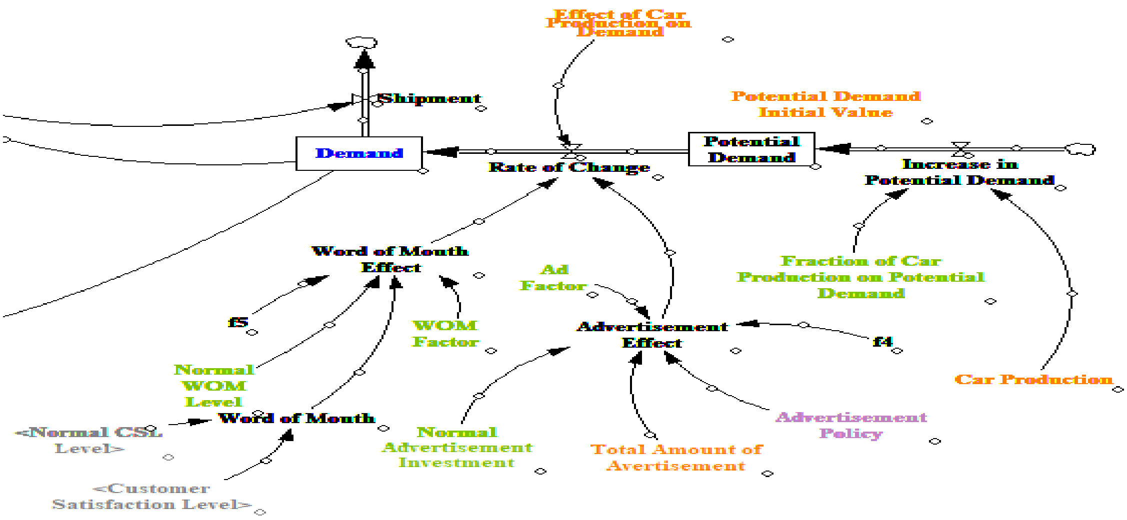


Fig.4 Demand Section of the model

2- The production level is dependent on the production variable and available raw materials. The production factor is directly related to the human resource productivity, workload, and available human resource. On the one hand, the demand indirectly specifies the workload through determining the desirable inventory. On the other hand, the raw materials could be ordered according to the demand prediction. Finally, the "semi-manufactured" product is generally transported from the production line to the repository, where they are ready to be shipped once the plastic appendages are removed.

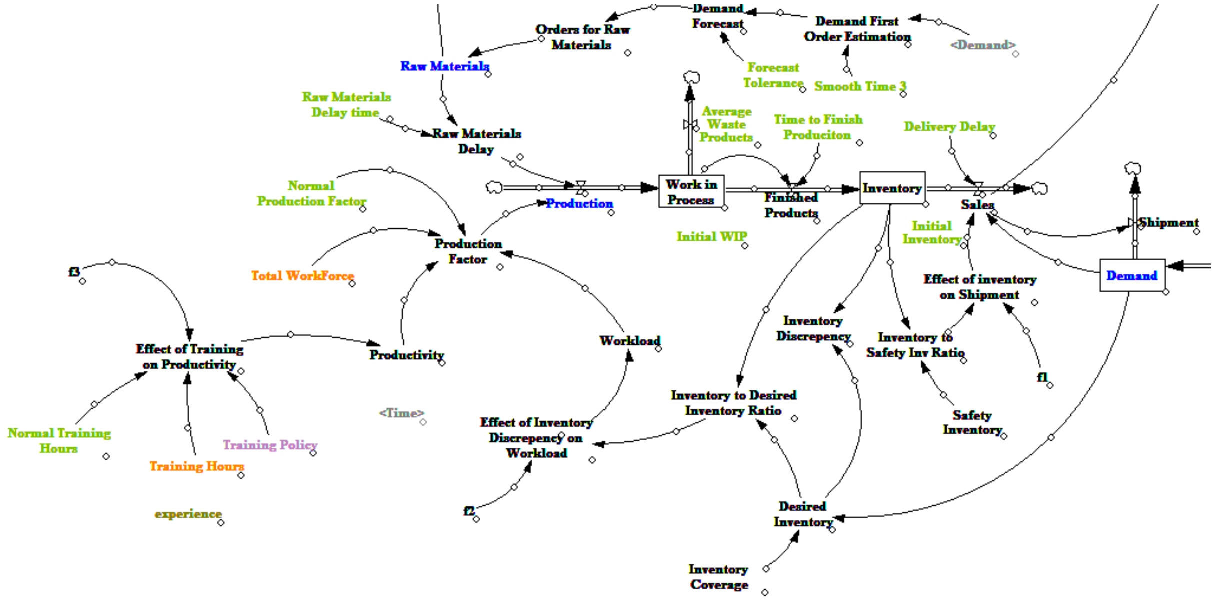


Fig.5. Production section of the model

3- The profit variable is determined once the total cost is subtracted from the sales revenue. The sales revenue depends on pricing policies, and the total cost includes the costs of raw materials, payments, wages, and other costs.

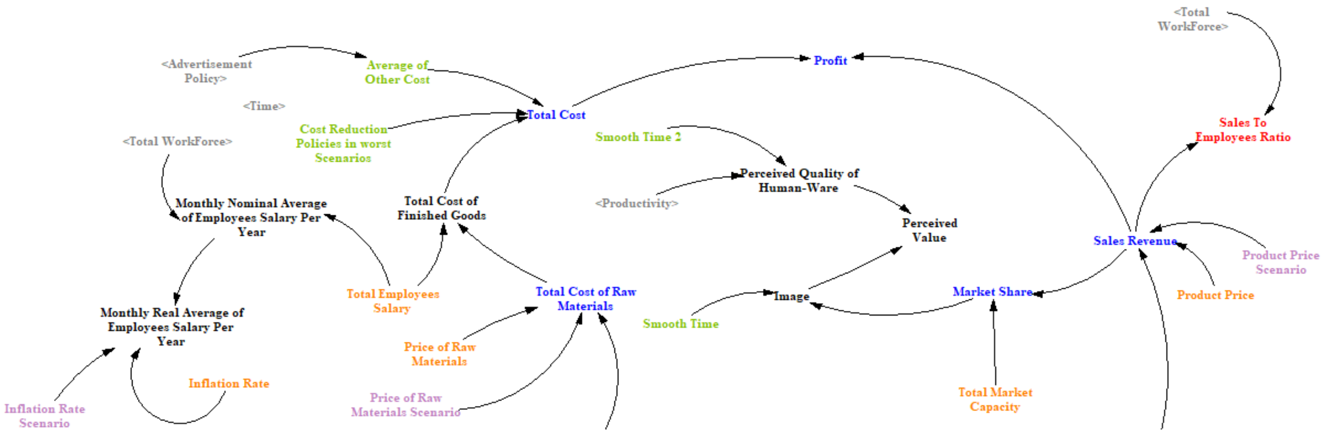


Fig.6. Profit section of the model

The main loops that form the model are as follows:

1- In figure 7, the negative feedback loop for the demand is demonstrated. As can be seen from the loop, an increase in the demand ultimately leads to an increase in production, which promotes the inventory. Plus, an increase in the inventory as a result of a production growth fulfills the demand through increasing sales and reducing the demand.

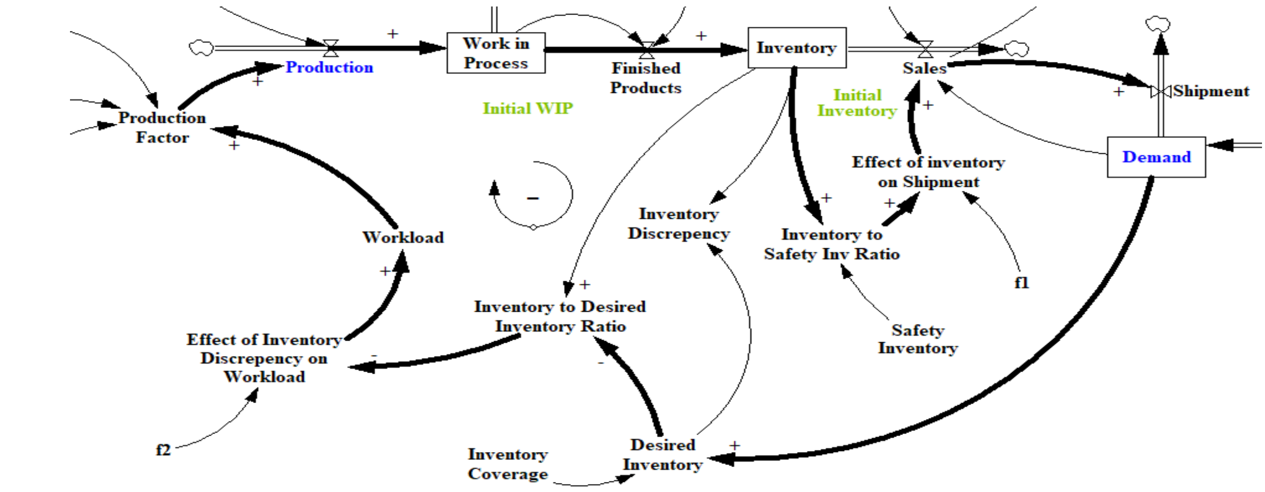


Fig.7. Demand negative feedback loop

2- The second loop illustrated here is also a negative feedback loop where increase in the demand results in an enhancement in ordering raw materials, which increases the sales. An increase in the inventory as a result of an increase in the production fulfills the demand through sales growth and demand reduction.

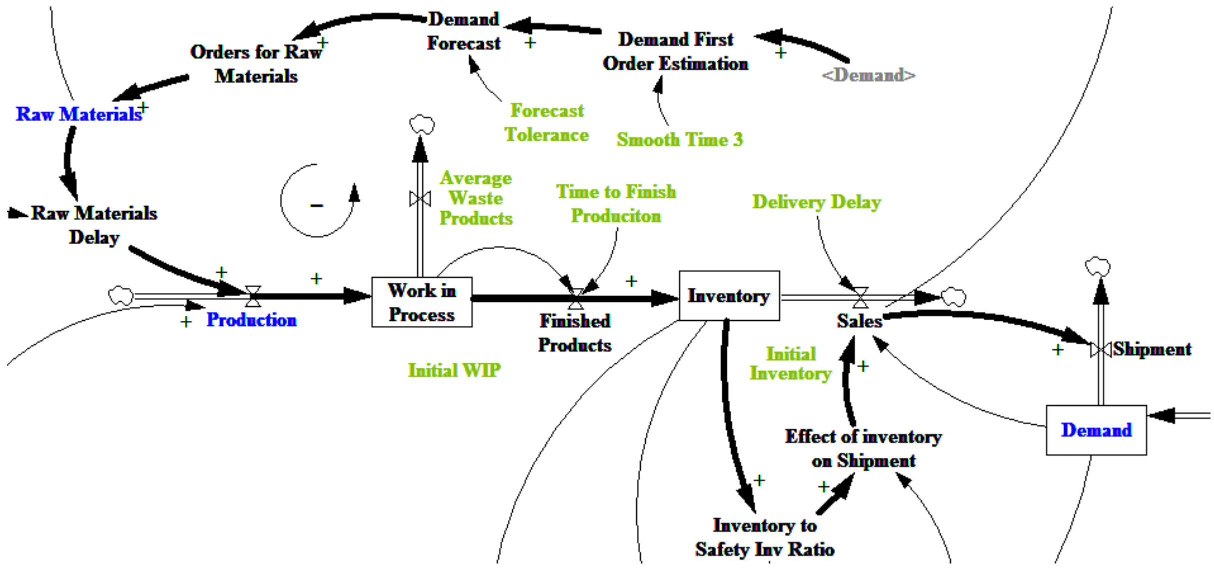


Fig.8. Inventory negative feedback loop

3- In the negative feedback loop illustrated in figure 9, an increase in the demand results in the reduction of workload and a decrease in production quantity. Thus, the inventory reduces as a result of a production decrease.

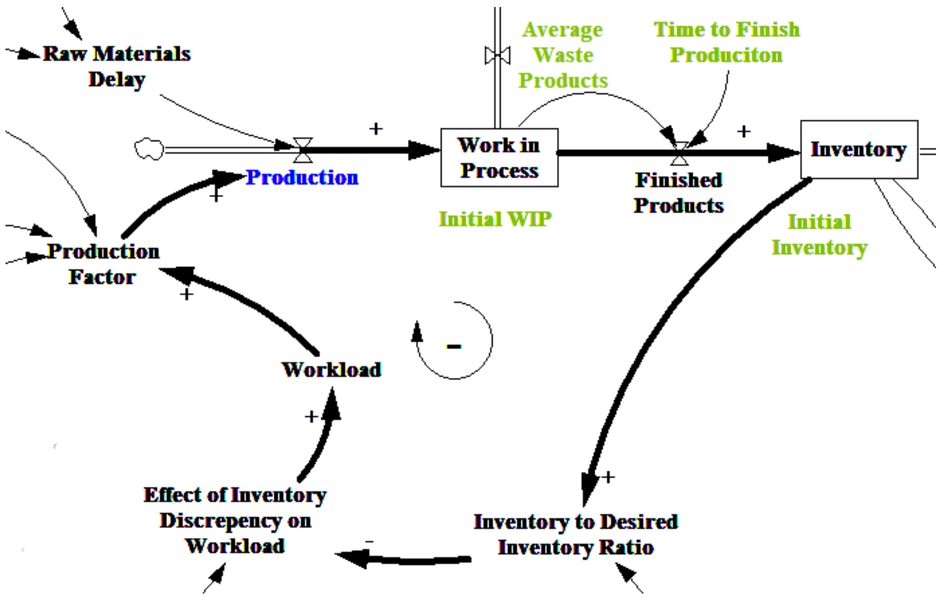


Fig.9. Production negative feedback loop

In the following section, important variables should be briefly described. It should be noted that the variables and parameters are color-coded according to the following:

- Variables or parameters assigned according to the external data (orange)
- Fixed parameters based on the default calculations derived from calibration and optimization (green)
- Variables whose behavior are extracted from the model's logic, but are compared to real data (blue)
- Variables for policy making (violet)

According to the Dynamic System logic, a number of the variables are to be regarded as a stock; specifically, the variables with a gradual, and yet significant ratio to us, change over time. In this regard, the following variables are noted as stock variables.

- Work in process: the amount of work in process in the company.
- Inventory: the amount of merchandise deposited in the warehouse.
- Demand: the severity of demand for the products. It should be noted that this amount is adjusted according to the organization's sales table based on the supply and demand economic equation.
- Potential Demand: a hypothetical variable for the demand growth rate used to anticipate the future conditions.
- Overall Advertisement: The overall amount of organizational investment in advertisement
- The average number of training hours for the staff

In formulations, the amounts are often divided into constants, to obtain normal values, to be comparable with the total value of the industry. For instance, 10 hours of training may be proper amount of time for a given industry, while it can be inadequate for another. Therefore, normal values are obtained to achieve a sensible answer for the intended industry. For the industry of our interest, the normal amount of training hours is 15[1].

Meanwhile, it should be noted that look-up functions are mainly used in order to make better relations between variables in the modeling. These functions enable achieving a relation between two variables stemming from different natures. Even though these functions are assigned as empirical cases, they are applicable to real conditions.

Figure 10 displays the effects and interactions of the variables mentioned above, entitled "Effect of Training on Productivity".

Fig.10. Effect of training on Productivity Comparison between Simulation and Real Data

- Total Work Force

The total number of staff in an organization (figure 11) according to the period that affected the production factors as well as the mean payed salary (Monthly Nominal Salary Average per Employee per Year)[2].

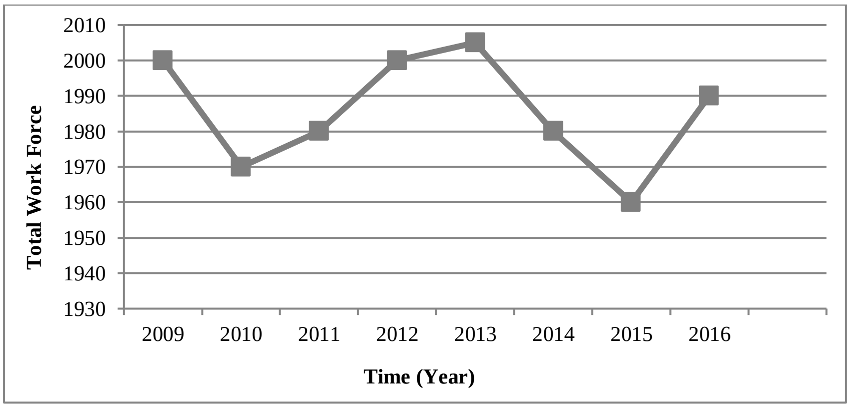


Fig.11. Total work force change based on real data

Total number of staff, in addition to qualitative variables (i.e. workload and productivity), includes the production input. This variable is one of the major production variables in the organization (figure 12).

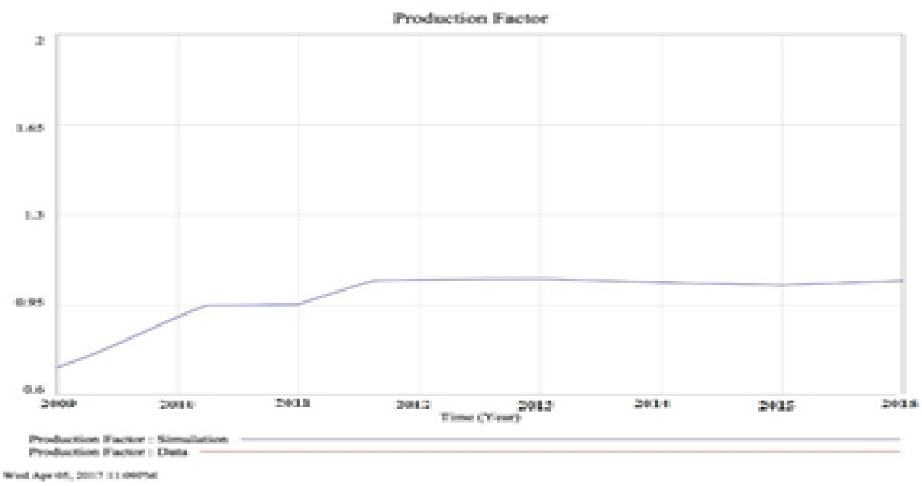


Fig.12. Production Factor Comparison between Simulation and Real Data

Price of raw materials: the price of raw materials according to the financial statements of the organization (figure 13).

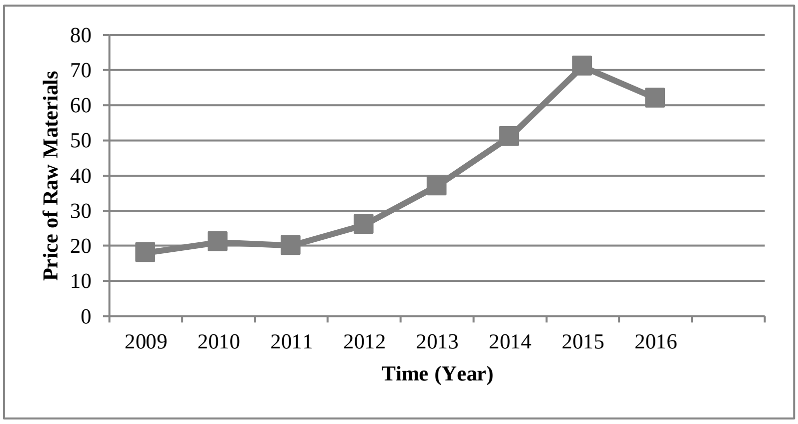


Fig.13. Price of consumed raw materials during last years

Total cost for raw materials are calculated by multiplying the price of raw material by the rate of orders (figure 14).

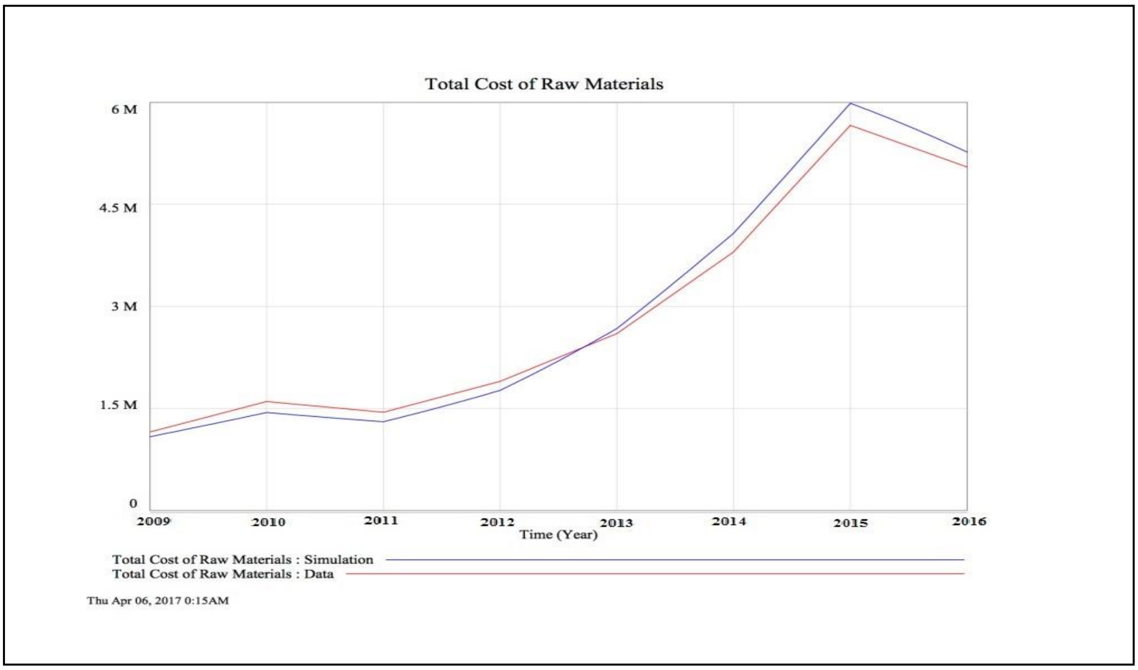


Fig.14. Total cost of raw materials comparison between simulation and real data

As can be seen in figure 13, the simulation results are in conformity to the data. The expenditures are in million IR Rials.

- Total Salary: the total payments to the staff, according to the financial statements of the organization (figure 15).

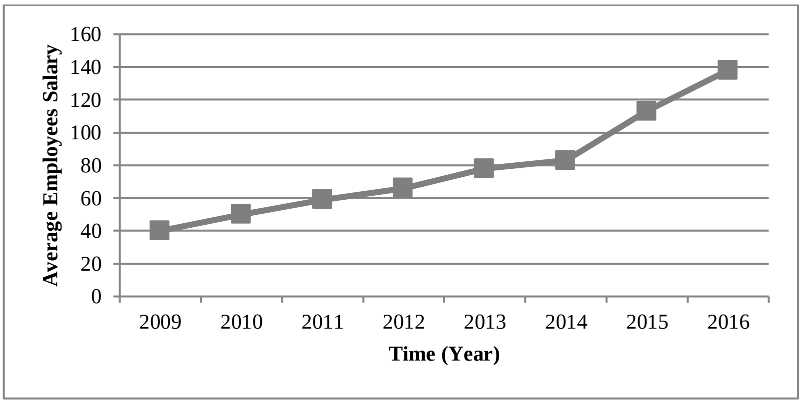


Fig.15. Average Employees Salary Based on Real Data

In addition to the other costs for raw materials, these values comprise main expenses of the organization. Specifically, the remainder of the expenses is regarded as "the average for the other costs", which the software considers as the best values in different years. Hence, the organization's overall expenditure is as depicted in figure 16:

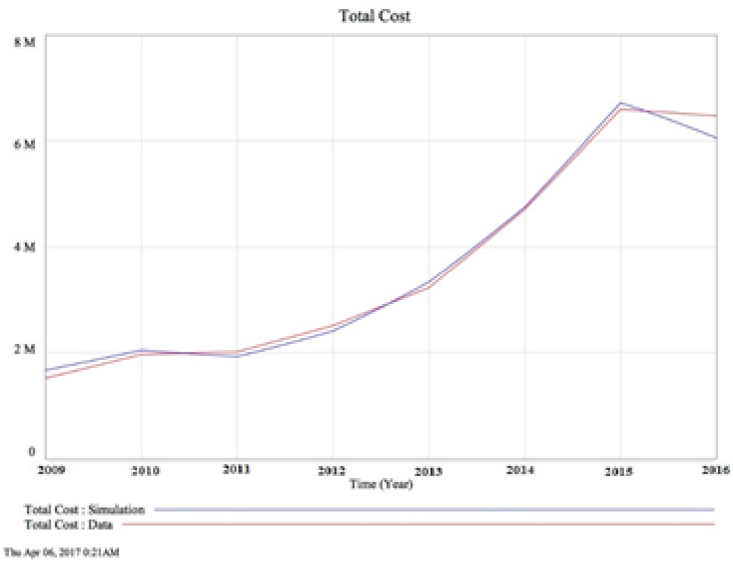
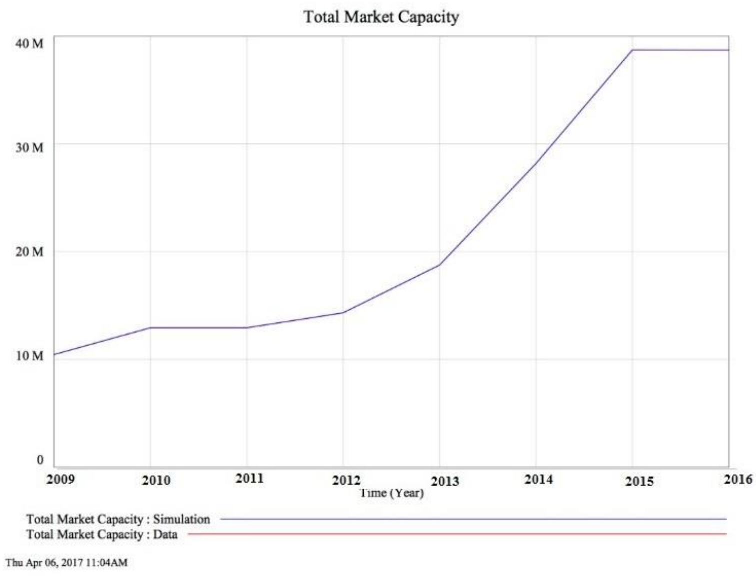


Fig.16. Total cost comparison between simulation and real data

- Inflation Rate: Inflation ratio is assigned according to data provided by the Central Bank of the Islamic Republic of Iran. This ratio is considered for the salary only, since it is highly influenced by the inflation. Other factors however, such as raw materials, are dependent on market structure. Therefore, their prices are assigned according to the supply and demand mechanism.
- Total Market Capacity: This value is derived from the management records of the organization. Using this value, the organization's market share is estimated using dynamic calculations (figure 17).



According to the values mentioned, and the organizational sales, the market share is determined and compared to real data (figure 18).

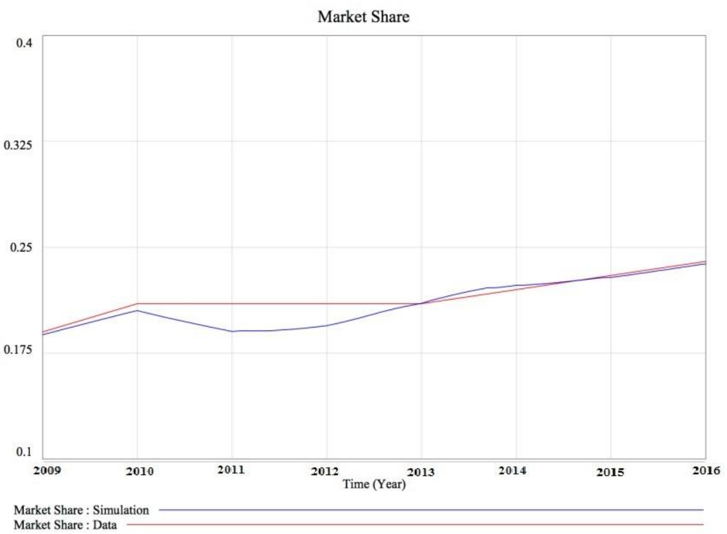


Fig.18. Market share comparison between simulation and real data

- Product price: The average price for the products was obtained from the financial statements. When the prices are multiplied by the organization's sale level, it reveals the organization income (figure 19).

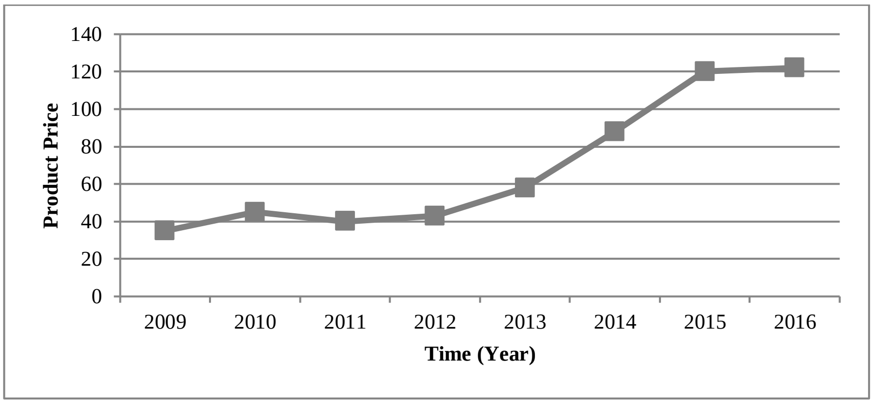


Fig.19. Product price based on real data

It should be noted that the sale is a function of the demand currently present for the products (figure 20).

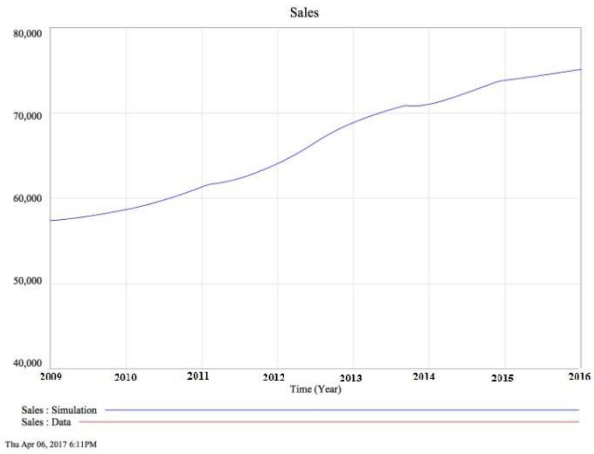


Fig.20. Sales Comparison between Simulation and Real Data

- Potential Demand Initial Value: This value is achievable via the real data from the industry, yet an initial value of 100,000 was considered for our initial objectives.

Fixed parameters based on the default calculations derived from calibration and optimization: In this section, the defaults for the fixed parameters are described initially. Then, the derived values for these parameters are presented by simulation (table 9).

Table 9. Fixed Variables

Lower limit	Variable	Upper limit
14	<=normal training hours<=	40
0	<=initial WIP (Work in Process) <=	50000
0	<=initial inventory<=	100000
1	<=time to finish production<=	5
1	<=delivery delay<=	1.5
Lower limit	**Variable**	**Upper limit**
1700	<=normal production factor<=	1900
40000	<=average of other costs<=	600000
0	0<=smooth time	
0	<=fraction of car production on potential demand<=	1
800000	<=car production<=	1000000
0	<=forecast tolerance<=	15000
0	<=normal WOM (Word of Mouth) level<=	10
0	<=raw materials delay time<=	1
2000000	<=normal advertisement investment<=	5000000
0	<=smooth time 3<=	1
60000	<=WOM factor<=	80000
60000	<=Ad factor<=	80000
90	<=normal CSL (Customer Satisfaction Level) Level<=	98

Values obtained from the optimization process are demonstrated in table 10.

Table 10. Optimum level of fixed variables

variable	optimum level	variable	optimum level
normal training hours	15	forecast tolerance	6923
initial WIP (Work in Process)	50000	normal WOM (Word of Mouth) level	10
initial inventory	71280	raw materials delay time	0.384
time to finish production	1	normal advertisement investment	2107000
delivery delay	1	smooth time 3	1
normal production factor	1714	WOM factor	60000
average of other cost	507720	Ad factor	60000
smooth time	354.35	normal CSL (Customer Satisfaction Level) Level	90.97
fraction of car production on potential demand	0.2	car production	900000

Optimization: For the optimization process, in addition to the functions mentioned earlier along with their limits, it is necessary to consider the relative weights of the values (table 11) for which data is provided to fit its behavior.

Table 11. The relative weights

variable	relative weight
sales revenue	1
production	0.024
demand	0.024
profit	0.2
total cost	0.6
market share	0.000000076
raw materials	0.0247
total cost of raw materials	0.4616
Customer Satisfaction Level	0.000032

3-2- Model validation

One critical part of the system dynamics is model validation. The model validity is a prerequisite to reassure validation of the model results. Several tests have been established to validate dynamic models; these are categorized in two groups of structural and behavioral. The structural and behavioral tests investigate the model behavior and output validity. Among the structural tests, for instance, boundary adequacy test and structural assessment may be mentioned. A sensitivity analysis (one of the essential tests to evaluate the validity and reliability of different models), reflective behavior, inconsistent behavior, and behavior prediction are also among the behavioral tests (Barlas,1996). In the methodology of systemic dynamics, the relationship types between variables and the validity of numerical values are determined by the groups of specialists associated with the topic. Also, in this paper for the suggested model, the groups of experts in the Barez Industrial Group, as well as the structural assessment and boundary adequacy tests, have been applied.

- **Boundary Adequacy Test:**

This test aims at answering the two fundamental questions: 1. Have the active variables in the model been considered as endogenous? 2. Has the time limit been regarded properly?
It observes whether important concepts and variables correlated to the topic are within the model boundary and also whether these variables are endogenous to the model. To answer; it should be stated that referring to the sentiments of experts in recognizing the variables impact on the model boundary and using the gained data, the boundary adequacy test was thoroughly examined. It is worth mentioning that the data time limit is in 8 years by the year 2017, which has been involved the economic fluctuations touching the tire industry, the fundamental changes in macroeconomic parameters, and key variables at the studied industry level.

- **Structural Assessment Test:**

This test tries to answer the fundamental question of whether the model structure is compatible with the rules and decision-making process governing the studying system.
The structure assessment test scrutinizes the model behavior compatibility with its structure. In the simulated model, in the positive and negative feedback, the behavior of the variables required to be exponential and goal-seeking, respectively. Therefore, as given in the previous section in the presented dynamic SBSC model, the variables that make up the negative feedback loops have goal-seeking behavior in the simulated model.

4- Scenario planning

The environment governing the economic foundations and organizations includes uncertainties that should be analyzed. As discussed in section 1, the scenario planning technique is capable of modeling the uncertainties affecting an organization. Since the economic sub-system governing an organization has a crucial effect on the organization, it is considered to be based on economic variables.

Moreover, practices that a manager may undertake to increase the profit include increasing revenue and decreasing costs. Therefore, two general approaches are available for the manager. In other words, this will become an organization profit optimization problem, which is a problem with two objective functions. The first objective function is maximizing the revenue, while the second objective is minimizing costs. It should be mentioned that there exists an inconsistency between these objective functions (i.e. activities that can increase the revenue will often result in an increase in expenditures). Moreover, moving towards decreasing the costs may result in a decrease in revenue as well.

Internal policies of organizations are mainly planned based on the two mentioned goals, where it primarily concentrates on increasing the production and revenue, whereas decreasing the costs stands as the secondary policy organizations set.

Given that sheer economic variables are important in environmental scenarios affecting organizations, three economic growth variables including inflation rate, annual exchange rate growth, and annual car production growth are considered in our study. Furthermore, three major potential scenarios that organizations are facing in the current situation include Optimistic (economic growth scenario), Realistic (average long-term economic situation), and Pessimistic (continuity of the current sanctions).

On the other hand, we identify the key variables in the organization and clarify their status in each environmental scenario. Then, we analyze each status within the organization variables in the frame of organizational internal policy. Accordingly, two internal policies are feasible for the organization:

- Policy A: maximum production level, and maximum expenses for sales, advertisement and R&D
- Policy B: increasing productivity, as well as decreasing the costs and productions to a certain required level.

The basis in which the internal policies of the organization are evaluated, is its profit. Modeling outlet for each policy in a scenario presents a profit trend within the time frame. Finally, the profit trend with regards to each internal policy is determined in each scenario. Two main factors remained dormant in the productivity trend of the organization are the amount of profit as well as its sustainability. In other words, any variation in profit as a trend will either include the amount of profit or demonstrate the productivity sustainability in the time frame. According to this explanation, the manager may sacrifice the productivity for a considerable short term profit and/or vice-versa, or it may be more preferable to sustain the profit during a period regardless of its amount. The components of the environmental scenarios affecting the organization and its internal policies are explained in tables 12, 13, and 14.

Table 12. Scenario No.1- Economic growth

Economic growth	% 8	Economic growth	% 8
Inflation	% 10	Inflation	% 10
Annual exchange rate growth	% 10	Annual exchange rate growth	% 10
Annual state car production growth	% 15	Annual state car production growth	% 15
Internal policy of organization A		Internal policy of organization B	
Production level in maximum state		Increase in productivity	
Maximum sales and advertisement		Decrease in production cost to required level and not more	

Table 13. Scenario No.2- Average long term economic Situation

Economic growth	% 2	Economic growth	% 2
Inflation	% 15	Inflation	% 15
Annual exchange rate growth	% 20	Annual exchange rate growth	% 20
Annual state car production growth	% 5	Annual state car production growth	% 5
Internal policy of organization A		Internal policy of organization B	
Production level in maximum state		Increase in productivity	
Maximum sales and advertisement		Decrease in production cost to required level and not more	

Table 14. Scenario No.3- Continuity of Current Sanctions Situation

Economic growth	% -4	Economic growth	% -4
Inflation	% 35	Inflation	% 35
Annual exchange rate growth	% 35	Annual exchange rate growth	% 35
Annual state car production Growth	% -10	Annual state car production Growth	% -10
Internal policy of organization A		Internal policy of organization B	
Production level in maximum state		Increase in productivity	
Maximum sales and advertisement		Decrease in production cost to required level and not more	

5- Results

In this section, the dynamic model is simulated according to the assumptions presented in the environmental scenarios section. The internal policies as well as the trends for the key variables are analyzed in subsequent periods. In the following, we analyze the trends for each key variable in the model.

A: Inventories

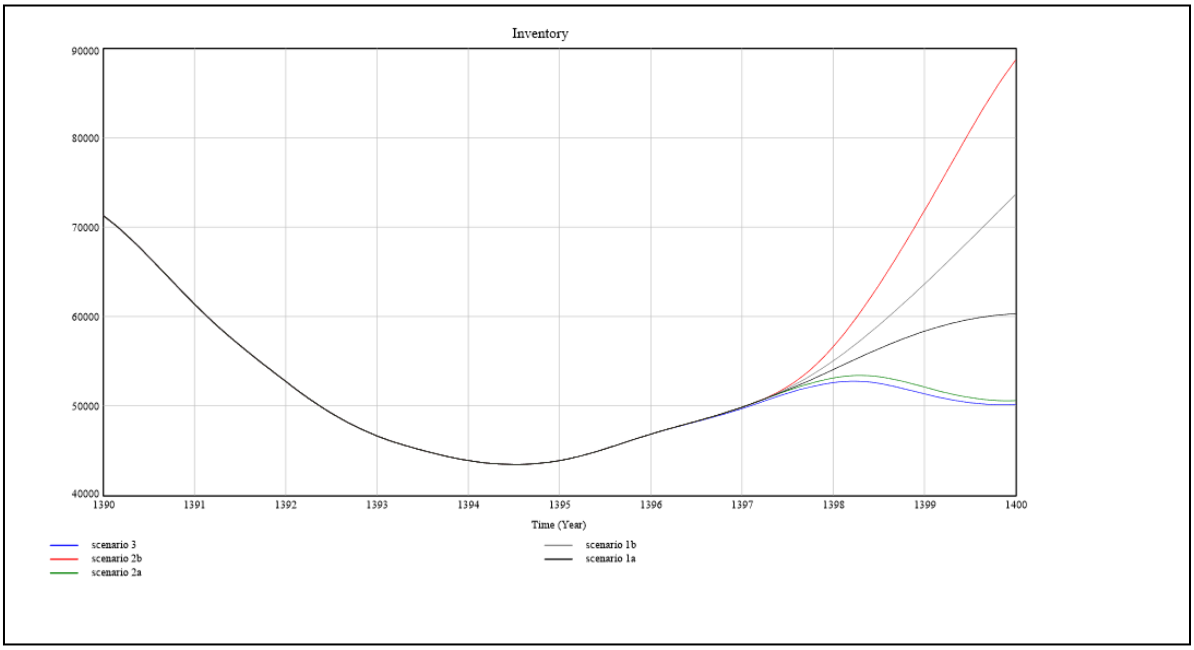


Fig.21. Inventory Behavior in Scenarios

As can be seen in figure 21, there is a significant difference between inventory trends in policies A and B for each environmental scenario. On the other hand, if only one specific internal policy is selected (policy A or policy B), there is no significant difference between the three scenarios. Therefore, the future trend for the organization inventory is independent of the environmental scenarios, and is only dependent on the internal policies of the organization. In other words, any variation in the level of inventory under the organization control is dependent on production, advertisement, and productivity policies. If the production level is maximized with drastically more sales and advertisements, the inventory is significantly decreased. However, if the policy is to increase the productivity and decrease the production costs, the trend for the inventory will increase.

B: Profit

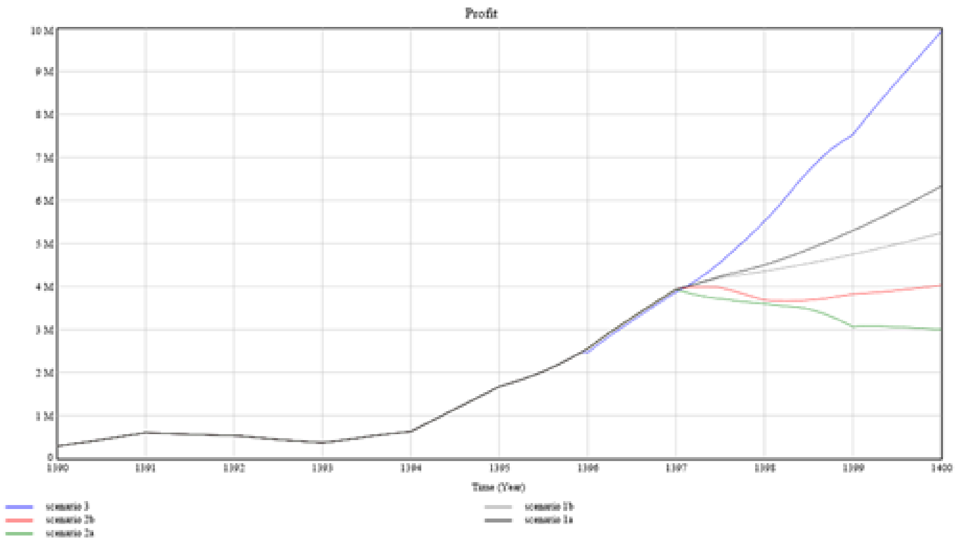


Fig.22. Profit behavior in scenarios

As can be seen in figure 22, if Scenario 1 is accomplished, execution of policy A will then leads to an initial productivity, but there is a significant decrease in the gradient of the profit growth. On the other hand, execution of policy B in Scenario 1 commences with an intense growth and maintains this gradient. A similar outcome will occur in case of accomplishment of scenario 2. Therefore, regardless of the environmental that scenario occurs in, the organization should choose to pursue policy B, since the productivity trend for both B1 and B2 is increasing with a significant ratio. This result is notable, since if the manager concentrates on the productivity, the productivity increase policy and production cost decrease should certainly be considered. Moreover, if the third scenario is executed, which is the continuous increase in inflation ratio, other external factors such as demand decrease are overwhelmed, leading to significant variation from other scenarios and consequently, the profit will experience an exponential growth. The reason for this outcome is some fixed costs such as work force salary and overhead costs.

C: Sales Revenue

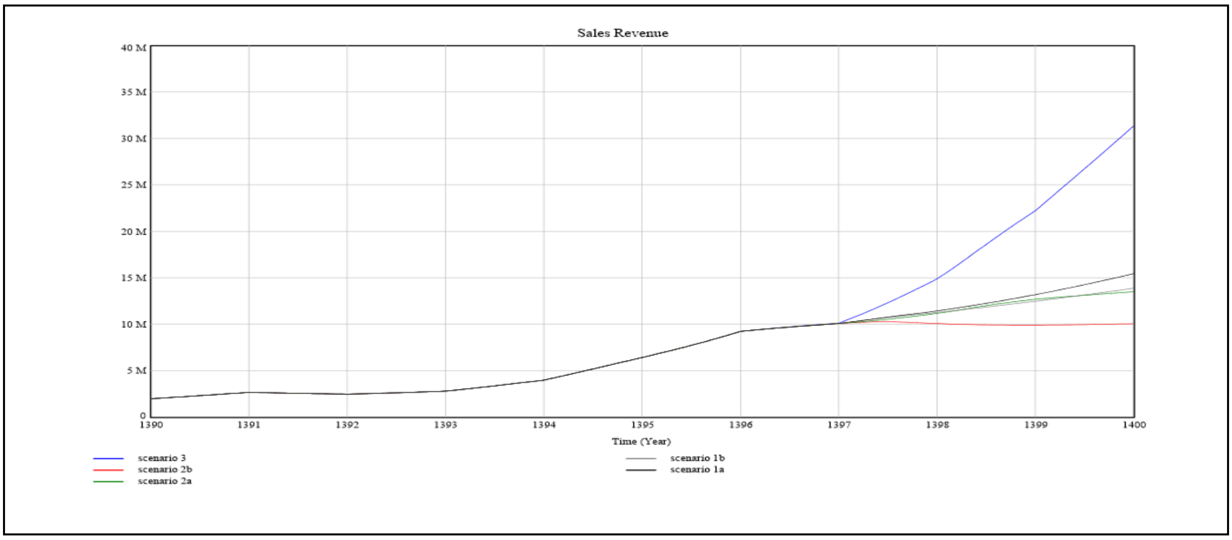


Fig.23. Sales revenue behavior in scenarios

In figure 23, no notable differences can be witnessed among the graphs. A more detailed analysis however, reveals the fact that in case of either first or second environmental scenarios, a higher revenue is obtained by executing Policy B. Therefore, the result will increase the productivity and therefore, production costs will decrease further. Once again, it can be shown that the third scenario will result in a substantial difference in sales revenue. Obviously, the increase in the inflation ratio is the major stimulator in this situation.

D: Sales level

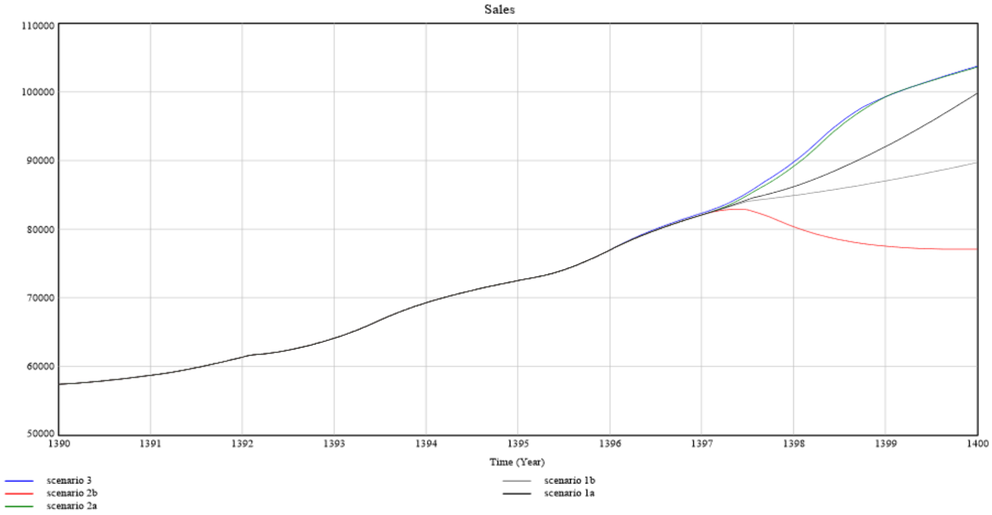


Fig.24. Sales level behavior in scenarios

As can be seen in figure 24, regardless of the economic growth scenario or the average long-term economic situation scenario, the sales level will have a constantly increasing trend through executing the productivity increase and production costs decrease policy. Moreover, in either scenario, the sales level commences with a very low gradient, and experience a decrease in its growth gradient which will lead to an approximately stable trend through the execution of the policy of maximizing the production level, increasing sales activities, and increasing the advertisement. In case of the third scenario however, the sales growth trend will be bounded by the decrease in demand. Thus, for all three environmental scenarios, the organization will obtain a very high level of sales, simply by choosing the policy to increase the productivity and decrease its production costs.

E: Total cost and cost of raw materials

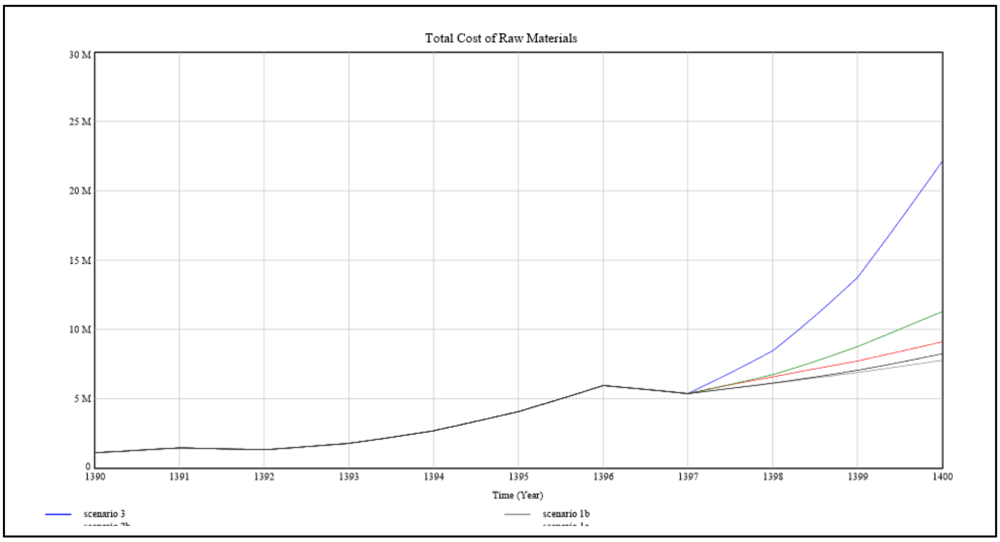


Fig.25. Total cost of raw materials behavior in scenarios

Figure 25 indicates that if the economic growth scenario and/or the continuity of the current situation scenario occurs, choosing Policy B will result in lower total costs compared to Policy A. Clearly, the cost contains both the total cost and the cost of raw materials. However, it can be interpreted that the total cost in the third scenario (i.e. inflation rate increase and economic growth decrease) will occur with an increasing trend, which is distinguishable from other situations.

F: Demand

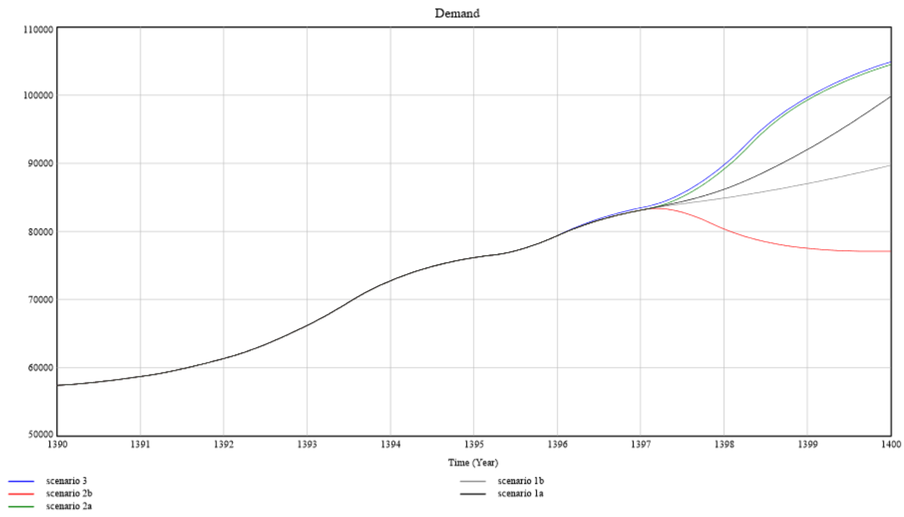


Fig.26. Demand behavior in scenarios

Analysis of the demand as demonstrated in figure 26 indicates that maximizing the production level and increasing the sales and advertisement (Policy A) in all three environmental scenarios will result in higher growth in demand. The reason for this outcome is that the Policy A concentrates on advertisement tools and progression of sales, which will ultimately result in an increase in demand. A notable point here is that the decrease in car production and economic growth (as is in the third scenario) will not result in a different demand trend. The reason for this outcome is twofold: 1) Barez Co. is a domestic market leader and hence, it is capable of maintaining its market share regardless. 2) In an economic crisis, the costumers are likely to keep their vehicles for longer periods, resulting in an increase in demand for tires. In spite of these two reasons, the demands growth slope is going to decrease gradually.

G: Production

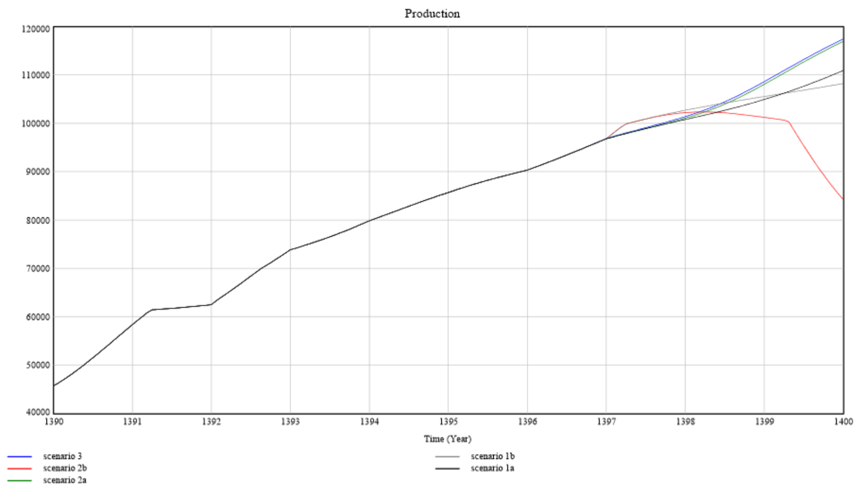


Fig.27. Production behavior in scenarios

Considering the three scenarios demonstrated in figure 27, even though the production trend is increasing, the increase in policy A is more than that of the policy B. In such case, an increase in productivity as well as a decrease in the cost and production (policy B) will result in lower production level. However, maximizing the production level is one of the main components in policy A, while the difference between the two policies is not significant in the first scenario. The second scenario on the other hand, reveals more drastic difference between the two policies. Finally, the third scenario is likely to support the increasing trend of production, due to the analysis mentioned for the trend in demand.

6- Conclusion

In this paper, an integrated dynamic BSC model was proposed to cope with uncertain and turbulent environments. Most studies published in this area are limited to the traditional BSC framework and do not address the role of external stimulus. Moreover, the results generally do not address real situations. In this paper, the dynamic sustainability BSC model was expanded with economic and environmental stimuli that pose crucial effects on the performance of an organization. The developed model was validated via a comparison between the simulation results and the data obtained from the history of the company. An optimization method was employed to optimize the variables in the dynamic model in order to make a more thorough simulation model and finally, three general scenarios were planned based on the real situation, along with the analysis of the two main policies in each scenario. As indicated in the results, policies and decisions made by strategic managers in turbulent environments lead to very different results in all important aspects of the organization. In other words, a common model cannot be adopted by the organizations for both stable and turbulent environments. In addition, in numerous situations, the impact of external factors on the performance of the organizations is more crucial compared to the internal policies and decisions made by the managers. However, the major limitation of this research is the insufficiency in the historical data, since the recorded data in the BSC model (at Barez Co.) was limited to less than 10 years. Moreover, some external variables occurred with the fuzzy TOPSIS method were ignored to simplify the proposed model. Furthermore, some internal and external variables were not measurable and therefore, were omitted from the proposed model.

In summary, the following suggestions are presented according to the conclusions:

- Using an optimization approach to perform simulations and presenting the optimal solutions to the decision makers
- System of Systems Methodologies (SOSM) could be utilized to further develop the interrelationship between different related subjects in our proposed model to solve decision making problems in real-world dynamic environment problems.

References

Ahmad, S., R. M., Tahar, F., Muhammad-Suhhi, A. B., Munir, and R. A., Rahim. (2016). "Application of system dynamics approach in electricity sector modelling: A review." *Renewable and Sustainable Energy Reviews* 56: 29-37.

Agrawal, S., R. K., Singhx, and Q. Murtaza. (2016). "Outsourcing decisions in reverse logistics: Sustainable balanced scorecard and graph theoretic approach." *Resources, Conservation and Recycling* 108: 41-53.

Barlas, Y. (1996) 'Formal aspects of model validity and validation in system dynamics', System Dynamics Review, Vol. 12, No. 3, pp.183–210.

Barnabè, F., and C. Busco. (2012). "The causal relationships between performance drivers and outcomes: Reinforcing balanced scorecards' implementation through system dynamics models." *Journal of Accounting and Organizational Change* 8 (4): 528-538.

Barnabè, F. (2011). "A "system dynamics-based Balanced Scorecard" to support strategic decision making: Insights from a case study." *International Journal of Productivity and Performance Management* 60 (5): 446-473.

Bianchi, C., and G. B. Montemaggiore. (2008). "Enhancing strategy design and planning in public utilities through 'dynamic' balanced scorecards: insights from a project in a city water company."

System Dynamics Review 24 (2): 175-213.

Chai, J., and E.W.T. Ngai. (2015). "Multi-perspective strategic supplier selection in uncertain environments." *International Journal of Production Economics* 166: 215-225.

De Salles, D.C., A. C. G., Neto, and L. G. Marujo. (2016). "Using fuzzy logic to implement decision policies in system dynamics models." *Expert Systems with Applications* 55:172-183.

Figge, F., T., Hahn, S., Schaltegger, and M. Wagner. (2002). "The sustainability balanced scorecard linking sustainability management to business strategy." *Business Strategy and the Environment* 11: 269-284.

Forrester, J. (1961). *Industrial dynamics*. Productivity press: Cambridge (MA).

Funtowicz, S. O., and J. R. Ravetz. (1990). *Uncertainty and quality in science for policy*. Dor-drecht, Netherlands: Kluwer Academic Publishers.

Ghosh, D., and L. Olsen. (2009). "Environmental uncertainty and managers' use of discretionary accruals." *Accounting, Organizations and Society* 34,188–205.

Hoque, Z. (2014). "20 years of studies on the balanced scorecard: Trends, accomplishments, gaps and opportunities for future research." *The British Accounting Review* 46 (1): 33-59.

Hsu, C. W., A. H., Hu, C.Y., Chiou, and T.C. Chen. 2011. "Using the FDM and ANP to construct a sustainability balanced scorecard for the semiconductor industry." *Expert Systems with Applications* 38 (10): 12891-12899. doi:10.1016/j.eswa.2011.04.082.

Junior, A. N., de Oliveira, M. C., &Helleno, A. L. (2018). Sustainability evaluation model for manufacturing systems based on the correlation between triple bottom line dimensions and balanced scorecard perspectives. Journal of Cleaner Production, 190, 84-93.

Kang, J.S., Chiang, C.F., Huangthanapan, K. and Downing, S., (2015). Corporate social responsibility and sustainability balanced scorecard: The case study of family-owned hotels. *International Journal of Hospitality Management*, *48*, pp.124-134.

Kaplan, R., and D. Norton. (1996). *The balanced scorecard*. Harvard Business Press.
Kaplan, R., and D. Norton. 2004. *Strategy Maps: Converting Intangible Assets into Tangible Outcomes*. Boston, MA: Harvard Business School Press.

Khakbaz, S. B., and N. Hajiheydari. (2015). "Proposing a basic methodology for developing balanced scorecard by system dynamics approach." *Kybernetes* 44 (6-7): 1049-1066. doi:10.1108/K-12-2014-0287.

Koul S., O. A., Falebita, J. F. K., Akinbami, and J. B. Akarakiri. (2016). "System dynamics, uncertainty and hydrocarbon resources modeling." A systematic review. *Renewable and Sustainable Energy Reviews* 59,199–205.

Lu, M. T., Hsu, C. C., Liou, J. J. H., & Lo, H. W. (2018). A hybrid MCDM and sustainability-balanced scorecard model to establish sustainable performance evaluation for international airports. Journal of Air Transport Management, 71, 9-19.

Nielsen, S., and E. H. Nielsen. (2008). "System dynamics modelling for a balanced scorecard: Computing the influence of skills, customers, and work in process on the return on capital employed." *Management Research News* 31 (3): 169-188. doi:10.1108/01409170810851276.

Nikolaou, I., K., Evangelinos, and W. L. Filho. (2015). "A system dynamic approach for exploring the effects of climate change risks on firms' economic performance." *Journal of Cleaner Production* 103: 499-506.

Nikolaou, I.E. and Tsalis, T.A., (2013). Development of a sustainable balanced scorecard framework. *Ecological Indicators*, *34*, pp.76-86.

Ozcan-Deniz, G., and Y. Zhu. (2016). "A system dynamics model for construction method selection with sustainability considerations." *Journal of Cleaner Production* 121: 33-44.

Poles R. (2013). "System Dynamics modelling of a production and inventory system for remanufacturing to evaluate system improvement strategies." *International Journal of Production Economics* 144: 189-199.

Rabbani, A., M. Zamani, A., Yazdani-Chamzini, and E. Kazimieras Zavadskas. (2015). "Proposing a new integrated model based on sustainability balanced scorecard (SBSC) and MCDM approaches by using linguistic variables for the performance evaluation of oil producing companies." *Expert Systems with Applications* 41 (16): 7316-7327.

Sterman, J., (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World*. Irwin McGraw-Hill, New York (NY).

Sekhar Pedamallu, C., L., Ozdamar, H., Akar, G. W., Weber, and A. Özsoy. (2012). "Investigating academic performance of migrant students: A system dynamics perspective with an application to Turkey." *International Journal of Production Economics* 139 (2): 422-430.

Supino, E., Barnabè, F., Giorgino, M.C. and Busco, C., (2019). Strategic scenario analysis combining dynamic balanced scorecards and statistics. *International Journal of Productivity and Performance Management*.

Tang, O., and J. Rehme. (2017). "An investigation of renewable certificates policy in Swedish electricity industry using an integrated system dynamics model." *International Journal of Production Economics*. Advance online publication. doi:10.1016/j.ijpe.2017.03.012.

Vanegas, C.A.L., Cordeiro, G.A., de Paula, C.P., Ordoñez, R.E.C. and Anholon, R., (2018). Analysis of the utilization of tools and sustainability approaches in the product development process in Brazilian industry. *Sustainable Production and Consumption*, *16*, pp. 249-262.

Vecchiato, R. (2012). "Environmental uncertainty, foresight and strategic decision making: An integrated study." *Technological Forecasting and Social Change* 79: 436–447.

Walker, W. E., P., Harremoes, J., Rotmans, J. P., Van Der Sluijs, M. B. A., Van Asselt, P., Janssen, and M. P. Krayer Von Krauss. (2003). "Defining uncertainty-a conceptual basis for uncertainty management in model-based decision support." Integrated Assessment 4 (1): 5-17. doi:10.1076/iaij.4.1.5.16466.

Wieteska, G. (2015). "Environmental uncertainty accompanying purchases in the B2B Market." 20th International Scientific Conference Economics and Management-2015 (ICEM-2015). Procedia-Social and Behavioral Sciences 213: 911-917.

Zhang, T., and L. Gao. (2008). "Study on the Application of Dynamic Balanced Scorecard in the Service Industry." 2008 *International Conference on Intelligent Computation Technology and Automation***.**

Zhang, T. (2012). "An Overview of Dynamic Balanced Scorecard." In: Deng W. (eds) Future Control and Automation. *Lecture Notes in Electrical Engineering* 173. Springer, Berlin, Heidelberg.

Zhao H., and N. Li. (2015). "Evaluating the performance of thermal power enterprises using sustainability balanced scorecard, fuzzy Delphic and hybrid multi-criteria decision making approaches for sustainability." *Journal of Cleaner Production* 108: 569-582.