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A Study on Productivity Model of Supply Chain in Industrial Units by System Dynamic Approach

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Abstract. In this decade, due to the current competitive environment, reputation of industrial brands is markedly dependent upon the performance of their supply chain. Therefore, it is necessary to examine the factors affecting their supply chain so as to increase the competitiveness of their chain. Productivity is among the most important factors in the advancement of industry and its evaluation requires the identification of its important criteria. Thus, using interviews with experts and industry executives and applying basic concepts of system dynamics, it was endeavored in this research to identify the effective factors in the productivity of supply chain including 27 variables and then suggest a model to evaluate the productivity of supply chain in industrial units. Once the model was implemented and analyzed by the simulation software Vensim, the responses were graded and the desired results were presented from among them.

Keywords: Productivity, supply chain, system dynamics analysis, industrial units, vensim.

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1. Introduction

Industry sector has a special importance in Iranian economy. This sector has been one of the most competent sectors in country's economy. According to Statistical Center of Iran, it has supplied over 40 percent of GDP, 30 percent of employment, and 35 percent of non-oil exports. It is a complicated task to design a model appropriate for the equipment and facilities of industrial units with regard to their environmental conditions and information within a supply chain in order to achieve maximum productivity. Indeed, if the factors effective in the increase of productivity within a supply chain can be predicted using a model and industrial units can then be developed utilizing these effective factors, it would be possible to prevent a huge part of the private capital from being wasted; the capital that can lead to economic growth of the country. Moreover, such a model can be a good guide for many authorities and professionals of country's industry thinking about the increase of their productivity within the supply chain. Thus, organizations have recognized that in order to gain customer satisfaction and staying in the competition, they only can survive by resorting to supply chain and the close cooperation between suppliers, producers and customers, which finally leads to an increase in productivity; because today the competition is not between companies and organizations, but in the supply chain [6].

Since the strength of any research is first dependent on the deep and appropriate study of the background and theoretical principles of the research area, it is necessary at first to define the concepts related to productivity, supply chain, and to examine system dynamics.

The first known use of productivity in economic culture dates back to two centuries ago. In industrial countries, it is regarded as a culture and way of thinking, and an approach to progress and improve what there is. Productivity is a concept used to show the ratio of the output to input of an individual, unit, or organization [13]. Some believe that the history of management studies began with Woodrow Wilson. He raised the science of management in 1887. The term "productivity" was first used by Franois Quesnay, the economist and mathematician of physiocracy (Government of Nature) school. Having proposed the Economic Table,

Quesnay believed that the power of any government is subject to the increase of productivity in agriculture [10].

In 1883, another French called Littre defined productivity as the knowledge of production technique. With the beginning of scientific management movement in the early 1900s, Frederick Winslow Taylor and Frank and Lillian Gilbreth conducted studies on the division of labor, improvement of methods, and specifying standard time in order to increase the efficiency of workers. Paying attention to productivity and its importance in production has been considered as a serious matter in Iran and this has led to the opening of a new chapter in total quality management [7]. If the productivity of a company is higher than that of their rivals, that company's profit margin would grow. Productivity has been defined and interpreted in various ways. Efficiency is a concept that evaluates the costs of resources spent in the process of achieving the goal; in a way that comparing the resulting outputs and the spent inputs determines the efficiency. In order to measure the efficiency, the costs of supplying human resources, the costs of using the equipment, maintaining the facilities, the ROI rate and the like are considered [10].

In this interpretation of efficiency, the most efficient supervisor is the one whose unit can work with the lowest costs of material and daily wage. Efficiency is related to the appropriate performance of tasks in the organization; that is, the decisions taken to reduce the costs, increase the production, and improve the product quality [10]. In fact, both effectiveness and efficiency are required to be productive. Efficiency is the ratio of real product (or services provided) to the expected product, while effectiveness is the extent to which goals are achieved in the organization. Productivity considers the sum of efficiency and effectiveness [1]. It is should be noted that managers always try to increase the organizational efficiency and effectiveness by making use of their scientific experiences. Improvement and renovation of organization is a process by which the knowledge and functions of behavioral sciences are utilized to increase the effectiveness.

In many parts of the world, especially in industrial countries in the 1980s, companies looked for techniques and strategies through which they could reduce their production costs and compete in different mar-

kets. Some of these techniques included Just-in-Time System (JIT), Kanban system, lean production, total quality management system (TQM) and so on. Companies managed to reduce their costs to the extent possible using these techniques; however, the rival companies have reduced their production costs to the extent possible using the same techniques. Thus, other potential opportunities should be found to reduce the costs and stay in the competitive market. Supply chain is one of the fields in which there are lots of potential opportunities to reduce the costs [11].

A supply chain includes all stages (members of supply chain) that are directly or indirectly effective in meeting customer's demands. Supply chain includes not only manufacturers and factories, but also dealers, retailers and their customers. In any organization like a factory, the supply chain includes all other factors effective in meeting customer's needs [2]. In a typical supply chain, raw materials are sent from suppliers to factories. Then the products manufactured in factories are sent to intermediate and distribution storehouses. Eventually, they are sent to retailers from there and reach the final customer or the consumer. Therefore, a product goes through different stages of a chain to reach the consumer. In some of these stages, the product is stored and in some others, it is transported; that is, supply chain is a set of storages and transportations. The members of a typical supply chain include suppliers, raw materials storehouses, production centers, distributors, retailers, and final customers [11]. Supply chain consists of three parts: suppliers, producers, and distributors. Figure 1 depicts a typical supply chain [5].

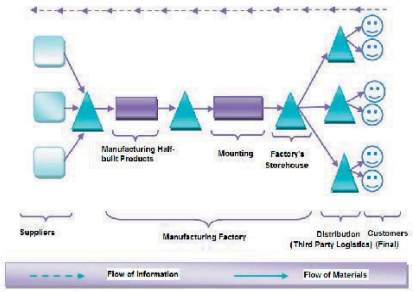

Fig 1. Structure of a supply chain [5].

System dynamics is a computer-assisted approach to analyze complex issues by relying on policy analysis and design. This was first called industrial dynamic [3]. The principles and mechanisms of system dynamics were first raised and studied in the 1940s and 1950s. System dynamics is a way of understanding certain types of complex system issues. This discipline is in fact originated from industry and its related issues. It was first concerned with some management issues such as instability in production and employment, low growth or incompatibility of organizational activities and decrease in market share. Once known as industry dynamics, system dynamics found widespread application in solving various issues at the beginning of its emergence. This phenomenon developed and spread through different fields-from research and development project management to urban planning, destruction and growth of human population, understanding the effects of exponential growth and its states in the finite world, the reduction of natural resources and even the testing of medical theories including diabetes [9].

As industry dynamics was renamed to system dynamics, this phenomenon turned to a way of understanding and recognizing certain types of complex issues in a system and solving, planning, monitoring and coordinating its components. The issues existing in this system have the two characteristics of dynamism and feedback structure. According to this dynamism, system's quantitative and qualitative dimensions change over time and according to the feedback structure, during its transformation process, the system gives certain information in each stage to its previous and next stages. In other words, this science is used to understand, comprehend, and analyze the behavior and movements of system components. This science is so capable that it can be used to model different simple and complex issues and examine the changes originated from the interaction between variables and the identification of their future behaviors in different periods of time [4].

2. System Dynamics in the Optimization Process of Productivity in Supply Chain

System dynamics method is a materialistic simulation method based on feedback relations which not only involves the users of each model in its development, but also creates a considerable simplicity and speed in the definition of system and model development. The possibility of group development of models and the capability and simplicity of model modification in reaction to system changes is among capabilities of this method [8]. The application of system dynamics modeling in supply chain management has its roots in industrial dynamic. The model of a production and distribution model, "Forrester Model", is put forward as six systems of interactive flow including flows of information, raw materials, demands, money, human resources, and capital equipment. It is based on the development of using system dynamics simulation model explained by Forrester, analyses and explanations about supply chain management [3].

After Forrester who basically saw supply chain as a part of an industrial system, researchers covered a range of issues from inventory management to integration of global supply chain in terms of policy design. Although using industrial dynamic modeling of supply chains has emerged again after a long period of stagnation [12], some techniques were gradually developed to integrate the supply chain and its management because of the relationship between these matters. In order to increase productivity in the supply chain, we need to fully understand the definition and evolution of supply chain. Productivity is examined as one of the most effective factors for the growth of industrial units. System dynamics is a powerful method of gaining useful insights in dynamic complex situations, which is increasingly used to design more successful policies in companies and public policy-making [9]. In the optimization process of productivity in the supply chain of industrial units, it is important to have a systematic view on the qualitative and quantitative examination of all factors. In this research, factors were examined quantitatively in order to increase and decrease the overall productivity.

Attempting to reveal the realities of the world and modeling them

is not a new thing. In fact, the history of new science begins when it was made possible to find mathematical models to express, among others, natural, social, industrial, and agricultural phenomena. Thus, experts provide mathematical patterns to explain natural phenomena and representations of social life [4]. Therefore, it was endeavored in the present study to present the model and causal loops at first, and then its flow diagrams with regard to some variables and effective factors in productivity within the supply chain of industrial units. In order to do so, the model variables are first introduced.

3. Introduction to Variables

From a systematic point of view, it is crucially important to have valid and appropriate inputs and variables in order to have a good output. The variables used in this model were collected through observations and primary interviews between the researcher and the personnel, factory managers and elites in the area under study. It should be noted that the data, information and variables provided here are related to the studied industrial units between 2011 and 2013. The variables used here are shown in Table 1.

The analytical method used in this research is simulation and modeling method. There are various applications and software for simulation; however, Vensim was used in this research. The causal-loop diagram of supply chain productivity model for industrial units is presented in Figure 4. The parameters provided in the supply chain model are put separately in the three categories of suppliers, producers and distributors for a better understanding.

The reliability and validity of data collection instruments are crucially important in scientific studies. Before starting field and executive work, it is necessary to test the data and the designed model on a small group of factory managers and knowledgeable professionals to find its probable internal inconsistency and ambiguities. In this way, one can be assured that questions do not lead to the confusion and ambiguity of respondents and participants. The tool used in this research

Table 1. Variables in Model Development (writers)

Types of Variables	Name of Variable
Surface variables	Ordered raw materials
	Raw materials inventory
	Storehouse inventory
	Income
	Profit
	Overall cost
	Overall productivity
Independent variables	Logical ordering
	Sales, administrative and public costs
	Salary and wage costs
	Energy costs
	Maintenance and overhaul costs
	Expert forces
	Machinery
	Input per machinery
	Transportation costs
	Outsourcing costs
Dependent variables	Raw materials costs
	Constant costs
	Production capacity
	Customer's logical demands
	Distribution productivity
	Production productivity
	Suppliers' productivity
Rates	Ordering
	Raw materials
	Production
	Sale rate
	Variable costs
	Investment

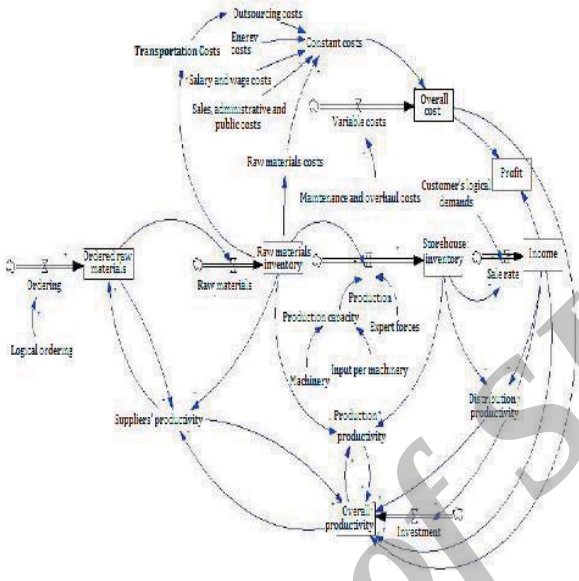

Fig 2. Productivity model flow diagram

to test the reliability of measuring instrument was sensitivity analysis. This method shows that if different values are given to an analytical model, the results of the primary values obtained after testing the model are logical. Goodness process was carried out for the supply chain productivity model and the expected results were obtained.

4. Model Analysis

The model presented in this research was designed for the supply chain of industrial units and it was endeavored to include the effective factors in the productivity of supply chain in the model as much as possible. As it can be seen in the model, there are seven surface variables on which six flows are stored and 10 constant variables affecting seven variables and cause any changes made to any of the parameters to show different results. The input was analyzed for each of the variables, in a way that after any changes made to any of the parameters, the related diagrams and tables were extracted. Figures 3 and 4 show the diagram resulted from the change that a 20% increase in the raw materials inventory made

on the income and overall productivity. As it is seen in the diagrams, the increase in the raw materials inventory leads to an increasing trend in income and overall productivity.

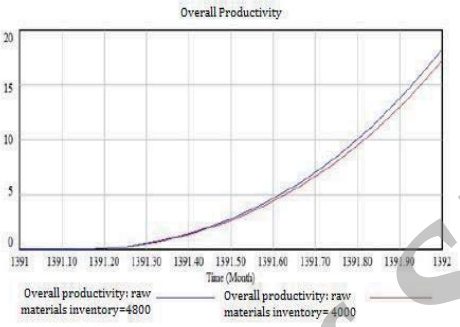

Fig 3. Income diagram resulted from a 20% increase in raw materials inventory

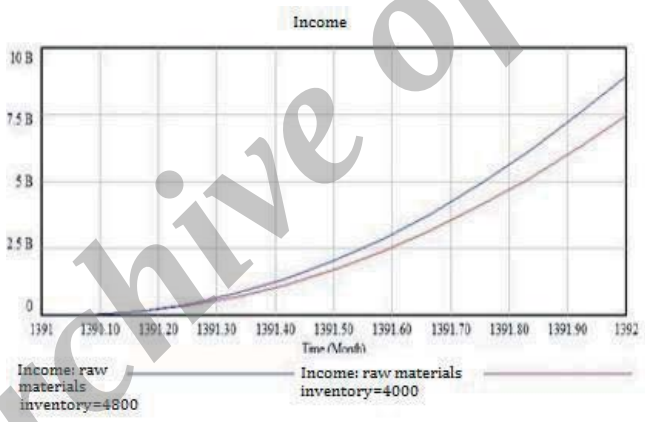

Fig 4. Overall productivity diagram resulted from a 20% increase in raw materials inventory

5. Discussion on the Model

Using system dynamics model makes it possible to see the effect of all factors simultaneously and obtain the result in the shortest time; in a way that when we want to see the effect of a factor on the increase of productivity level, we can find all the effects it has on each of the factors

by inserting the desired value and testing the model. Using system dynamics simulation approach, we can simulate the amount of overall effect of each factor on the level of productivity by considering the direct and indirect effects of that factor in a virtual and dynamic environment and predict its effect on time, expense, and quality of the project. Finally, the identification of factors that reduce productivity and using appropriate guidelines can lead to an increase in productivity and contribute to the improvement of project and reach temporal and economic goals. It is defined in the design and completion process of our model that how different parameters are related to each other. The ranking of the seven parameters for the evaluation of surface variables in the supply chain of industrial units indicates that the field of raw materials supply is of the highest rank of importance from the viewpoint of decision-makers and managers in these companies. In the present competitive environment, managers consider the price dimension to have a higher rank than the quality dimension, which shows that the general attitude of this supply chain is only based on the reduction of prices and increase of profit in short-term.

6. Conclusion

Testing the model indicated that all parameters raised in this research have considerable effects on the overall productivity of the supply chain in industrial units. Considering the results obtained from utilizing system dynamics model, it was revealed that all three categories of supply productivity, production productivity, and distribution productivity have direct and mutually beneficial effect on the overall productivity; in a way that an increase in any of them leads to an increase in the overall productivity and a decrease in any of them leads to a decrease in the overall productivity. This study was designed to find a method for evaluating productivity in the supply chain of industrial units. Considering the model designed for this study, a set of factors and components effective in industry was studied over time.

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