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Designing the green new product development model: system dynamics approach (Case study: small and medium food industries in Iran)

Abstract

Nowadays, paying attention to environmental issues is one of the main concerns in the field of new products. Along with changes in the environment and a rise of awareness concerning environmental protection, the industry has begun to do research and develop products reflecting environmental preservation needs. In many countries including Iran, because of the need to respond customer requirements quickly and increased complexity of product design; selecting the right set of new product development (NPD) is critical to long-term success of the firm. Thus in this research, first we tried to study the effective factors on green new product development (GNPD) in SMEs. Then, we went through predicting the future situation and identifying the effective factors on GNPD .In this regard, it was found that green projects level and efficiency of rework increased by the reduction in the time needed for each project. Also regarding the current model, we could conclude that with a decrease in the normal returned goods, revenue and efficiency of rework increased. The changes in the scheduled completion time of the model derived us to the conclusion that a decrease in the end time of planning increased the firm revenue and the level of green projects.

Keywords:
New product development, green product, system dynamics

Introduction

In today‘s competitive market conditions, organizations are increasingly confronting with product improvement challenges in introducing a new product to the market earlier than their competitors (Kowang, et al, 2014). As González et al. (2014) indicated, product development could be defined as a transformation activity based on customer needs, organizational strategies, and an internal and external environment.

In last decade, a considerable attention has been paid to innovative activities and processes of an organization both managers and scholars (Kanyamon Wittayapoom, 2014). Along with changes in the environment and a rise of consciousness concerning environmental protection, the industry has done researches on developing products which reflect the needs for environmental preservation as well as allowing them to maintain their market share and competitive advantage (Chang-Chun Tsai, 2012). Additionally, the new concept of ―Green New Product Development‖ is emerged due to the governmental regulations, environmental standards, and increasing demand for green products. In the 21st century, industrial development has been replaced by sustainable development (Azar, Andalib Ardakani, 2014).

Green new product development (GNPD) is one of the most important determinants of sustained company performance, therefore; it creates a key challenge for firms (Huang, Jim Wu, 2010). Nowadays, an increased debate and interest in green product development are clearly observed (Lin, et al, 2013) and green new product development has become a key strategic consideration for many companies (Wang, et al, 2015).

Over the last decades, firms have added ecological considerations in their product development strategies, which led to an increase in the number of green product developments, as well as an increased attention to the development and launch of the green product. The innovations may be the result of a growing awareness of the fact that green products represent a ―significant market potential‖ (Driessen, et al, 2013). An increase in the environmental trend has led the green new product development to become a critical factor for companies in obtaining sustainable development and it contributes to the transformation towards a sustainable society (CarrilloHermosilla et al., 2010).

Green new product development includes many underlying qualities. The environmental impact of the products occurs in terms of three dimensions: materials, energy, and pollution. In each of the three dimensions, the environmental impact may be decreased or a positive contribution may be realized (Dangelico, Pontrandolfo, 2010).

The purpose of GNPD implementation into business activities is to improve environmental and economic performance (Jabbour, et al, 2015). Numerous studies have been carried out to examine and identify the factors promoting adoption of GNPD. Ilker Murat Ar (2012) investigated the impact of green new product development on firm performance and its competitive capability. He concluded that GNPD significantly positively affected both firm performance and competitive capability. Huang, Jim Wu (2010) sought to identify the factors influencing the performance of green new product development. Their results showed that corporate environmental commitment, environmental benchmarking, and cross-functional integration had positive effects on green product development performance.

Lin, Tan, Geng (2013) concluded that market demand was positively correlated to both green product development and firm performance; while, green product development performance was also positively correlated to firm performance.

On the other hand, small and medium enterprises (SMEs) were considered as an engine for economic growth all over the world. In recent years the Islamic Republic of Iran has encouraged the expansion of agro industry in order to supplement the oil industry as a source of export products. This policy is based on the availability of a wide range of high-quality food crops in the country. According to the Ministry of Industry, in 1995-98 the manufacturing value-added generated by the food industry amounted to US$2,335 million, 13.2 percent of the total manufacturing value-added generated in that year. Thus, the food industry is the second most important source of value-added after the petroleum refining industry. The food processing industry's dependence on imported inputs is 10.7 percent compared with 45.6 percent for the metal industry. In many countries including Iran, due to the need to respond customer requirements quickly, increased complexity of product design and rapid changes in technologies, it is critical to select the right set of NPD in the food industries for obtaining long- term success In this research, first we tried to study the effective factors and variables of green new product development in food industry. Then, while simulating the current situation- greenness of new product development in food industry – we went through predicting the future situation and identifying the effective factors on GNPD by using the system dynamics (SD) technique. Revenue was of high importance for organizations. Many people believed that green new defined projects and attention to the environment would increase the revenue of the organization. Therefore, studying the following assumptions in this study, we aim to answer this question that how the effect of the greening process of green new product development projects on revenue and efficiency of rework was defined.

1- When the time required for each project reduces the production of green projects and efficiency of rework will increase.

2- The revenue and efficiency of rework will increase with an increase in assigned facilities and staffs for each project.
3- When the scheduled completion time for defined green project gets more compressed, it will result in an increase of the organization revenue and the green projects level quality.

Literature review

New product development

New product development (NPD) is crucial in various industries to shorten a product way to market and improve the product quality. The literature has provided a number of definitions for what constitute a new product development. Product development definition is used by different researchers in slightly different ways (Ale Ebrahim et al., 2010).

Generally, new product development can be defined as a collection of activities that taking into consideration the company's competitive strategy seek to achieve the specification of a completely new product or the improvement of an existing one based on market needs, market opportunities and technical and technological possibilities and restrictions, (Crawford & Di Benedetto, 2008).

Over the years, new product development has been refined considering consumers (Hoffman et al. 2010; Fuchs et al., 2010), the development process (Cooper, 2009; Fu¨ ller, 2010; Sandmeier et al., 2010), the nature of the product (Decker and Scholz, 2010), the channel (Lan et al., 2007), the nature of the marketing venue (Fu¨ ller et al., 2009; Arakji and Lang, 2007), and the source of the product concept (Wyld, 2010). Despite the evidence for attempts in continuous improvement, the need for change still exists. Rodríguez et al. attempted to summarize the application of system dynamics to the planning and management of R&D projects, enabling the assessment - before their effective application- of the impact that certain organizational practices are going to have on the evolution of the work and its final outcome. Kortelainen et al. (2008) in their paper present a theoretical contribution to the field of innovation management through forming a system of the process of innovation in an industrial firm, and demonstrates how the process is linked to the capabilities and learning as well as how the learning affects the competitive advantage of the firm through new product development. Learning through action in NPD has important implications to competitiveness especially after immediate future.

There are many factors which influence the success or failure of product development, as well as a broad range of relative domestic and international research on the subject. Overall, the literature related to the key success factors can be roughly divided into several areas.

Through factor analysis, Cooper and Kleinschmidt (1991) proposed 48 factors for 177 firms. In this process, 13 fundamental factorial dimensions were derived, namely, the manufacturer‘s experience, resource compatibility and suitability, product superiority and consistency, and market competitiveness etc. Considering procedures in new product development, Dwyer (1990) contended that 13 main activities such as proposed product strategy, employee centripetal force, and technology which included within 7 factors covering 21 key factors were involved in product development. Barczak (1995) measured the importance of new product development for 365 telecommunication firms by analyzing their new product development strategy, company structure, and procedures. Bovea and Pérez-Belis concentrated on an integration of environmental concerns and standard production concerns such as cost, safety, and functionality in the design phase (Bovea and Pérez-Belis, 2012).Comoglio and Botta (2012) focused on evaluating companies in Italy automotive industry holding ISO 14001 certificate for at least 3 years to assess their sustainable development in comparison with ISO 14031 standards.

In their examination of new products, Cooper and Kleinschmidit (1990) emphasized on four factors, including overall success (gauged by profitability); domestic and foreign market shares; opening new windows of opportunity (both product and market windows); and meeting sales and profit objectives. Yap and Souder (1994) related seven critical assessment criteria, of which they advanced the technical level of the new product, sources of technology, new product characteristics and marketing strategies. Barczak (1995) correlated new product development success with 3 criteria covering product strategy and product organization. Lester equated successful new product development with support of senior managers, the product concept and project management (Lester, 1998). Dangelico and Pujari (2010) presented life cycle evaluation as a prominent factor in new product development. Hong and Hartley (2011) spoke of the prominent importance of modular design. Primavera demonstrated the great importance of sources of project funding in successful new product development.

Green new production success

Product development is vitally important to firms competing in new and existing markets (Calantone et al., 1995). Moreover, the ability to commercialize products successfully is crucial for firms wishing to compete in the marketplace (Griffin and Page, 1996). Paladino (2007) defined ―new product success as the ability of a new product or innovation to avoid failure in the marketplace‖. To modify the definition of Paladino (2007), this research defined green new product success as the ability of a green new product or innovation to compete in the marketplace. There is considerable variance in terms of what constitutes new product success. Some studies considered new product

outcomes such as competitive advantage, quality, or uniqueness (Li and Calantone, 1998; Song and Montoya-Weiss, 2001); whereas, some examined market-based outcomes including market share or profit (Atuahene-Gima, 1996; Gatignon and Xuereb, 1997). Additionally, several studies have investigated the productivity-related outcomes such as cycle time or production superiority; while, others have explored product-related outcomes such as production innovation performance (Atuahene-Gima, 2005; De Luca and Atuahene-Gima, 2007). New production studies typically captured success either as an objective assessment (return on investment, sales, market share, profits) or as a subjective assessment (managerial perceptions of how well a new product performed according to expectations) (Troy et al., 2008).As new product strategy researchers (Im and Workman, 2004; MontoyaWeiss and Calantone, 1994; Paladino, 2007) have recommended to adopt multiple measures of green new product success to assess the different perspectives of green new product performance including green production innovation performance (Chen et al., 2006) and financial performance (Clemens, 2006; Judge and Douglas, 1998). This study referred to the definition by Chen et al. (2006) and defined green product innovation performance as performance in product innovation that is related to green innovation including product innovations related to energy conservation, pollution prevention, waste recycling, toxicity elimination, or green product designs. Financial performance is the degree to which firms are more profitable rather than their competitors (Clemens, 2006; Judge and Douglas, 1998).

Related GNPD research

Greening or GNPD is not a well -defined concept (Chen, 2001). Chen (2001) described typical green attributes listed on various green consumer guides including recyclability, recycled content proportion, fuel efficiency, toxic content reduction, emission-related performance, efficient packaging and etc. Hart (1995) proposed product stewardship from a natural-resource-based view of the firm. Product management has adopted life-cycle method for analyzing product-development process, taking an environmentally proactive posture toward raw material and component suppliers in order to minimize the environmental impact of the entire supplier system. Pujari et al. (2003) defined GNPD as product development within which environmental issues are explicitly integrated in order to create the least environmentally harmful product that a firm has recently produced. Berchicci and Bodewes (2005) argued that GNPD is a general term, which encompasses a range of issues, from the redesigning the existing products to creation of new products and services driven by environmental concerns.

There are very few studies focused on the GNPD and GNPS. Some studies utilized success stories to demonstrate that aligning environmental issues with NPD can improve market performance

(Baumann et al., 2002). Other research has offered guidelines, manuals, tools, and advice to engineers and managers to assist them in integrating environmental concerns with the NPD process (Mackenzie, 1997). Additionally, numerous papers were carried out to examine and identify the factors promoting the adoption of GNPD (Johansson, 2002) such as the integration of environmental professionals (Ehrenfeld and Lenox, 1997) and top management support (Ehrenfeld and Lenox, 1997; Pujari et al., 2003). As the growing concern of ecological issues had begun to form, society and the government have started to be aware about these issues and begin to make changes to contain the negative impacts of these problems. Green marketing and product development have been deemed the best ways forward for a business to be able to conform to new rulings from the government, and also to be able to comply with the behavior of consumers from field studies in to the wants and needs. The firms believed that the ideas of green marketing such as implementing a green supply chain, green products design, packaging, pricing and promotion are beneficial to society and the environment; and therefore it has taken priority over conventional marketing initiatives. Furthermore, the firms should present notable efforts to its customers in a manner that shows the firm is actively trying to decrease its environment risk. In conclusion, implementing green marketing and green product development strategy are not convoluted, but rather a relative concept that consistently differs over the time (Yan and Yazdanifard, 2014).

Furthermore, empirical studies have investigated that in what ways firms have tried to get engaged in GNPD (Gutowski et al., 2005; Lenox et al., 2000). Although these studies have increased our understanding of GNPD and contributed the development of a systematic approach to dealing with environmental issues in product development, there has been a dearth of research drawing on existing theoretical frameworks in NPD and organizational innovation literature (Baumann et al., 2002; Pujari et al., 2003). The logic behind GNPD is not significantly different from conventional NPD, but rather involved in adding a further level of complexity into NPD process. Therefore, this research integrating the literatures of innovation, NPD, and environmental strategies has built up the theoretical framework.

The most important factors in green new product development

Being an entirely new industry, the designations of green product or environmentally conscious product ‘covered a wide variety of different products with distinct characteristics. For this reason, no consensus has yet been formed on its definition.

To achieve purposes of the study, green products are classified into the following seven categories based on the discussion of Grave (1992), Peattie (1992), Makower et al. (1993) and Chen (2001):

1. It must be Environmental Protection Certified by the government.
2. It must use fewer raw materials or be readily recyclable.

3. It must be harmless to animal and plant life or produce less pollution.

4. It must be capable of being repeatedly used, replenished or sustainable.

5. Its performance must consume less energy.

6. It must reduce pollution.

7. Its manufacturing process must produce less pollution.

Regarding the GNPD literature (Berchicci and Bodewes, 2005; Johansson, 2002; Pujari and Pujari et al., 2003), it was found that the primary factor influencing the performance of GNPD was corporate environmental actions such as top management support, environmental policy, and environmental benchmarking. The literature on green NPD has shown that processing information about non-market stakeholders, such as regulators and special interest groups, was a critical antecedent of green product innovation (Hermosilla, Río, and Könnölä, 2010; Driessen and Hillebrand,2013). Green company policy, which is the second main antecedent of green product development, referred to the level of commitment of a firm that was demonstrated through its values, norms and management practices to initiatives that limit the environmental impact of the firm. Green company policy had a major influence on green product development (Dangelico and Pujari, 2010; Berchicci and Bodewes, 2005).

Another important product characteristic of green NPD is the newness of the innovation (Seebode, et al., 2012), which was found to be associated with both market orientation and performance. Most firms acknowledged integrating environmental laws and regulations such as Registration, Evaluation and Limitation of chemical substances into the process of green new product development. Hence, it could reduce the hazardous environmental risk; while satisfying the consumers‘expectations of green consumption (Tsai, Chuang, Chao, & Chang, 2012).

The firms can practice the green new product development to standardize the product modification and manage the raw materials according to environmental concerns and consequently decrease the negative impacts on human health and environment (Tsai, Chuang, Chao, & Chang, 2012). The effective factors in green new product development are given in the following. (See Table 1)

Table 1. The effective factors on GNPD

Number	***Scholar***	***Variable***
1	Huang, Y. C., & Jim Wu, Y. C. (2010)	Corporate environmental commitments
2	Paladino, A. (2007).	Financial indicators
3	Tsai, C. C. (2012)	Projects in progress
4	Paladino, A. (2007).	Sources of project funding

5	Huang, Y. C., & Jim Wu, Y. C. (2010)	Strategic attitude of the company
6	Ar, I. M. (2012).	Market share
7	Tsai, C. C. (2012)	Completed projects
8	Renwick, et al., (2013)	Reward systems for environmental performance
9	Daily and Huang (2001)	Human resource management activities
10	Cooper, R. G. (1995)	Profitability
11	Tsai, C. C. (2012)	Project team ability
12	Tsai, C. C. (2012)	Recovery/ recycling rate of the new green products
13	Wang, X., Chan, H. K., & Li, D. (2015)	Green product design
14	Pujari, et al.,(2003)؛ Tsai, C. C. (2012)	Top management support
15	Daily and Huang (2001)	Employee satisfaction
16	Wei and Morgan (2004)	Consumer image
17	Huang, Y. C., & Jim Wu, Y. C. (2010)	Green technology
18	Rodrigues, et al. (2006)	Schedule completion time
19	Tsai, C. C. (2012)	Remanufactured goods
20	Huang, Y. C., & Jim Wu, Y. C. (2010) ؛ Tsai, C. C. (2012)	R&D strength
21	Huang, Y. C., & Jim Wu, Y. C. (2010)	Superiority of the new green products
22	Jabbour, C. J. C (2015)	Assigned staffs
23	Tsai, C. C. (2012)	Environmental laws
24	Sammer, K., & Wüstenhagen, R. (2006)	The rate of environmental standards
25	Rodrigues, et al. (2006)	Efficiency of rework
26	Tsai, C. C. (2012)	New projects of green product development

Research methodology

This research aims to simulate and analyze the current and future situation of green new product development in the food industry. The major steps in this paper are shown in the following flowchart. (See Figure 1)

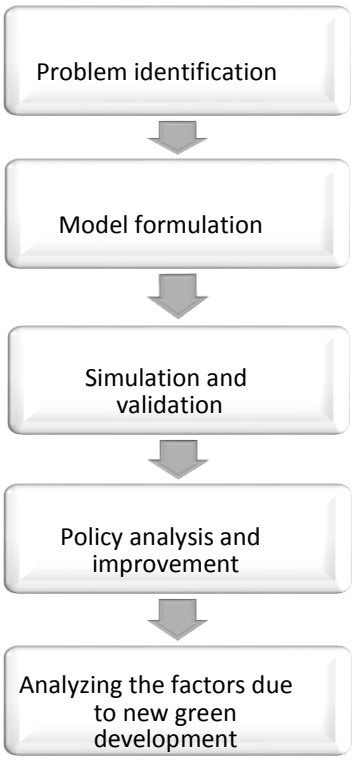

Fig1. Major step

To use this method, at first it was necessary to focus on an accurate and comprehensive definition of the current problems. Then the causal loop model for effective factors on GNPD was designed based on the experts 'idea and review of the literature. Afterwards, once the flow model for GNPD was designed, we started to calculate and define the each variable of the equations. Finally, we could study the effects of factors on GNPD and create the scenarios with the simulation and running the designed model for GNPD.

Modeling GNPD

In this study, system dynamics approach was used to identify the effect of main factors on the green new product development. It was necessary to develop a model for a dynamic system that was practical, to get the causal and specific flow diagram. Views of experts were used in this study. Once the factors affecting the development of green new product were identified and confirmed, the next step was to develop causal diagram using system dynamics approach. The SD methodology

was adopted for structural and policy analysis of the developmental projects. The modeling and simulations were done using Vensim. (See Figure 2)

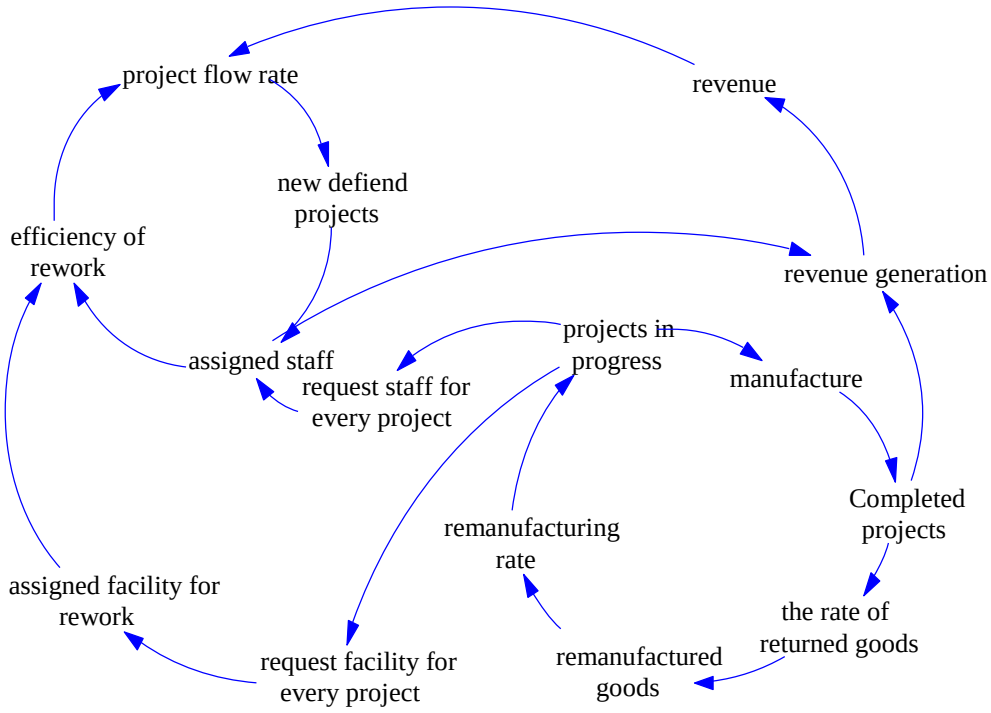

Figure2. Causal loop diagram of the dynamics of NPD

In this research, it was tried to use the most effective factors on GNPD. The important factors included the newly defined projects, projects in progress, project flow rate and revenue, the efficiency of rework, staff and facilities assigned for each project, and etc.

After charting the causal diagram, the flow diagram was prepared as it is shown in Figure 3. (See Figure 3)

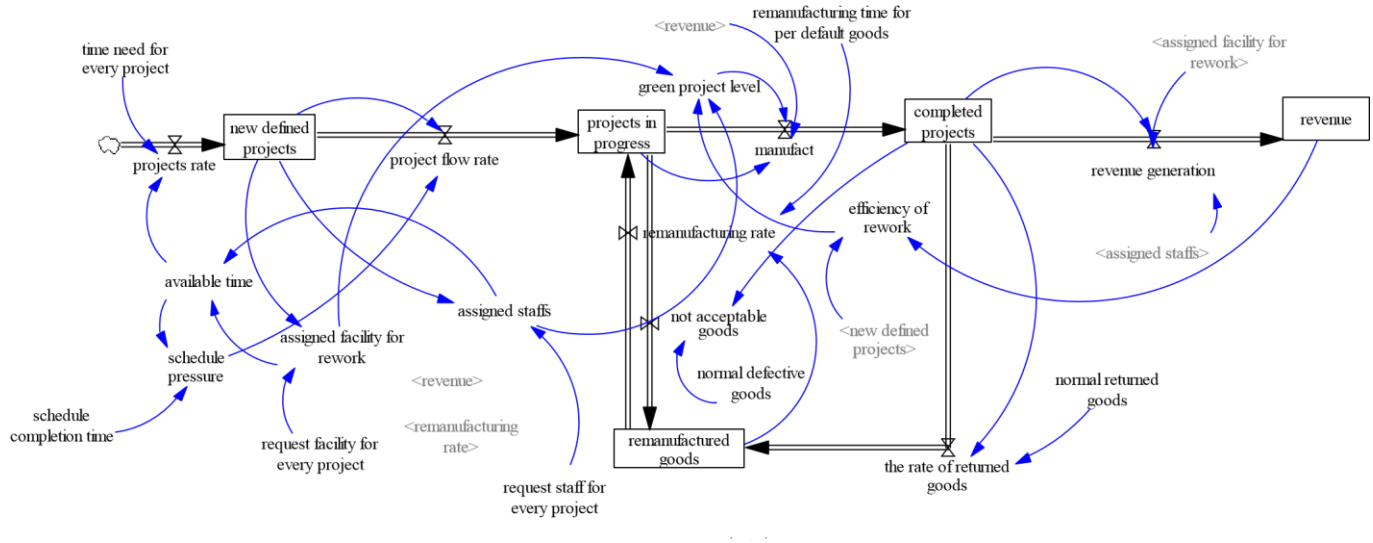

Figure3. Flow diagram of GNPD dynamics

As figure 3 showed, we had to consider some factors like available time, schedule pressure, the time needed for each project and schedule completion time to define the green new projects. When defining the new projects, the required facility and staff for each project must have been focused on. The required facilities were allocated to many of the defined projects and in this way, the projects progressed. As projects progressed, the possibility of production and selling the green products was created. Company revenue was achieved by selling the green products. We can point to the assigned facilities as another important factor in reducing the revenue. On the other hand, there was the possibility of returning the percentage of company`s consuming products and their manufacturing in the format of reverse logistics cycle. According to table 2 on page 7 showing the effective factors on GNPD, in this study, the most effective factors were just focused on. The most important factors were extracted from Table 2. The table below contains the most effective factors on GNPD, their equation, and type. (See Table 2)

Table 2. Equations of system dynamics model

Variable	**Equation**	**Type**
New defined projects	Projects rate-project flow rate	Stock

Projects in progress	Project flow rate + remanufacturing rate - manufacture-not acceptable goods	Stock
Remanufactured goods	Not acceptable goods +the rate of returned goods remanufacturing rate	Stock
Completed projects	Manufacture-revenue generation-the rate of returned goods	Stock
Revenue	Revenue generation	Stock
Projects rate	Available time/time need for each project	Flow
Project flow rate	If then else (schedule pressure<0,new defined projects, 2)	Flow
Remanufacturing rate	Remanufactured goods*remanufacturing time per default goods	Flow
Not acceptable goods	Normal defective goods*stock	Flow
The rate of return goods	Normal returned goods*stock	Flow
Manufacture	If then else (revenue>0, projects in progress*green project level,0)	Flow
Revenue generation	0.8*stock-assigned staffs-assigned facility for rework	Flow

Dynamic simulation and results

The model has been simulated, a number of results were obtained. In the first scenario, figure 4 depicted the required time for each project. When the time needed for each project reduced, as shown

in figures 5 and 6, the level of green products and efficiency of rework increased. (See Figure 4, 5& 6)

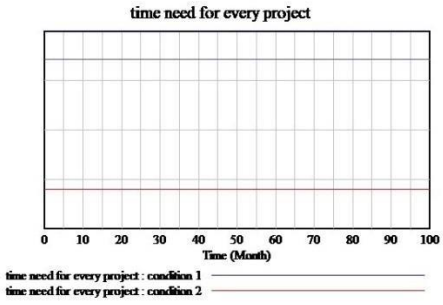

figure 4

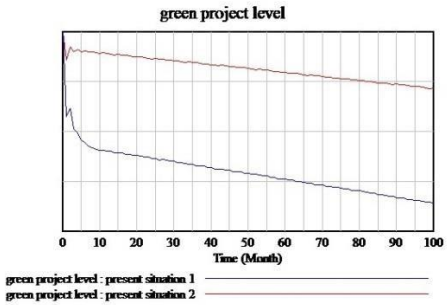

figure 5

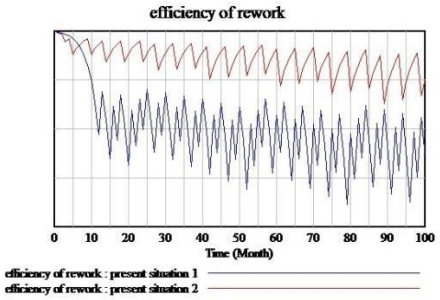

figure 6

In the next scenario, the impact of an increase in the number of staffs and facilities required for each project on the variable revenue and efficient of rework was studied. An increase in the number of required staffs and facilities for each project showed that the organization paid more attention to greening its productions. Therefore, it is important to increase the number of assigned staffs and facilities for green projects. Hence, it could be concluded that with an increase in the number of assigned staffs and using the facilities for greening GNPD projects, the organization‘s revenue increased as it can be seen in figure 10 while having a positive effect on the efficiency of rework as shown in figure 9. (See Figure 7, 8, 9& 10)

figure 7

figure 8

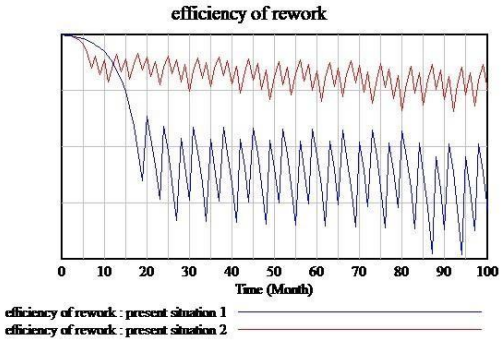

figure 9

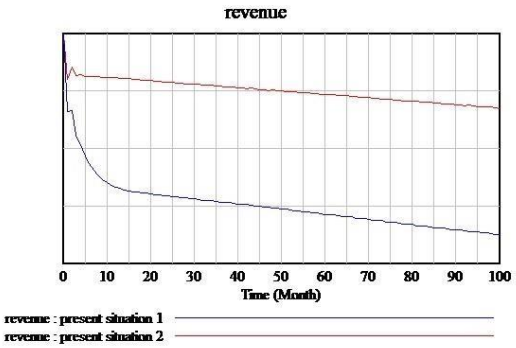

figure 10

The third scenario showed the behavior of the variables with the decrease in scheduled completion time. This reduction led to an increase in the level of green projects and the revenue of the company. (See Figure 11, 12& 13)

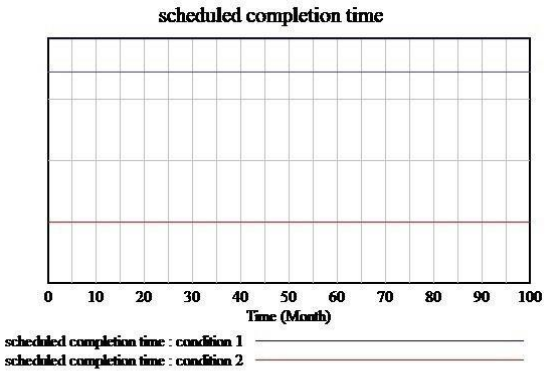

figure 11

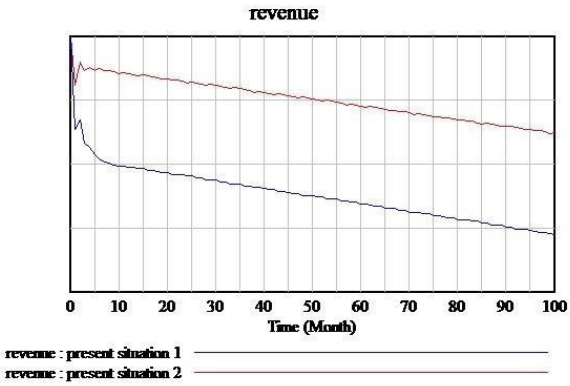

figure 12

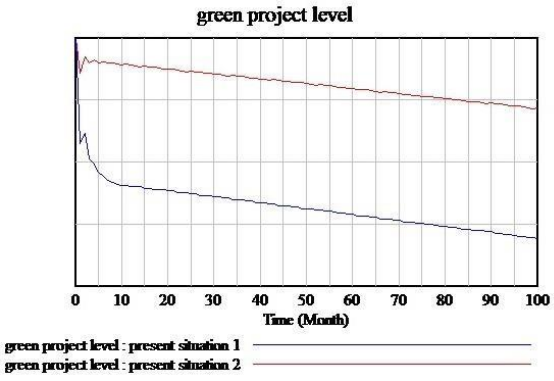

figure 13

Limitations and scope for future research

In the case of simulation models all models were wrong, so no model was valid or verifiable in the sense of establishing their truth. The question, that clients and modelers face, is never whether a model is true but whether it is useful (Sterman, 2000). The main thrust in this paper is to study the dynamics of a GNPD in manufacturing sector of food industry in Yazd.

Some of the main explicit limitations and scope of future research are listed below:

- Remanufacturing time for per default goods, available time, normal defective goods, and normal returned goods were kept steady; this is not necessarily the same for all cases and it often varies time to time. In future research, these parameters can be studied and varying inputs can be presented.
- In this model, only one change is required. Thus in future research, required multiple changes can be incorporated.
- There is no maximum limit set for staffs in this model, but in a real case, the number of personnel working in a project is often finite.

Conclusion

In this study, we tried to identify the effect of the main factors of the green new product development using system dynamics approach in food industry in Yazd province. Using flow charts, three scenarios were examined; then the behavior of key variables of the model was analyzed based on different policies.

Then, following points can be concluded according to the results of the simulations:

In the first scenario, the effect of reducing the time needed for each project on green projects level and efficiency of rework was examined. It was found that a reduction in the required time for each project increased the green project level and efficiency of rework.

We concluded that revenue and efficiency of rework increased with an increase in the number of required facility and staff for each project. In the last scenario, it was found that reduction of the scheduled completion time increased the revenue and green project level.

In this study, we found out that Factors such as the time needed, scheduled completion time, and the staff and facilities required for each project plays a key role in new product development in food industries in Yazd. In order to increase the revenue, the organization should try to reduce the scheduled completion time to gain more profits in a shorter period of time.

It is proposed that the organization should pay special attention to the projects of GNPD to increase its revenue.

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