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Dynamic modeling to determine production strategies in order to maximize net present worth in small and medium size companies

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Abstract: Determining production rate considering costs and revenues in order to maximize profit is one of the applied problems in small and medium size factories. Mostly existing models in production planning consider production system statically and specify production rate, although the factors determining production rate include many different changes in practice. In fact, by increasing the production rate or mass production, production costs can be reduced. Costs reduction will result in sales price falling. Then, sales price will affect the demand and demand can increase. Demand increase will lead to more income and this process will repeat again. In this paper, a model will be proposed for production system of small and medium size companies regarding costs, revenues and dynamic reaction of systems against changes, by applying system dynamics and Vensim software. Since Iran is a developing country, the model will be analyzed and validated for a medium size factory and then some policies will be presented to improve the factory situation in the future.

Keywords: *Dynamic modeling; Cost parameters; Inventory; Net present worth; Production; System dynamics*

1- Introduction

Production planning and inventory control have been widely applied in industrial manufacturing environments throughout the world, along the human movement toward automation. There are various models in production planning and inventory control, such as static and dynamic models, that all their purpose is exact planning. From the managers' point of view, cost parameters are one of the most effective variables in production rate. These parameters have been widely used in production models in order to do exact planning. It can be referred to Economic Order Quantity (EOQ) (Love, 1979) among the static production models, and Material Requirement Planning (MRP) and Optimum Production that are often used for production scheduling (Browne *et al.*, 1996) among the dynamic production models.

The main objective of each company in a safe market is to determine the economic production rate to attain the maximum profit. For this purpose, the factory management attempts to maximize its profit taking the cost and revenue parameters into consideration. In a real manufacturing environment, systems are mainly specified as dynamic and with regard to different effects on system, such as: profit effect or Net Present Worth (NPW) effect on capacity development rate, unit sales price effect on demand, customer order rate effect on net hire rate and so on. This reality is often ignored in modeling and costs for various static and dynamic production models are specified statically. However, we know that we couldn't easily consider the costs as static. Some researches have been done about keeping distance from fully static parameters. As an example, Mula *et al.* (2007) presented a model for minimizing costs in MRP, and in order to avoid completely static cost and production parameters investigated Fuzzy MRP. They introduced the propounded cost parameters by fuzzy numbers, but dynamic production effects have not been considered again. One of the tools for examining real systems in dynamic conditions is System Dynamics. System Dynamics was brought up by Forrester (2007a) for the first time and during recent 50 years has grown rapidly. System Dynamics is an approach to discover nonlinear dynamic behaviour and study structure and parameters of the system. The other main objective of that is designing the effective and stable policies that modify system performance. It also provides the possibility of testing new procedures and policies before performance (Sterman, 2000).

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System Dynamics is one of the efficient tools in real and dynamic conditions. Forrester (2007b) has also investigated on the lines of using system dynamics and its growth in the future 50 years. Homer (2007) presented a critique about future development of system dynamics declared by Forrester, too.

System Dynamics is also used in manufacturing systems modeling. Baines and Harrison (1999) studied researches done in different manufacturing systems that have used system dynamics tool.

Lai *et al.* (2003) proposed an alternative viewpoint with concentration on a general and integrated attitude for JIT production by applying system dynamics. Inventory systems have been considered more than other sections of a manufacturing system by system dynamics tool. As a matter of fact, inventory models are a sample of exact production planning models. Sterman (1989) introduced a general model of inventory management system that forms fundamental decision making structure in an environment. The model consists of two sections:

1) Inventory and system material flow physical structures,

2) Predominant principles on decision making in order to control the system. Sterman stated that in the most real positions of inventory management, feedbacks' complexity among variables prevents from determining an optimal strategy and then propounded a decision model for obtaining local reorder point based on heuristic methods. More extended models in the connection of inventory management systems have also been stated by Sterman (2000). Yasarkan and Barlas (2005) worked on the generalized inventory control model for inventory management problems, too.

Another application of System Dynamics and in fact its origin is the supply chain management (SCM) presented by Forrester (1958, 1961). Metz (1998) defined integrated supply chain management in this manner: Integrated supply chain management is an integrated and process-oriented approach to purchase, produce and deliver goods or offer services to customers - It is materials' information and cash flows management. In fact, supply chain management is also an approach in exact production planning that takes production into consideration in some section of the chain (Chopra and Meindi, 2001).

Supply chain including distribution and manufacturing models has been examined by Ozbayrak *et al.* (2007). Barlas and Aksogan (1999) developed a three-level model including a production level by using system dynamics tool. They studied a case in garment industries by means of system dynamics to develop a three-level chain consisting of supplier, producer and retailer. Their purpose for this simulation was developing and studying inventory policies in order to increase retailer's income and decrease his / her costs.

Accomplished study presented new stable policies for ordering in continuous-discrete systems in case of demand oscillations. Of course, it should be noted however supply chain management lessens costs due to true and exact management, but costs have not been considered in supply chain management directly.

In case of effectiveness of cost parameters can refer to Kofjac *et al.* (2007). They studied a causal loop diagram as Fig. 1 to show the effect of parameters and then made a model by means of fuzzy theory, but they didn't examine the system dynamically again.

Cakravastia and Diawati (1999) defined logistic performance in supply chain by three key attributes: product quality, cost and delivery time as Fig. 2 and then investigated time behaviour of key variables including orders, work in process, deliveries, delivery delay, total demand and net profit by using a dynamic model.

One of the important decision-making factors in the production rate of factories is net present worth (NPW), especially for make-to-order and make-to-stock systems (Naim *et al.*, 2007). Naim (2006) showed the effect of NPW in a manufacturing and control system to select the parameters in the ordering section.

In this paper, total revenue, total costs and profit are obtained by applying a dynamic cost and revenue system and their interactions, and then NPW is calculated. In this manner, with regard to effects of NPW and other parameters on production, the best production strategies are achieved in a factory as a sample.

In the next section, a dynamic modeling to determine production strategies (DMTDPS) is presented.

In section three, DMTDPS model is applied for a case study. Verification and validation tests are done in section four. In section five, regarding the simulated model, certain strategies for stable growth in the factory are presented. At the end, the paper is summed up with conclusion, an appendix and references, respectively.

2. Dynamic modeling to determine production strategies

Small and medium size factories in the developing countries form the main part of productions among the rest. These factories have to adapt production costs and revenues to obtain profit for survival. As a matter of fact, stability and production rate of these factories are dependent to costs or otherwise to net profit a lot. In this situation, costs are obtained dynamically and by feedback from the environment. So, the researchers decided to use system dynamics for simulating the production system. Some costs and revenues that can be considered per production unit in a small or medium size factory are as follows:

- Sales price per unit,
- Production cost per unit,
- Transportation cost per unit,
- Shortage cost per unit in a period of time,
- Inventory cost per unit in a period of time,
- Workforce cost per person in a period of time,
- Backlog order cost per unit in a period of time.

Summation of these costs results in total production cost by regarding demand and production rates. On the other hand, total revenue is calculated from sales rate and price. Profit is obtained by the difference of total cost and total revenue. The interactions of demand rate and prices are not considered in the static models. These models are created to make profit by taking demand satisfaction into consideration, and then production rate is achieved. But what takes place in the real world is that cost and revenue parameters change interactively and production rate is specified in a closed loop. Thus, the difference of total costs and total revenue determine profit and production rate, and obtained profit itself leads to some changes in costs, revenues and production rate. It can be simply said putting market demand under observation until the profit increases, production ascends via increasing the capacity rate with some delays, and factories are able to decrease production costs due to mass production experience.

Decreasing costs can affect unit sales price, and this matter influences the demand. Repetition of this process causes the system to become dynamic. In this paper, the researchers could generalize a model as Fig. 3 to determine production strategies by considering production logic in the small and medium size factories and studying a case.

According to Fig. 3, cost parameters determine production costs, unit sales price determines revenue and then profit is obtained. It is obvious that interest rate is an effective parameter in the production systems. Therefore, in order to correctly analyze the system, the profit is converted to net present worth (NPW). This concern has been analyzed by Naim (2006, 2007). Thus, it can be mentioned that regarding target production, NPW affects production rate with some delays via capacity increase rate and net hire rate. Inventory level and backlog orders are also determined by considering the production rate and minimum shipment time. So, when NPW ascends, the producer often decides to increase the production rate to make more profit by regarding customers order rate and increasing the factory capacity.

Production increase in the length of capacity increase, decreases production costs and unit sales price due to mass production experience of the producer. Also, decreasing unit sales price causes the demand to increase.

Having the mentioned changes in view and because of dynamic nature of DMTDPS model, production rate or optimal production strategies can be determined. With regard to Fig. 3 and discussed subjects, four effects have been considered on production parameters. These effects are as follows:

- Effect of production on unit sales price,
- Effect of unit sales price on demand,
- Effect of NPW on capacity increase rate,
- Effect of production on production cost per unit.

The main advantage of DMTDPS model is that future factory situation and optimal strategies for growth can be examined by collecting correct information and their effects. It should be noted the effect of production on unit sales price and the effect of unit sales price on demand can be specified decreasingly, constantly or increasingly in the certain industry according to economic theories. DMTDPS model consists of five state variables: Inventory, backlog, workforce, capacity and net present worth. These variables are formulated in Table 1.

As it was said before, the profit is also one of the main factors to determine production rate in small and medium size factories. The calculations of production rate, total costs, total revenue and profit are summarized in Table 2.

As Fig. 3 shows, production rate and NPW have been placed in a reinforcing loop. In reality, NPW acquired from production influences the production rate with some delays via capacity change rate, existing capacity, net hire rate, existing workforce, and target production. As a matter of fact, when NPW reaches the minimum value, production capacity is also lessened to minimum capacity after a while.

On the other hand, when NPW grows exponentially, the production rate is led to maximum nominal capacity of the factory regarding the produced commodity and industry nature.

In order to correctly analyze, the parameters of DMTDPS model must be specified based on real factory performance.

3. Case study (Iran Gas and Pipe Company)

Although DMTDPS model can be used in various cases, it has been established to examine Iran Gas and Pipe Company situation in this paper. This model is not limited to special state in each modeling stages. In order to study and examine present situation of company, suggest future production strategies, and verify and validate DMTDPS model, activities of this company are described.

Gas and Pipe Company has been established in 1996 in Iran along with technology development and the necessity of industrializing developing countries and considering the need of Iran to pipe and relevant connections in water, gas and sewage industries.

The domain of this company's activities is production of different types of polyethylene pipes, polymer palette, FFS polyethylene rolls, shrink film, polyethylene tanks and electro-fusion connections with the participation and investment of internal and external corporations and incorporations. Products, competitive advantages and production volume of this company have been listed in Appendix 1.

Necessary information has been collected to examine the company's situation and to establish stable growth strategies. Table 3 consists of profit, sales and capital changes. Demands in conformity with plans and forecasts until 2010 are brought in Table 4.

It should point out for the purpose of profit comparing to determine factory situation regarding high inflation in the developing countries, especially in Iran, profit should be converted to net present worth. As an example, if inflation rate is determined 20% per year according to World Bank statistics and 2003 is assumed as base-year, profit percentages will not show special growth and will just represent a steady state.

To analyze the company's situation by DMTDPS model, the necessary parameters have been listed in Table 5.

Four relational tables between different production components have been presented in DMTDPS model to provide the interactions of components. These tables have been estimated as Figures 4 to 7 for Iran Gas and Pipe Company's production system. DMTDPS model has been simulated by Vensim software, parameters of Table 5 and Figures 4 to 7, and the outputs of simulated model have been presented in Figures 8 to 10.

Production rate, workforce, and backlog orders reach equilibrium after a short while, but inventory grows fast and NPW declines. These outputs will be used to analyze the present situation of Iran Gas and Pipe Company, model verification and validation, and making policies.

4. Verification and validation

Verification and validation tests in system dynamics are classified in three groups as Table 6 (Sterman, 2000). These tests are done to confirm the correctness of modeling and examine the results from the viewpoint of validity.

All above tests should be accomplished to validate the proposed model completely. Verification, dimensional-consistency, boundary-adequacy and parameter verification tests have been performed implicitly during studying and modeling Iran Gas and Pipe Company. Since test c is relevant to policy implications, it will be investigated in section 5. As a general rule, a question is propounded in each test, and its answer leads to verification and validation of proposed model. Some accomplished tests are described as follows:

- Extreme-Conditions Test: This test investigates the equations of proposed model in the extreme points. Equations must show true conditions of system in the extreme points. As an example, if unit sales price increases a lot so that customer order rate gets zero, backlog orders will not exist, too. This matter results in shipment rate gets also zero. DMTDPS model confirms this case. This test will be performed easily for other extreme conditions, too.

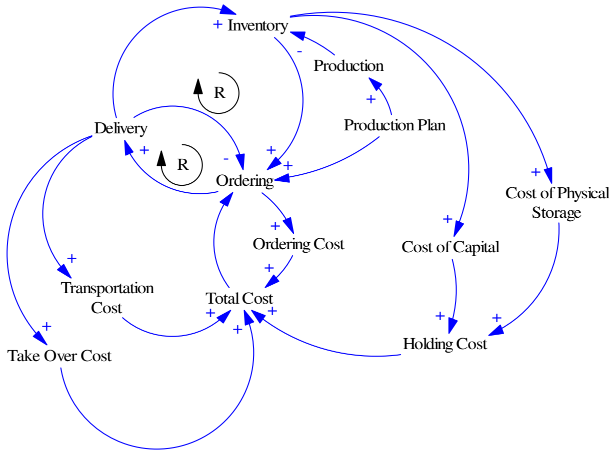

Figure 1: Causal loop diagram to determine economic order quantity (Kofjac *et al.,* 2007).

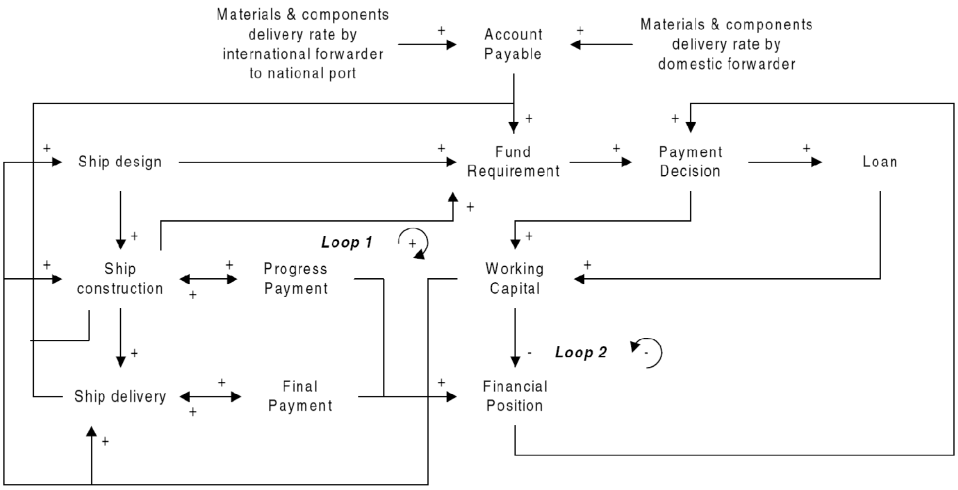

Figure 2: Causal loop diagram of cash flow in supply chain logistic (Cakravastia and Diawati, 1999).

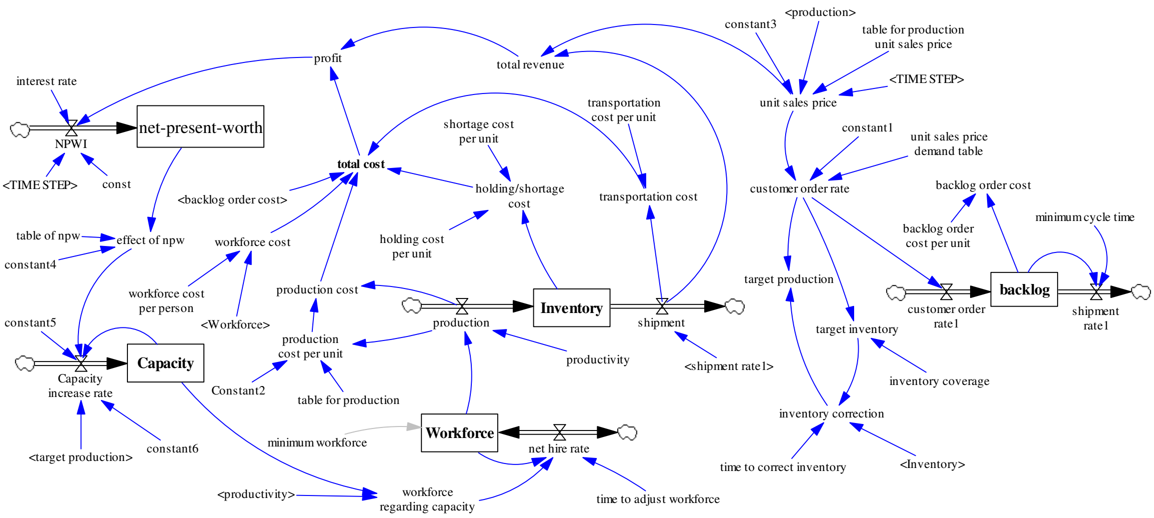

Figure 3: Flow diagram of dynamic modeling to determine production strategies (DMTDPS).

Table 1: State variables of DMTDPS model.

State Variables	1	Inventory = ∫(production-shipment)+Inventory(0)	production = Workforce* productivity shipment = backlog/minimum cycle time
	2	Backlog = ∫(customer order rate-shipment rate)+Backlog(0)	customer order rate = SMOOTH(unit sales price demand table(unit sales price/constant1),1)
	3	Workforce = ∫net hire rate+Workforce(0)	net hire rate = (workforce regarding capacity-Workforce)/time to adjust workforce
	4	Net-Present-Worth = ∫NPWI+NPW(0)	NPWI= profit/(power((1+interest rate),TIME STEP/const))
	5	Capacity = ∫capacity increase rate+Capacity(0)	capacity increase rate = IF THEN ELSE((SMOOTH(effect of npw*constant5,12)+(Capacity/constant6))<(target production/constant6), SMOOTH(effect of npw *constant5,12), 0)

Table 2: Production rate, total cost, total revenue and profit calculations.

Total cost=	Workforce cost+ Production cost+ Transportation cost+ Holding/Shortage cost+ Backlog order cost	Workforce cost= Workforce*workforce cost per person Production cost= production*production cost per unit Transportation cost= shipment*transportation cost per unit Holding/Shortage cost= IF THEN ELSE (Inventory>=0, Inventory* holding cost per unit, -1* Inventory* shortage cost per unit) Backlog order cost= Backlog*Backlog order cost per unit
Total revenue=	Shipment*Unit sales price	
Profit=	Total revenue-Total cost	
Production=	Workforce*Productivity	

Table 3: Profit, sales and capital (Million Rials).

Year	2003	2004	2005
Profit	38709	187795	232541
Profit increase in comparison with previous year	---	480%	120%
Sales	124475	228985	686955
Sales increase in comparison with previous year	---	84%	300%
Capital changes	25000	75000	2250000

Table 4: Demands in conformity with plans until 2010.

Water	43908 Km
Sewage	24910 Km
Total	**250000 Ton**

Table 5: Parameters of Iran Gas and Pipe Company.

No.	Parameter	Value
1	Interest rate	2.3% / Month
2	Transportation cost per unit	70 Rial/Ton
3	Shortage cost per unit	0 Rial/(Ton*Month)
4	Holding cost	300000 Rial/(Ton*Month)
5	Workforce cost per person	1700000 Rial/(Person*Month)
6	Backlog order cost per unit	60000 Rial/(Ton*Month)
7	Initial capacity	10000 Ton/Month
8	Productivity	21.5 Ton/(Person*Month)
9	Minimum workforce	170 Person
10	Time to adjust workforce	1 Month
11	Time to correct inventory	2 Month
12	Minimum cycle time	1 Month
13	Inventory coverage	1/2 Month

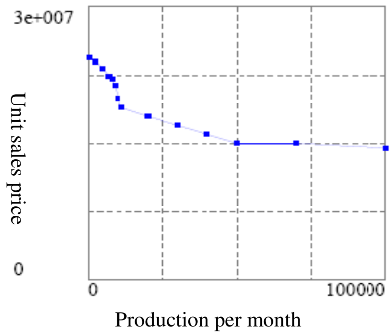

Figure 4: Unit sales price in terms of monthly production.

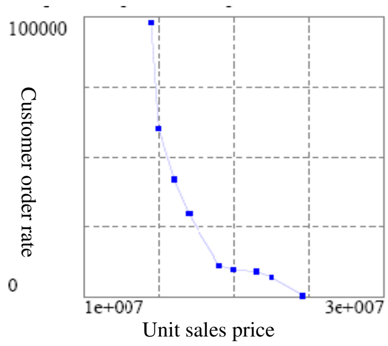

Figure 5: Customer order rate in terms of unit sales price.

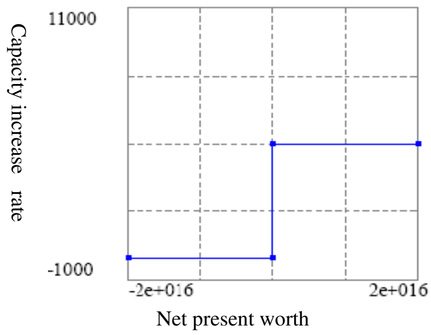

Figure 6: Capacity increase rate in terms of net present worth.

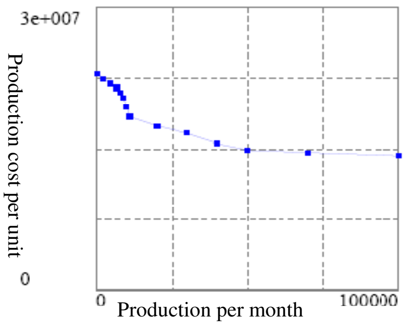

Figure 7: Production cost per unit in terms of monthly production.

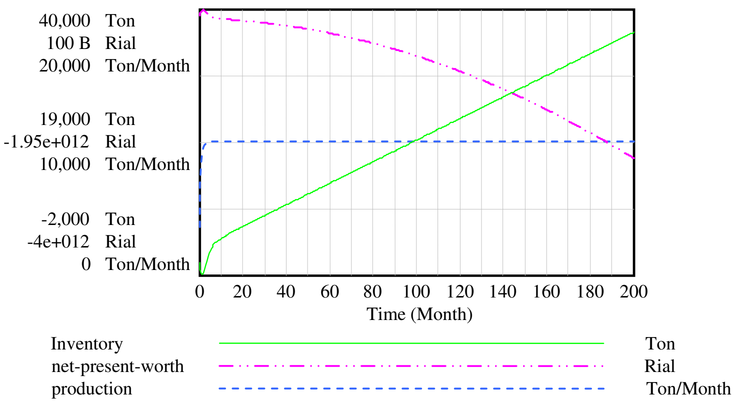

Figure 8: Simulated values for inventory, NPW and production.

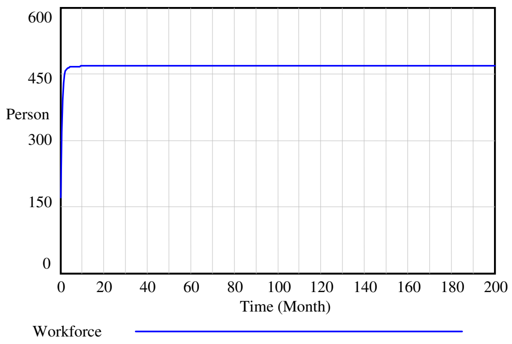

Figure 9: Simulated values for workforce.

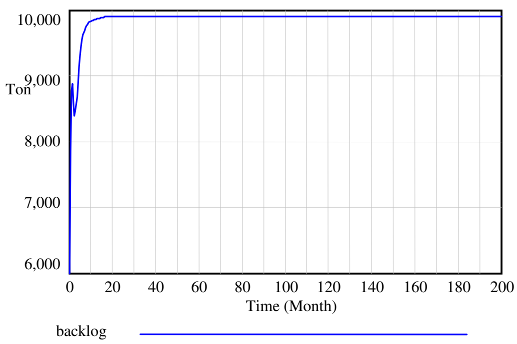

Figure 10: Simulated values for backlog.

Table 6: Verification and validation tests of DMTDPS model.

a	Validating Model Structure	a.1	Verification
		a.2	Dimensional-Consistency
		a.3	Extreme Conditions
		a.4	Boundary – Adequacy (Structure)
		a.5	Parameter Verification
b	Validating Model Behaviour	b.1	Behaviour Reproduction
		b.2	Behaviour Anomaly
		b.3	Behaviour Sensitivity
c	Validating Policy Implications	c.1	Changed Behavior Prediction
		c.2	Policy Sensitivity

- Behaviour Reproduction Test: This test examines the model behaviour in conformity with reality. The performed simulations in DMTDPS model (Figures 8 to 10) verify system behaviour. About system behaviour and forecasting, considering other parameters will be explained more in the policy-making section.
- Behaviour Anomaly Test: This test investigates the circumstances of creating anomalous behaviours in the case of changing assumptions. If minimum cycle time for delivering orders to customers increases, an anomalous behaviour will happen which is not an unexpected event. As it is predicted, production will continue according to previous trend, but inventory and backlog will increase simultaneously. This concern will have a negative effect on NPW and will lead the system to an unsuitable situation. These behaviours have been shown in Fig. 11, 12. Determining the real and suitable time for delivery withholds this anomalous behaviour.
- Behaviour Sensitivity Test: This test examines model sensitivity against probable parameters changes. Otherwise, this test investigates the correctness of model when parameters change. The behaviour of DMTDPS model has been confirmed relative to parameters changes. Table 7 shows acquired results from model sensitivity analysis concerning parameters changes in a 50% interval from initial value as linguistic variables.

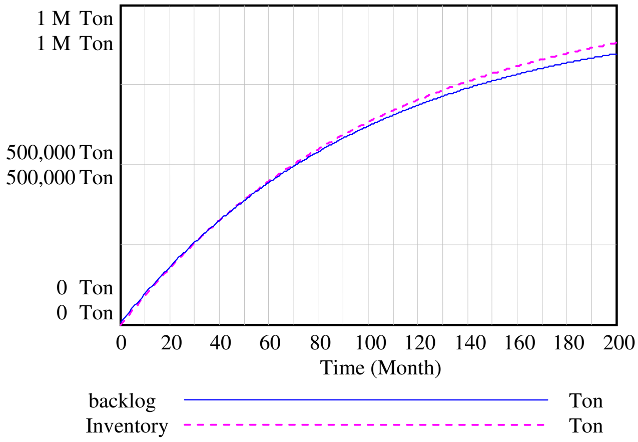

Figure 11: Inventory and backlog considering high delivery time.

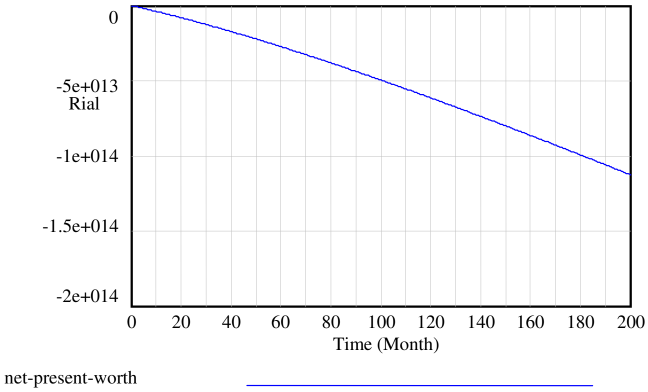

Figure 12: NPW considering high delivery time.

Table 7: Classification of parameters sensitivity of DMTDPS model concerning changes.

Parameter	Criteria		
	NPW	Production	Backlog
Interest rate	Low	Low	Low
Transportation cost per unit	Low	Low	Low
Shortage cost per unit	Low	Low	Low
Workforce cost per person	Low	Low	Low
Initial capacity	High	High	High
Time to adjust workforce	High	High	High
Time to correct inventory	Low	Low	Low
Inventory coverage	Low	Low	Low
Backlog order cost per unit	Low	Low	Low
Productivity	Medium	Medium	Medium
Minimum cycle time	High	High	High
Minimum workforce	Medium	Medium	Medium
Holding cost per unit	Medium	Low	Low
Table of NPW	High	High	High
Unit sales price demand table	High	High	High
Table for production unit sales price	High	High	High
Table for production	High	High	High

5. Policy-making to modify Iran Gas and Pipe Company performance

Dynamic modeling was performed for Iran Gas and Pipe Company in Sections 2 and 3, and simulated results were obtained by Vensim software. In Section 4, the proposed model was verified and validated by applying some tests. Taking the performed sensitivity analysis test and complete perception of system behaviour into account, we proceed to apply efficient policies to utilize the facilities toward stable development more properly.

The proposed policies are established for the purpose of attaining more profit and not declining NPW that is the main factor toward stable development of company.

Changed behaviour prediction (correct prediction of system behaviour as a result of dominant policy change) and policy sensitivity (dominant policy change by making reasonable changes in parameters' values or equations formulation) tests are performed in this section by applying proper policies automatically.

Policy1: Production cost per unit reduction*:* As realities in Fig. 8 show, Iran Gas and Pipe Company has descending and negative NPW. This matter will lead to company's loss and bankruptcy. The first policy to attain profit or stable growth of NPW is the reduction of production cost per unit. By training the workforce, preventing of losses or any process that decreases production costs, production cost per unit is reduced by 20%.

This 20%-reduction causes NPW to grow and inventory and backlog to decrease. The effect of 20%-reduction in production cost per unit and NPW, inventory and backlog are shown in Fig. 13, 14, respectively. This reduction lessens the total costs and increases NPW.

These changes, in turn, result in some changes in capacity, workforce and shipment rate. Shipment rate increase affects the production rate, and as a result, the inventory.

So, the inventory grows. On the other hand, existing time delays cause the shipment rate to increase and inventory to decline. This dynamic behaviour continues and inventory fluctuations form like Fig. 14. These oscillations are diminished during the time.

Policy2: Delivery time reduction: As it was seen in parameters sensitivity analysis section, model is extremely sensitive against orders delivery time (minimum cycle time) change. By proper planning and delivery time reducing from 1 month to 15 days, NPW will ascend and inventory level and backlog will be adjusted in the desired inventory level. Delivery time reduction policy causes production to grow constantly. These cases are observed in Figures 15 and 16.

By reducing the delivery time, shipment rate increases and backlog orders consequently decrease.

So backlog order costs and, as a result, total costs decline and NPW grows. Likewise, production rate and demand begin to increase to a certain maximum value. This matter leads to a constant production by considering the economic value of backlog order costs. Constant production also sets the inventory in a specific level.

Policy 3: Delivery time reduction and productivity increase: If in addition to delivery time reduction, workforce productivity is also increased by proper and on-time training, NPW will have more stable and faster growth in comparison with policy 2. This case has been shown in Fig. 17.

6. Conclusion

In this paper, a dynamic model was presented to maximize net present worth of production in a sample factory by using system dynamics simulating tool and Vensim software. This model was verified and validated based on studies in Iran Gas and Pipe Company. As it was seen, the effective factor on the system's performance is NPW. Regarding the negative growth of NPW in the studied case, sensitivity analysis was applied on parameters and three policies were presented to increase NPW. Simulating the DMTDPS model by proposed policies led up to stable growth of NPW. Approximate stability of inventory and backlog in the desired inventory level and slow and stable growth of production are advantages of these policies. This matter facilitates exact production planning. DMTDPS model can be generally used in small and medium size factories by selecting proper parameters.

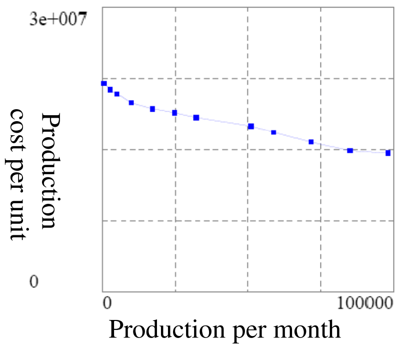

Figure 13: 20%-reduction in production cost per unit.

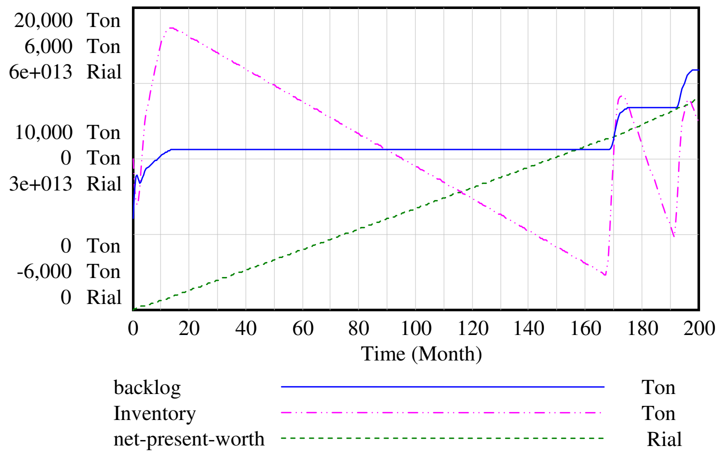

Figure 14: Simulated NPW, inventory and backlog as a result of 20%-reduction in production cost per unit.

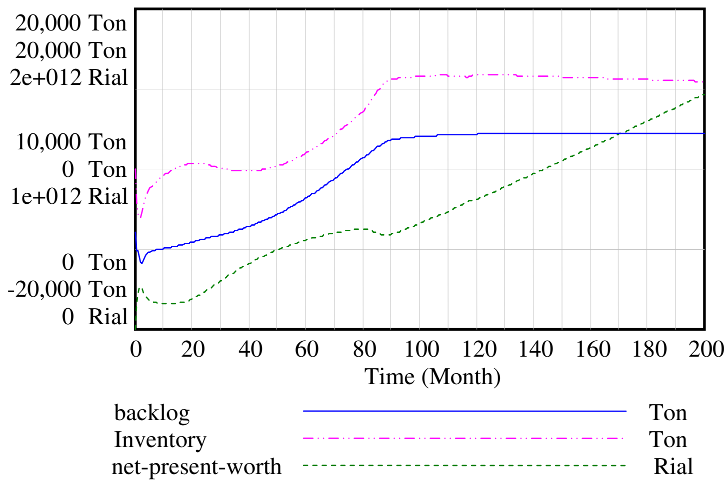

Figure 15: Simulated NPW, inventory and backlog as a result of delivery time reduction to 15 days.

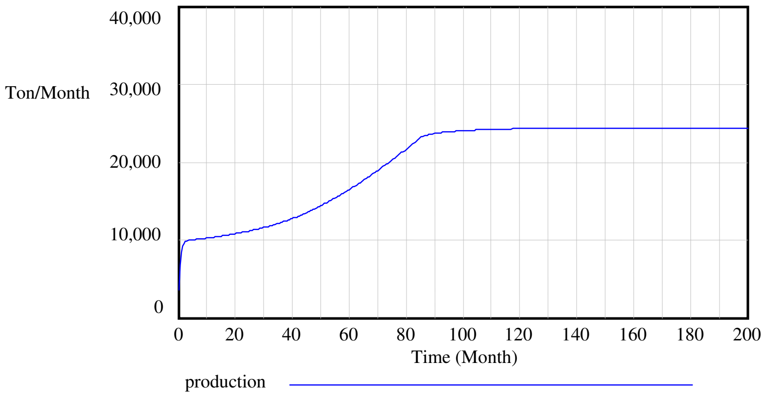

Figure 16: Simulated production as a result of delivery time reduction to 15 days.

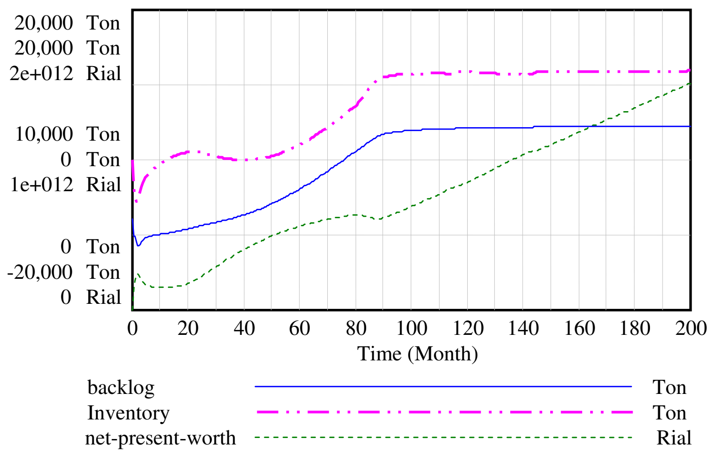

Figure 17: Simulated NPW, inventory and backlog as a result of delivery time reduction to 15 days and workforce productivity increase to 26 Ton/(Person*Month).

Appendix 1. Products and competitive advantages of Iran Gas and Pipe Company

1.1. Products of Iran Gas and Pipe Company

- Sewage two-layer pipes (Corrugated) 13476-116961 PREN Europe, 100 mm-1200 mm (Under license of Drossbach, Germany),
- Gas one-layer pipes based on Europe CEN 1555 Standard, 16mm-450mm (Under license of Wavin, Netherlands),
- Polyethylene, sewage and tanks based on DIN 16961 Standard (Under license of Drossbach, Germany),
- Water one-layer pipes based on DN 8074 Standard, 16mm-450mm (Under license of Wavin, Netherlands),
- Electro-fusion connections based on EN 10204-20 Standard (Under license of George Fisher, Swiss),
- Different kinds of FFS polyethylene rolls for packing polymer materials (Petrochemical Packing Industries),
- Different kinds of compounding polymer palettes,
- Different kinds of shrink and stretch films,
- Different kinds of polyethylene tanks.

1.2. Competitive advantages of Iran Gas and Pipe Company

- Low weight,
- Easy transportation,
- Easy installation,
- Resistant against shock,
- High lifetime,
- Firm installation,
- High flexibility,
- Resistant against decay and rusting,
- Resistant against earth's repulsion,
- Low friction coefficient.

1.3. Productions volume of Iran Gas and Pipe Company

Table 8: production in terms of different products (Ton).

Water one-layer	10000
Gas one-layer	15350
Sewage	23150
Sewage connections	2500
Electro-fusion connections	250
Tanks	1000
Palette	4000
FFS	6000
Shrink	2000
Total	64250

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