Responsiveness of Inventory Order Cycle Policies (IOCP) with Unpredicted Events Occurrence through System Dynamics Modeling: A Case Study in Consay Company

Abbas Mogbel Baerz, Alla Talal Yassin, Adel Azar, and Seyyed Esfehany

***Abstract*—Most organizations have to cope with the short term random movements in supply and demand. In today's competitive marketplace, achieving manufacturing excellence has become critical for success. This paper examines the behavior of firm over time using system dynamics model as a basis for setting inventory situations. Consay Company Discount Store (in Poland) stocks socks in its warehouse and sells them through an adjoining showroom. The store keeps several brands and styles of socks in the stock; however, its biggest seller is Super socks marketing. A simulation model was created in order to examine the behavior of the inventory model over time. The store wants to determine the behavior of the inventory by using system dynamics (SD). The results of simulation showed that the long run behavior of the company is significantly different, depending on the inventory model chosen.**

***Index Terms*—Behavior, system dynamics, inventory, responsiveness, order cycle.**

I. INTRODUCTION

Inventory is defined as a stock or store of goods. These goods are maintained on hand at or near a business location so that the company may meet the demand and fulfill its reason for existence. Inventory types can be classified into four groups: raw material, WIP1, finished goods and MRO2 goods.

The company usually keeps larger inventory than it is required to meet the demand and to keep the factory running under the current conditions of demand. If the company exists in a volatile environment where demand is dynamic, an on-hand inventory could be maintained as a buffer against unexpected changes in demand. This buffer inventory can also serve to protect the company if a supplier fails to deliver the raw materials at the required time, or if the supplier's quality is found to be substandard upon inspection. Other reasons for maintaining an unnecessarily large inventory include taking advantage of quantity discounts, or ordering more goods in advance of an impending price increase.

The inventory cycle for a company is composed of three phases. The first step is the ordering or administrative phase, which is the amount of time it takes to order and receive raw materials. The second step is the production phase, which is the work in progress phase. The last step is the finished goods and delivery phase.

The inventory cycle is measured as a number of days. Demand is relatively constant over time, and no shortages are allowed. The lead time for the receipt of orders is constant and the order quantity is received once at all. Safety stocks are buffer added to the on hand inventory during the lead time while the stock-out is an inventory shortage. The service level is probability that the inventory available will meet the demand during the lead time.

The main tool of system dynamics is representing the system being studied as an influence graph. The influence graph indicates the major variables in a system and the influences have these on each other as a sense-making device, allowing an analyst to organize and understand a complex problem domain.

The influence diagram is then manually converted into more complexes called a 'stock and flow' diagram. It includes nodes for each of the model's parameters. The stock and flow diagram is used to develop a set of equations, which are used in a numerical simulator to generate the behavior of the system. This case study is a make-to-order case for industries considered for the Consay Company (Poland).

II. RESEARCH OBJECTIVES

There are three main objectives for the research. First, to build a SD performance assessment framework model for the inventory order cycle policies (IOCP). Second, to identify the performance drivers in IOCP. Finally, to investigate and understand the dynamic behavior that characterizes IOCP.

III. LITERATURE REVIEW

Ardalan analyzed the effects of a special order during the sale period on the inventory costs [1]. He reviewed the joint effect of marketing and inventory policy on total profit by taking a general price demand relationship for determining the retailer optimal price and optimal ordering policy [2].

(SD) models, First introduced by Forrester [3], have proven their applicability to analyzing strategic scenarios as well as simulation of policies and operations in manufacturing systems [4]. Application of SD in

Manuscript received December 27, 2001; revised February 13, 2012.

Abbas Moghbel Baerz is with Management and Economics, Tarbiat Modares University, Tehran, Islamic Republic of Iran, (e-mail: moghbela@modares.ac.ir, Tel:+98-9121300468)

Alla talal is with Management and Economics, ICCI Member in Iraq. (e-mail:allatalal@yahoo.com, Tel:+98-93751174: +964-7714811910)

Adel Azar, Faculty of Management and Economics, Tarbiat Modares University, Tehran, Islamic Republic of Iran,

Seyyed Esfehany is with Amir kabir University, Tehran, Islamic Republic of Iran

[1] WIP (Work-in-process)

[2] MRO (Maintenance, repair, and operating supplies)

manufacturing systems was focused mainly on pure-inventory and how the system can be designed and analyzed to respond to unanticipated demand with maximum stability and minimum cost [5]. Some studies have reviewed the dynamic behaviors of a variety of complex systems in the domain of human activity systems such as organizational management [6, 7].

These systems are characterized by a lack of explicit knowledge about the fundamental mechanisms of the system work, as well as a lack of quantitative information on how such mechanisms operate. The presented modeling approach differs from previous inventory order cycle models [8, 9] as it considers more performance measures to determine the best order cycle policy. The objective of the present research is to explore the best inventory cycle policy to be adopted.

IV. The System Dynamics Approach

System dynamics deals with the mathematical modeling of dynamic systems and response analyses of such systems with a view toward understanding the dynamic nature of each system and improving the system performance. Response analyses are frequently made through computer simulations of dynamic systems. A system is a composed of a set of acting together to perform a specific objective. A component is a single functioning unit of a system, and it is called dynamic if its present output depends on the past input. But if current output depends only on the current input, then the system is known as "static". The output of a static system remains constant if the input does not change. The output changes with time if the system is not in a state of equilibrium.

SD models have been applied to various fields in the natural and social sciences. There are still countless problems and issues where correct understanding is a problem and the dominant theories are event-oriented rather than dynamic in nature [10]. Within the realm of SD modeling, understanding the connection between SD model structure and behavior in complex model formulations is a big challenge [11]. The fundamental modes of observed behavior in dynamic systems are exponential growth, goal seeking and oscillation.

SD is a policy modeling methodology based on the foundations of (1) decision making, (2) feedback mechanism analysis and (3) simulation. Decision making focuses on how actions are to be taken by decision-makers. Feedback deals with the way information generated provides insights into decision-making and affects decision-making in similar cases in the future. Unlike in a real social system simulation provides decision-makers with a tool to work in a virtual environment where they can view and analyze the effects of their decisions in the future. SD has many steps in the process of simulation. Fig.1 illustrates seven steps of it.

Forrester was the first person who used the concept of SD in an article entitled "Industrial Dynamics: A Major Breakthrough for Decision Makers", which appeared in Harvard Business Review in 1958. His initial work focused on analyzing and simulating the microlevel industrial systems such as production, distribution, order handling, inventory control and advertising. Forrester expanded his SD techniques in "Principles of Systems" in 1968, where he detailed the basic concepts of SD in a more technical form, outlining the mathematical theory of feedback SD [12].

Fig. 1. The Process of simulation.

The approach of SD was created and developed by a group of researchers led by Forrester at the Massachusetts Institute of Technology (MIT) in the late 1950s. SD builds on information-feedback theory, which provides symbols for mapping business systems in terms of diagrams and equations, and a programming language for making computer simulation [13]. A SD model captures the multiple feedback loops underlying the endogenous behavior of a particular problem. Simulation enables exploring "what-if" scenarios and policy tests in something approaching a laboratory setting, leading to growing confidence in particular policies and strategies [14, 15]. It has a long history analyzing complex problems in a variety of application domains, ranging from environmental or public policy, corporate strategy, security, healthcare and operations management, to change management. However, it has no extensive application in the marketing literature. The characteristics of the marketing decision environment–multiple inputs and outputs, delayed effects and nonlinearities– are precisely the characteristics that laboratory experiments suggest that managers could not do well intuitively [16]. Inventory policy involves deciding appropriate stock levels, reorder points and quantities. After setting stock policy, the effect and cost are evaluated. The simulation is provided with a database of product data that can be added to and changed [17].

V. Causal Loop Diagrams

Causal Loop Diagrams (CLDs) have been used in standard system dynamics practice for purposes connected with simulation modeling. They are nowadays mostly used prior to simulation analysis, to depict the basic causal mechanisms hypothesized to underlie the reference mode of behavior over time, that is, for articulation of a dynamic hypothesis of the system as endogenous consequences of the feedback structure[18]. They also form a connection between the structure and the decisions that generate system behavior. Later, CLDs have started to be used for purposes not necessarily related to model building, namely, for detailed system description and for stand-alone policy analysis [19].

The other common notations for SD and system thinking are Stock-and-Flow Diagrams (SFDs). Proponents of SFDs criticize the ambiguity and lack of detail in CLDs, which prevents simulation of the modeled systems and prefer at least to start with stocks [20]. CLDs have been used for brainstorming and then to switch to an SFD, which models the system exactly. This raises the question that how CLDs can be used as a base for an SFD [21] .

CLDs can be a good start for system modeling. However, the transition to SFDs is not straightforward. The information on SFDs is hidden in the CLDs and collapsed into links and factors. Extraction of stocks and auxiliaries from the CLDs requires further investigation of the links and what they represent. This process may increase the number of factors in the system. In order to further develop the CLD, the modeler is, therefore, required to have in-depth knowledge about the system considered. The main difference to the work presented here is the dynamic change of the CLD into an SFD, and on the other hand, a link-centered way of looking at these diagrams, contrasting the factor-centered way introduced [22].

VI. Quantication

The process of turning an SFD into a model is called Quantication, which will be briefly discussed here. In order to quantify an SFD, the modeler has to provide (i) Start and end time for the simulation run, (ii) Formulas for allow and auxiliary factors, including the speciation of the delay values or functions for all links in SD, (iii) Values or time independent functions (i) for all input factors, (iv) Initial values for all stocks, and (v) Initial values or time-dependent functions for all factors, which have outgoing dependencies with delays. The data in (iv) and (v) are often simply assumed to be zero. Another technique to avoid having to specify (v) is to simulate the model until it may reach a steady state, in which case one simply discards the initial time segment of the simulation. SD is both a system enquiry methodology [23] and a modeling approach. A model is a substitute for an object or a system [24] and some systems can be modeled in terms of levels and rates. Levels are the states of a system, which would exist even though the system was brought to rest. Rate variables are control variables that regulate the flow into and out of the levels, the flow of decisions, but flow rates themselves are not input to the decisions.

VII. Case study (The Polish Consay Company)

The SD model is not limited to special state in every modeling stage. Although the model can be used in various cases, it has been established to examine the Consay Company's situation in this study. In order to study and examine the present situation of the company, suggest future production strategies, and verify and validate the model, the activities of this company will be described here. The domain of this company's activities is production of different types of sock with the participation and investment of internal and external corporations and incorporations.

VIII. Model description

The development of an appropriate model for inventory order cycle in RMS, which incorporates different parameters involved in that process, is an essential step. Appendix (1) shows a system dynamic model for unpredicted events for responsiveness inventory order cycle in RMS.

The model expresses the order quantity as a stock level controlled by other parameters. In addition, it incorporates the inventory, shipment rate, production rate, demand, utilization, order rate, total value sales orders waiting to be filled, order fulfillment rate, production per customer, minimum cycle time, order delay, order delay effect, normal delivery delay, order cycle, look up order delay, new customer, normal effective referral fraction, customers, capacity and customer order rate. In this study, a continuous-time model is used because it provides an acceptable, approximation of the continuous process in RMS. Finally, similar dynamic characteristics can be obtained using discrete-time models [25] . Deterministic data are used in the analysis to provide a simple and yet effective comparison among the various scenarios.

IX. Mathematical models description

Any attempt to design a system must begin with a prediction of its performance before the system itself can be designed in detail or actually built. Such prediction is based on a mathematical description of the system's dynamic characteristic. This mathematical description is called a "mathematical model", which is classified into linear and nonlinear differential equations. The linear differential equations (LDE) may be classified as linear time-invariant differential equations and linear time varying differential equations.

X. Model nomenclature

* Order cycle = Interval of time or period between the placing (which means the act of finding a single buyer or a group of institutional buyers for a large number of shares in a new company or a company that is going public) of one set of orders and the next. * $I(t)$= Inventory, * $Sh\ R(t)$ = shipment rate, the desired shipment rate is calculated as a function of the current backlog and the target responsiveness time. * $PR(t)$ = production rate, * $OR\ (t)$ = order rate, * $SOWF(t)$ = value-sales-orders waiting to be filled, * $OFR(t)$= order fulfillment rate, * $PPC(t)$ = production per customer, * $MCT(t)$ = minimum cycle time, * $OD(t)$ = order delay, * $ODE(t)$ = order delay effect, * $NDD(t)$ = normal delivery delay, * $LOD(t)$ = look up order delay, *$NC(t)$ = new customer, *NER(t) = normal effective referral fraction, *$Cu\ (t)$ = customers, *$Ca(t)$ = capacity: the target responsiveness time. It represents the manufacturer's goal for the interval between the placement and receipt of orders. The responsiveness time is a major performance measure of these responsive systems and tends to be low.

XI. Model logic

A. *Total value-sales-orders waiting to be filled:*

The equation for the order rate (Eq. 1) is determined by customer's order rate, order delay effect and products per customer. Total value sales orders waiting to be filled are controlled through integration of order rate and order fulfillment rate (Eq. 2):

OR (t) = COR *(t)* * ODE *(t)* * PpCu*(t)* Eq.1

SOWF (t) =INTEG (OR *(t)*) – FR *(t)* Eq.2

The order fulfillment rate has three components: total value sales orders waiting to be filled, cycle time, and capacity (Eq. 3). New customers are determined from order fulfillment rate and products per customer (Eq. 4):

OFR (t) = MIN (SOWF *(t)*)/minimum CT, Ca Eq. 3

NCu = OFR *(t)* / PpCu*(t)* Eq. 4

B. Inventory and order delay

The inventory mechanism in the developed model follows the same SD introduced by Sterman [7]. The inventory is controlled by the inventory gap between the production rate and the shipment rate level (Eq. 5).

I (t) = PR (t) – ShR *(t)* Eq. 5

The order delay is fulfilled by the total value sales orders waiting to be filled and the order fulfillment rate (Eq. 6). Order delay effect is given by the look up order delay and order delay

with normal delivery delay (Eq. 7).

OD (t) = SOWF *(t)*/OFR *(t)* Eq. 6

ODE (t) = LOD (t) (OD/NDD *(t)*) Eq. 7

C. Customer

The customer order rate level is calculated as the difference between the customer and the normal effective referral fraction Eq. 8, while customer is the integer of new customers Eq. 9:

CuOR(t) = Cu*NERF*(t)* Eq. 8

Customer = INTGER (NCu) Eq. 9

XII. Verification and Validation:

By using extreme condition tests, the structure of the model was directly validated[26]. Input values such as zero or infinity make the model behave as a realistic system. Extreme values were assigned simultaneously to all input variables in order to analyze the value of the output, which should be reasonable for a real system under the same extreme condition. The "Reality Check" function of Vensim simulation was used to achieve this. It is test in system dynamics and these tests are done to confirm the correctness of modeling and examine the results from the viewpoint of validity. Verification, dimensional- consistency, boundary adequacy and parameter verification tests have been performed implicitly during studying and modeling of the Consay Company.

The test is relevant to policy implications; it will be investigated in the following. As a general rule, a question is propounded in each test, and its answer leads to verification and validation of the proposed model. Without discussing the details, the interactions of this SD model are as follows. (There will be three levels to be modeled: inventory, total value sales orders waiting to be filled, and customers):

In this model, it is assumed that all the demand is being satisfied. The customer is a function of a random factor that introduces random fluctuations. The order rate level influences positively the order fulfillment rate while customer level influences the customer order rate. The new customer was modified by the costumer level with normal effective referral fraction and products per customer. In this model, it is assumed that if the inventory is high, the company lowers the product price. Capacity is an issue that every operation is faced with. Furthermore, it is an activity, which can profoundly affect the efficiency and effectiveness of the operation. It is concerned with making sure that there is some sort of balance between the demand placed on an operation and its ability to satisfy that demand. If an operation has too much capacity at any point in time, it will be underutilizing its resources. If it has too little capacity, its costs will be low (because its facilities will be fully utilized), but its customer service will be poor because it is either turning customers away or making them wait for their products and services. This will potentially undermine the company's success in the future. Therefore, there are serious consequences of getting the balance between demand and capacity wrong.

XIII. Numerical Simulation Results and Analysis

In order to illustrate the dynamic behavior and performance of the inventory policies, the SD Model demonstrates a sudden step change in the demand to give a dramatic shock to the system and represents cyclic demand fluctuating scenarios for which RMSs are designed. Policy differs from rules or law. While law can compel or prohibit behaviors, while policy merely guides actions toward achieve a desired outcome. Policies also refer to the process of making important organizational decisions. It is typically described as a principle to guide decisions and achieve rational outcome(s).Three responsiveness inventory order cycle policies are selected for the assessment of SD model:

A. Policy1: Making-to-order Performance and Chase Demand Plan:

The first policy is based on making to order for reducing inventory and increasing the level of customization, which is achieved by setting the products per customer demand to 1. Fig. 2 shows the first pattern that demonstrates a sudden step change in products per customer to give a dramatic shock to the system. The system responds well to such change.

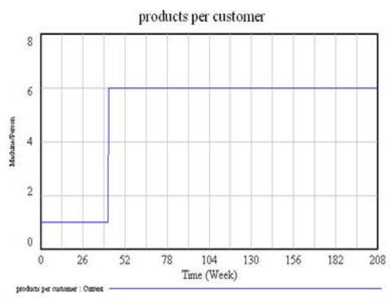


Fig. 2. Products per customer graph for sudden change scenario.

Dynamic modeling was performed for the Consay

Company and the simulated results were obtained by Vensim software. The correct prediction of system behavior as a result of dominant policy is changed by preceding efficient policies to utilize the facilities toward stable development and dominant policy is changed by making reasonable changes in the parameters' values or the equations formulation.

By setting products per customer demand to 1 the customers system immediately responds to the customer order rate and new customers shock by increasing the customer level to 25% Fig. 3. The total value sales order waiting to be filled is in turn decreased to match the demand increase Fig. 4. Production strategy is whereby the Output increase or decrease in the step with rising or falling demands, respectively. As demand varies, business strategy involves matching supply with the demand.

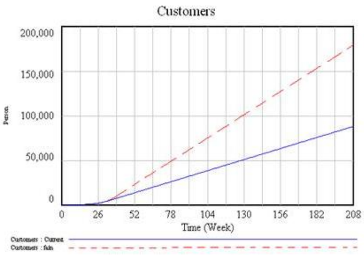


Fig. 3. Customer graph.

Fig. 4. Total value sales graph.

The strategy is suitable for the end suppliers of a product or service who can closely match supply and demand. A problem associated with this strategy is that, in periods of low demand, the company will be working below its maximum capacity and may have to make staff redundant. Methods of chasing demand include: employing staff on overtime when necessary, employing flexible and casual labour, buying in components that are usually made in-house; and outsourcing elements of the production process. This strategy is in contrast to a level output strategy, where the output is at the rate of the average demand. The plan for matching output to the customer needs, demands a production control plan that attempts to match capacity to the varying levels of forecasted demand. Chase demand plans require flexible working practices and place varying demands on equipment requirements. Pure chase demand plans are difficult to achieve and are most commonly found in the operations where output cannot be stored or where the organization is seeking to eliminate stores of finished goods.

B. Policy 2: Fixed and Changeable Demand

Some unpredicted events for responsiveness of the inventory order cycle policy in the Consay dynamic model have been reviewed on the basis of the importance (from the results of a questioner designed for this proposes). We assumed that increasing demand in the dynamic marketing effects on the inventory level and production rate. Fig. 5 shows the inventory level when the initial value for the inventory was 100,000 socks and with a product rate 1000 socks/day. The first pattern (the continuous line) demonstrates an inventory level when the product rate is equal to 1000 socks/day while the second one with the stable previous demand and a product rate is equal to 6000 socks/day.

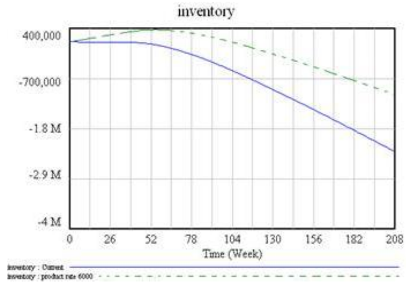
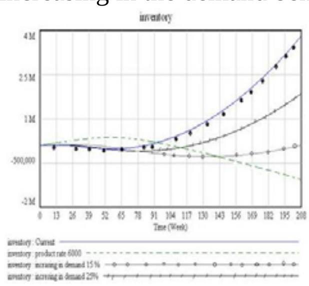


Fig. 5. Inventory graph.

The first pattern in Fig. 5 shows that the inventory level will be stable for 52 weeks and then the inventory level will be decreased. The second pattern in Fig. 5 illustrates the dynamic behavior when the company increases the product rate to 6000 socks/day and the effect remains ascending until 78 weeks, then the effect takes a decreasing trend.

In order to illustrate the dynamic behavior and performance of the inventory level, the effect of increasing demand from (10%) to (25%) on the inventory level was reviewed. Fig. 6 shows the dynamic behavior for the inventory level for the two demand patterns. Fig. 7 shows the product rate that company must realize with request to the increasing in the demand behavior.



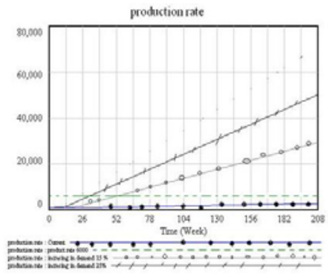


Fig. 6. Inventory level with 15-25% increase in the demand graph.

Fig. 7. Product rate level with 15-25% increase in the demand graph.

Other unpredicted events for the responsiveness of inventory order cycle policies reviewed when the demand will be decreased while the company stables the product rate. Fig. 8 shows the inventory level when the demand is decreased to (50%) with a stable production rate.

The first pattern shows that the inventory level will be stable for 78 weeks and then its level will decrease to its minimum level. The second pattern shows that when the demand decreases to (50%), the company could keep the inventory level for 104 weeks. Under this situation, the inventory cost will be increased and will, in turn, decrease the company's profit.

Other unpredicted event for responsiveness of inventory order cycle in the Consay Company was viewed when the demand was decreasing while was product rate increasing.

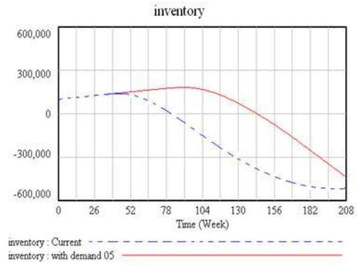


Fig. 8. Inventory level with 0.5 demand graph.

Fig. 9 shows that the increase in the product rate with the decreasing demand will cause an increasing of about 20% in the inventory level. Under this situation, the inventory cost will be increased, leading to decreasing in the company's profit.

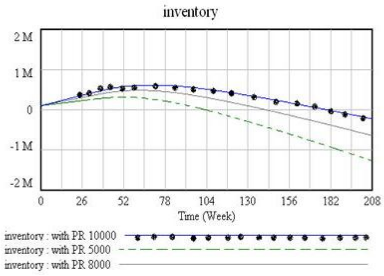


Fig. 9. Different inventory level for product rate graph.

XIV. Conclusion

In this paper, a dynamic model was presented to the responsiveness of Consay Company inventory by using the system dynamic's simulating tool and Vensim software. The aim is to help reconfigurable manufacturing systems to investigate the best policy for various demand scenarios. The Model, which was based on the system dynamic approach, reflects the dynamic nature of modern market demand patterns. The important is the behavior of different parameters of the model, not the numbers generated in the model runs. Different scenarios were developed merely to expose the system's behavior. Thus, they are mostly qualitative and may not represent any realistic future. This model was verified and validated based on the studies in the Polish Consay Company. Sensitivity analysis was applied on the parameters, and policies were presented. Simulating the model by the proposed policies led up to stable approximate stability of the inventory in the desired inventory policies. This matter facilitates exact production planning. The model can be generally used in Consay Company by selecting proper parameters.

References

[1] A.ARDALAN, "Optimal ordering policies in response to a sale," *IIE Trans*, 1988. 20, pp. 292-294.
[2] A.ARDALAN, "Optimal prices and order quantities when temporary price discounts result in increase in demand," *European J. of Op*. Res., 1994(72), pp. 52-71.
[3] Forrester, J.W., "Industrial dynamics," Cambridge, *MIT Press*. 1961.
[4] E.Chu, "A review of simulation studies on supply chain management," Publication: *Journal of Academy of Business and Economics*, 2003.
[5] J.D.Sterman, "Business dynamics: System thinking and modeling for a complex world," London, Irwin McGraw- Hill., 2000, pp. 1-600.
[6] Jay W. Forrester, "Counterintuitive behavior of social systems," *Technology Review*, Jan 1971. vol. 73(No. 3), pp. 52-68.
[7] J.D.Sterman, "Business dynamics: Systems thinking and modeling for a complex word," Irwin-McGraw-Hill 2000. ISBN 978-0-07-231135-8, pp. 1-917.
[8] M. R Goodman, "study notes in system dynamics Portland," Oregon: *Productivity Press*. 1989.
[9] R.G.Coyle, "System dynamics modeling: A practical approach," London: *Chapman and Hall*. 1996.
[10] Sterman, J.D.o.c., pp.1-600.
[11] G.P Richardson, "Problems for the future of system dynamics," *System Dynamics Review* 1996. 12(3), pp. 141-157.
[12] E. Wolstenholme, "System enquiry: A system dynamics approach," NY: John Wiley and Sons, Inc., 1990.
[13] J.O., R. Homer, "Maps and models in system dynamics: A response to Coyle." *System Dynamics Review*, 2001. 17, pp. 347-355.
[14] Ford, A.I., "Modeling the environment: An introduction to system dynamics models of environmental systems," *Sland Press Washington*, DC. 1999.
[15] Haraldsson and Sverdrup, I.W., J. and Mulligan, M, "Finding simplicity in complexity in biogeochemical modeling," (eds.) Environmental modeling: Finding simplicity in complexity, 2003. *Wiley* (New York), pp. 211-213.
[16] H.V. Haraldsson, "Introduction to systems thinking and causal loop diagrams," Technical report, *Department of Chemical Engineering. Reports in Ecology and Environmental Engineering*, 2004. Lund University, pp. 1–49.
[17] J.R. Burns, "Simplied translation of CLDs into SFDs," In *Proceedings of the 19.International Conference of the System Dynamics Society, Atlanta, GA*, 2001.
[18] Randers, J.J.R. and Communications, "Guidelines for model conceptualization," in Elements of the System Dynamics Method. MA: Pegasus, 1980. ed. Waltham, pp. 117-139.
[19] Homer, H. J.Oliva, and R Oliva, (2001). "Maps and models in system dynamics: A response and to Coyle," *System Dynamics Review*, pp.347–355.
[20] Ford, o.c., 1999.
[21] Haraldsson and Sverdrup, o.c., 2003.
[22] Burns and J.R Ulgen, "A component strategy for the formulation of system dynamics models," In *Proceedings of the 20. International Conference of the System Dynamics Society*, 2002. Palermo, Italy.
[23] Wolstenholme, E.o.c., 1990.
[24] J.W. Forrester, "Principles of systems," Cambridge, 1968. *MIT Press*.
[25] D.R. Towill, S.d.-b., "Methodology, and applications," Comput. Control Eng. J. 4 (5) (1993) 201–208.
[26] I, S.J.B., "Business dynamics: Systems thinking and modeling for a complex world," rwin/McGraw-Hill, 2000.