Control Returnability Inventory Using System Dynamic Modeling and Fuzzy Logic

Muhammad Talha[1], Syed Ahmad Helmi[1,2], and Azanizawati Ma'aram[1]
[1]Faculty of Mechanical Engineering,
Universiti Teknologi Malaysia,
81310 Johor, Malaysia
muhammadtalhashoaib@hotmail.com, helmi@utm.my, niza@utm.my

[2]Center for Engineering Education
Universiti Teknologi Malaysia,
81200 Skudai, Johor Bahru

Muhammad Hisjam
Department of Industrial Engineering, Faculty of Engineering,
Sebelas Maret University
Surakarta, Indonesia
hisjam@staff.uns.ac.id

Abstract

Currently, most of the companies manage inventory in a traditional supply chain approach. But due to the company's policies in return services and remanufacturing processes, a traditional supply chain is not really effective. The importance on working on inventory control is because of the difficulty of having a stable inventory control due to bullwhip effect which reduces the performance of supply chain. There is now Close Loop Supply Chain (CLSC) use for the benefit of companies as it is very effective in reverse logistic flow. This effects the collection and distribution planning, inventory control, and production planning which reduces the effect in returnability which will increase the performance of the company. This project focuses on inventory control. This work successfully develops System Dynamic (SD) model of the system for returns, using close loop diagrams, to have effective management of inventory control and remanufacturing and/or production planning. Fuzzy Logic is used in the model analysis to optimize inventory control and reduce the bullwhip effect in the real-world. This fuzzy decision makes the system less uncertain and creates lower bullwhip effect.

Keywords
Returnability; Bullwhip Effect; System Dynamics Modeling; Fuzzy Logic

1. Introduction

The managers and policy makers face challenges at increasing rates due to the increasing pace of social, commercial, environmental and industrial evolution. However, such revolutions create complications of the system which is growing very fast (Sterman, 2000). The past actions can cause chain reactions that have many unexpected side effects and such effects create problems. Many times, the problem worsens, or sometimes new problems are created as the policies executed to resolve important problems fail.

This paper brings forward the report about System Dynamics (SD) modeling that can analyze business applications where it emphasizes on business policies and strategies. SD models are used to design strong policies for success which need to be understood first. As an organizations performance is interrelated to its internal structures and operating policies that is connected to those of suppliers, competitors, manufacturers and customers and retailers. It helps improve humans understanding for the different possibilities on how the organization is performing which is the aim of system thinking and SD model. The tool pursues human-like behavior, therefore the reasoning is based on human-like attributes that includes physical and technical system, reasoning, social psychology economics and further social science. To accelerate effective change in the organization and learn how to implement it, managers must learn in a way to work efficiently with the policy maker where a build System Dynamic model is to resolve crucial real-world problems.

The next part of the report is the work on the fuzzy logic system. It is an effective tool that helps decide based on experience operator knowledge. On behalf of the practical experience of the operator, a rule-based system is created. This is based on the prior experience of the operator. It works like Artificial Intelligence (AI) software and just like a subset of AI which takes decision on conditions (Negnevitsky, 2005). Since SD is based on non-linear system, a nonlinear logic system is appreciated for which fuzzy logic is perfectly suited. It can have multiple inputs with multiple outputs that can be fit in with, and it does not have the limits for the number of inputs and outputs if it is a reasonable number. Fuzzy logic works effectively where the model of a system could not be made by conventional method (Dingle, 2014).

The products supplied are sometimes returned due to end of product life cycle, unsatisfactory merchandise or order cancellation. Apparently negative orders are return of excess goods and this assumption is further in detail to cover unlimited and costless returns. It shows that if negative orders are allowed, this does not match inventory literature instead the research done on bullwhip effects has assumed that excess stock can return where during the return process there are no additional cost incurred (Chatfield, 2013). The demands from the customers may exhibit low variation but demands placed at higher level nodes upstream cause increasingly greater level of variation for which the end nodes of the upper supply chain steam show the greatest variation (Chatfield, 2013).

The research objective is to develop a methodology that can minimize or mitigate the oscillations occurring in a returnability by utilizing the techniques of SD Modeling and fuzzy logic. There is a need to develop the model related to returnability which accounts different facilities and variables and use it as a tool that helps effective and efficient decision making using operation to optimization.

2. Literature Review

Productions and inventory functions are not only the reason for the cause of the Bullwhip effects but also operation instability and transportation providers can create increment of bullwhip effect (Costantino, 2015). The machine dependability, process capability and supply inconsistency could also be the possible reasons for the bullwhip effect (Taylor, 2000). Companies face tremendous challenges when dealing with bullwhip effect. The common indicators of such effect would be extreme level of inventory, unsatisfactory forecasts, scarce or excessive capacities, substandard consumer service, uncertain production planning and control due to accumulated backlogs and overdue shipments (Ingalls, 2005).

SD model is a mean to produce and illustrate the mental nodes of a difficult problem in the real world that a person holds. A powerful model and procedures for simulation of the more than what mental models are limited to, new policies are proposed, new skills are worked on, services on scientific reasoning methods are improved including group procedure and lastly it helps individuals and teams to coup up with defensive practices.

Selecting the right membership function plays a critical role in designing a fuzzy logic controller. The shape of membership function could be defined based on efficiency, convenience and simplicity. Many different membership functions have been introduced in the literature, however, the commonly used membership functions are triangular, trapezoidal and Gaussaian (Youssefi, 2011). The fuzzy output is determined by the degree of fulfillment and the consequent part of the rules. The most common techniques to modify the output fuzzy set are truncation using min function or scaling using prod (product) function (Youssefi, 2011).

Integration of SD and Fuzzy Logic has been researched which showed effective results such as one proposed this method to create a rapid model prototyping process of developing a pandemic dynamics model. This can facilitate quantitative analysis for policy making in pandemic mitigation interventions (Ng, 2010). Another paper developed carbon-tax design in the residential sector where with system dynamics the consumers' behavior and the continuous tax-control mechanism depending on few important feedbacks are simulated and then shows how aggregate external data driving this model and stemming from different sources with various credibility levels using fuzzy for better control (Kunsch, 2008). Another paper that integrated these is risk management studies on projects (Nasirzadeh, 2008).

These papers help to understand how similar problems were solved using system dynamics and fuzzy logics. Many of these papers have shown problems related to manufacturing or remanufacturing and decision making. However, there is hardly any paper that shows integration of fuzzy logic in system dynamics in returnability. Thus, this paper will present how such integration is done.

3. Data Analysis and Model Making

A step-by-step method is used to create a SD model of the system. Firstly, Casual Loop Diagram (CLD), a qualitative model, is made that will consider the important factors and variables that have relation between each other or will affect the behavior of the whole system. This will look for the feedback loops that are very necessary to know. Later a Stock and Flow Diagram (SFD) is made, a quantitative model by looking at CLD and then categorize the variables into stock, flow or auxiliary variables. This model can also be used to simulate different conditions with different constraints which are related to returns (Poles, 2010).

Figure 1 shows CLD for the return. A CLD is developed that shows the cause and effects, including relationship and feedbacks for the whole system which a qualitative modeling with seven feedback loops, showing the relationship. The focus of this model is on serviceable inventory, recoverable inventory, productions and remanufacturing.

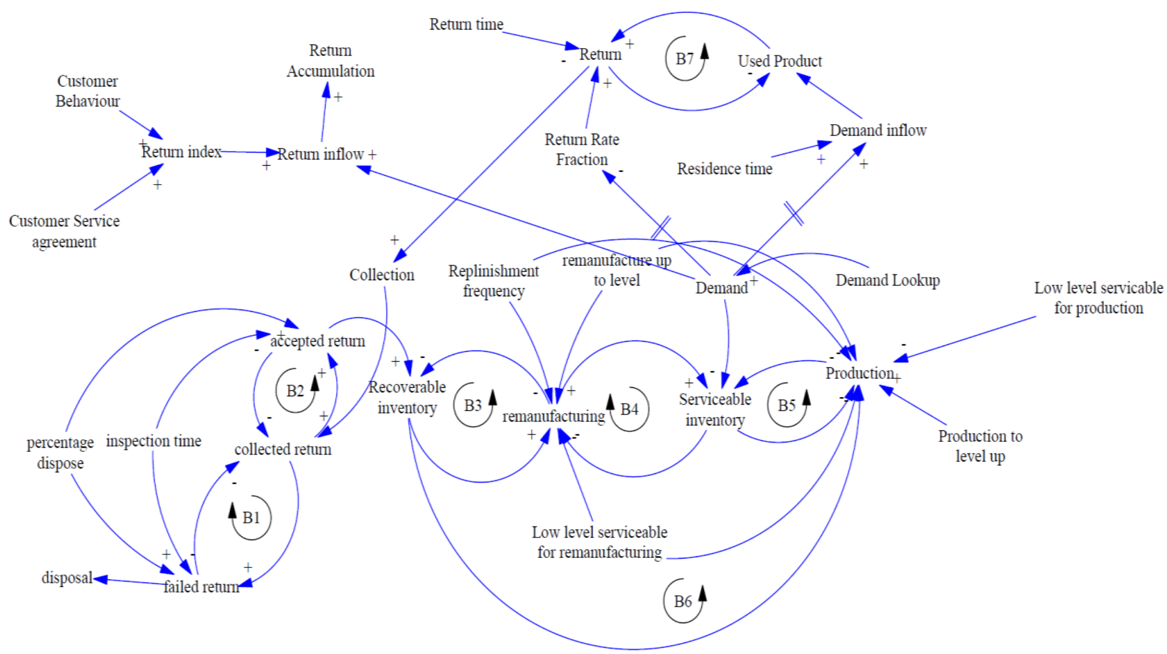

Figure 1: Casual Loop Diagram for the return

Figure 2 shows SFD of the system model. This is developed with the help of CLD, where it needs to identify what variables are stocks and what are flow variables and what are auxiliary variables. The dynamic relationship is shown for production and inventory for remanufacturing in SFD which is set of numerical equations. The equations are used in Vensim where different model validation techniques are used which includes Direct Structure Validation, Boundary Adequacy Test, Dimensional Consistency, Parameter Assessment and Integration Error Tests.

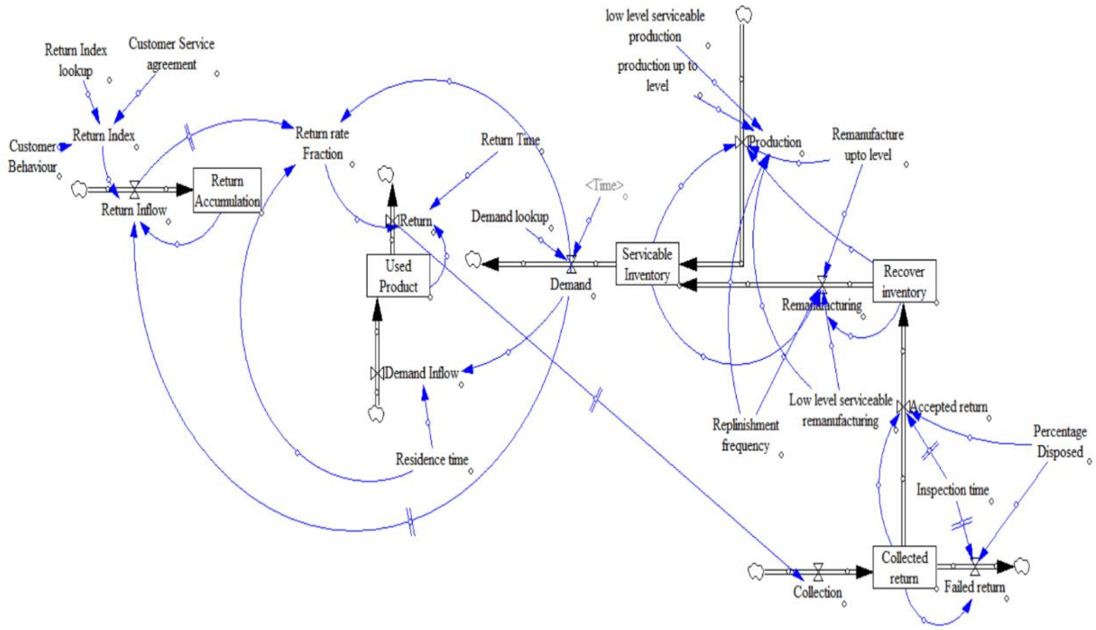

Figure 2: Stock and Flow Diagram

As the models are created and verified, the objective to create a fuzzy system is formulated. The supply chain model uses the judgment of the decision makers for replenishment policies which is considered as a soft variable. There are two major phases in modeling a soft variable with fuzzy logic in the proposed simulation model. The first phase is to find relation between input and output which can be presented as a fuzzy inference system in MATLAB® and define fuzzy rules. The second phase is to transform the Fuzzy Inference System (FIS) into the form of a mathematical representation which can be implemented in the constructed simulation model in Vensim®.

Three inputs have been identified in this regard which are recoverable inventory level, serviceable inventory level and incoming demand and two outputs as remanufacturing and production. An assumption is done, due to scope limitation that the current membership function is made with equal distributions of range of values instead of using algorithm, for example 0-33% of the relative value is low, 34-66% is medium and 67-100% of the relative value is considered high. Since there are 3 inputs, different combinations make 27 combinations rules.

The aim of this system is to optimize the target level of inventories which is serviceable inventory and recoverable inventories. For this reason, by using MATLAB Simulink on fuzzy controller, example is taken for the scenario of the company where there are returns and carried forward inventory and with the given demand, there will be the production and remanufacturing to be done which can control the inventory better.

To keep simplicity, the values are input at a specific instant. This means that pulse of values is sent to make the fuzzy controller decide the output. This analogy can be used in such a way that the manager can do aggregate planning or make short term schedule. For example, at the end of each week, a manager can look at the inventory level 52 times and decide the right number of production and remanufacturing. So, this way every week there is a specific value of demands and inventories level. The fuzzy will then simply decide the right amount to work on the number of products.

The study has 5 scenarios model made using fuzzy logic controller with different inputs. To compare these outputs, the next step is to make a table for the 5 scenarios in which change in production and change in remanufacturing is done. Once this comparison is done when fuzzy is not used and using the amount required to fulfill demand, it will show the difference in oscillation. This fuzzy logic decision making can reduce the amplitude therefore reduce the bullwhip effect. The reason being the delays that are not accounted therefore the decision are based on current situation. Fuzzy can be helpful to account the delays.

4. Results

SD simulation model for the closed loop supply chain is made for inventory of remanufacturing and production. The objective of the simulation was to see the model relationship between factors that affects the system for return process. The main factors were residence time and return index where return index was due to service agreement with customers and customer behavior.

The SD modeling process has step by step to complete, where firstly it started with the making of CLD which was qualitative modeling and description of main feedback loops. Then the model involved quantitative approach with SFD that included numerical formulas. The model was then tested for validation for extreme condition test and behavior test including homogeneity of the units. After validation, simulation analysis was done using different parameters to see the return process like residence time, service agreement with customers and their behavior.

The inventory cost in a manufacturing company is high therefore there is a need to have the cost least enough to give best customer service. This shows the performance of the company in terms of inventory handling and therefore with the help of the model, further steps are taken by using fuzzy controller to optimize the inventory and in addition reducing the bullwhip effects.

5. Conclusion

In the production and remanufacturing and its inventory there are some important factors a manager must identify. This paper has used some important factors that cause impacts in the inventory, thus cause production and remanufacturing changes. With the help of the SD model, the study was able to not only recognize the control strategies in the system of remanufacturing, but also improve the whole system related to returns and within closed loop supply chain. The model is mainly based on electronic consumer industries where the variables and factors are quite similar in returns, including the inventories for remanufacturing and production run. Therefore, the model could work on many electronic consumer-based companies where managers could understand the impact of the variables and therefore could compare the models, and simulate them with real world. However, this model is also usable for other manufacturing industries that are not related to electronic, but changes could be done on their variables and relationships. This SD Model could be added for further research where it can be integrated with other factors such as capacity and facilities planning, information sharing, supply chain management, etc. These additional combined models will give bigger scope for bigger closed loop supply chain. However, other endogenous, exogenous and excluded variables should be included where different assumptions could be used.

Acknowledgements

The author would like to thank The Center for Engineering Education of Universiti Teknologi Malaysia and Fundamental Research Grants Scheme (FRGS) under the Ministry of Education Malaysia, Vot Number R.J130000.7824.4F957 and the Sebelas Maret University, Surakarta, Indonesia for partly supported this research.

References

Chatfield, Dean C., and Alan M. Pritchard. "Returns and the bullwhip effect." *Transportation Research Part E: Logistics and Transportation Review* 49, no. 1 (2013): 159-175.

Costantino, F., Giulio, D.G., Ahmed, S., and Massimo, T. "SPC forecasting system to mitigate the bullwhip effect and inventory variance in supply chains." *Expert Systems with Applications* 42, no. 3 (2015): 1773-1787.

Dingle, Norm. "Artificial Intelligence: Fuzzy Logic Explained." *Retrieved October* 6 (2011): 2014.

Ingalls, R.G., Bobbie L. Foote, and Ananth Krishnamoorthy. "Reducing the bullwhip effect in supply chains with control-based forecasting." *International Journal of Simulation and Process Modelling* 1, no. 1-2 (2005): 90-110.

Kunsch, P., and Johan Springael. "Simulation with system dynamics and fuzzy reasoning of a tax policy to reduce CO2 emissions in the residential sector." *European journal of operational research* 185, no. 3 (2008): 1285-1299.

Nasirzadeh, F., Abbas Afshar, Mostafa Khanzadi, and Susan Howick. "Integrating system dynamics and fuzzy logic modelling for construction risk management." *Construction Management and Economics* 26, no. 11 (2008): 1197-1212.

Negnevitsky, Michael, and Vsevolod Pavlovsky. "Neural networks approach to online identification of multiple failures of protection systems." *IEEE Transactions on Power Delivery*20, no. 2 (2005): 588-594.

Ng, T.S., Shao Wei Lam, and Mong Soon Sim. "Pandemic Dynamics with Social Effects: Rapid Model Prototyping with Fuzzy Logic", Proceedings of the 28th International Conference of the System Dynamics Society, (2010)

Poles, R., "System Dynamics modelling of closed loop supply chain systems for evaluating system improvement strategies." (2010).

Sterman, John D. *Business dynamics: systems thinking and modeling for a complex world*. No. HD30. 2 S7835 2000. 2000.

Taylor, D.H, "Demand amplification: has it got us beat?" *International Journal of Physical Distribution & Logistics Management* 30, no. 6 (2000): 515-533.

Youssefi, H., V. Nahaei, and J. Nematian. "A new method for modeling system dynamics by fuzzy logic: Modeling of research and development in the national system of innovation." *Journal of Mathematics and Computer Science* 2, no. 1 (2011): 88-99.

Biographies

Muhammad Talha is a M. Sc. Industrial Engineering graduate from Universiti Teknologi Malaysia (UTM) with B. Eng. Mechanical Engineering degree from University of Nottingham. Currently he is in a consultant firm. After completing his Masters, he had joined GE aviation to work on a Six-sigma project where he earned the prestigious “Impact Award” by the organization. Prior to joining UTM as post-graduate student, after completing his bachelors, he worked with two multinational companies; Philips Pakistan, 3M Pakistan and a local Malaysian firm. However, his interest in manufacturing and engineering management influenced him to pursue his Master degree in the area. He has also developed key artistic and organizational skills as he worked in both individual and group projects. He is also passionate about the manufacturing industry as a whole and is driven to deliver high-quality work that will solve problems and develop new horizons and frontiers in the industry.

Syed Ahmad Helmi is a faculty member at the Faculty of Engineering, Universiti Teknologi Malaysia. He received his Bachelor of Science in Mechanical Engineering, Master of Engineering in Advanced Manufacturing, and PhD in Engineering Education. He is currently a fellow at the Centre for Engineering Education, and head of the university Research Group in Engineering Education (RGEE). Prior to joining UTM, he worked as a maintenance engineer at INTEL, Malaysia, as research officer at the Standard and Industrial Research Institute of Malaysia (SIRIM), and as mechanical and industrial engineer at Sime-Darby, Malaysia. His research focuses on Mechanical Engineering, Industrial Engineering and Engineering Education. His recent work includes academic change management, complex engineering problems, manufacturing systems and optimization, supply chain, and systems dynamic modelling. Over the years, he has conducted several workshops on Outcomes-Based Education (OBE) particularly in Student Centred Learning (SCL) throughout Malaysian higher institutions, and international institutions such as in Indonesia, Korea, India, China, Turkey, Morocco, Qatar, Pakistan, and Afghanistan. He has published several books and more than 80 papers in journals and conference proceedings.

Azanizawati Ma’aram is a senior lecturer at the School of Mechanical Engineering, Faculty of Engineering, Universiti Teknologi Malaysia (UTM). She obtained her Bachelor of Engineering (Mechanical-Industrial) and Master of Engineering (Advanced Manufacturing Technology) from Universiti Teknologi Malaysia, Malaysia. She pursued her Doctorate of Philosophy (Ph.D) (Management) at the University of Liverpool, United Kingdom. She has held several positions including Head of Industrial Panel, Postgraduate Coordinator for Master of Science (Industrial Engineering), and Laboratory Coordinator for Industrial Engineering. She is a member of the International Association of Engineers (IAENG), the Board of Engineers (BEM) Malaysia and the Malaysia Board of Technologists (MBOT). She has taught courses in industrial engineering, supply chain management (undergraduate and postgraduate level), engineering management and safety, work design, ergonomics and research methodology. Her research interests include supply chain management, performance measurement, lean manufacturing, sustainability, ergonomics and safety. She is currently active as a Project Leader and a Project Member on numerous research projects and has secured several grants funded by the university and Ministry of

Education (MoE) that involve hospitals and industry collaborators. She has also conducted training on behalf of private companies and university on analysis of data.

Muhammad Hisjam is with the Department of Industrial Engineering, Faculty of Engineering, Universitas Sebelas Maret, where he has been there since 1998. He received his Bachelor degree from Universitas Gadjah Mada, Indonesia in 1986, and a Master degree from Institut Teknologi Bandung, Indonesia in 2002. He received his Ph.D. in Environmental Science from Universitas Gadjah Mada, Indonesia in 2016, with his dissertation titled: "Sustainable Supply Chain Model in Export Oriented Furniture Industry in Indonesia (Case in Perum Perhutani)". His research interests are in supply chain, logistics, business and sustainable development. He has published several papers in journals, conference proceedings, and chapter books in his research area.