

# A System Dynamics Framework for an Integrated Forward-Reverse Supply Chain with Fuzzy Demand and Fuzzy Collection Rate under Possibility Constraints

Debabrata Das and Pankaj Dutta

**Abstract**— Reverse supply chain management has been an area of growing attention during the last decade in industry as well as in academia due to its high economic impact, increasing social awareness and strict legislations. In this paper, we develop a simulation model based on system dynamics methodology to analyze the long-term behavior of a multi-echelon forward-reverse supply chain with fuzzy demand and fuzzy collection rate by incorporating various recycling activities, namely; collection, product refurbishing, component reuse and refurbishing, and raw material recovery. The uncertainty issues associated with acquisition and collection of used product in the proposed reverse logistics network has been quantified using possibility measures. In the proposed model, it is assumed that the customer can exchange their old used product with a fresh new product in a primary market or a relatively better refurbished product in a secondary market at a discounted price. In the simulation study, we compare the bullwhip effects of different logistics participants over time with and without product exchange policy. Our results suggest that the inclusion of product exchange policy in the primary as well as in the secondary market reduce the order variation and bullwhip effect at both retailer and distributor level. Finally, sensitivity analysis is performed to examine the impact of various parameters on recovery process and bullwhip effect.

**Keywords**— Reverse Supply Chain, Bullwhip Effect, Fuzzy Collection Rate, System Dynamics, Possibility Measures

## 1. INTRODUCTION

IN a world of finite resources and disposal capacities, recovery of used products and materials is a key to support the growing population at an increasing level of consumption. Pagell *et al.* [1] pointed out that product remanufacturing is the most desirable option for end-of-life product management than a scrap or spares recovery since it minimizes the environmental impacts, results in lower loss of value, and can create new market opportunities. Refurbished products are often offered as an alternative to the original products in a secondary market to the customers those are attracted by the brand, but do not wish to pay the price of a new product (e.g. electronics and automobile) [2].

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In the present study, we address the benefits of employing product exchange (PE) policy both in primary as well as in secondary markets to increase the collection rate of used products and consequently selling of refurbished products.

Fleischmann *et al.* [3] provided a review of the quantitative models for reverse logistics in which they reported that most of the papers in the area of integrated reverse logistics are confined to single issues while comprehensive approaches are rare as variety of factors are involved in a general framework and the complexity of their interdependencies. System dynamics (SD) is a powerful methodology for obtaining the insights of these kinds of problems having dynamic complexity; but there are very few literatures which modeled the integrated aspects of forward and reverse supply chain using SD. Spengler and Schroter [4] modeled an integrated production and recovery system for supplying spare parts using SD to evaluate various strategies. Georgiadis and Vlachos [5] developed a SD model to evaluate the effect of environmental issues on long-term decision making in collection and remanufacturing activities.

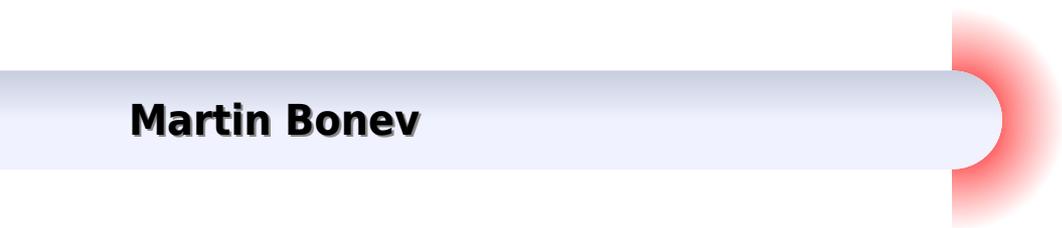
In real supply chain problems, input data or parameters are frequently imprecise because some information is either incomplete or unobtainable. Fuzzy set theory gives a strong mathematical structure to capture such imprecise and to model a real decision-making problem. In this paper, we develop a SD framework for an integrated forward-reverse supply chain by incorporating fuzzy demand, fuzzy collection rate and fuzzy satisfaction rate of demand. The uncertainty issues associated with acquisition and collection of used product have been quantified using possibility measures.

As the quality and quantity of used products return to the collection points are uncertain in the reverse channel, the systematic distortion is inevitable and bullwhip effect may occur at retailer, distributor and manufacturer level. There are very few literatures that consider order variations and bullwhip effect in an integrated reverse supply chain ([6]-[7]), but it is yet to receive attention in the context of SD framework ([8]-[9]).

In this paper, we propose a SD framework for an integrated reverse logistics (RL) network to analyze the forward as well as backward movements of product through different stages of supply chain network with three way recovery (TWR), namely; product refurbishing, component reuse & refurbishing, and raw material recovery. We bring

# A System Dynamics Framework For An Integrated Forward

**Martin Bonev**



## **A System Dynamics Framework For An Integrated Forward:**

*IAENG Transactions on Engineering Technologies* Gi-Chul Yang, Sio-Iong Ao, Xu Huang, Oscar Castillo, 2012-12-28 This volume contains revised and extended research articles written by prominent researchers participating in the conference. Topics covered include engineering physics, communications, systems control theory, automation, engineering mathematics, scientific computing, industrial engineering, and industrial applications. *IAENG Transactions on Engineering Technologies Special Issue of the International MultiConference of Engineers and Computer Scientists 2012* offers the state of art of tremendous advances in engineering technologies and physical science and applications and also serves as an excellent reference work for researchers and graduate students working with on engineering technologies and physical science and applications.

Managing Reverse Logistics Using System Dynamics: A Generic End-to-end Approach Martin Bonev, 2012-03

As legislations have become stricter and the competition on markets is getting stronger, companies facing return flows strive for the implementation of efficient and cost effective reverse logistic procedures. At the same time when managing reverse logistics they are not only confronted with a high degree of uncertainties concerning the quality, quantity and timing of the product returns, but also with a dynamically changing environment. Various aspects such as the increasing amount of return flows, shorter repair and lead times, as well as increasing disposal costs, affect the reverse logistic system and need to be managed proficiently. Additionally, handling product returns requires supportive computer aided modelling tools that are capable of handling the dynamic and complex characteristics of the reverse logistic system and allow an improved estimation of the impact of a changing environment and management decisions. For the purpose of this study, the system dynamics modelling approach has been identified as particularly suitable for illustrating the system in question, with a special focus on understanding the dynamic behaviour over time. A generic system dynamics model has been exemplarily created and simulated using the program iThink. The model comprises end to end processes of the main reverse logistic activities related to customer returns and has been used for studying the strategic design and optimization of the reverse logistic system. In order to consider relevant uncertainties, as well as environmental concerns and economic efficiency, representative policies have been applied, where inter alia, with the help of the graphical illustration of the processes, effective strategies could be implemented. A general evaluation of the system dynamics methodology has revealed the significant advantages of using supportive modelling techniques for strategic decision making. Particularly for complex systems that change over time, such as reverse logistics, applying appropriate computer aided modelling tools in order to anticipate the overall effect on processes caused by varying surroundings has proven essential. An effective utilization of system dynamics may significantly reduce the forecasting and planning risks within individual frameworks such as capacity planning. Moreover, the generic approach allows the application of the model to any other industry that is characterized by uncertain capacity utilization and varying technical, economical and legal conditions.

**Assessing and Optimizing the Reverse Logistic Process Using Computer Aided**

**Modelling Techniques** Martin Bonev, 2011-08-09 Inhaltsangabe Introduction As the world population is growing continuously and emerging markets are expanding natural resources are being used even more intensively Because of the scarcity of natural resources industry faces a changing business environment Due to government regulations companies nowadays must handle not only in terms of efficiency but also of sustainable development and new market opportunities Thus with the progression of the logistics sector in recent years supply chain management and especially the concept of reverse logistics have become more important for both industry and science By utilizing reverse logistics companies aim at maximizing their product revenue while reducing the costs of product returns Accordingly implementing an effective concept of reverse logistics while manufacturing environmentally friendly products has become a strategic issue In order to meet the requirements companies are confronted with the problem of reducing the uncertainties regarding the quality quantity and timing of the product returns In this context a high level of uncertainty leads to a strong increase in complexity compared to the traditional forward supply chains Using modern computer aided modelling techniques such as system dynamics helps to counteract this complexity since they not only enable a better understanding of the dynamic behaviour of such complex systems but also allow an improved estimation of the impact of a changing environment and management decisions This thesis contributes towards an improvement of the strategic decision making process in the field of reverse logistics by providing a generic simulation model which can be used to analyse the influence of different environmental and economical policies with respect to prevailing market conditions To achieve this objective the following approach is proposed In Chapter 2 the theoretical foundation of reverse logistics is characterized forming the framework for the subsequent analytical approach concerning the appropriate model development For this purpose first an overview of the state of the art concerning the processes and influencing factors within the field of reverse logistics is provided This is achieved by describing the theoretical background of the topic including a characterization of the impact of individual reverse logistic activities on each other and on their environment Afterwards current challenges and trends when

**Routledge Handbook of the Resource Nexus** Raimund Bleischwitz, Holger Hoff, Catalina Spataru, Ester van der Voet, Stacy D. VanDeveer, 2017-12-14 In recent years the concept of the resource nexus has been both hotly debated and widely adopted in research and policy circles It is a powerful new way to understand and better govern the myriad complex relationships between multiple resources actors and their security concerns Particular attention has been paid to water energy and food interactions but land and materials emerge as critical too This comprehensive handbook presents a detailed review of current knowledge about resource nexus related frameworks methods and governance including a broad set of inter disciplinary perspectives Written by an international group of scholars and practitioners the volume focuses on rigorous research including tools methods and modelling approaches to analyse resource use patterns across societies and scales from a nexus perspective It also provides numerous examples from political economy to demonstrate how resource nexus frameworks can illuminate issues such as

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## **Table of Contents A System Dynamics Framework For An Integrated Forward**

1. Understanding the eBook A System Dynamics Framework For An Integrated Forward
  - The Rise of Digital Reading A System Dynamics Framework For An Integrated Forward
  - Advantages of eBooks Over Traditional Books
2. Identifying A System Dynamics Framework For An Integrated Forward
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an A System Dynamics Framework For An Integrated Forward
  - User-Friendly Interface
4. Exploring eBook Recommendations from A System Dynamics Framework For An Integrated Forward
  - Personalized Recommendations
  - A System Dynamics Framework For An Integrated Forward User Reviews and Ratings

- A System Dynamics Framework For An Integrated Forward and Bestseller Lists
- 5. Accessing A System Dynamics Framework For An Integrated Forward Free and Paid eBooks
  - A System Dynamics Framework For An Integrated Forward Public Domain eBooks
  - A System Dynamics Framework For An Integrated Forward eBook Subscription Services
  - A System Dynamics Framework For An Integrated Forward Budget-Friendly Options
- 6. Navigating A System Dynamics Framework For An Integrated Forward eBook Formats
  - ePub, PDF, MOBI, and More
  - A System Dynamics Framework For An Integrated Forward Compatibility with Devices
  - A System Dynamics Framework For An Integrated Forward Enhanced eBook Features
- 7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of A System Dynamics Framework For An Integrated Forward
  - Highlighting and Note-Taking A System Dynamics Framework For An Integrated Forward
  - Interactive Elements A System Dynamics Framework For An Integrated Forward
- 8. Staying Engaged with A System Dynamics Framework For An Integrated Forward
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers A System Dynamics Framework For An Integrated Forward
- 9. Balancing eBooks and Physical Books A System Dynamics Framework For An Integrated Forward
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection A System Dynamics Framework For An Integrated Forward
- 10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
- 11. Cultivating a Reading Routine A System Dynamics Framework For An Integrated Forward
  - Setting Reading Goals A System Dynamics Framework For An Integrated Forward
  - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of A System Dynamics Framework For An Integrated Forward
  - Fact-Checking eBook Content of A System Dynamics Framework For An Integrated Forward
  - Distinguishing Credible Sources

13. Promoting Lifelong Learning
  - Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
14. Embracing eBook Trends
  - Integration of Multimedia Elements
  - Interactive and Gamified eBooks

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