Development of an Integrated Framework of RFID Based Supply Chain of Perishable Products

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Development of an Integrated Framework of RFID Based Supply Chain of Perishable Products

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CERTIFICATE

This is to certify that the thesis entitled "***Development of an Integrated Framework of RFID Based Supply Chain of Perishable Products***" is being submitted by ***Mr. Chandrakumar Mukundaji Badole*** **(ID No.2010RME107)** to the Malaviya National Institute of Technology, Jaipur for the award of the degree of **Doctor of Philosophy** in Mechanical Engineering is a bonafide record of original research work carried out by him. He has worked under our guidance and supervision and has fulfilled the requirement for the submission of this thesis, which has reached the requisite standard.

The results contained in this thesis have not been submitted in part or full, to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

Perishable product supply chains (PPSCs) face tremendous pressure of supplying the right quantity of product at the right time with optimum quality. This is because of cut throat competition that exists in the globalized market. Inadequate information system makes the routine supply chain process more complicated rather than resolving the problems faced by supply chains. Because of limited shelf life, the perishable products continuously undergo deterioration in quality from the time of production until consumption.This is a major challenge for meeting customer’s quality requirement. Spoilage is another big problem of perishable products and it is caused principally due to excess stock and flawed stock rotation. Effective stock rotation ensures that products are taken from the storage in the correct order as determined by their sell-by dates. Besides the aforementioned complications, product proliferation, seasonality, limited market places, and varying weather conditions are the other challenges faced by the supply chain partners on a day-to-day basis.

Therefore, having a sound information system at all nodes of a supply chain is necessary for sharing timely information at every stage of the supply chain. This will help in the proper planning and execution of all supply chain activities in the right direction. The Radio frequency identification (RFID) would be a better solution for resolving the problems of the supply chain. RFID technology with its unique characteristics can enhance data collection processes along the supply chain. It is an automatic identification and data capture technology. This technology with the appropriate IT infrastructure would help major distributors and manufacturers as well as logistics operations, healthcare system, defense industries, and the systems dealing with complex, global PPSCs in which products and product shipments must be traced

and identified in a non-contact, wireless fashion using a computer network as perishable items are subjected to degradation.

The supply chain of non-perishable and perishable products has been widely investigated. However, research on the incorporation of newer technologies such as RFID and its benefits to the supply chain is scare and in preliminary stages. Most of the research in the area of perishable products consider unrealistic situations and the models are very difficult to implement in real situations. Majority of the researchers have considered the unrealistic condition of zero lead time. On the other hand, due to lack of knowledge regarding calculation of benefits, return on investment (ROI) of RFID, and system in the supply chain, most of the engineers do not incorporate it in their organizations and thus are devoid of the advantages of RFID system while companies such as Wal-Mart and Dell are gaining from it.

Motivated by the aforementioned facts, the proposed research work presents the frame work for an RFID-based supply chain of perishable products. In this frame work, a mathematical model was developed for the total supply chain cost and order quantity. While developing the model, realistic situations that prevail at any node of supply chains were considered. The frame work provides suggestions for minimizing the total cost of the supply chain as the effect of RFID in a PPSC. The model was constructed considering single order differential equations in the integral form.

The total cost consists of various supply chain cost elements, namely, replenishment cost, holding cost, deterioration cost, backlogging cost, opportunity cost, and crashing cost. In the current study, all these cost elements were considered for the total cost calculations to arrive at more accurate results than those of the earlier studies. A complete modeling framework was analyzed using the MATLAB programming platform. The model was validated considering a case study with the realistic conditions of the demand pattern, deterioration rate, and rate of backlogging. A sensitivity analysis was performed for the deterioration and backlogging parameters to determine their effect on the total cost, order quantity, and shortages. Independent parameters were optimized using the Response Surface Methodology (RSM). Analysis of variance was performed to check the significance of independent parameters on the total cost and order quantity. The deterioration rate, inventory in hand time, shortage time, and backlogging parameters were observed in the decreasing order of significance. Surface and contour plots were drawn for evaluating the interactive effects of parameters on the total cost and order quantity. Over all, it is concluded that implementation of RFID helps reduction in total cost of PPSCM, which is a major objective of all industrial establishments.

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CHAPTER 1
INTRODUCTION

1.1 Background

Modern industrial enterprises operate in a rapidly changing world. They are understressed by global competition, managing worldwide procurement and unforeseeable markets, supervising geographically distributed production plants, and striving for the provision of outstanding products and high-quality customer service (Gigler et al., 2002). Owing to this, companies have made huge efforts for streamlining their internal business processes. Fundamental changes are required in the role and form of supply chains and the way in which they innovate and conduct business and research. Efforts were also made for identifying and enhancing the core activities pertaining to the product value chain, and massive investments were made in new intra-company information and communication platforms such as data warehouse or enterprise resource planning (ERP) systems (Sergio Terzi and Sergio Cavalieri, 2004). Properly designed supply chains would help industries to relieve their difficulties to a certain extent if the supply cabins are adequately implemented.

Supply chain management (SCM) is defined as the integration of key business processes from end user through suppliers that provide products, services, and information and add value to the customers and stakeholders (Lambert and Cooper, 1997). The concept of SCM has evolved around the customer focused corporate vision, which drives changes throughout a firm's internal and external linkages and then captures the cluster of interfunctional and interorganizational integration and coordination (Wang and Liu, 2007). However, as a new way of conducting business, firms have also begun to realize the strategic importance of planning, controlling, and designing supply chains with an objectiveto enhance the operational efficiency, responsiveness, and profitability of the firms and its supply chain partners. The only way to achieve the objective of SCM is to develop and implement appropriate mathematical models in right directions (Min and Zhou, 2002).

Over the past decades, researchers and practitioners have investigated various aspects of SCM with prime focus on timely and right decision about economic order quantity (EOQ), replenishment policies (Nair and Closs, 2006 and Rau et al., 2003), coordination (Kheljani, et al., 2009; Pokharel, 2008; and Zhou and Li, 2007), and pricing strategies (Konstantin and Charles, 2009; Levin Yuri et al., 2009 and Gerard and Robert, 2009). Maintaining sufficient stocks of inventory to satisfy customer demand with appropriate level of profitability is a prime concern of every industry; however, this is a difficult task. High level of inventory blocks the capital, leading to reduced profit margin, and low level of inventory leads to shortage and loss of goodwill of the company. Many researchers, (Thangam and Uthayakumar, 2009; Dye et al., 2007; Webster and Weng, 2008; Li et al., 2007; Chung et al., 2007; and Bramorski 2007) have addressed this problem of inventory control by developing mathematical models and providing algorithms to resolve the problems. Even though the above mentioned problems are common to all types of supply chains, in any given context, the solutions to these problems differ depending on the type of supply chain under consideration as well as the type of material that the supply chain deals with.

Perishable product supply chain is one of the typical examples supporting the above statement. Basically, PPSCs differ from other supply chains and are very difficult to manage (Nair and Closs, 2006 and Rau et al., 2003). The basic difference between PPSCs and other supply chains is that, there is a continuous change in the quality of raw materials from the time it leaves the producer until the finished product reaches the consumer (Dabbene et al., 2008a). These difficulties mostly arise because of the limited shelf life of the products, which start deteriorating and then are treated as waste. It is estimated that nearly 32% of the Indian agricultural products go waste because of inadequate supply chain infrastructure (Rajurkar and Jain, 2011). A brief review of PPSC is presented in the following sections.

1.2 Perishable product supply chain

Perishable product supply chain (PPSC) is a multidirectional network that integrates all activities from production until the consumption of a product at the customer end. Like any other supply chain, PPSC represents a system of well-defined sequences of economic activities. It integrates the flow of material, money, and information from one stage to the other with the objective of supplying the product of right quality at the right time to the customer maintaining optimum level of profitability (Haring et al., 2007 and Tempelmeier, 2006). Even though it appears very simple, managing a perishable product is very difficult, and PPSCs suffer from great difficulties and challenges (He et al., 2010; Olsson and Tydesjo, 2010; and Li and Mao, 2009).

The changing global market scenario, high level of competition, obsolescence of perishable products due to short shelf life and changing customer demands (Roberto D., Salvatore C. and Jose M. F. 2014), are among the key challenges faced by the PPSCs. Furthermore, inherent uncertainty of supply networks, proliferation of product variety, and shortening of product life cycles are among the other factors in the existing PPSCs that need to be improved. These supply chains compete with a growing variety of products, short delivery time, higher cycle service levels, high quality, and lower costs (Rong et al., 2009 and Chan and Chan, 2010). Perishability imposes an intense pressure on managers to manage the supply of perishable products. It adds an additional cost of disposal of outdated items, leading to out-of-stock situations and also loss of customer faith, if not effectively managed (Chande and Dhekane, 2005 and Duan, Q.T. and Liao, W. 2013).

Managingan optimum amount of perishable inventory is anotherchallengefor customer satisfaction. Higher amount of inventories lead to obsolescence (Mohammad R. and Ali S. N. 2014), whereas, stock-outs can seriously affect the reputation of a firm. Moreover, customer and market fragmentation and specializationcause a rapid increase in product demand variation (Rajurkar and Jain, 2011). However, the total market volume does not increase as fast as the number of products that are being offered. This leads to a decreasedvolume per product type. Other sources of demand variations include the seasonality of production, weather conditions (Mehmet S. N. et al., 2015), and biological nature of products. This results in input variation and unpredictability, which can create a big problem for retailers in terms of satisfying customer demand. Lastly, maintenance of logistics and production systems for providing quick response is the biggest challenge faced by PPSCs (Jayaram and Tan, 2010; Hsiao, 2008; Hsiao et al., 2010; and Tsolakis, N. K. Et al. 2014). Aperishable product gets spoilt and its shelf life reduces if not handled properly during transportation. If the information regarding reduced shelf life of the items is not updated, an outdated item may get delivered to the customer. In such a case, there may be an additional cost of replacement of item and also loss of goodwill of the company. To control and resolve some of the PPSC related problems, the incorporation of a new and advanced technology such as radio frequency identification (RFID) in the supply chain system is necessary (Ranky, 2006**)**.

Radio Frequency Identification (RFID) is an automatic identification and data capture technology, which is composed of three elements: a tag formed by a chip connected with an antenna; a reader that emits radio signals and receives answers from tags in return, and finally a middleware that bridges RFID hardware and enterprise applications. RFID technologies combined with the appropriate information technology infrastructure help the major distributors and manufacturers. Its implementation is found highly appreciable in logistics operations, such as the healthcare system and defense industries, andin such establishments that deal with complex, global supply chains, in which products and product shipments must be traced and identified in a non-contact, wireless fashion using a computer network because of cost, or security, or safety, or because parts are subject to corrosion, or food / medicine is subject to quality degradation, or other reasons (Wilke and Braunl, 2001). RFID systems can track the items in real time without product movement, scanning, or human involvement. Using active RFID tags, it is possible to dynamically update information on it. RFID systems provide complete visibility of product movement in the supply chain (Zhou, 2009). This may help to make early decisions about inventory control in case there is any interruption in the supply. Nowadays, RFID is increasingly being used to resolve transportation problems and for material and product identification (Sobhi M. and Radu F. B. 2015). The improved information accuracy through RFID will allow companies to substantially reduce out-of-stocks and back orders. They are also likely to find themselves with lower overall average inventory. This suggests an opportunity for making remarkable improvement, that is, the companies can potentially reduce reorder quantities and target inventory levels without hampering customer service levels.

RFID partially or completely, eliminates the time and efforts required for counting during loading or unloading of the items. This results in the reduction of the total lead time for the arrival of an order (Peter, 2005). RFID can increase a company's efficiency and provide financial benefits to both companies and consumers. However, RFID, like any newly implemented technology, presents new system threats and decisions about incorporating adequate controls over the new technology (Higgins and Cairney, 2006)**.** On the other hand, opportunities for its application in various fields are vast. The key driver for implementing RFID is that even in largely distributed, more stochastic than deterministic business environments, adaptive organizations and enterprises must quickly react to demands, else they may lose business. Therefore, they must reduce waste and improve efficiency at all fronts. The most important aspect of this strategy is to have exact knowledge about the quantity, location, and quality of products they have in stock (Ranky, 2006).

Over the past decades, various researchers have contributed in the area of PPSCs, and have specifically focused on developing optimal order quantity policies, replenishment, coordination, pricing, and inventory management policies. However, studies on the impact of newer technologies such as RFID in supply chain of perishable products are in the preliminary stage. Many researchers are quantifying the potential benefits of RFID (Kok et al., 2008 and Kazim, 2010). The current study is an attempt to ascertain the benefits of RFID to the perishable product supply chain.

1.3 Research gap

The research on perishable product supply chains dates back to 1950. The prominent researchers working in this area were Ghare and Shrader (1963); Covert and Philip (1973); and Shaha (1977), who modeled the economic order quantity for the perishable inventory model with linearly changing demand rate (deterministic), constant deterioration rate, and finite planning horizon. Since then, researchers including Datta and Pal (1998) have presented an EOQ model considering deterioration as the variables and power demand pattern. Studies on modeling with deteriorating items, time-varying demand, and shortages continue with great dynamism, and provide new dimensions to supply chain studies (Benkherouf, 1995; Goswami and Glaudhuri, 1991; and Teng et al., 1995). The common characteristic of all the aforementioned studies is that they allow for shortages while unsatisfied demand is completely backlogged.

The recent research trend observed in PPSC management is more inclined toward modeling the pricing strategies than product decaying characteristics. For example, the concept of dynamic pricing has been introduced to account for the loss of inventory due to obsolescence (Chew et al., 2009; Dye et al., 2007). In this strategy, the price of the product was suggested to be reduced as the shelf life and quality of the product degrades gradually. This strategy is helpful in boosting demand for products that could otherwise have been lost in spoilage. Further, nowadays customers are very weary of product quality, and they prefer to buy a product that is “last in first out” (LIFO) over the one that has been on the shelf for a long period of time (Cohen and Prastacos, 1981)**.** In such situations, inventory losses can only be reduced by managing and maintaining an adequate quantity of perishable products. In order to do so, we need an information tracking system that can provide the information on remaining product life and movement of inventory in the supply chain.

On the basis of a comprehensive literature survey, it is understood that almost every aspect of SCM has been focused by the researchers, including EOQ, replenishment policies, sourcing and pricing, dynamic pricing, shelf space availability, coordination, supplier selection, distribution network design, discounts, and promotions. It is observed that, lead time is a crucial parameter that affects the operational costs, service levels, and demand uncertainty in a short life PPSC. However, most of the literature available on short life products have focused on the order quantity as a decision variable and neglected the decision on lead time, that is, when to order. Because of the complexity of the decision based on both the lead time and order quantity, the optimal ordering policy with controllable lead time have not been fully addressed (Warburton, 2004 and Kamensky and Kaya, 2008, 2009). Lead time can be controlled at the added expenses on advanced technology, software used for forecasting, utilizing advanced transportation facility, and incorporating new technologies such as RFID in the supply chain system (Song et al., 2011). RFID can drastically reduce the lead time andthus result in the reduced order quantity and uncertainty, but the cost of RFID is additional. Therefore, the higher the magnitude of technology incorporation the lower will be the lead time. Previous research shows that the higher the extent of implementation of such technology, the lower the lead time (Ouyang and Chuang, 2001). Overall, it is observed that RFID shows a pronounced reduction of lead time and increased certainty in supply chain decisions (Jones et al., 2005).

However, it is also observed that most of the modeling work is performed without considering the realistic situations that prevail at any node of the supply chain. Majority of the researchers have considered the condition of zero lead time and have completely ignored the perishability effect, lead time, varying demand, and the effect of RFID. Formulation of beneficial impacts of newer technologies such as RFID remains unattended. On the basis of the aforementioned facts, it can be argued that following areas of supply chain havenot been adequately covered. Furthermore, previous research work that has already been carried out in the area of perishable product supply chains lacks the following aspects.

- Most of the models developed earlier deviate from considering actual situations that exist at different nodes of SCM. Assumed zero lead time. (Skouri and Papachristos, 2002; Wu et al. 2006; Roy et al. 2009; and Chang et al., 2010).
- Research in the area of incorporation of new technology such as RFID in SCM of perishable products has not received much attention and is in the preliminary stage.
- Mathematical models that have formulated the beneficial impact of RFID in the PPSCs are not available.

The impact of RFID on PPSC under realistic situations has not been adequately considered by earlier researchers. Therefore, formulating the impact of RFID on PPSC considering the most realistic situations that prevail at different nodes of PPSC and calculating the cost effectiveness of the RFID system is necessary. The current study is an attempt to bridge this gap by formulating the impact of RFID on PPSC considering perishability effect, lead time, and varying demand for overall total cost and order quantity.

1.4 Research objective

In the era of technology explosion and advancement, many of the supply chain engineers and managers are not confident of incorporating newer and promising technologies such as RFID in their industrial establishments. This is primarily because of the lack of proper methodology available for calculating the benefits of this ever-growing technology. Consequently, the managers are in a dilemma regarding the possibility of facing adverse effects of incorporating RFID in their industries. . This is because the previous research using mathematical modeling did not adequately cover the real ground situations that prevail at the supply chain node. Many studies have considered the condition of zero lead time while dealing with the PPSC modeling, which can not be true in the real sense. In the current study, the combined effect of lead time, RFID, and deterioration have been formulated considering variable deterministic demand pattern that includes possible supply chain costs. To bridge the aforementioned research gap, the research objectives are summarized as follows:

- To conduct a comprehensive literature review on supply chain management (SCM) to bridge the research gap.
- To formulate a comprehensive mathematical model for PPSC including different costs, namely, replenishment cost, holding cost, deterioration cost, backlogging cost due to shortage, opportunity cost, and crashing cost.
- To formulate total cost function and determine the optimum order quantity.
- To formulate models for different casesincluding the following:
    - Model with complete backlogging
    - Model when RFID is implemented
    - Model with instantaneous deterioration and complete backlogging
    - Model with instantaneous deterioration and RFID is implemented

- To determine the impact of RFID on PPSC in terms of total cost and order quantity.

The outline of the thesis is given in the following section.

1.5 Outline of the thesis

The thesis comprises of six chapters. The first chapter includes an introduction along with an explanation of the background for this study. It also includes the basic information regarding the perishable product supply chain and the problems and challenges faced in day-to-day activities. The research gap and the research objectives of the thesis are also highlighted in this chapter. In the second chapter, an exhaustive literature review is presented to understand the recent research position in this area of supply chain and to identify the gap in research. The literature review is presented in two parts: the first part includes a review of 302 research papers based on mathematical modeling in broad spectrum of supply chain and the second partpresents a review of theresearch related to radio frequency identification (RFID). The review highlights the state of art of the research position on RFID. At the end of this chapter, a short note on RFID is presented to summarize this promising technology including its comparison with the barcode system.

The third chapter discusses the adopted research methodology. Various stages of the proposed research from the beginning until the outcome of research are described. The generalized problem is formulated using a simple analytical method to facilitate its understanding at the ground level of supply chain. The developed modelis then validated using the MATLAB programming platform. The fourth chapter demonstrates step-by-step development of the model framework considering the assumptions, notations, and various supply chain costs, which suits the best realistic situation at any node of supply chain. A RFID-interfaced supply chain block diagram is described in this chapter to understand the potential benefits of RFID in PPSC. An inventory variation graph according to the variable demand function and the effect of perishability is explained in this chapter. Furthermore, four different cases of the general model are developed and discussed in this chapter.

The fifth chapter explains the model validation considering a case study, which is based on realistic situation that prevails at any node of supply chain. The model is optimized for best set of conditions for minimum total cost using the Response Surface Methodology (RSM). Adequacy of the model tested, ANOVA, and the optimized parameter values along with the effect of individual parameters and their interactions on total cost and order quantity are presented in this chapter. In addition, a sensitivity analysis for the deterioration parameter and backlogging parameter to study their effect on order quantity and the total cost of supply chain is presented in this chapter. The sixth chapter concludes the study wherein research outcomes, conclusion, and future scope of this study are presented.

CHAPTER 2
LITERATURE REVIEW

Background

In the present globalised and competitive market scenario, it is necessary to keep pace with the quality, cost and the time of delivery. Perishable products must be delivered within its shelf life to avoid obsolescence. The lead time and its variability however impose extreme difficulties to the supply chain partners to stick to the commitment of timely delivery of the product. Even today, in the era of technological advancement, many industries do not have confidence over utilization of technologies like RFID in their organizations to overcome the problems arising due to lead time and its variability.

Keeping this view in mind a comprehensive and state of art literature review is presented in this chapter. In the initial stage a broad literature review is carried out considering 302 papers on supply chain modelling. This covers a complete spectrum of supply chain management. A detailed classification and analysis of the literature is presented for each head of classification. It was concluded that even after a large research work carried out in both the fields i.e. perishable and non-perishable product the research on utilization of newer technology like RFID to overcome routine problems is not sufficiently covered. This was a motive force to consider this topic for the research. In the second stage, around 95 numbers of papers that cover RFID, its constructional details, its impact on perishable product supply, lead time, and a response surface methodology were reviewed. Over all around 400 research papers have been reviewed for this research work. Detailed review is presented below.

Part A

General Review on Supply Chain Modeling

2.1. *INTRODUCTION*

Intense global competition is forcing organizations to offer low-cost, high-quality, reliable products. To compete, products must be delivered on time and with greater design flexibility. Industries strive to satisfy customer needs while maintaining acceptable levels of profitability. Intelligently applied, SCM is sufficiently mature to enhance the survival of industries in this era of global competition. According to the council of logistic management, SCM is the process of planning, implementing and controlling the efficient, cost-effective flow and storage of raw materials, in-process inventory, finished goods and related information from point-of-origin to the point-of-consumption for the purpose of conforming to customer requirements (Simchi-Levi et al., 2003). SCM objectives are to enhance the operational efficiency, responsiveness, and profitability of firms and their supply chain partners. These objectives can be realized by designing, developing, and implementing SCM situational (need-oriented) models. Models must change to accommodate changing scenarios. Review of the prior modeling literature analyzed in this paper revealed a wide range of models.

Although there are many publications in the SCM domain, only a few authors have attempted to provide a comprehensive review of the SCM modeling literature. Interestingly, most of the review papers have considered only a single aspect, such as simulation, case studies, surveys, or performance measurements. Many researchers (Croom et al., 2000; Tan Keah, 2001; Min and Zhou, 2002; Sergio and Sergio, 2004; Sachan and Datta, 2005; Gunasekaran and Kobu, 2006; Vaart and van Donk, 2008; and Rajurkar and Jain, 2010) have authored review papers in this area. The paper presented by Min and Zhou is particularly informative about SCM modeling. The authors developed taxonomy for classifying the modeling literature. However, their work is restricted to categorizing SCM modeling according toasingle-dimension model type, such as deterministic, stochastic, or hybrid. Consequently, there is a need to develop a more extensive review paper that emphasizes the full spectrum of SCM and to classify the literature in additional detail. To that end, this chapter presents a comprehensive review and categorization of the modeling literature that encompasses the complete spectrum of SCM. It provides both academicians and practitioners with an in-depth review of current SC issues, existing models, and a clear direction for future research.

In addition to reviewing SCM literature, the other contributions of this chapter lie in organizing the current SC modeling work by: i) arranging publications in an orderly manner to facilitate searching, ii) classifying the literature with respect to topical coverage, iii) examining the outcome of publications, and iv) identifying gaps and providing insight for further research.

2.2 *METHODOLOGY AND SCHEME OF REVIEW*

The volume of SCM literature is growing rapidly. For this review, SCM papers from leading international journals were collected from multiple databases like Science Directory, Google Scholar, ABI/INFORMS, and IEEE Explore among others. From the more than 500 papers dated between 2001 and 2014, 302 papers were selected because of their relevance to modeling. A paper's potential relevance to our study was determined by careful examination of its abstract, introduction, and conclusions. Only those papers that reflected modeling on any aspect, activity, or function of SCM were considered for further review. Following the initial selection, each of the 302 papers was reviewed in greater detail. Each paper was assessed independently to determine the area of modeling, methodology, modeling tool(s), product type, production type, year of modeling, stochastic or deterministic, general or Information Technology (IT) driven, type of industry, simulation, and area of IT application (See Table 2.1).

Table 2.1:Distribution of Research Papers from Various Journals

Sr. No.	Name of Journal	No. of Papers	% Con-tribution	Rank
1	International Journal of Production Economics	89	29.47	1
2	European Journal of Operational Research	74	24.5	2
3	Computers and Chemical Engineering	15	4.97	4
4	Expert Systems with Applications	13	4.31	5
5	Computers & Industrial Engineering	12	3.97	6
6	Mfg Service And Operations Management	08	2.65	7
7	IIE Transaction	08	2.65	7
8	Decision Support Systems	07	2.32	8
9	Omega	06	1.99	9
10	Applied Mathematical Modelling	06	1.99	9
11	Simulation, modelling, practice and theory	06	1.99	9
12	Management Science	06	1.99	9
13	Fuzzy Sets and Systems	05	1.66	10
14	IEEE Transactions	04	1.33	11
15	Robotics and computer integrated manufacturing	04	1.33	11
16	Journal of Operations Management (OTM 4)	03	0.99	12
17	Computers in Industry (UC)	02	0.65	13
18	IJPDLM	02	0.65	13
19	Engineeringapplications of artificial intelligence	02	0.65	13
20	Beta	02	0.65	13
21	ProductionPlanning and Control	02	0.65	13
22	Decision Science	02	0.65	13
23	Flexible Services and Manufacturing Journal	02	0.65	13
24	Mathematical and Computer Modelling	02	0.65	13
25	Others (one paper each)	20	6.62	3

The other journals contributing one research paper each are:

International Journal of Production Research, Advances in Engineering Software Applied Energy, TsinghuaScience and Technology, Information Sciences, Advanced Modelling and Optimization, Journal of Food Engineering, Journal of Operation

Research Society, Computers and Electronics in Agriculture, The Journal of Systems and Software, International Conference on Automation and Logistics, Journal of Process Control, Journal of Chinese Institute of Industrial Engineers, Research communication, Sadhana,System engineering, Winter simulation conference, International Journal of Integrated Supply Management, International Journal of Operations & Production Management and Transportation Research.

2.3 *LITERATURE CLASSIFICATION FRAMEWORK*

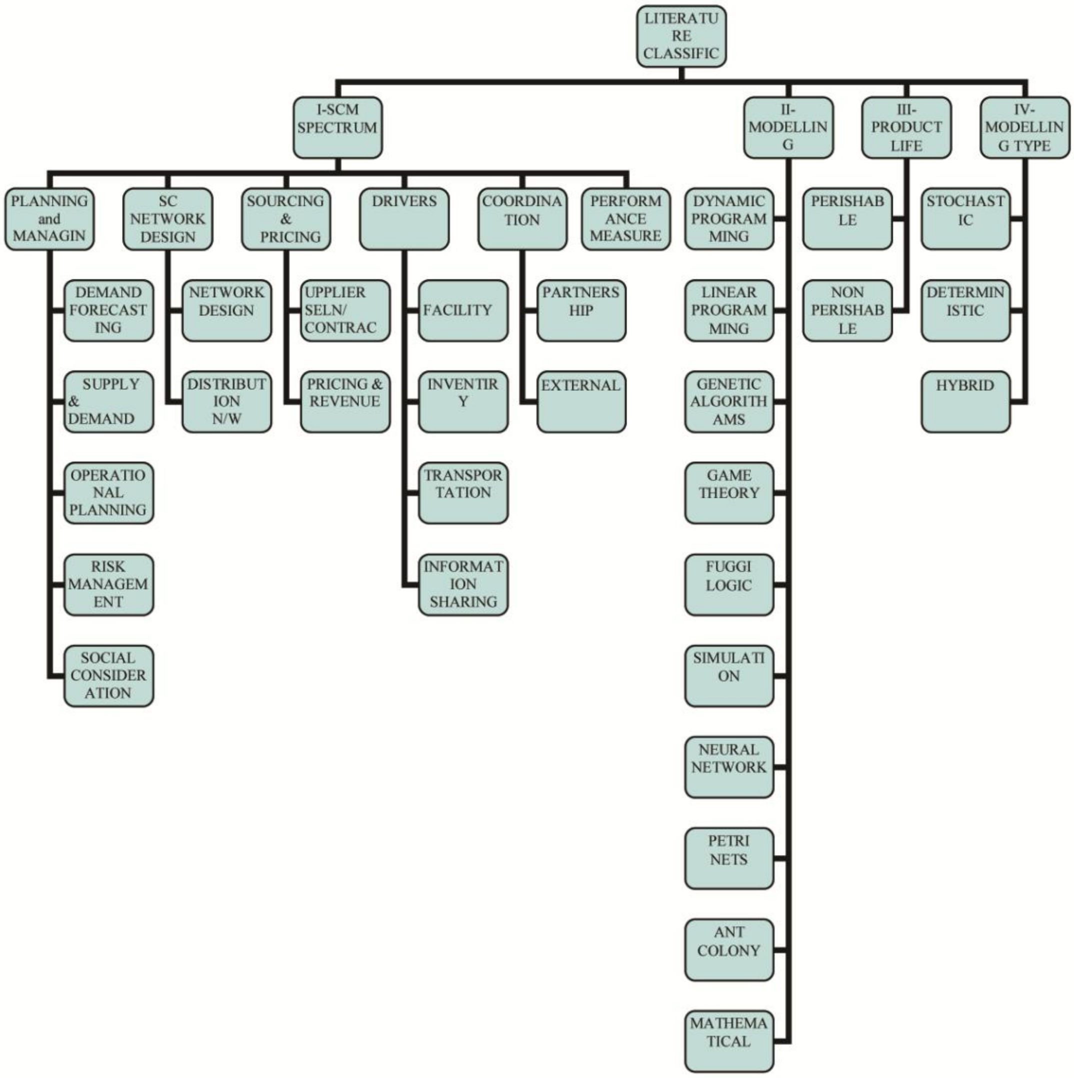


Figure 2.1: Literature Classification Framework

Figure 2.1 is the framework used to classify the 302 modeling papers. It depicts a graphical structure to help visualize the growth of publication categories of interest. The initial classification of SCM literature focuses on the spectrum of SCM planning and management; SC network design and pricing; SC drivers and, coordination and performance measurement. Additional classification is based on analytical tools or methods used by researchers. Product lifecycle aspect like perishability is identified as a potential category on its own right. Finally, the type of model, i.e., stochastic, deterministic, or hybrid is considered as the other major classification category for existing SC modeling literature. l.

2.3.1 Planning and Management

The literature related to supply chain planning and management (SCP&M) covers several key issues that include demand forecasting, planning supply and demand, operational planning and scheduling, risk management and social/environmental consideration. Demand forecasting is a base for future business activities. Consequently, forecasting accuracy has a pronounced impact on management's key decisions. Planning the supply, according to the demand, is a major activity for every stage of SC. Planning has an impact on purchasing raw material and is closely linked to the production of finished goods and transportation. Figure 2.2 presents a graphical summary of related work published during the past ten years in the planning and management category.

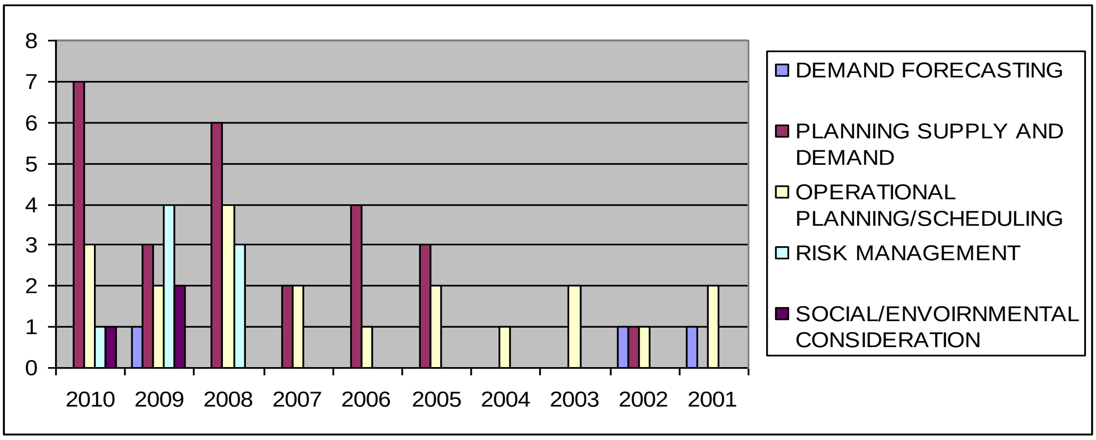


Figure 2.2: Year-wise Publication Data of Literature on Planning and Management

As shown in Table 2.2, researchers have focused more on planning supply and demand (such as inventory control, replenishment strategies, ordering policies, and lead-time) than on other aspects (such as demand forecasting and the social and environmental considerations). In addition, there has been a constant stream of publications on operational planning issues (such as production scheduling, procurement, and risk analysis in managing a multi-stage supply chain). Table 2.2 below identifies the elements of research carried out by various researchers in SC planning and management by their decision focus, research objectives, and methodologies. Figure 2.2 also partitions the work by the area of application such as perishable or non-perishable products.

Table 2.2: Authors Contributing to Supply Chain Planning and Management

Decision	Authors	Research theme	Methodology used	Other Info.
Demand	Bongjuet al., (2002)	Forecasting model	G A	NP CS
Forecasting	Yossi et al., (2001) Jayet al., 92009)	Collaborative forecasting Decision making	Fluid analogy Mathematical	NP DT NP SM
Planning Supply and	Wu et al., (20013) Mark S et al., (2010)	Replenishment model	Linear Programming	NP ST NP SM
Demand	Cai et al., (2010) Xie et al., (2010)	Advanced order strategies	Game Theory	NP DT NP ST
	Chang et al., (20010)	Cost effectiveness	Mathematical	PSST

Decision	Authors	Research theme	Methodology used	Other Info.
	Hsieh et al., (2010b) Rob A.C.M. et al., (2007)	Inventory model, cost effectiveness	Mathematical Simulation	PSDT PSST
	Shuklaet al., (2010)	Overall cost reduction	Taguchi	NP SM
	Jose et al., (2009) Carolineet al., (2008)	Supply management Supply management	DP, Simulation Simulation	NP ST PSSM
	David P. et al., (2009)	Ordering policies	Fuzzy sets	NP ST
	Chaharsooghi et al., (2008)	Reinforcement learning	Beer game	NP ST
	Xiaoet al., (2008)	(R, nQ)inventory policies	Mathematical	PS ST
	Torabi et al., (2008)	Flexible return policy	MILP	NP ST
	Ding Ding et al., (2008)	Master planning	Sensitivity A	NP ST
	Zhao X. B., et al., (2007)	Inventorypolicies	Markov chain	NP ST
	Kuo et al., (2008)	Multi-period planning	MILP	NP DT
	Xie et al., (2010) Rao et al., (2007) Hendricks et al., (2009)	Customer demand and Inventory status Demand, supply variation	Fuggy logic Mathematical Mathematical	NP ST PSDT NP SM
	Chen et al., (2006) Wang et al., (2005) Alexandre D. et al., (2002)	Cycle time Demand Lead time	Fuggy logic GA Markov model	NP ST NP HY NP ST
	Venkatadriet al., (2006)	e-Commerce	MILP	NP ST
	Wan et al., (2005)	Analyzing supply chains	Simulation	NP SM
Operational Planning / Scheduling	Alebachew et al., (2010) Tadeusz, (2009)	Procurement, fabrication Product assembly, distribution scheduling	MILP MILP	NP HY NP ST
	Ghaeli et al., (2008) Drzymalski et al.,(2008) Liu et al., (2007)	Hybrid systems System dynamics and Managing events	Petri net Petri net Petri net	PSSM NP NP SM
	Ivanov et al., (2010)	Planning and operations	Struc. Dynamics	NP CM
	Wang et al., (2010)	Coordination	Sensitive Anlysi	NP ST
	Sahin et al., (2008)	Productionscheduling	Simulation	NP SM
	Mustafa et al., (2007)	SCbehaviour	Simulation	NP SM
	Oscar et al., (2003)	CONWIP SC policy	Simulation	NP SM
	Hung et al., (2006)	Operational policies.	Simulation	NP CS
	Spitter et al., (2005)	Capacity constrained (SCOP) policy	Linear Programming	NP DT

Decision	Authors	Research theme	Methodology used	Other Info.
	Huang et al., (2005)	Design constraints of SC	DP, GA	NP DT
	Sérgio et al., (2004) Nirupam J. et al., (2002)	Supply management	Agent-based Simulation	NP NP SM
	Lodree Jr. et al., (2008) Yin et al., (2003)	Production planning	Mathematical Markov chain	PS ST NP ST
	Perea L. et al., (2003)	Decisionpolicy	DP	NP ST
	Dong et al., (2001) Wang, (2008)	Analysing mfg. SC Model predictive control	Petri net Simulation	NP SM NP SM
Risk Mana-gement	Tuncel et al., (2010) Tiaojun X. et al., (2009)	Risk management Information mechanism	Petri net Game Theory	DT SM DT
	Kull et al., (2008)	Supply risk	Simulation	NP ST
	Wolf et al., (2009)	Base-stock policy	Markov chain	NP ST
	Azaron et al., (2008)	Multi-objective	Mathematical	ST HY
	Tsai et al., (2008)	Cash flow risks	Simulation	NP DT
	Xiao et al., (2009)	Price–service competition	Game Theory	NP DT
	Wu et al., (2008)	Risk evaluation models	Simulation	NP SM
Social Con-sideration	Balan S. et al., (2010) Bojarski et al., (2009)	Green sc management SC planning and design	Lagrangian MILP	PS ST PS ST
	Cruz, (2009)	Corporate (CSR)	MILP	NP ST

2.3.2Supply Chain Network Design

Network design decisions are the most important SC decisions because their implications are significant and are long-lasting. When designing an SC network, four drivers (facility, inventory, transportation, and IT) need to be considered. These drivers define competitive strategy and enhance SC profitability. The following authors have presented their work with respect to the design of supply chain networks. Table 2.3 classifies work with respect to research objective, modeling type, and product life.

Table 2.3: Authors Contributing to Supply Chain Network Design

Decision	Researcher	Research theme	Methodology used	Other Info.
Network	Maria I. et al., (2010)	Multi-product, reverse flow	MILP	ST MM NP
Design	Shabnam et al., (2010)	Equilibrium model	Nash Equi	DT MM NP
	Jack G.A.J. et al., (2000)	Dynamic behavior	Simulation	SM PS
	Kim & Cho et al., (2010)	Profit maximization	D P	DT MM NP
	Altiparmak et al., (2006)	Solution to problem	G A	HY SM NP
	Wang H.S., (2009)	Partner selection	Ant colony	ST MM NP
	Hadi et al., (2009)	Equilibrium model	MILP	DT MM NP
	Gumas et al., (2009)	Design effectiveness	MILP ANN	HY MM NP
	Fengqi et al., (2008)	Responsive/ economic	MILP	ST MM NP
	Ertungaet al., (2008)	Profitability	MILP	ST MM NP
	Pierreval et al., (2007)	Customer behavior	Simulation	SM NP
	Che et al., (2007)	Qualitative/quantitative	Linear pro	DT MM NP
	Chatfield et al., (2007)	Order fulfillment	Simulation	SM NP
	Wang et al., (2007)	Productsdevelopment	GA FS	ST MM NP
	Candas, (2007)	Logistic Net. Design	Linear pro	ST MM NP
	Sourirajan et al., (2007)	Lead time, safety stock	LR	DT MM NP
	Altiparmak et al., (2006)	Solution to problem	GA	ST SM NP
	Choudhary et al. ,(2006)	Lead time	Linear pro	ST MM NP
	Lamothe et al. ,(2006)	Product selection	MILP	ST SM NP
	Chakravarti et al., (2002)	Supplier selection	MILP	DT MM NP
	Gigler et al., (2002)	Product Quality	DP	SM PS
	Lakhal et al., (2001)	Strategic issues	MILP	ST NP MM
Distribut-ion	Liang et al., (2009)	Overall cost reduction	FMLP	ST MM NP
Network	Hill et al,(2008)	Ware house	MILP	ST MM NP
Design	Liang (2008)	Cost reduction	FMLP	ST MM NP
	Monthotipkul et al., (2008)	Inventory/distribution	MILP	ST MM NP
	Shaojun W. et al., (2006)	Just in time	MILP	DTMM PS
	Gunther et al., (2006)	Logistic centre	DS	DT MM NP
	Vaidyanathan J. et al., (2003)	Logistic	MILP	SM NP
	Banerjee et al., (2003)	Order shipment	Simulation	SM NP

ANN- Artificial Neural Network, LR-Lagrangian relaxation, FMLP-Fuzzy Multi-objective Linear Programming, DS- Dynamic Sequencing, FS-Fuzzy Set, DP- Dynamic Programming.

2.3.3 Sourcing and Pricing

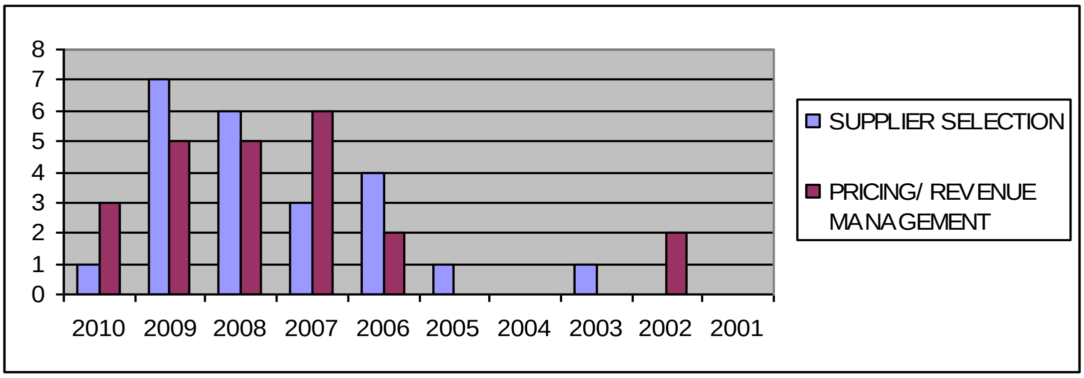


Figure 2.3:Year-Wise Data of the Literature on Sourcing and Pricing

Sourcing is the set of business process required to purchase goods and services. Sourcing includes selection of supplier, contract decisions, product design collaboration, and the material procurement and evaluation of the suppliers' performance.

Burden reduction is an important aspect of SCM. However, pricing relates to decisions of setting prices and discounts of the product in order to maintain certain levels of profit margins. Figure 2.3 shows the number of research papers credited to each category.

2.3.3.1 Supplier selection / contracts

After conducting supplier scoring and assessment analysis, firms can select desirable suppliers using a variety of mechanisms such as off-line competitive bids and reverse auction or direct negotiation. Inadequate supplier and partner selection leads to the loss of trust in all stages of SC. Following the process of supplier selection, contracts between buyers and suppliers are signed. Various types of contracts are possible, such as product availability, buy-back and returns, revenue sharing, quantity flexibility, cost coordination, agent efforts and performance improvement. Researchers (Ru and Wang, 2010; Xu, 2010; Zhao and Shi, 2009; and

Li et al., 2009) have modeled for supplier selection, contracts and focused on supply chain structure, to accept integration or decentralization and which contracting strategy a business should choose. The authors found that supply chains that decentralize perform better under high degree of product substitution between supply chains. However, (Kheljani et al., 2009; Pokharel, 2008; Zhou and Li, 2007 and Wang and Liu, 2007) have considered the issues of coordination between buyer and potential suppliers in the supplier selection process. The authors have characterized market demand as a fuzzy variable and proposed single-period and long-term contracts to coordinate the two members, supplier and buyer in the supply chain. The comparison of the effectiveness of the two contracts, which indicates that a long-term contract is more effective than a single-period contract in improving the profit potential of total SC was made in the research. It has also considered estimated demand from various retail units, capacity commitment by suppliers, assemblers and third party warehouses as constraints in order to develop a two-objective decision-making model for the selection of suppliers and warehouses for a SC network design. Wang et al. (2007) characterized quality, budget, and the demand as fuzzy variables in a fuzzy vendor selection expected value model and a fuzzy vendor selection chance constrained programming model, to maximize the total quality level.

It was suggested that the contracts are essential in resolving conflicts in order to reduce global loss of efficiency (Jean-Henet and Adra, 2008). Using market demand as a fuzzy variable, long-term contracts increase the profit potential more than short-term contracts was studied by (Frascatore and Mahmoodi, 2008; Wang et al., 2008; Wang et al., 2009 Amin et al., 2009; Ali et al.,2009 and Chen et al., 2006). The authors evaluated the efficiency of different types of contracts between the industrial partners of a SC. It proposes a price compliance regime for contract where the penalties, in the form of price for non-compliance on quantity, are enforceable on both parties. Their research work is also concerned with the coordinating quantity decision problem in a SC contract. The authors proved that the retailer expects to obtain higher profit under proper ordering policies, which can also maximize the expected profit of the SC. Pascal et al., (2006) have proposed a multi-behavior planning agent model using different planning strategies. Whereas, (Mathur and Shah, 2008) have proposed a price-compliance regime for contracts where the penalties, in the form of price for non-compliance on quantity, are enforceable on both parties. Researchers (Cao and Yao, 2007) modeled for a retailer's fixed order, call-option purchase, put-option purchase and manufacturer's production, under one order and two-period production mode. Ryu and Lee (2003) have reduced lead times at a cost that can be viewed as an investment considering dual-sourcing models with stochastic lead times and constant unit demand. With the intention of providing new dimensions to the SC, (Kannan and Tan, 2010; Robert and Serguei, 2009; Gilbert and Xi, 2006; Huang and Sethi, 2005; Frascatore and Mahmoodi, 2008 and Xiao and Yang, 2009) also worked in this regard. Their concern is to analyze the impact of supplier selection and buyer-supplier engagement on the performance benefits attributable to buyer-supplier relationships, and the effect of these benefits on broader measures of buyer performance. Buyer coordination to the supply chain in the presence of default risk. To explore production and outsourcing decisions for two original equipment manufacturers (OEM) that produces partially substitutable products and have opportunities to invest in reducing the manufacturing cost. And to study a two-stage purchase contract with a demand forecast update.

2.3.3.2 Pricing and revenue management

For SC, pricing is an important lever to increase profit by better matching supply and demand. Pricing may influence demand for price sensitive customers. Pricing has an effect on the revenue generated and on revenue management. Revenue management has significant impact on SC profitability. Revenue management is necessary when the product value varies in different market segments, the product is highly perishable, demand is seasonal, or the product is sold in both bulk and the spot market. There are various pricing strategies in response to pricing and profit sharing for coordinating supply chains, transfer pricing and transportation cost allocation, co-investment programs for capital development, advertising and pricing. Many authors explored these pricing strategies andmodeled dynamic pricing and pricing in the presence of strategic customers are (Wei and Choi, 2010; Edward,2008; Perron et al.,2010; Konstantin and Charles, 2009; Yu et al., 2009; Levin Yuri et al., 2009and Gerard and Robert, 2009). These researchers provide background for changing pricing policies according to the changes in marketing strategies, customers, environment and product life considerations. Reza and Mahsa (2008) have developed and solved a model for minimizing costs while minimizing the sum of backorders and surpluses of products in all periods. Mickael et al. (2008) proposed to implement Activity Based Costing (ABC) while a mean-variance (MV) analysis of supply chains under a returns policy is carried out by Choi et al. (2008).

Gonzalo et al., (2007) presented a novel approach for holistically optimizing the combined effects of operations and finances in SCM. Chen and Chen, (2007) dealt with the joint decisions on pricing and replenishment schedule for a periodic review inventory system. Hammond and Beullens, (2007) examined issues surrounding the recent European Union directive regarding waste of electric and electronic equipment. Gjerdrum and Shah, (2002) have worked on inventory-holding policy. Chang et al., (2006) established an economic-order quantity model for a retailer to determine its optimal selling price, replenishment number and replenishment schedule with partial backlogging. However, (Yang and Zhou, 2006) analyzed the effects of duopolistic retailers' different competitive behaviors, including models like Cournot, Collusion, and Stackelberg on the optimal decisions of the manufacturer and on the duopolistic retailers themselves. Federgruen and Heching et al., (2002) modeled multi-locational combined pricing and inventory.

In real-life business, for perishable products, the demand is a function of the selling price, the age, and the credit period. Perishability gives rise to intense pressure to follow a dynamic pricing strategy in order to avoid losses due to obsolescence. However, the current papers propose an algorithm for single-period inventory replenishment problems with the expected profit objective are (Thangam and Uthayakumar, 2009; Dye et al., 2007; Webster and Weng, 2008; Li et al., 2007; Chung et al., 2007 and Bramorski 2007).

2.3.4 Supply Chain Drivers

SC drivers play a vital role in achieving the performance level of a supply chain.Drivers have a great influence on the balance between responsiveness and efficiency of the SC. Major SC performance drivers are facility, inventory, and transportation, and information technology. Year-wise research data are presented graphically in Figure 2.4.

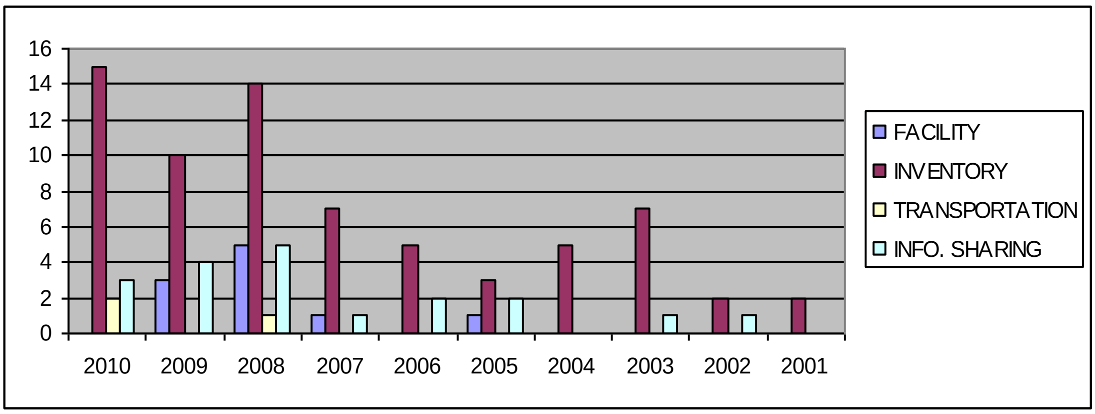


Figure 2.4: Year-Wise Data of the Literature on SC Drivers

2.3.4.1 Facilities

Facilities and their corresponding capacities are the key drivers of SC performance in terms of responsiveness and efficiency. The researchers namely (Meng et al., 2009; Li et al., 2009and Uster and Keskin, 2008) have optimized the allocation of capacities among different facilities and product items for a decentralized SC. However, Kaihara, (2001) formulated a discrete resource allocation problem for a virtual market in a dynamic environment. Panagiotis and Lazaros, (2008) have explained the constrained-based optimization for production allocation and work-load balance. However, (Chew et al., 2009; Manuel et al., 2008; and Federgruen and Heching, 2002) have determined the price and inventory allocation for a perishable product with a predetermined lifetime, finite waiting room, and a single server. A number of authors like (Hsieh and Wu, 2008; and Li et al., 2010) have developed the model on coordination for capacity allocation, ordering, and pricing decisions with demand and supply uncertainties. Whereas, (Yang and Yang, 2007) explained the importance of a premium-payment scheme involving capacity acquisition in order to build higher capacity.

2.3.4.2 Inventory

Inventory is spread throughout the SC, including raw materials, work in progress, and the finished product. Inventory is a major source of cost in SC and has a pronounced impact on responsiveness. Inventory plays a significant role in finalizing the competitive strategy of the firm (Kannan et al., 2010; Shen-Lian et al., 2008 and Miner, 2001). In their research an inventory system with closed-loop SC including product return after recycling was analyzed. Whereas, (Qing long et al., 2008) focused research on open-loop reverse SC. The researchers, (He et al., 2010; Olsson and Tydesjo, 2010; Li and Mao, 2009; Vila-Parrish et al., 2008; Li et al., 2007 and Lawrence et al., 2006) have modeled the inventory system for perishable products inventory management for a different scenarios. The researchers, (Sodhi and Tang, 2009and Jung et al., 2008) have developed a linear programming (LP) model for deterministic SC for different issues like SC planning under uncertain demand and management of integrated safety stock for multi-stage supply chains under production capacity constraints. On the other hand, the implications of coordinating price markdown policies with SC policies of inventory replenishment, including transportation expediting on retail performance of a perishable product has also been studied by (Rajurkar and Jain, 2011; Nair and Closs, 2006 and Rau et al., 2003). Table 2.4 summarizes the prior works on inventory modeling with different objectives, methodologies, and modeling type.

In addition to what is shown in table 2.4, the other studies that focused on inventory management with respect to order distribution for customer demand, inventory positioning, and order sequencing include (Wong et al., 2009) who modeled for the impact of information sharing in VMI partnership that allows the supplier to obtain actual sales data in a timely manner and determine the rebate for retailers. The researchers (Li and Sridharan, 2008 and Kaminsky and Kaya, 2008) have developed linear programming model for inventory control and scheduling in uncertain environment and Pitty et al., (2008) have simulate the inventory control in refinery.

Table: 2.4 Research Work in the Area of Inventory Management

Factor	Authors	Research objective	Methodology used	Modeling type
Bullwhip	Peidro et al., (2010)	Uncertainty reduction	Fuggy Set	MM
Effect (safety inventory)	Mehdi M. et.al., (2009)	Uncertainty reduction	Fuggy Set	SM
	Wuet al., (2009)	Uncertainty reduction	Nash Equilibrium	MM
	Zarandi et al., (2008)	Uncertainty reduction	GA NN Fuggy Set	SM HY
	Xiao et al., (2010)	Coordination	Game Theory	MM
	Yanfenget al., (2008)	Demand management	Mathematical	MM
	Copini et al., (2010)	Impactof human	Bear Game	MM
	Nienhaus et al., (2006)	Behaviour on B E	Bear Game	SM
	Wafa O. et al., (2008)	Planning	D P	MM

Factor	Authors	Research objective	Methodology used	Modeling type
	Fernando et al., (2007)	Effect of disturbances	Simulation	SM
	Saad et al., (2006)	Uncertainty reduction	Linear programing	SM PS
	Sheu, (2005)	Safetystock	Mathematical	MM
	Jung et al., (2004)	Customersatisfaction	Linear programing	SM
	Dong et al., (2004)	Planningprocess	Linear programing	MM
	Lin et al, (2004)	Demandrealizations	Z Transform	MM
	Gupta et al., (2003)	Quantify B E	Linear programing	MM
	Potter et al., (2010)	Bullwhip reduction	Simulation	SM
	Wang et al, (2008)	Impact of lead time	Mathematical	MM
	Spiter et al., (2005)	Impact of lead time	Mathematical	MM
	Chopra et al., (2004)	Lead time, safety stock	Mathematical	MM
	Rong et al., (2009)	Ordering Behaviour	Beer game	SM
Vendor	Yu et al., (2009)	Optmarketing strategy	Nash Game	MM
managed	Darwish et al., (2010)	Optmarketing strategy	Mathematical	MM
inventory	Yu et al., (2009)	Optmarketing strategy	Game Theory	MM
(VMI)	Nachiappan et al., (2007)	Optmarketing strategy	GA NILP	MM
	Piplani et al., (2003)	Optmarketing strategy	Mathematical	CS
	Paksoy et al., (2010)	Multi goals	MILP	MM
	Yang, (2010)	Impact of inflation	Mathematical	MM
	Gumus et al., (2009)	Impact of inflation	MILPANN	MHY
	Wang, (2009)	Impact of inflation	Fuggy Set	MM
	Giannoccaro et al., (2003)	Impact of inflation	Fuggy Set	SM
	Jiang et al., (2009)	Dynamicinvcontrol	Simulation	SM
	Disney et al., (2003)	Effectof (VMI) on BE	Z Transform	MM
Cycle	Odonnell et al., (2009)	Impact of promotions	GA	MM
Inventory	Tsai, (2007)	Impact of promotions	MILP	MM
	Halati et al., (2010)	Incentives	Mathematical	MM
	Chen et al., (2010)	Coordinationcontracts	Mathematical	MM
	Chung et al., (2007)	Multi variable problems	Mathematical	MM
	Kaihara, (2001)	Agentnegotiations	D P	MM
	Dhumal et al., (2008)	Coca Cola inv. mgt	Game theory	MM
	Kaminski et al., (2009)	MTO & MTS strategy	Mathematical	MM
	Stephenet al., (2008)	Stock allotment	D P	MM

GA-Genetic algorithms, NN-Neural Network, NILP- Non-integer Linear Programming, MILP-Mixed integer Linear Programming, PS-Perishable

Haringetal., (2007) and Tempelmeier, (2006) have proposed MILP and mathematical model for inventory replenishment with certain demand to reduce overall cost. Bai et al., (2007) have developed heuristic and metaheuristic for inventory control and shelf space allocation for perishable products. Chiang and Monahan et al., (2005) developed the Markove chain based model for inventory management. The following researchers have also worked in this regard and provided the valuable contributions are, (Grahovac and Chakravarty, 2001; Fandela and Stamme, 2004; Cheung and Yuan, 2003; Viswanathan and Piplani, 2001 and Chen and Huang, 2006). Their concern inventory distribution in a supply chain with expensive low-demand items, strategic SCM with focus on product life cycles and recycling, order commitment and fulfillment, coordinating supply chain inventories and fuzzy analysis of order fulfillment in supply chains.

The overall distribution of SC driver literature is presented in figure 2.5. It is observed that researchers have shown the most interest in inventory management. This observation reveals that inventory is the most important SC driver, with 70.45% of the total distribution. Next come IT with 14.77% distribution. IT is considered the heart of SCM and today's requirement for industrial information systems. Facilities are in third position (11.36%) followed by transportation (3.4%). This distribution suggests that in the future researchers should develop models for efficient and economic logistical routes and facilities.

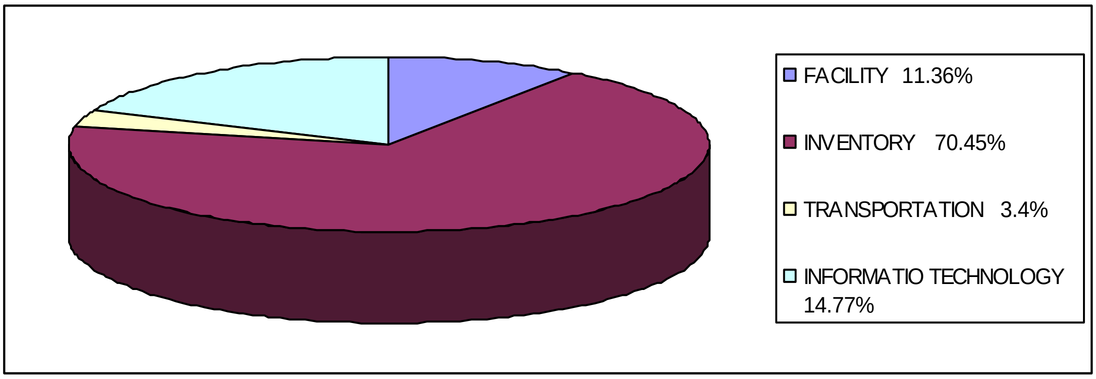


Figure 2.5: Overall Distribution of Literature on SC Drivers

However, readers should understand that a very strict demarcation in the distribution is not possible. There may be certain overlaps in the publications analyzed. For example, it is observed that literature on transportation is overlapped with inventory management, warehousing, and replenishment policies.

2.3.4.3 Transportation

Different transportation modes have a significant impact on the responsiveness and efficiency of the SC. Faster transportation can be costly, but it improves responsiveness. Dell Computer Corporation, for example, uses air freight to reduce inventory and to provide fast delivery. Important contribution to this section of SC has been provided by (Jayaram and Tan, 2010) who proved that information integration, third party logistics provider (3PL), selection criteria, performance evaluation, and relationship building are positively correlated with a firm's performance. Hsiao, (2008) and Hsiao et al., (2010) have developed a model for optimal multi-stage logistics and inventory policies with production bottlenecks in a serial SC. A pull and reverse-pull algorithm was designed to solve the multi-stage logistics and inventory problem with a production bottleneck in a serial SC.

2.3.4.4 Information sharing

Information does not have a physical presence. However, information thoroughly affects every aspect of SC. It serves as the connection between different stages of the SC, thereby improving coordination among stages, reducing the bullwhip effect, and maximizing overall SC profitability. Information also plays a vital role in performing routine operations of each stage, thereby avoiding false steps. A number of researchers have analyzed the value of demand information sharing and developed the model to quantify the benefits of IT in the SC context, these are (Fu and Zhou, 2010; Wu and

Cheng, 2008 and Raghunathan, 2003), who have analyzed the value of demand information sharing and developed the model to quantify the benefits of IT in the SC context. However, Thoneman, (2002) has analyzed the impact of sharing advance demand information (ADI) on improvement of supply-chain performance. The researchers Kurata and Yue (2008), and Zhang and Zhang, (2007) have also modeled trade promotion and the trade-off mode of business strategy using demand information sharing. Zhang et al. (2006) have evaluated the benefits of a strategy of sharing shipment information, where one stage in a supply chain shares shipment quantity information with its immediate downstream customers. Whereas, Funda and Robinson Jr. (2005) and Chen et al. (2001) have investigated the impact of information sharing and physical flow coordination in a make-to-order supply chain comparing the relative impact of both the criterion. And Chu and Lee, (2006) has modeled the situation and found that, in equilibrium, whether the retailer reveals or withholds the information depends on two things, the cost of revealing the information and the nature of market demand signal that the retailer receives. The researchers (David and John, 2009; Muthusamy et al., 2008; Yao and Dresner, 2008 and Chen and Lee, 2009) have carried out important research on applicability of information sharingin decision making, resolving conflicts, inventory management and managing the variability in ordered quantity in multiproduct SC and with product substitution.

Currently, world-class industries are inclined toward the adoption of radio frequency identification (RFID) in their information systems, due to its added advantages. However, it is found that most RFID work is in the preliminary stage. Even today in the Indian scenario, the authors have very limited exposure to this area. The adoption of RFID technology is gaining momentum rapidly as technological, societal, and competitive pressures push firms to transform and innovate themselves.

In this regards, Lee and Lee, (2010) have presented the SC RFID investment evaluation model. This work provided a basis for enhancing our understanding of RFID value creation, measurement, and ways to maximize the value of this technology. Whereas, Yang et al., (2009) studied the robustness of different supply chain strategies under various uncertain environments using signal to noise (S/N) ratios. The simulation results show that e-shopping has the most robust performance in uncertain environments. Another valuable research in this area is carried out by (Nikitin and Rao, 2006; Chande et al., 2005; Kazim Sari, 2010 and Zhou, 2009). Their concern is to study, back scattering from RFID tags, and impact of RFID on supply chain of perishable products, impact of RFID on SC performance and applicability of RFID in item level information visibility.

2.3.5 Coordination

Coordination enhances relations between various SC actors. It helps to have access to timely information regarding demand at all stages of SC. Information availability reduces forecasting errors and hence the bullwhip effect. This section is sub-categorized as: partnership, and external (inter-organizational) coordination. The year-wise research work in this area is presented graphically in figure 2.6.

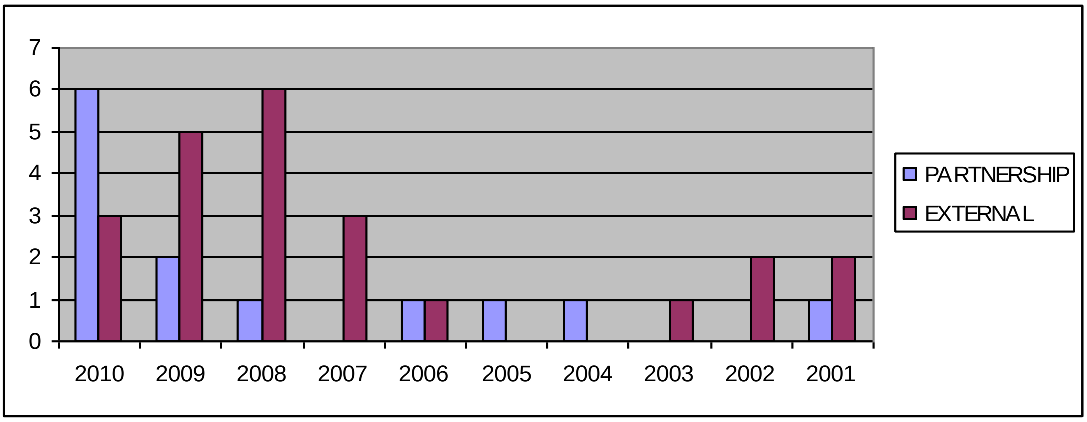


Figure 2.6:Year-Wise Data of the Literature on Coordination

2.3.5.1 Partnership

It is understood that a strategic partnership is one of the best ways to reduce the bullwhip effect in the SC. Strategic partnerships enhance coordination at different stages of SC. Chong Wu and Barnes (2010) have developed a decision method to use in selecting partners. The authors, Wen et al., (2010) and Ryu and Yucesan (2010) have solved the multi-stage logistic and inventory problem with a production bottleneck in a serial SC. However, Li et al., (2010) described a multi-agent simulation model for analyzing the dominant player's behavior of SCs. However, Lodree Jr. et al., (2010) have investigated coordination between production and shipment schedules to fulfill the retailer's order as quickly and cost effectively as possible. Other researchers are (Amaro and Barbosaet al., 2009; Blackhurst et al., 2008; Li and Liu, 2008; Xu and Zhai, 2010; Chang et al., 2006; Cheung and Lee, 2002; Balakrishnan et al., 2004; NgLeon et al., 2001 and Wang and Yigal, 2002), who worked in this area to account for demand and pricing uncertainty on product portfolios. Their research is focused on selecting SC partners at different phases of the product life cycle; coordinating between warehouses and retailers; discovering SC conflict affecting system performance; coordinating SCs by controlling upstream variability propagation; coordinating stock rebalancing in an SC; and other issues. So also Oh et al. (2010) developed a collaborative fractal-based supply chain management model based on a trust for the automotive industry.

2.3.5.2 External Coordination

Coordination among the different stages of SC and among different industries forming SC is very essential to improve SC performance. Every stage shares current information with others and thereby improves SCM decisions. The researchers (Xu and Zhai, 2010; Zhang and Huang, 2010; Arshinder et al., 2009; Esmaeili et al., 2009; Hammami et al, 2009 and Chen and Xiao, 2009) have emphasized in their research the importance of coordination between different stages of SC that leads to reduction of overall cost. Silv et al., (2009) introduced a new SCM technique. This new technique was based on modeling a generic SC with suppliers, logistics and distributors using ant colony optimization. Likewise, Choi et al., (2008) investigated the issues of channel coordination like risk sharing and pricing policies in a SC. De Boeck and Vandaele, (2008) proposed a model for coordination and synchronization of material flows in SCs. A coordination problem in a single-manufacturer with multiple heterogeneous buyers situation was investigated by Sarmah et al., (2008). Nagarajan and Sosic, (2008) described the construction of the set of feasible outcomes commonly seen in SC models for SC partners. Lee and Rhee, (2007) examined return policies in a Newsboy framework. More importantly, Xiao et al., (2007) investigated the coordination mechanism for an SC with a single manufacturer and two competing retailers when demands are disrupted. Other researchers who worked in response to the coordination among different stages and actors of the SC are (Burer et al., 2008; Tullari et al., 2008 and Ounnar et al., 2007) with the objective of modelling buyer-supplier negotiations and customer supplier relations. Both these models deserve their own importance for the SCM, dealing with such important issues.

The value of intercompany coordination was understood by Roder et al., (2006), who developed a simulation-based decision support system using a modular modelling concept in order to evaluate the benefits of an inter-company coordination. Gupta and Weerawat, (2006) compared three different mechanisms that a manufacturer, whose revenues depend on order delays, may use to affect its component suppliers inventory decisions. Banerjee et al., (2003) examined the effects, in terms of some selected criteria, of two lateral transshipment approaches in a two-echelon supply chain network, with a single supply source at the higher echelon and multiple retail locations at the lower. Coordinating producer and supplier is one of the main issues of supply chain management (Zimmer, 2005). The author investigated this issue by means of a single-period order and delivery planning model within a Just-in-Time setting. Whereas, (Boyaci and Gallego, 2002) analyzed coordination issues in a supply chain consisting of one wholesaler and one or more retailers under deterministic price-sensitive customer demand. Carlos and Mark, (2001) presented a model for the optimization of a global supply that maximizes the after tax profits of a multinational corporation and that includes transfer prices and the allocation of transportation costs as explicit decision variables. Bogata and Bogata, (2001) influenced by the earlier research of Girlich (1999) presented the quantitative method of building up the model of spatial hierarchy as the result of spatial games.

2.3.6 Performance Measurement

Performance measures and matrix management are essential for effectively managing SC operations, particularly in a competitive global economy. Performance measurements provide information necessary for decision-making and for taking corrective actions. It is said that "no measurement, no improvement" (Gunasekharan et al., 2006) Chiang et al., (2009) modeled the stochastic nature of SC focusing on efficiency and robustness. Lau et al., (2008) demonstrated the effects of information sharing and early order commitment on the performance of four inventory policies used by retailers. Angerhofer and Angelides, (2006) modeled the constituents, key parameters and performance indicators to improve the performance of a collaborative SC. Simulation models have been developed to evaluate alternative SC designs with respect to quality, lead-times, costs, and customer service level by (Persson and Olhager, 2009 and Yoo et al., 2006).

The concerns of various other researchers for performance measures of the SC are presented. Jain et al., (2008) worked on flexibility, profitability, quality, innovativeness, pro-activity, speed of response, cost and robustness. Kainuma and Tawar, (2006) worked on multiple attribute assessment of an SC, studied flexibility and adaptability in delivery quantity, focused on food quality. Gong, (2008) and Das and Abdel-Malek, (2003) studied total system flexibility as measured by an economic index. Campuzano et al., (2010) evaluated the behavior of fuzzy estimations. Franca et al., (2010) studied the impact of quality defects. Tsai, (2006) researched performance of R&D and quality design for cost reduction. Lin et al., (2005) studied quality management. Reiner, (2005) reported on food quality. Fleisch and Tellkamp, (2005) worked on inventory inaccuracy and performance in a retail SC. Wang et al., (2004) studied multi-warehouse and multi-retailer scenarios. Erol and Ferrell Jr., (2003) worked onqualitative and quantitative factors of the performance measures of the supply chains. The authors (Petrovic, 2001and Georgiadis and Vlachos, 2005) have reported on SC behavior and performance in the presence of uncertainty and fuzzy demand for strategic SCM. Capkun, et al., (2009) have studied the relationship between inventory and financial performance in manufacturing companies. Whereas, Zhu, et al., (2010) have highlighted the impact of information on SC flexibility and its performance.

The broad spectrum of SC literature is illustrated by figure 2.7. This diagram shows that SC driver research accounted for 34.11% of the total literature reviewed. SC drivers are further divided into facilities, inventory, transportation, and IT.

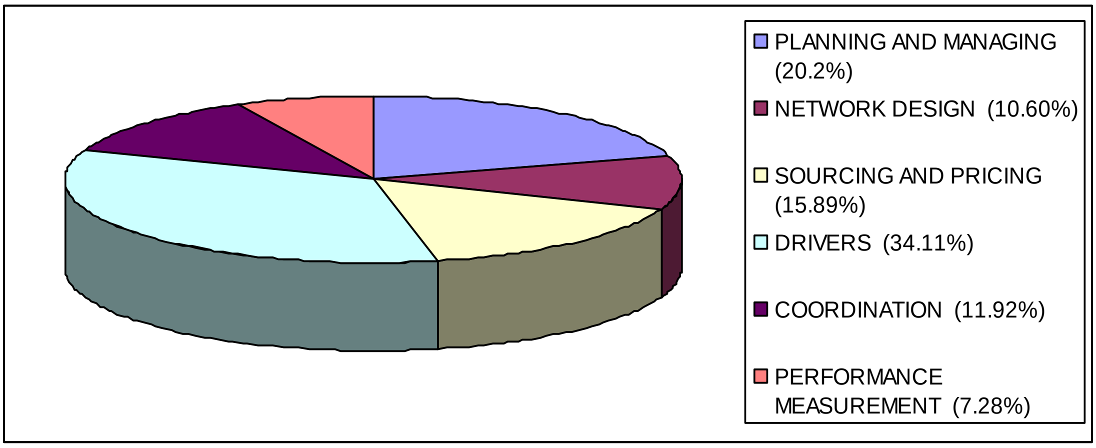


Figure 2.7: The Overall Distribution of Literature According to the Spectrum of SCM

The next largest category of research accounts for 20.2% of the literature. The primary components of this category include SC planning and management. Specific areas are discussed in their respective sections. Sourcing and pricing account for 15.89% of the overall literature. Network design accounts for 10.60%. Coordination, which is the essential component of all SCs, accounts for 11.92%. Performance measurement is last with 7.28%.

2.3.7 Modeling Tool / Analytical Method Used

A year-wise research work that uses various analytical methods and modeling tools is presented in table 2.5.

Table 2.5: Literature Classification According to Analytical Methods and Modeling Tool

1	ModelingTool	10	09	08	07	06	05	04	03	02	01	Total
1	Dy. programming	3	4	2	2	1	3	-	2	1	3	21
2	Genetic algorithm	2	2	1	1	2	-	-	-	1	-	9
3	Linearprogramming	8	12	15	7	4	1	6	3	2	1	59
4	Game theory,	10	13	6	2	4	-	-	2	1	2	40
5	Simulation	5	5	11	2	4	6	-	1	3	5	42
6	Fuzzy logic	4	5	4	4	5	1	-	2	-	-	25
7	Neural network	-	3	-	-	-	-	-	-	-	-	3
8	Taguchi/ DoE	1	1	-	-	-	-	-	-	-	-	2
9	Petri net	1	-	3	1	-	-	-	-	-	1	6
10	Ant colony	-	2	-	-	-	-	-	-	-	-	2
11	Mathematical	13	10	19	9	8	5	2	5	3	2	75
12	Markov chain	-	1	1	1	1	1	-	2	1	-	8
13	Sensitivity analysis	3	-	3	1	1	-	-	1	1	-	10

It is seen that most of the researchers are inclined toward optimization modeling using linear programming (LP) or mixed-integer programming (MIP). It is also observed that the trend of optimization modeling increased from 2001 to 2010, with 59 papers in this category.

Simulation modeling depicts future process performance, which provides a strong base for design and development of the system. Researchers have given due importance to simulation methodology in the recent years with 42 papers. Simulation plays an important role in multi-decisional context of SC, Sergio and Sergio. Game theory, the classical evolutionary technique, has 40 papers. However, the genetic algorithm, neural network, Taguchi, ant colony, and Petri Net show minimal use. The numbers of papers in these categories are 9, 3, 2, 2, and 6 respectively. Fuzzy logic provides a strong base to model in uncertain environments, with 25 research papers. Dynamic programming, Sensitivity analysis, and Markov chain have 21, 10, and 8 papers, respectively. However, researchers who rely on mathematical modeling using differential equations, integration, matrices, linear equations, and calculus account for 69 papers.

2.3.8 Product Life Consideration

Product life literature is classified according to products that are perishable or non-perishable. Readers should understand that out of 302 papers we identified 35 papers on perishable products. In the perishable category, the authors developed a pricing framework, discounted pricing schemes, consideration of product shelf life, temperature impact analysis, carbon footprint, inventory management and replenishment, and managing fresh food quality, etc. Very few papers are cited in perishable SCM that explored the impact of new technologies like RFID. The perishable products involved are agricultural, meat, and milk. The reviewed year wise data on perishable products is presented graphically in Figure 2.8.

Figure 2.8 shows that research work has changed its trend beginning in the year 2004 to the present. From 2004, research activities increased consistently for both the categories. Year 2008-9 is observed to be a peak for both categories. A perishable product's shelf life puts intense pressure on SC planning and design. Many authors have recognized the need for model development. Recently, considerable research is being carried out on perishable product supply chain. However, no literature was found that signified and quantified the benefits and losses of incorporating cold storage to improve the shelf life of products, and accordingly to design and develop the model. Hence, more attention must be paid toward the SCM of perishable products.

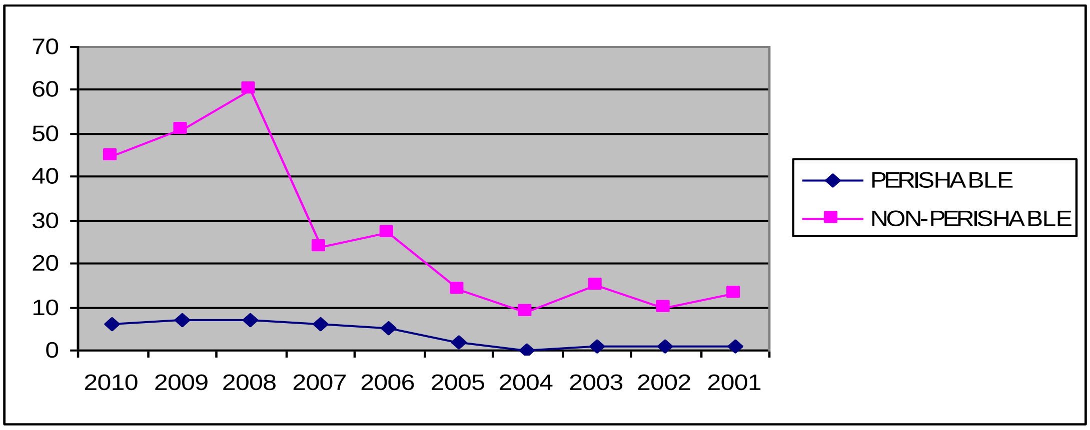


Figure 2.8: Graphical Presentation of Literature According to Perishable, Non-Perishables

There is a need to manage quality, quantity, and price of perishable products. There is an immediate requirement to satisfy the demands of the world's drastically increasing population.

2.3.9 Modeling Type

Three classes of modeling types are identified: deterministic, stochastic, and hybrid. Deterministic models assume all of the model's parameters are known and fixed. There is no scope for uncertainty involved. Deterministic models repetitively produce only a single value for a given set of conditions. Stochastic models, on the other hand, allow for uncertainty in the model's parameters. There parameters are susceptible to the changing environment. Stochastic models are optimal control theoretic and dynamic programming models. Hybrid models represent a category introduced to take in to account mixed characteristics. Hybrids include both deterministic and stochastic parts. Hybrid models also depend on multi modeling tools and multi-objective models. It was observed that the authors are more inclined to build stochastic models where the demand remains uncertain. The numbers of stochastic models are seen to increase rigorously to the end of the decade. Significant research was carried out during the period of 2007 and onwards, the years 2008-09 were at the peak. Deterministic modeling follows the stochastic modeling at nearly the same trend but the number of research papers lies far below the stochastic modeling. The numbers of research papers with hybrid (multi-tool, multi-objective) modeling are the least of all.

Table 2.6: Literature Classification According to Modeling Type

TYPE/YR	10	9	8	7	6	5	4	3	2	1	TOTAL
STOCHASTIC	26	29	30	15	13	4	4	10	4	4	139
DETERMINISTIC	14	8	13	8	9	4	1	3	3	3	66
HYBRID	2	5	2	1	1	1	1	00	1	1	15

A comprehensive review of the literature on supply chain modeling in the last decade (2001-2011) has been presented. Out of initial review of more than 700 papers, 302 papers were selected for further review and analysis. In order to facilitate the review process and identify the potential gaps for future research, a review framework has been suggested by classifying the SC literature into four main groups: supply chain management, product lifecycle, modeling tools used, and types of models used. Furthermore, we strongly believe that future research work should focus on assessing the current level of the SC processes. It is important to identify critical SC business areas and establish performance measures for continuous assessment of profitability, efficiency, responsiveness, and improvement. One must incorporate new technologies, including GPS and RFID.

SC research on perishable products is comparatively scarce. Only 35 papers out of 302 were found on perishability. Shelf life exerts large pressure on SC designers to acquire optimization between cost and quality. Around 32% of the agricultural products get deteriorated due to inadequate perishable supply chain management. Many of the studies suggested that the key to success in perishable SCM lies in the integration of activities involved, cooperation, as well as coordination and information-sharing throughout the entire SC (Rajurkar and Jain 2011 and Ming-Feng 2010). Increasing competitive pressures and market globalization are forcing firms todevelop SCs that can quickly respond to customer needs. To remain competitive, these firms must reduce operating costs while continuously improving customer service. This can be possible by incorporating new techniques such as game theory, genetic algorithms, fuzzy logic, ant colony, dynamic programming, fuzzy linear programming, stochastic linear programming, simulation and other soft computing techniques to solve the problems in SC.

The development of a methodology or framework to formulate strategies for perishable SC and implementation of suitable planning and scheduling systems for effectively managing operations of SC is required to achieve the objectives. There is a need to design and implement a suitable information system network. For example, RFID is must for improving the financial effectiveness of supply chain management. The development of new pricing strategies must occur in order to reduce waste and maintain profitability of the SC. More consistent efforts are needed to design, develop, and implement appropriate models. These models should justify cost, quality and quantity to the mixed economic and explosively increasing population of the several countries.

Part B

Review on RFID based SUPPLY Chain of Perishable Products.

In the early stage of our research work, a comprehensive literature review was carried out considering 302 research papers from about 40 reputed international and national journals, international conference proceedings and research thesis. The supply chain modelling based literature was only considered for reviews that were sourced from science direct, IEEE explore, Spingerlink, Google scholar etc. The out come of the review is that the research on adoption of new technology likes RFID in controlling the supply chains of perishable products is scare and in the preliminary stage. Very few researchers have contributed in this region of supply chain management and the beneficial impacts of this technology have not been quantified mathematically and fruitfully. The researchers are found to have assumed the RFID benefits in certain percentage using different notations. In the following sections, review of literature on perishable product supply chain (PPSC), pricing strategy, effect of lead time on PPSC, and impact of newer technology like RFID have been presented in more detail.

2.4 Perishable Product Supply Chain

The focus of researcher on the supply chain of perishable product dates back form 1950 onwards.The important early contributors were (Ghere and Shrader, 1963; Covert and Philip, 1973 and Shah, 1977 who modeled economic order quantity for perishable inventory. Dave and Patel, (1984) have developed an inventory model with deterministic but linearly changing demand rate, constant deterioration rate and finite planning horizon. Whereas, Sachan (1984) has extended the work of Dave and Patel (1984) to allow for shortages. Datta and Pal (1988) have presented an EOQ model considering variables deterioration and power demand pattern. Research work on modelling with deteriorating items, time-varying demand and shortages continued by (Goswami and Glaudhuri, 1991; Benkherouf, 1995; Hariga, 1996; Chakrabarti and Chaudhri, 1997; Hariga and Alyan, 1997 and Teng et al., 1999). The common characteristic of all the above papers is that they allow for shortages while unsatisfied demandis completely backlogged. Wee and Mercan (1999) have considered an inventory model over a finite planning horizon with constant demand and deterioration rates. Additionally, they assumed that only a fraction of demand during the stock out period is backlogged. Other researchers who used the idea of partial backlogging are (Wee, 1995, 1999; and Chang and Dye, 1999).

Bhunia and Maiti (1999) developed a deterministic inventory model over a finite planning horizon with constant rate of deterioration, linearly increasing demand, and complete backlogging of the excess demand. The new contribution of their paper was the introduction of a replenishment cost function, which is linear with respect to the lot size. The authors considered policies with replenishment cycles of equal length. Taking into account the assumption of linearly increasing demand, this seems to be a rather restrictive condition, because it narrows the set of all admissible policies. The research concern have seen broaden its scope by encompassing other important aspect of PPSC like pricing strategy which is covered in the following section.

2.5 Pricing Strategy

At the start of 21st century research dynamism has changed and the researchers have found to work on another concepts of supply chains. Pricing policies with or without discounts, coordination, replenishment policies, quality management and information sharing was the main concern. Xiyu et al., (2007) have studied the impact of coordination with option contract under two period production modes. It was inferred that incorporating call option, put option and quantity flexible strategy increases total profit of the whole supply chain and profit of retailer and manufacturer, and through selecting proper option price policy can achieve coordination of supply chain and improve the ability of supply chain to deal with uncertain demand. Jianet al., (2010) have investigated the sourcing strategy of a retailer and the pricing strategies of two suppliers in a supply chain under an environment of supply disruption in a centralized and a decentralized system and devise a coordination mechanism to maximize the profits of both suppliers. However Arshinder et al., (2009) proved that by designing the contracts as per the requirements of the supply chain members as well as the whole supply chain, supply chain performance may be improved. Xiao et al., (2008) studied the optimal initial quantity, the optimal wholesale price, and the optimal retailing price is studied under the assumption that both the decision makers are risk-neutral. On basis of the optimal solutions for the centralized system as a benchmark, a simple cost sharing mechanism is developed to coordinate the supply chain under consideration. However, Naira, et al., (2006) evaluated the implications of coordinating price markdown policies with supply chain policies of inventory replenishment, and transportation expediting on retail performance of a short lifecycle product.

The main drawback of perishable product supply chain is the quality degradation that leads to reduction in price as the shelf life goes on reducing. This gives rise to the concept of dynamic pricing. The important research on pricing strategies was carried out by (Dasci, 2003), where the concept of dynamic pricing was put-forth. The research presents a two-period model to analyze the dynamic pricing behavior of two profit-maximizing firms that have equal inventories of perfectly substitutable and perishable products. The research on dynamic pricing was followed by Chande et al., (2005) who introduced benefits of information technology in their research. The other researchers who provided the new dimensions to the concept of dynamic pricing are (Chen and Chen et al., 2007; Lowrence, et al. 2006; Dye et al., 2007; Chew, 2009 and recently Rajurkar and Jain, 2011). The main concern of these researchers was to compromise price according to the reduced shelf life of product so that profit would not get hampered. The next section presents review on replenishment policy.

2.6 The replenishment policy

Improper replenishment policies lead supply chain to either over stock or stock out which causes the loss of good will and many other unwanted activities like back ordering etc. this have great impact on supply chain efficiency and responsiveness affecting customer service cycle level. Replenishment policies were studied by Rob and Broekmeulen et al., (2007) who suggests a replenishment policy for perishable products which takes into account the age of inventories with very simple calculations. It claimed that in an environment, which contains important features of the real-life retail, their new policy leads to substantial cost reductions compared with a base policy that does not take into account the age of inventories. (Chang et al., 2010 and Hsieh et al., 2010) were two other important researchers who gave new dimensions to SCM of perishable products by introducing stock dependent demand and with stock-dependent selling rate and capacity constraint respectively. This work was supported by Rajurkar and Jain (2011). The importance of information at all stages of supply chain has been studied by (Ferguson and Ketzenberg, 2006 and Yasutaka, et al., 2006). The author suggests that information at every stage plays very vital role in SCM. It has effect on every activity of SCM. Indequate information leads SCM to collapse early. It improves retail product quality, service cycle level and good will of company. Rong et al., (2009) have provided an optimization approach to maintain fresh food quality throughout the supply chain. From the literature review it is observed that most of the literature cited above has considered the condition of zero lead time, which may not be a real situation at any node of supply chain. Lead time is very important parameters as per PPSCs are concern. Therefore, the literature review pertain to the effect of lead time is presented in the following section.

2.7 The Impact of Lead Time on SC OF Perishable Product

Study and research on the impact of lead time on supply chain and inventory management dates back to the mid of twentieth century. Lead time has been considered very important parameters for designing supply chains by many researchers. Gross and Soriano (1969) have proved that the safety inventory and the inventory in handare reduced if the lead time is reduced. Also reduction in lead time lead to improve the service level to the customer. Das, (1975) in his research shown that with uncertain lead time the order quantity as well as minimal inventory cost is more sensitive. If lead time is high it leads to larger order quantity, higher possibility of stock outs and higher shortages. Chopra et al., (2004) have found out that lead time has great impact on cycle service level that leads to the company good will. They said that for cycle service level above 50% reducing lead time decreases the reorder point and safety stock which is the prime concern of perishable product supply chains. However, Warburton, (2004) in their research defined Bull Whip Effect (BWE) as a ratio of replenishment delay to the time span of forecasting smoothening. It is observed that as replenishment delay is increase, BWE also increased and the safety inventory shoot up above and below the average inventory. In the following section, research work carried by Warburton et al, is presented in greater depth.

2.7.1 Warburton et al.'s Model of BWE

The researchers have studied the impact of bullwhip effect arising due to larger lead times on the inventory level in the supply chain. The analysis starts with the simple supply chain equations and retailers attempt to minimize their inventory while maintaining sufficient on hand to guard against fluctuations in demand. The inventory, *I(t)*, at any time (t) is depleted by the demand rate, *D(t)*, and increased by the receiving rate, *R(t)*, so the inventory balance equation is:

$$\frac{dI}{dT} = R(t) - D(t) \quad (1)$$

and

$$R(t) = O(t - \tau) \quad (2)$$

For the demand term, a step function surge in demand is analyzed, which is a rich source of insight when seeking an understanding of the trade-offs involved in tuning an ordering policy. Also, since the equations are linear, any arbitrary demand can be built from a suitable linear combination of step functions. The lead-time, τ is the time from the issue of orders until the receipt of the goods from the supplier. Thus, the receipts are equal to the orders placed at a previous time. The second equation merely expresses the fact that the receiving rate is equal to the order rate with lead time τ.

It is usually suggested that some kind of smoothing should be applied to the demand data. Otherwise, excessive fluctuations occur resulting in increased production costs. Exponential smoothing is easy to implement and relatively accurate for short-term forecasts which is suitable for perishable products. The tunable parameter, *Ta,* controls the amount of smoothing to be applied to the raw demand. The smoothed demand is given by equation

$$Ds(t+\partial t) = Ds + \frac{(AD(t) - Ds(t))\partial t}{Ta} \tag{3}$$

and the smooth demand contribution to the order rate is then

$$O_d(t) = D_o + d\{1 - exp(-t / Ta)\} \tag{4}$$

The inventory replenishment goal in the ordering policy is to bring the actual inventory towards the desired inventory:

$$Oi(t) = \frac{Io - I(t)}{Ti} \tag{5}$$

Io represents the desired inventory. This policy has the advantage that it replaces deficits due to a surge in demand, and the tuneable parameter, *Ti*, acknowledges that the deficit recovery should be spread out over time T. The order rate and inventory equations make up the system to be solved. Equations (1) and (2) can be solved exactly in terms of the Lambert W function **(**Corless, et al., 1996).

The result is that the entire, exact solution for the inventory and orders is:

$$I(t) = Io - dt \text{ for } t \le \tau \tag{6}$$

and

$$I(t) = ID - dT + A\exp[Wt / \tau] \tag{7}$$

where,

$$W = W(-\tau / T) \tag{8}$$

The Lambert W function.

The simulation results of the solutions can be seen in Figure 5.1, where it is clear that the response of the inventory depends sensitively to the ratio of the replenishment delay□ τto the inventory deficit parameter *Ti*. Larger replenishment delays increase the divergence of the inventory response (large overshoots). However, the parameter, *Ti*, can be tuned so that the inventory returns exactly to the desired level without overshoot. The inventory response for the critical value, *T*i is* also shown in the figure 2.9 Also cording to the author, the bullwhip effect (BW) is the ratio of retailer order rate to the demand rate.

Therefore,

$$BW = \frac{O(\tau)}{d} = \frac{I_D - I(\tau)}{Td} = \frac{\tau}{T} \qquad (9)$$

Thus the results of figure 2.9 equally holds good for equation (9)

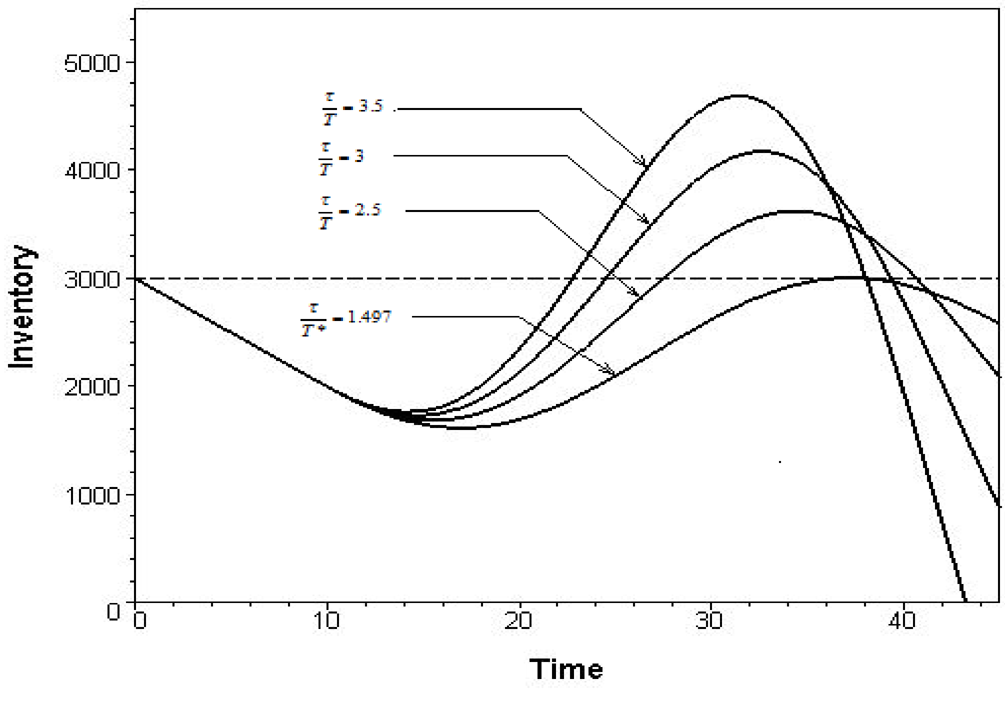


Figure 2.9: Effect of lead time variation on the inventory level [Warburton et al.]

Lead time can effectively be reduced by incorporating newer technology like RFID in the supply chain system. Wang et al., (2008) have studied the multidimensional effect of lead time on SCM. It is found form their research that the order rate is influenced by lead time. As lead time is increased, the order rate oscillates more frequently. Total inventory and inventory in hand is greatly influenced by increased lead time. Also higher lead time makes total inventory and inventory in hand more oscillatory. Chen et al., (2005) have studied the importance of value of lead time information in a single-location inventory system. They have studied concept at two levels, namely, no information sharing and full information sharing. Numerical evidence of their research suggests that the value of lead time information can be significant to the retailer, and it is benefited more if it shares information with the supplier. Song (1994) has supported the above research. It says that larger lead time requires higher base stock and variable lead time increases the average cost of supply chain. Increased lead time leads to higher lead time demand of product and higher base stock to compensate higher possibility of stock outs. The other researchers who worked in this area with same concern are Souriranjan et al., 2007; Matteo, 2010 and Balakrishnan, 2004. It is understood from the above discussion that lead time has a great impact on operations of perishable products supply chains. Every supply chain manager would try to reduce the lead time to achieve benefits of reduced lead time. The related literature is presented in more concise and tabular form in the following section.

2.8 RFID and its Impact on SC of Perishable Product

The RFID systems have been used by the industries in the developed countries to facilitate day to day operations. It has a great potential to change the way of doing business. The companies like Wall-Mart, DHL, McDonald's, BMW, Daimler Chrysler AG, Boeing, Hyundai, Toyota, McCarran International Airport, US, and Virgin Atlantic Airways has incorporated RFID which has shown its merits of advantage in multidirectional flourishing the business towards prosperity. It took companies to the high level of profitability and the customer satisfaction. An overview of RFID system is presented in this chapter. Basic components and constructional details of the system, working principle, advantages over barcode system and limitations have been explained in following paragraphs.

Radio Frequency Identification (RFID) is an automatic identification and data capture technology which is composed of three elements: a tag formed by a chip connected with an antenna; a reader that emits radio signals and receives in return answers from tags, and finally a middleware that bridges RFID hardware and enterprise applications. RFID technologies with the appropriate IT infrastructure help both major distributors and manufacturers, as well as other logistics operations, such as the health-care system, defense industries, and others, dealing with complex, global supply chains in which products and product shipments must be traced and identified in a non-contact, wireless fashion using a computer network, because of cost, or security, or safety, or because parts are subject to corrosion, or food/medicine is subject to quality degradation, or other reasons (Wilke and Braunl, 2001; Brzozowski, 2004; Glidden, et al., 2004 and Knights, Henderson, and Daneshmend, 2004) All of these requirements point to an automated wireless, readable sensory-based identification method, and network, that offers more functionalities and is significantly valuable than the existing methods. RFID has the potential to change the way we do business all around the world **(**Ashley, 2004)**.**

RFID technology can increase a company's efficiency and provide other benefits to both companies and consumers; however, RFID, like any newly implemented technology, presents management with issues of new system threats and decisions about incorporating adequate controls over the new technology (Leslee and Tim, 2006). There are many valid reasons for carrying out research and deployed in industry the wireless, computer networked, sensory-based part identification methods, tools and technologies. The application fields and opportunities are vast. The key driver is that even in chaotic, largely distributed, more stochastic than deterministic business environments, adaptive organizations and enterprises must react to demands quickly, else a competitor will take the business. Therefore, they must reduce waste and improve efficiency at all fronts. The most important aspect of this strategy is to know exactly what parts they have in stock, exactly where these parts are, and in what condition/state of assembly, or preparedness (Ranky, 2006).

Furthermore, major distributors dealing with complex, global supply chains must be able to trace their shipments in detail, either because of cost, security, safety, quality degradation (as it is in the case of temperature, humidity, and/or shock sensitive components or drugs), and other reasons. While the improved information accuracy through RFID deployment will allow companies to substantially reduce out-of-stocks and back orders, they are also likely to find themselves with higher overall average inventory. This suggests a remarkable improvement opportunity, namely that companies can potentially reduce reorder quantities and target inventory levels without hurting customer service levels. This opportunity to reduce inventory and, at the same time, improve customer service levels can be applied not only across multiple tiers in the supply chain, but also within a single store (backroom and on-shelf replenishment). For example, accurately knowing the on-shelf inventory of products will enable replenishment of the shelf stock in an on-demand manner, thereby allowing the company to reduce the overall average store inventory without sacrificing product availability to customers.

The review on RFID based perishable product supply chain literature is presented in the following table 2.7, in more concise form. Most of the literature available is related to explaining the basics of RFID. However certain literature covers the important aspect of inventory management i.e. RFID utilization in reducing inventory inaccuracy due to shrinkage and inventory counting errors. The research concern, methodology used and the research outcome is mentioned against the respective researchers in the table.

Table 2.7: Research on effect of RFID on PPSC

Author and year	Research concern	Methodology used	Research outcome
Ranky,(2006)	Introduced the RFID with constructional details.	TH	To understand RFID basics conceptually
Jones, et al., (2005)	Benefitsof RFID on SC	TH	In understanding RFID impacts.
Bottani, et al., (2010)	RFID for retailers, assembly automations, grocery retailing	TH	Quantitative assessment of potential reduction in BWE
Roh, et al., (2009)	Gettingclearances in cargo yards and managing shipment in the yards	CS TH	Developed the scale and scope for RFID adoption
Tzeng, et al,. (2008)	Economicalassessment of investment and benefits of RFID	CS	RFID improves both the processes and businessopportunities
Lee, et al., (2010)	Economicalassessment of investment and benefits of RFID	MM	RFID to improve the ordering efficiency, JIT efficiency, and operating efficiency.
Hsu et al., (2008)	Cargo clearance process.	MM	RFID technology is appropriate for handling cargos with high value of reduced time.
Kok et al., (2008)	Breakevenanalysis for adoption of RFID in the business organization	MM, DOE	It was concluded that the RFID reduces the observation cycle time leading to betterinventory management
Wu, et al. (2006)	Challengesto implement the RFID technology	TH	RFID technology is still becoming mature and there is still much promise for the future.
Pietro, et al., (2010)	RFIDrisks	TH	Risks consideration
Ryu, et al. (2009)	RFID protocols, rules and regulations	TH	Protocols to be followed
Estrada et al.,(2002)	Value of RFID in cold chains		RFID improves quality
Jedermann,et al.2007	Importance of RFID in cold chains		And life of product
Zhou, (2009)	Item -levelinformation visibility	MM	Improved decision making

Author and year	Research concern	Methodology used	Research outcome
Agrawal et al., (2009)	Analyze the impactof information sharing and lead time on the BWE	MM	RFID technologies can reduce the BWE
Joshi,(2000) Simchi-L., et al., (2000) Fleisch, et al., (2005)	Simulation for impact of information sharing on BWE	SM	Sharing information at different stages of SC, reduces BWE
Kok et al.,(2007) Lee et al., (2004) Kang et al.,(2004)	Impact of RFID to overcome routine challenges	MM	Improved Profitability
Gaukler et al., (2005)	Impact t of RFID on supply visibility in the (Q, R)policy.	MM	Total cost saving up to 35%
Atali et al., (2006)	Impact of RFID on inventory inaccuracy.	MM	Improved inventory counting, and better decision
Kok et al., (2008)	RFID to reduce shrinkage errors	MM	Longinspection cycle can increase investment dramatically
Sahin, (2004) Sahin et al., (2007)	Effect of inventory inaccuracy on performance of SC	MM	RFID to reduce inventory inaccuracy
Rekik et al., (2007a) Rekik et al. (2007b).	Quantified impact of inventory inaccuracyon inventory management	MM	RFID has a great potential to reduce inventory inaccuracy
Tellkamp, (2006)	Model to analyze the potential impact of RFID on product availability.	MM	RFID to improved product availability, quality and service level
Gaukler, (2007)	An analytical model in order to analyze the cost of RFID technology and also its benefits.	MM	RFID can reduce costs by about 2.8% - 4.5%.
Sarac et al., (2007)	Proposed newsvendor model for impacts of RFIDon inventory inaccuracy	MM	RFID to improve inventory inaccuracy

2.9 *Comparison of RFID with Barcode System*

RFID and barcodes are similar in that they are both data collection technologies, meaning they automate the process of collecting data. However, they also differ significantly in many areas. Although this comparison primarily focuses on the advantages of RFID over barcodes, RFID will not completely replace barcode technology. Barcodes offer some advantages over RFID, most notably their low cost. The major points of comparison of RFID with barcode system are summarized in the following table.

Table 2.8: Comparison between Barcode and RFID System

Point of Comparison	RFID	Barcode
Line of Site	Not required (in most cases)	Required
Read Range	Passive UHF RFID: - Up to 40 feet (fixed readers) - Up to 20 feet (handheld readers) Active RFID: - Up to 100's of feet or more	Several inches up to several feet
Read rate	10's, 100's or 1000's simultaneously	Only one at a time
Identification	Can uniquely identify each item/asset tagged.	Most barcodes only identify the type of item (UPC Code) but not uniquely.
Read/Write	Many RFID tags are Read/Write	One at a time read only
Technology	RF (Radio Frequency)	Optical (Laser)
Interference	Like the TSA (Transportation Security Administration), some RFID frequencies don't like Metal and Liquids. They can interfere with some RF Frequencies.	Obstructed barcodes cannot be read (dirt covering barcode, torn barcode, etc.)
Automation	Most "fixed" readers don't require human involvement to collect data (automated)	Most barcode scanners require a human to operate (labour intensive)
Counterfeiting	Not possible	Easily
Physical size	Post stamp to a book	Larger than the smallest RFID tag
Cost	Cheaper	Costlier
Lifespan	Multiyear lifespan	Degrades due to handling
Robustness	Veryrobust to handling	Sensitiveto environment, and generally degrade once used
Dynamic Updates	RFID tags may be written to and offer on-board memory for information retention	Once a barcode is printed it remains frozen. Are not supportive of updates.
Security	Extremely high security is possible with RFID tags	Barcodes have much lower levels of security, and can be more easily reproduced

It is understood from the table above that RFID has multifold advantages over existing barcode system in respect of cost, robustness, span of coverage, automation, security and many other aspects. The next section describes the research methodology.

CHAPTER 3
RESEARCH METHODOLOGY

In this chapter, an overview of the research methodology adopted for achieving the objectives of the proposed research work is presented. The methodology used for the development of RFID-based framework for perishable product supply chain is presented. It is used for the development of framework and mathematical models with various costs of supply chain. Data analysis along with the overall research plan is presented in this chapter.

3.1 Introduction

It is understood from a comprehensive literature review that research on the utilization of a new technology such as RFID is in preliminary stagesand has received limited coverage. Consequently, the managers of the companies are not prepared for the utilization of benefits of incorporating RFID in their organizations. As discussed earlier, most of the studies in this field just narrate the theoretical benefits of RFID but do not provide any mathematical background to justify it. However, some mathematical models developed are complex in nature to understand and to implement inrealistic situations. Majority of the research work in the area of perishable product supply chainhave not considered the actual situation of a finite lead time. Therefore, developing a framework that can provide relatively simple iterative approach to model RFID benefits and to overcome the problems and challenges of supply chain on a day-to-day basis is necessary. Therefore, the aim of the current study is to develop a simple, mathematical RFID-based frame work that will be helpful for providing solutions to overcome the day-to-day problems of supply chain, to some extent.

The specific purpose of the proposed framework is to evaluate the cost effectiveness of RFID that is incorporated in supply chain and overcome the apprehensions related to the incorporation of this newer technology. It is proposed that the utilization of RFID may reduce the overall cost of the supply chain, particularly for perishable products where there is tremendous pressure of consuming the products before they get obsolete. The generalised problem is formulated using simple mathematics so that it could be explained at the ground level of supply chain. It is analyzed using the MATLAB software. MATLAB is a powerful language for technical as well as scientific computing. It can be used for mathematical computation, modelling and simulations, data analysis and processing, visualization and graphics, and developing algorithms. The standard MATLAB programme has tools that can be used for solving common problems. Apart from this, MATLAB has optional toolboxes that are collection of specific programmes designed to solve problems of wide range of domains, including engineering and technology, science, and fluid dynamics.

In the proposed framework, MATLAB is used to develop a programme for evaluating the total cost function, which is based on realistic situations and constraints. The programming platform provided by MATLAB is a more user-friendly than the other available programming methods. Moreover, MATLAB provides various functions and tool boxes and allows easy customization of these standard tools for specific purposes. The MATLAB software is easily accessible and is available in the market for the users. Considering the usefulness and easy availability of this software, MATLAB was chosen to analyse the data for the currentstudy.

The model developed in this study is atotal cost model that can be implemented at all nodes of supply chain. The proposed work specifically evaluates the cost effectiveness of RFID because the overall cost along with savings are the main driving forces for decision makers for incorporating RFID in the system. Based on the available literature, the major impact of RFID in supply chain is to the reduction of lead time, which has a pronounced impact on the performance of supply chains. While considering the various costs of supply chain using RFID, the cost of individual component of RFID is not included. This is because of cutting edge technology and the standard catalogues of the cost are not available. The crashing cost concept is considered to accommodate the cost of RFID components. Therefore, it can be easily deduced that higher the RFID technology implemented, the higher will be the crashing cost and the lower will be the lead time.

In general, the model developed in this research work considered the most realistic situations considering actual perishability effect, lead time, and varying demand. To cope up with the situations, various costs are considered for overall cost equation as mentioned below.

- Replenishment cost
- Holding cost
- Backlogging cost
- Deterioration cost
- Opportunity cost
- Crashing cost

Using these costs, an overall cost model was developed without considering the impact of RFID. The model is then deduced to different sub-models considering different cases as follows:

- Model with complete backlogging
- Model when RFID is implemented
- Model with instantaneous deterioration and complete backlogging
- Model with instantaneous deterioration and RFID is implemented

The framework developed in this research work initially develops the overall cost models, and in the next stage it analyzes the data using the MATLAB software. The parameters are then optimized for minimum total cost of supply chain using Response Surface Methodology (RSM). The effect of individual parameters on total cost and order quantity is presented in subsequent paragraphs.

The complete research methodology is depicted in the figure below.

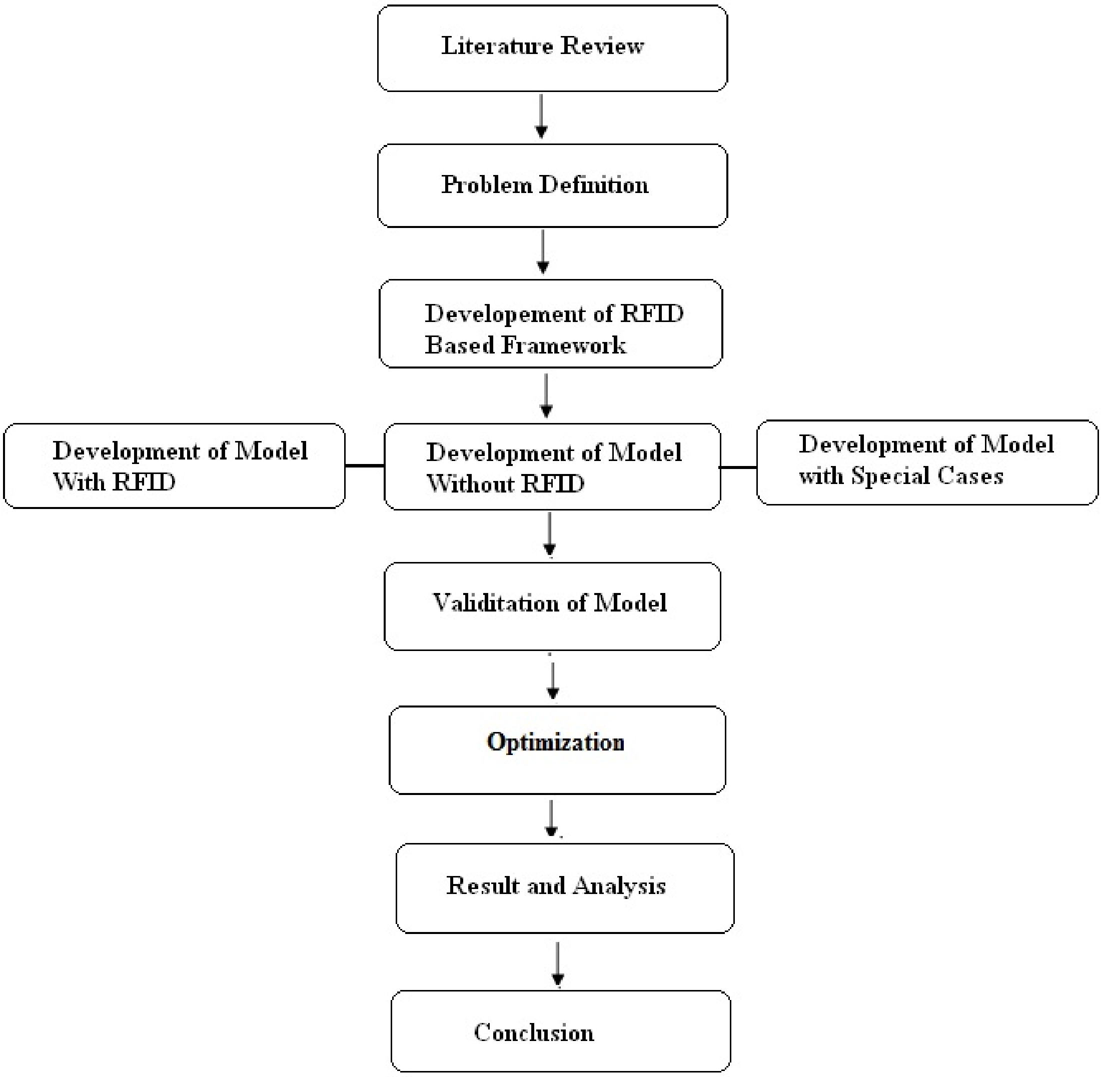


Figure 3.1: Outline of the Research

In order to achieve the research objectives, classical methodology as well as RSM was used.

3.2 Research Methodology

Analytical methods use mathematical principles to fully predict the implications of a theory, which enables researchers to examine complex relationships between the variables. They can be used to solve an equation in its entirety without any degree of estimation. By contrast, numerical methods can only attain an approximate prediction. Analytical methods are the preferred way to determine the outcome of a hypothesis when associated equations are simple and a precise answer is desired. Numerical methods are used for equations if they are complex in nature to solve. In the current study, analytical methods were used for mathematical formulation of the problem because this methodology gives nearly accurate results as compared to the other method and tools available. As discussed earlier in the literature review, most of the research that is dedicated to this area of supply chain uses the analytical method. Those researchers who have used analytical methods for their formulation are categorized as math type in the literature review. Most of the research dates back to the mid- twentieth century (Ghare and Shrader 1968) and most of the researchers have used the analytical method (Skouri and Papkritos, 2002 and Wu. et al., 2006).

In the current study, analytical methods were used for formulation of the total cost function. As described earlier, this study considers the most realistic situations that prevail at the retail shop (or at any node of the supply chain). Numerical methods were used to solve the total cost function. A quadrature formula was applied to determine the optimum values of the decision parameters, that is, the order quantity and total cost. We have plotted the total cost function as a function verses order quantity and the time at which the cycle inventory reaches zero. The model was validated considering the case with the most realistic situations that prevail at any node of supply chain. Independent parameters were optimized for minimum total cost and order quantity, as a response variable, using Response Surface Methodology (RSM). The Box–Behnken method was used in RSM for optimizingthe independent variables. The sensitivity analysis of the deterioration parameter and backlogging parameters is presented, shows impact on the total cost, order quantity, and shortage. The effect of individual parameters on the total cost and order cost is presented in the result and analysis chapter.

CHAPTER 4

MODEL FORMULATION

A mathematical model is a description about a system using mathematical concepts and the language. Mathematical models are used in all field of real life that includesnatural sciences and engineering, social science, political science and economics.It is the best way of representing the system that is surrounded by different constraints and affect the system response. The model also provides basic of understanding the performance of system in future when it met with changes in the surrounding. The quality and importance of the outcome of the system depends how well the model is developed.

Development of model needs to understand the system concept clearly and thoroughly. The method used for model should be simple to understand and easy to implement in the real life practices. In order to develop proposed frame work it is necessary to understand the concepts of some early important research work. Following paragraphs highlights some important research work in this context.

4.1 Background

Literature review indicates that large number of research work has been credited to the vast spectrum of supply chain management. As discussed earlier, most of the work is devoted to order quantity, discounts, coordination, supplier selection, different pricing and issuing policies. As the perishable product supply chains problems are concerned, the root cause for these problems have not much studied and explained in details. The basic challenge with perishable product supply chains is to deliver product before it get deteriorated. This challenge could be faced to maximum extent by controlling the replenishment lead time using newer technology like RFID. Though lead time is very important parameter in perishable product supply chain, most of the researchers in the area of perishable product supply chain have considered zero lead time in their research work. The lead time has pronounced impact on inventory level, demand satisfaction and overall cost of the supply chain as discussed in the literature review (Warburton et al 2004).

From the analysis of Warburton's model it was inferred that the lead time is the important factor for decision making at all levels of supply chain. Lead time and its variation have pronounced impact on the inventory level of the supply chain. Higher lead time results in boosting the bullwhip effect, higher inventory level, higher mismanagement and higher costs. The managers must try to control lead time, lead time variations and lead time demand variations to reduce inventory in hand sufficient to satisfy customer demand without shortage. To overcome such ambiguities in the supply chains, and the newer technology like RFID may provide the better solutions. This is equally important for the supply management of perishable product to reduce loss due deterioration and to provide fresh products to the customer with optimum cycle service level. This objective can be achieved by incorporating newer technology like RFID in the supply system. The utility of RFID can be better understood from the proposed RFID based supply chain architecture which is explained in the following pages.

4.2 RFID Based Supply Chain Architecture

For better understanding of the impact of RFID on supply chain, the RFID based supply chain architecture was proposed as shown in figure 4.1 (Badole C. M. et al., 2012). It provides information about material and information flow throughout the supply chain using RFID database. All the stages are interconnected to each other using RFID database, hence any stage can avail all pertinent information about demand, order quantity, age and quality of product, delay and order status at any stage. This information, Point of Scale (PoS) data can be used for planning and strategically decision making. Thus, demand uncertainty at every stage may be reduced to a great extent. The reduced uncertainty leads to the better management of inventory, reduced order quantity, reduced safety stock in supply chain, reduced shrinkage and certainly leads to the reduced overall cost.

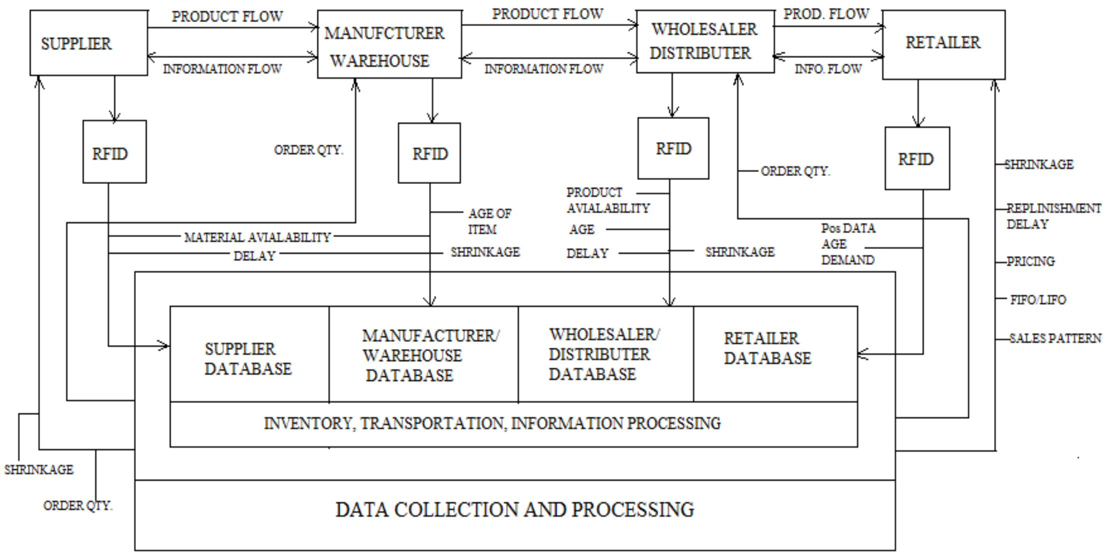


Figure 4.1: RFID based architecture of supply chain of perishable product

Using RFID sensors the quality of the product can be judged and based on the remaining available shelf life of product the newer pricing strategies can be incorporated to reduce the loss due to obsolescence. Based on the nature and purchasing habits of the customers, the decision can be taken regarding FIFO and or LIFO strategy to be implemented. Overall it is observed that RFID has pronounced impact in reduction of lead time and increased certainty in supply chain decisions (Peter Jones et al. 2005; Paul G. Ranky 2006).

RFID technology may increase a company's efficiency and provide other benefits to both company and consumers. However, RFID, like any newly implemented technology, presents management with issues of new system threats and decisions about incorporating adequate controls over the new technology (Higgins L. N. and Cairney T., 2006). But application fields and opportunities are vast. The key driver is that even in chaotic, largely distributed, more stochastic than deterministic business environments, adaptive organizations and enterprises must react to demands quickly, else a competitor will take the business. Therefore, they must reduce waste and improve efficiency at all fronts. The most important aspect of this strategy is to know exactly what parts they have in stock, exactly where these parts are, and in what condition / state of assembly, or preparedness (Ranky P. G., 2006). Furthermore, major distributors dealing with complex, global supply chains must be able to trace their shipments in detail, either because of cost, security, safety, quality degradation (as it is in the case of temperature, humidity, and/or shock sensitive components or drugs), and other reasons. The improved information accuracy through RFID application will allow companies to substantially reduce out-of-stocks and back orders. They are likely to find themselves with higher overall average inventory. This may suggests remarkable improvement opportunity, namely that companies can potentially reduce reorder quantities and target inventory levels without hurting customer satisfaction.

It has been observed from literature review, most of the research work is dedicated to study pricing, replenishment policies, issuing policy, order quantity and cost benefit of a perishable product supply chains. Maximum research carried out on perishable product supply chain do not considered the realistic condition of finite lead time. Almost researchers they have been referred by (Skouri and Papachristos, 2002 and Wu et al. 2006) have considered a condition of zero lead time for perishable product inventory management. It is understood that condition of zero lead time is a non practical scenario for any kind of inventory management.

In proposed model, most of the practical and realistic conditions that the supplier and retailer face in today's globalised environment have been considered. Therefore, this model/research work differs from others in the sense this model combines the effect of lead time as it is very important parameter, effect of perishability, varying demand and overall effect of newer technology like RFID. A model is developed for log concavely varying demand (Skouri and Papachristos, 2002; Chang et al. 2003; Lee et al. 2007; Wee, et al 2001; Youang, 2004 and Wu et al. 2006) according to the time which best suits the demand for perishable product. The combination of these conditions together reflects more realistic situation of the supply chain of perishable products. In all the works cited above, no work is specifically devoted to the perishable product inventory management with real situations. Hence, new model is developed considering these conditions.

In the normal situations, with RFID is implementation, the extent of this technology implementation will decide the reduction in lead time. This decides the amount of crashing cost. Obviously, when there is sudden rise in demand for product due to seasonality or discounts or promotions, some additional efforts would be required to further reduce lead time. Hence the crashing cost would increase accordingly. The additional efforts may be the adoption of sophisticated and fast servicing transportation and other related services (Joseph et al, 2011). The managers would maintain balance between lead time reduction and the crashing cost.

Another point considered in this cost formulation is that product being a perishable it is directly shifted to the shelves instead unloading truck in backyard and then shifting product to shelves from backyard. And hence in this analysis, the holding cost is the cost of number of units available on shelf at any time and it do not consists the cost of labour required for shifting product from backyard to shelf and maintenance of it.

The assumptions made above are practical and broadens the set of all policies. Initially, we formulate for total cost of perishable product supply chain considering the effect of RFID. Crashing cost was included that associate with implementation of RFID leading to reduction of lead time.

While developing model for perishable product supply chain following costs are considered.

- Replenishment cost
- Holding cost
- Backlogging cost
- Deterioration cost
- Opportunity cost
- Crashing cost

The above mentioned cost types are defined as follows.

- *Replenishment cost:* it consists of fixed set up cost per order including postage, telegraph, paper work etc and additional replenishment cost per unit of the order quantity includes transportation, inspection cost.

- *Holding cost:* it is the cost of physical inventory carried per unit time which equals to the cost of each unit multiplied by number of units carried per unit time.
- *Deterioration cost:* it is the cost of items that get deteriorated and become absolute and is equals to the cost of each unit multiplied by number of units deteriorated per unit time.
- *Backlogging cost:* it is the cost of fraction/full demand (units) backlogged during the period of shortage. This cost depends upon the rate at which the demand is backlogged or satisfied.
- *Opportunity cost:* it the cost of lost sales which is not fulfilled during shortage period which equals to the cost of each unit multiplied no of units that are not backlogged.
- *Crashing cost:* it is the cost of additional facility or technology incorporated in system to reduce lead time. This cost varies according to the variation in lead time and proportionately will lead to variation in inventory in the system.

4.3 The Model

4.3.1 Assumptions

- A finite planning horizon is considered that consists of n number replenishment cycles. Formulation is carried out per cycle basis.
- Cycle starts just after replenishment with maximum inventory and ends with negative inventory due to shortage. So, at the start of cycle, inventory is maximum.
- The product has some initial freshness value and it starts deteriorating after certain time t_d after replenishment. Hence for the period of t_0 to t_d there is no

deterioration and inventory varies as a function of demand. After t_d inventory varies as cumulative effect of deterioration and demand.

- Replenishment is considered as instantaneous.
- The finite lead time $T_l \neq 0$ is considered which a realistic situation is.
- The deterioration rate θ is considered as constant per unit time $(0 \leq \theta \leq 1)$ as the product is maintained under the same set of conditions.
- The demand is continuous log concave function of time f (t) such that $f'(t) \neq 0$ (Skouri, et al. 2002). The demand function which is logarithmically decreasing. This suits best for the perishable products where in demand decreases logarithmically as shelf life of product goes on decreasing
- The shortages are allowed in the cycle.
- The unsatisfied demands are backlogged partially with the rate exp $(-\alpha t)$ where *t* is the time between start of shortage till the next replenishment and $\alpha > 0$ is the cost dependent parameter. This justifies that whatever demand is to be backlogged, is backlogged at very high rate initially which decreases exponentially. This is essential to maintain the good will of customer.
- RFID do not have (except cold chains) impact on deterioration rate of perishable product and deterioration continues even after incorporation of RFID.

4.3.2 Notations Used

I = Inventory at any instant

t_o = Time of the start of cycle

t_d = Time of freshness of product, till this time there is no deterioration.

t_r = Time of placing the order, reorder point.

t_1 = Time of zero inventory after which shortage starts. Till this time the inventory is available in the cycle. It is also termed as inventory in hand time.

t_2 = Time of end of shortage and the system gets replenished

θ = Rate of deterioration

$f(t)$ = Demand rate which is log concave function of time

α = Backlogging parameter

Q = Lot size.

A = Fixed set-up replenishment cost per order

C_Q = Additional replenishment cost paid per unit of order quantity

C_H = Inventory holding cost per unit

C_D = Deterioration cost per unit of deteriorated items

C_S = Backlogging cost per unit of backlogged inventory

C_O = Opportunity or lost sale cost per unit of lost sales

C_C = Crashing cost per unit.

T_l = Lead time

= $t_2 - t_r$, the time laps between the reorder point and the replenishment point

I_{max} = Maximum inventory at start of cycle i.e. $t = t_o$

With this data base the inventory variation according to the demand and perishability effect, graph is plotted as shown below. In the figure 4.2, the inventory variation is divided in three regions which are (t_0 to t_d, t_d to t_1 and t_1 to t_2). Inventory at all three regions is formulated first and then total inventory per cycle is formulated.

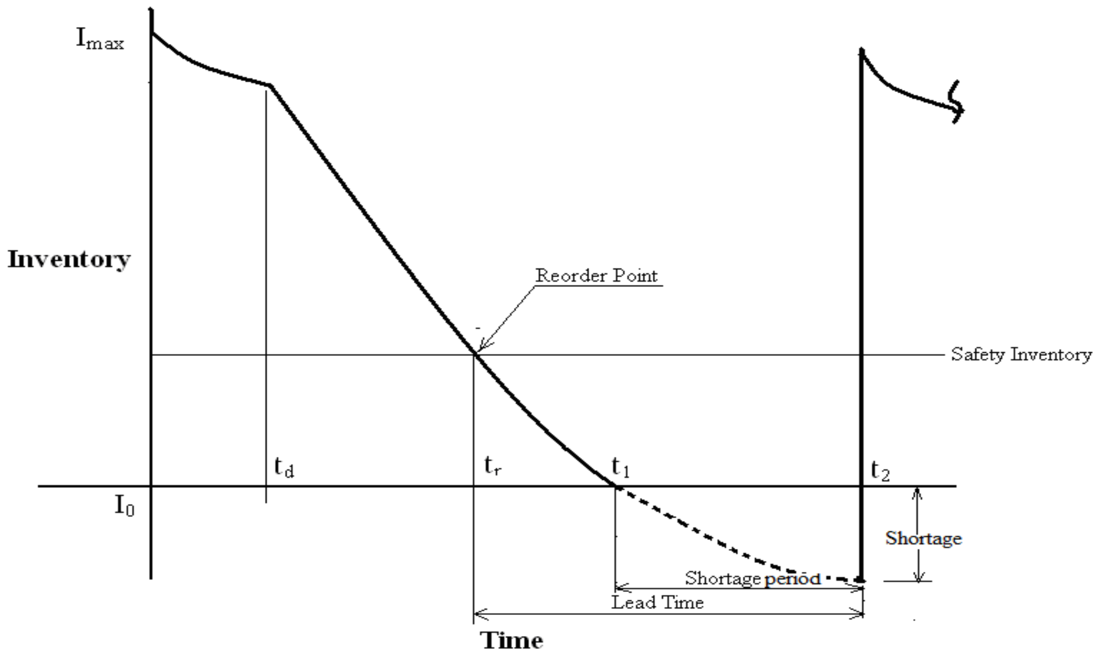


Figure 4.2: Variation of inventory with respect to time

The mathematical formulation of the problem is described as under.

4.3.3 Mathematical Formulation

Let us define inventory level I(t) at any time t as follows:

$$I(t) = \begin{cases} I_1(t), \; t_0 \le t \le t_d \\ I_2(t), \; t_d \le t \le t_1 \\ I_3(t), \; t_1 \le t \le t_2 \end{cases} \tag{1}$$

Where, $I(t_0) = I_{\max}$ and $I(t_1) = 0$.

Case (i) $t_0 \le t \le t_d$:The items start perishing after time t_d. Before that, we assume that the product is fresh. Therefore, the rate of change of inventory will depend on the demand.

$$\frac{dI_1(t)}{dt} = -f(t), \qquad I_1(t_0) = I_{\max}$$

Thus, the inventory $I_1(t)$ is given by

$$I_1(t) = I_{\max} - \int_{t_0}^{t} f(u)du, \;\; t_0 \le t \le t_d \tag{2}$$

It has been observed form figure 4.2, the inventory level is decreasing with time. The amount of inventory carried during $t_0 \le t \le t_d$ is the difference between the initial or maximum inventory and the inventory consumed while it was fresh. Mathematically,

Amount of inventory carried during $t_0 \le t \le t_d$ is calculated by

$$\begin{aligned} \int_{t_0}^{t_d} I_1(t)dt &= \int_{t_0}^{t_d} \left(I_{\max} - \int_{t_0}^{t} f(u)du \right) dt \\ &= I_{\max}(t_d - t_0) - \int_{t_0}^{t_d} (t_d - u) f(u)du \end{aligned} \tag{3}$$

Case (ii) $t_d \le t \le t_1$: During this period, perishability also comes into effect with demand. Therefore, the rate of change of inventory is given by

$$\frac{dI_2(t)}{dt} + \theta I_2(t) = -f(t), \; I_2(t_1) = 0 \tag{4}$$

Thus, the inventory $I_2(t)$ is given by

$$I_2(t) = \int_{t}^{t_1} e^{\theta(u-t)} f(u)du, \;\; t_d \le t \le t_1 \tag{5}$$

It can be observed from Figure 4.2, the inventory level is decreasing with higher rate as a combine effect of deterioration and demand with time. The amount of inventory carried during $t_d \le t \le t_1$ is calculated considering boundary condition, that is at $t_d = t_1$, Imax = $I_2(t_1) = 0$. Mathematically, Amount of inventory carried during $t_d \le t \le t_1$ is given by

$$\int_{t_d}^{t_1} I_2(t)dt = \int_{td}^{t_1}\left(e^{-\theta t} \int_{td}^{t_1} e^{\theta u} f(u)du \right)dt$$
$$= \frac{1}{\theta}\int_{t_d}^{t_1}\left(e^{(u-t_d)\theta} - 1\right)f(u)du \qquad (6)$$

Now amount of deteriorated items can easily be calculated from equation (6) which is given by

= $\theta \times$ (Amount of inventory carried)

$$= \int_{t_d}^{t_1}\left(e^{(u-t_d)\theta} - 1\right)f(u)du$$

Considering the continuity of I(t) at t_d, i.e. $I_1(t_d) = I_2(t_d)$, we get

$$I_{\max} = \int_{t_0}^{t_d} f(u)du + \int_{t_d}^{t_1}\left(e^{(u-t_d)\theta}\right)f(u)du \qquad (7)$$

Case (iii) $t_1 \le t \le t_2$: During this period, inventory goes negative and the unsatisfied demand is backlogged partially with the rate $\exp(-\alpha(t_2 - t))$. Therefore, the rate of change of inventory is given by

$$\frac{dI_3(t)}{dt} = -e^{-\alpha(t_2 - t)} f(t),\ I_3(t_1) = 0 \qquad (8)$$

The amount of backlogged inventory $I_3(t)$ is given by

$$I_3(t) = \int_{t_1}^{t} e^{-\alpha(t_2 - u)} f(u)du,\ t_1 \le t \le t_2$$

The amount of backlogged during $t_1 \le t \le t_2$ is given by

$$\int_{t_1}^{t_2} I_3(t)dt = \int_{t_1}^{t_2}\left(\int_{t_1}^{t} e^{-\alpha(t_2-u)} f(u)du\right)dt$$
$$= \int_{t_1}^{t_2} (t_2 - u)e^{-\alpha(t_2-u)} f(u)du \qquad (9)$$

The amount of lost sales is the difference of the demand arising and the demand backlogged during $t_1 \le t \le t_2$. Mathematically,

$$= \int_{t_1}^{t_2} f(u)du - \int_{t_1}^{t_2} e^{-\alpha(t_2-u)} f(u)du$$
$$= \int_{t_1}^{t_2} \left(1 - e^{-\alpha(t_2-u)}\right) f(u)du \qquad (10)$$

Lot Size: All next cycles should be replenished with minimum certain quantity isreferred here as a lot size or order quantity. That should include inventory consumed during freshness period of inventory plus inventory consumed as a combine effect of deterioration and the demand and the amount backlogged during shortage period of previous cycle as shown in figure 4.2. The lot size Q for the current cycle $t_0 \le t \le t_2$ is given by

$$Q = Max(I_1(t), I_2(t)) + Max(|I_3(t)|)$$
$$= I_{\max} + \int_{t_1}^{t_2} e^{-\alpha(t_2-u)} f(u)du$$
$$= \int_{t_0}^{t_d} f(u)du + \int_{t_d}^{t_1} \left(e^{(u-t_d)\theta}\right) f(u)du + \int_{t_1}^{t_2} e^{-\alpha(t_2-u)} f(u)du \qquad (11)$$

Lead Time: Lead time has a significant impact on order quantity decisions and operational cost of the supply chain. New technology like RFID provides the supply chain managers to reduce the uncertainties by providing the visibility of the inventory flow and accurate lead time information. However, implementing such technologies would require some additional cost, which is described here as “crashing cost”. Prior research shows that the higher the extent of implementation of such technology the lower will be the lead time and vice a versa (Ouyangand Chuang, 2001).It is also true that one needs to carry more inventories to avoid the stock outs if a product has a longer lead time.

The lead time $T_l = t_2 - t_r$ where $t_d < t_r < t_1$. The inventory carried and shortage will be depend upon the extent of technology incorporated that is crashing cost.In another words higher the technology incorporated, higher will be the crashing cost and lower will be the lead time (Song, Yang, and Luo, 2011) during $t_r < t < t_2$. As the replenishment point ($t = t_2$) moves away from the zero inventory point ($t = t_1$), the lead time increases as a result of reduced crashing cost which is analogues to the inventory carried. Therefore,

$$\text{Crashing cost } = C_c\left[\int_{t_r}^{t_1}\frac{1}{\theta}\left(e^{(u-t_r)\theta}-1\right)f(u)du-\int_{t_1}^{t_2}(t_2-u)e^{-\alpha(t_2-u)}f(u)du\right] \quad (12)$$

After deriving equations for all required quantities, the equation for total cost function was derived.

4.3.4 Total cost function

We have all necessary quantities to formulate the total inventory cost function:TC=Lot size×(Additional replenishment cost paid per unit of ordered item) +Fixed setup replenishment cost +Holding cost + Deterioration cost + Backlogging cost + Opportunity cost + Crashing cost

$$\begin{aligned} &= C_Q Q + A + C_H(\text{Totalinventory carried}) + C_D(\text{Amount of deteriorated items}) \\ &+ C_s(\text{Amount of Backlogged }) + C_O(\text{Amount of lost sales}) + \text{Crashing Cost} \end{aligned}$$

$$= C_H\left(I_{\max}(t_d - t_0) - \int_{t_0}^{t_d} (t_d - u) f(u)du + \frac{1}{\theta}\int_{t_d}^{t_1}\left(e^{(u-t_d)\theta} - 1\right) f(u)du \right)$$

$$+ C_D\left(\int_{t_d}^{t_1}\left(e^{(u-t_d)\theta} - 1\right) f(u)du \right) + C_S\left(\int_{t_1}^{t_2} (t_2 - u)e^{-\alpha(t_2-u)} f(u)du \right) + C_Q\left(I_{\max} + \int_{t_1}^{t_2} e^{-\alpha(t_2-u)} f(u)du \right)$$

$$+ C_O\left(\int_{t_1}^{t_2}\left(1 - e^{-\alpha(t_2-u)}\right) f(u)du \right) + C_c\left[\int_{t_r}^{t_1} \frac{1}{\theta}\left(e^{(u-t_r)\theta} - 1\right) f(u)du + \int_{t_1}^{t_2} (t_2 - u)e^{-\alpha(t_2-u)} f(u)du \right] + A$$

Rearranging the terms, the total cost function is given by;

$$TC = A + \int_{t_0}^{t_d} \left\{ C_H(u - t_0) + C_Q \right\} f(u)du + \frac{C_c}{\theta}\int_{t_r}^{t_1}\left(e^{(u-t_r)\theta} - 1\right) f(u)du$$

$$+ \int_{t_d}^{t_1}\left(e^{(u-t_d)\theta}\left\{ C_Q + C_H(t_d - t_0) + \frac{C_H}{\theta} + C_D \right\} - \frac{C_H}{\theta} - C_D \right) f(u)du \qquad (13)$$

$$+ \int_{t_1}^{t_2} e^{-\alpha(t_2-u)}\left\{ C_Q - C_O + (C_S - C_C)(t_2 - u) + C_O \right\} f(u)du$$

This represents the total cost model of the supply chain. This model is further deduced to different four models considering special cases as follows:

4.3.4.1 Model with complete backlogging

In a supply chain, during any cycle of replenishment the demand may arise during shortage period. The managers have to decide whether the aroused demand has to be backlogged in the forth coming cycle or let the demand be lost. If it is decided to backlog the demand, then one has to order this quantity in forthcoming cycle. If we set the backlogging parameter $\alpha = 0$ in total cost equation (13), we revert to the model with complete backlogging of the unsatisfied demand arises during shortage period. For this special case, the total relevant cost is given by

$$TC = A + \int_{t_0}^{t_d} \left\{ C_H (u - t_0) + C_Q \right\} f(u) du + \frac{C_c}{\theta} \int_{t_r}^{t_1} \left(e^{(u-t_r)\theta} - 1 \right) f(u) du$$
$$+ \int_{t_d}^{t_1} \left(e^{(u-t_d)\theta} \left\{ C_Q + C_H (t_d - t_0) + \frac{C_H}{\theta} + C_D \right\} - \frac{C_H}{\theta} - C_D \right) f(u) du \qquad (14)$$
$$+ \int_{t_1}^{t_2} \left\{ C_Q + \ (C_S - C_C)(t_2 - u) \right\} f(u) du$$

In this model, the decision maker have some flexibility to choose a suitable value of α ranging from 0 to almost any desired rate of partial backlogging, which fits better in realistic situations. Inventory variation will takes place according to figure 4.2.

4.3.4.2 Model with instantaneous deterioration and complete backlogging.

If td → to and α = 0 in the proposed model (13), we can obtain the corresponding inventory model for the instantaneous deterioration. In this case, the total relevant cost is given by

$$TC = A + \frac{C_c}{\theta} \int_{t_r}^{t_1} \left(e^{(u-t_r)\theta} - 1 \right) f(u) du$$
$$+ \int_{to}^{t1} \left(e^{(u-t_d)\theta} \left\{ C_Q + \frac{C_H}{\theta} + C_D \right\} - \frac{C_H}{\theta} - C_D \right) f(u) du \qquad (15)$$
$$+ \int_{t_1}^{t_2} \left\{ C_Q + (C_S - C_C)(t_2 - u) \right\} f(u) du$$

This model would be helpful for highly perishable products that deteriorate just after putting them on retailer shelves and complete backlogging of the unsatisfied demand arises during shortage period. In this model too, the decision maker has flexibility to choose a suitable value of α ranging from 0 to almost any desired rate of partial backlogging, which fits better in realistic situations.

The inventory variation will take place as shown in the figure 4.3 below

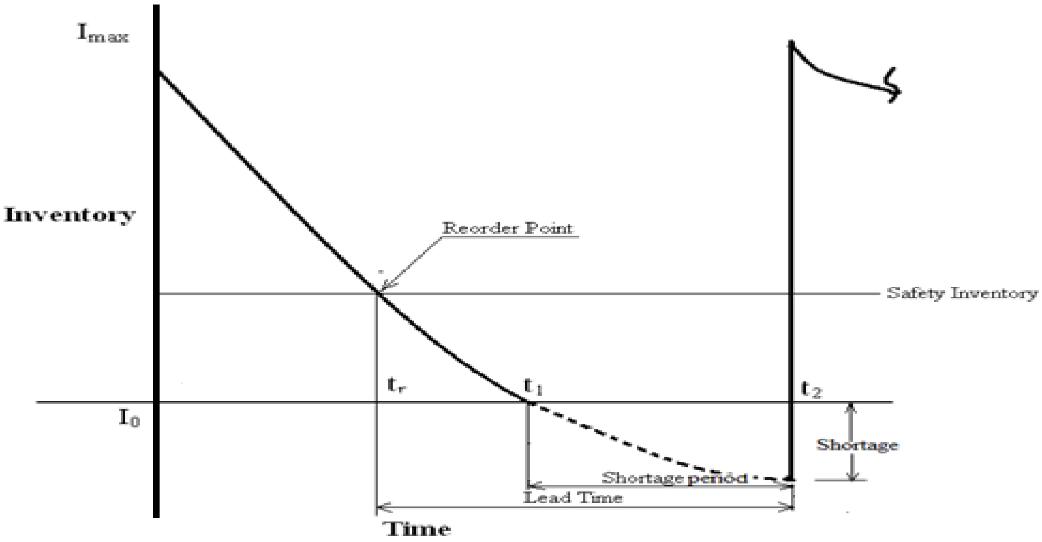


Figure 4.3 Variation of inventory for instantaneous deterioration and complete backlogging.

4.3.4.3 Model when RFID is implemented to the full extent

When RFID is implemented to the full extent, the time of replenishment tends to time of zero inventories, that is lead time tends to reduce. All the costs related to shortage and backlog would tend to minimize Therefore, by putting ($t_2 \rightarrow t_1$) in eq. (13), the inventory total cost function becomes

$$TC = A + \int_{t_0}^{t_d} \left\{ C_H (u - t_0) + C_Q \right\} f(u) du + \frac{C_c}{\theta} \int_{t_r}^{t_1} \left(e^{(u - t_r)\theta} - 1 \right) f(u) du$$
$$+ \int_{t_d}^{t_1} \left(e^{(u - t_d)\theta} \left\{ C_Q + C_H (t_d - t_0) + \frac{C_H}{\theta} + C_D \right\} - \frac{C_H}{\theta} - C_D \right) f(u) du \qquad (16)$$

This equation represents the lowest possible cost of supply chain as shortages and backlogging are nullified due to incorporation of RFID to full extent.

The inventory variation will take place as shown in the figure 4.4 as shown under.

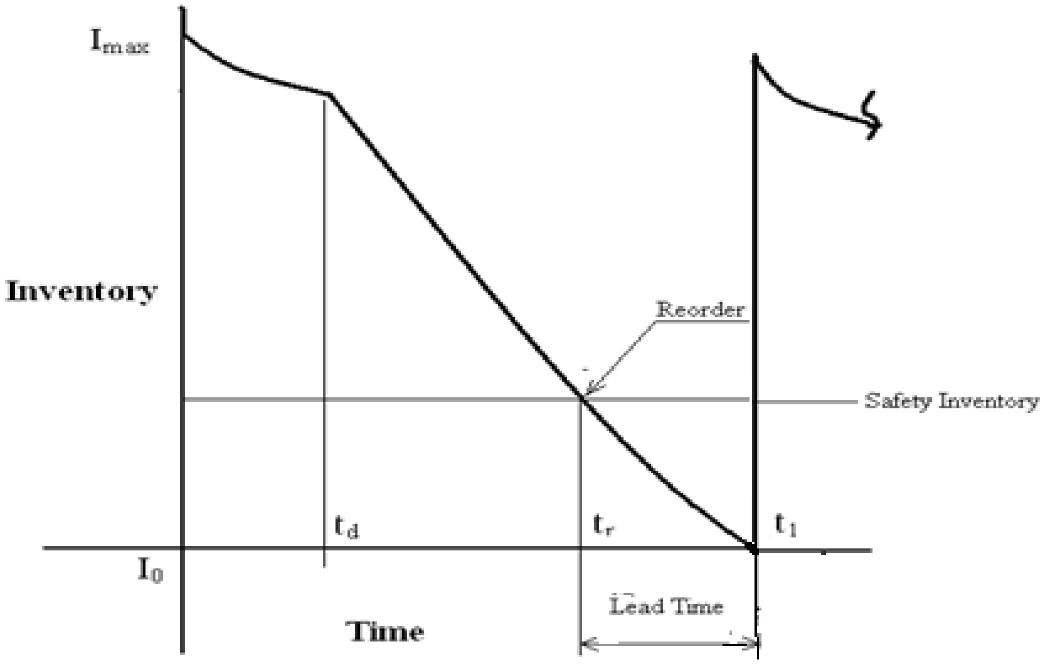


Figure 4.4 Variation of inventory when RFID is implemented to the full extent.

4.3.4.4 Model with instantaneous deterioration and RFID is implemented to the full extent

In this case the product starts deteriorating just after placing them on retail shelves. Such products are called as highly perishable products like mushroom. Therefore by putting $t_d \rightarrow t_0$ and $t_2 \rightarrow t_1$ in the proposed model (13), we can obtain the corresponding inventory model for the instantaneous deterioration without shortages. In this case, the total relevant cost is given by

$$TC = A + \frac{C_c}{\theta}\int_{t_r}^{t_1}\left(e^{(u-t_r)\theta} - 1\right) f(u)du$$

$$+ \int_{t_o}^{t_1}\left(e^{(u-t_d)\theta}\left\{C_Q + \frac{C_H}{\theta} + C_D\right\} - \frac{C_H}{\theta} - C_D\right) f(u)du \qquad (17)$$

The variation of inventory in this case is shown in figure 4.5 below.

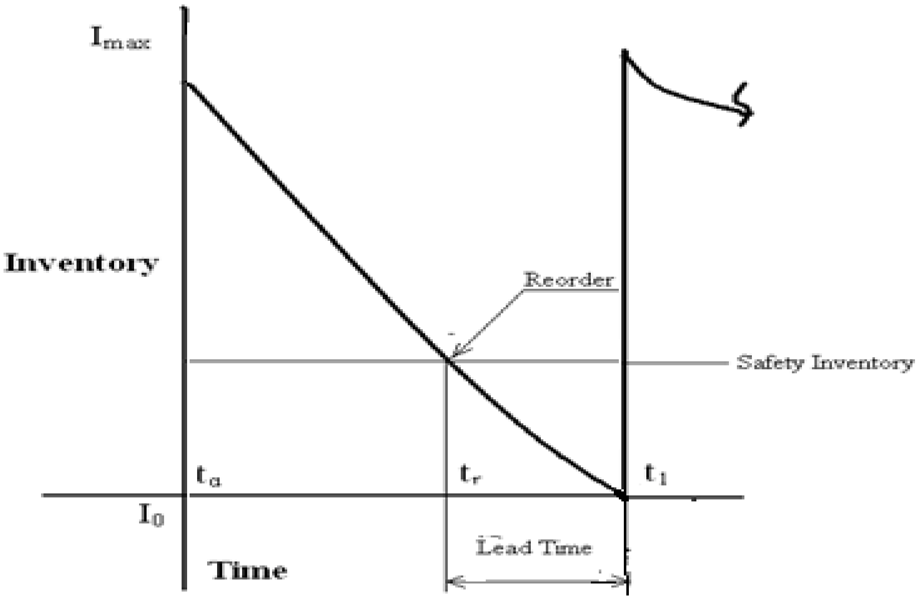


Figure 4.5 Variation of inventory with instantaneous deterioration and RFID is implemented to the full extent

This model suites for highly perishable products that deteriorates instantly after putting on retailer shelves and shortages and backlogs are nullifies as the matter of RFID implementation.

Thus, four different models have been derived from the main total cost function model. In the next section, analysis is carried out to validate the model. A model is programmed using MATLAB software and database. A step by step programming of the model is carried out and then considering the realistic situation, parameter values and the demand function a results are achieved and the model is validated. Finally, the parameters are optimized using RSM which is explained in the next chapter.

CHAPTER 5

RESULT AND ANALYSIS

Introduction:

In the previous chapter, the mathematical model for the total cost of supply chain along with four different cases was formulated. Because of the implicate form of the mathematical model, data were analyzed in two stages. In the first stage, classical analysis was performed considering the case of a supply chain where data was acquired from available literature and certain data was assumed to suit the proposed model. Effect of an individual parameter on the total cost of supply chain and order quantity, keeping other terms constant, was studied. In the next stage, the independent variables affecting the response variablestotal cost and the order quantitywere optimized for achieving the optimum values of response variables. In this chapter, the significance of each parameter along with the interactive effect of independent variables is studied on response variables. Optimum values of the parameters are determined for the minimum total cost of supply chain and the values were optimized using Response Surface Methodology (RSM).

5.1 Classical Approach

For analysis, the demand rate function is considered as $f(t) = \exp\left(-\frac{t^2}{2}\right)$, so that demand at any time t is $F(t) = \sqrt{\frac{\pi}{2}} erf\left(\frac{t}{\sqrt{2}}\right)$

The graph of the above function is drawn using MATLAB programming, which is as shown in the figure 5.1.

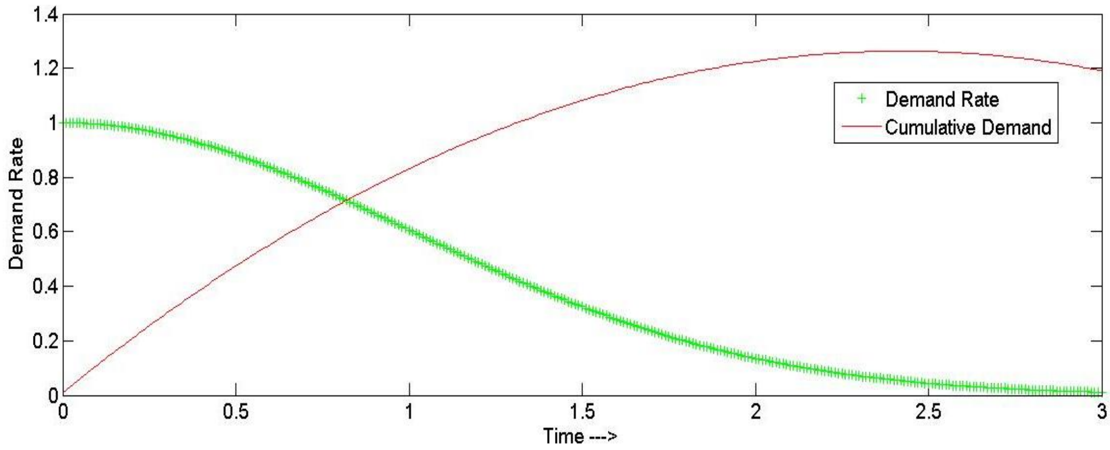


Figure 5.1: Graphical presentation of demand function

The consideration of this demand function for this research work suits the realistic situation that persists at any node of supply chain. The demand rate function is decreasing concave, which is true for perishable product that is replenished every day and its shelf life decreases day-by-day. As the shelf life of the product decreases, that is, the product approaches obsolescence, the demand for the product also approaches zero. This may be well explained considering an example of Saras Milk that gets replenished every day at a retail outlet. Even though it has a shelf life of 2 days, customers prefer the milk that is replenished on the same date of the demand. The green line on the graph shows the cumulative demand for the product until that time. Therefore, the inventory level at any time t is given by

$$I = \begin{cases} I_{\max} - \sqrt{\dfrac{\pi}{2}} erf\left(\dfrac{t}{\sqrt{2}}\right), & 0 \le t \le t_d \\ \sqrt{\dfrac{\pi}{2}} \exp\left(\dfrac{\theta^2}{2} - \theta t\right)\left\{erf\left(\dfrac{t_1 - \theta}{\sqrt{2}}\right) + erf\left(\dfrac{\theta - t}{\sqrt{2}}\right)\right\}, & t_d \le t \le t_1 \\ \sqrt{\dfrac{\pi}{2}} \exp\left(\dfrac{\alpha^2}{2} + 3\alpha\right)\left\{erf\left(\dfrac{\alpha + t_1}{\sqrt{2}}\right) - erf\left(\dfrac{\alpha + t}{\sqrt{2}}\right)\right\}, & t_1 \le t \le t_2 \end{cases}$$

Therefore, maximum initial inventory,

$$I_{max} = \sqrt{\frac{\pi}{2}} \exp\left(\frac{\theta^2}{2} - \theta t_d\right)\left\{erf\left(\frac{t_1 - \theta}{\sqrt{2}}\right) - erf\left(\frac{t_d - \theta}{\sqrt{2}}\right)\right\} + \sqrt{\frac{\pi}{2}} erf\left(\frac{t_d}{\sqrt{2}}\right)$$

Maximum backloggedinventory,

$$S = \sqrt{\frac{\pi}{2}} \exp\left(\frac{\alpha^2}{2} + 3\alpha\right)\left\{erf\left(\frac{t_1 + \alpha}{\sqrt{2}}\right) - erf\left(\frac{\alpha + t_2}{\sqrt{2}}\right)\right\}$$

and order quantity, $Q = I_{max} + S$.

The inventory variation function was programmedusing this formulation. The graphs obtained are depicted in the following figures.The inventory variation graph (tricolor) resembles the theoretical graph shown in the figure 5.2. This justifies the accuracy and correctness of our mathematical framework and model formulation.

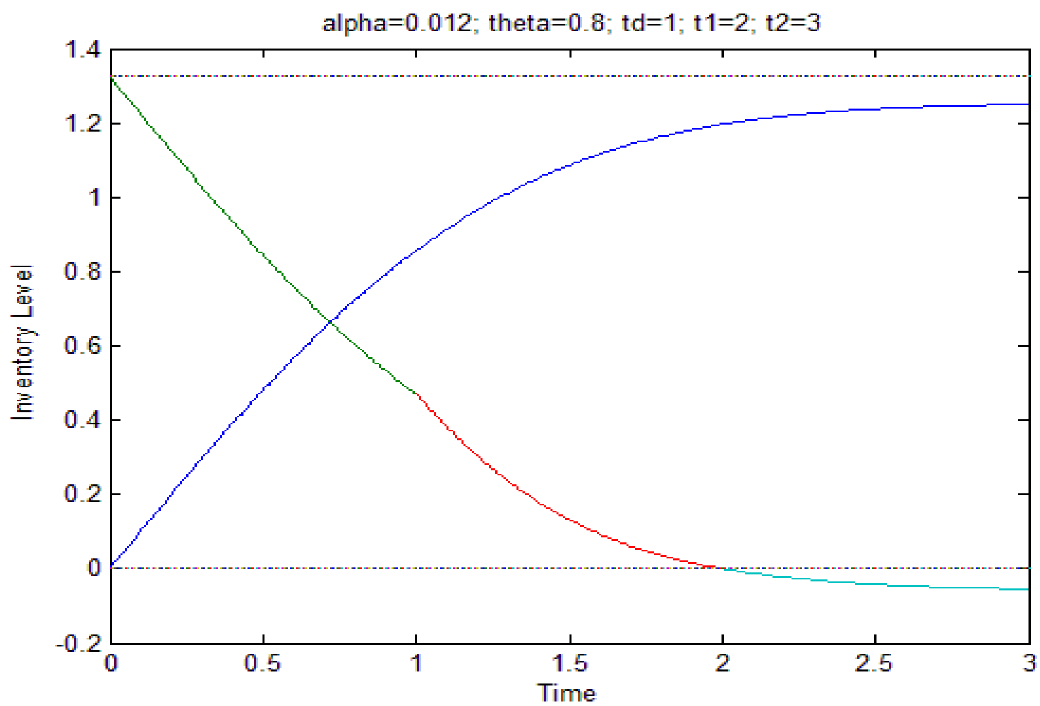


Figure 5.2: Inventory variation with time according to model

5.1.1 Model Validation

In order to validate the model, we considered various cost of supply chain of a perishable product as considered by early researchers (Skouri, et al., 2002) as Ch= 0.5; Cd = 5; Cq = 0.2; and Co=0.5. Furthermore, to suit our framework, we assumed the values for other parametersas: $\theta = 0.79$; $\alpha = 0.5$; td = 0.67; $t_1 = 1.5$, A = 10; Cc = 1.5; Cq = 0.2; and Cs = 3.5 with the notations used in the framework. The variables θ and α are the decision variables and each of them influences the managerial decision. This clearly indicates that the model can be applied to all range of perishable productse qually ranging from highly perishable to the least perishable product, in addition to the varying decision level of backlogging.

We obtained the following results for the different cases.

5.1.1.1 Case without RFID

In case without RFID, thesystem is not controlled and inventory can last at any point from zero inventories until the end of cycle time. The inventory is not replenished until the end of cycle (t_2 =2.5). The result is presented in table 5.1 and figure 5.3.

Table: 5.1 Effect of inventory in hand time (t_1) on order quantity and total cost

t_1	Q	TC
1.000000	1.720423	11.313993
1.100000	1.645334	11.309924
1.200000	1.590457	11.350726
1.300000	1.552904	11.429605
1.400000	1.529849	11.539472
1.500000	1.518606	11.673224
1.600000	1.516689	11.824002
1.700000	1.521858	11.985408
1.800000	1.532145	12.151674
1.900000	1.545869	12.317787
2.000000	1.561633	12.479559
2.100000	1.578314	12.633657
2.200000	1.595040	12.777579
2.300000	1.611164	12.909611
2.400000	1.626238	13.028746
2.500000	1.639975	13.134588

This implies that keeping the cycle time constant at t_2 = 2.5 and increasing t_1 where (inventory reaches to its zero value) from its lower value to higher value, the shortages gets reduced as a consequence of availability of inventory for a higher time period. However, even shortages and costs related to shortages are reduced, overall cost, that is, the total cost of the supply chain increases. This is because of holding physical inventory for longer time. Owing to which the holding cost superimposes the other shortage related costs, resulting in an increase in the overall supply chain cost. The collective deterioration and holding cost increases; this is also because of longer holding time of the physical inventory, which causes further deterioration of the product.

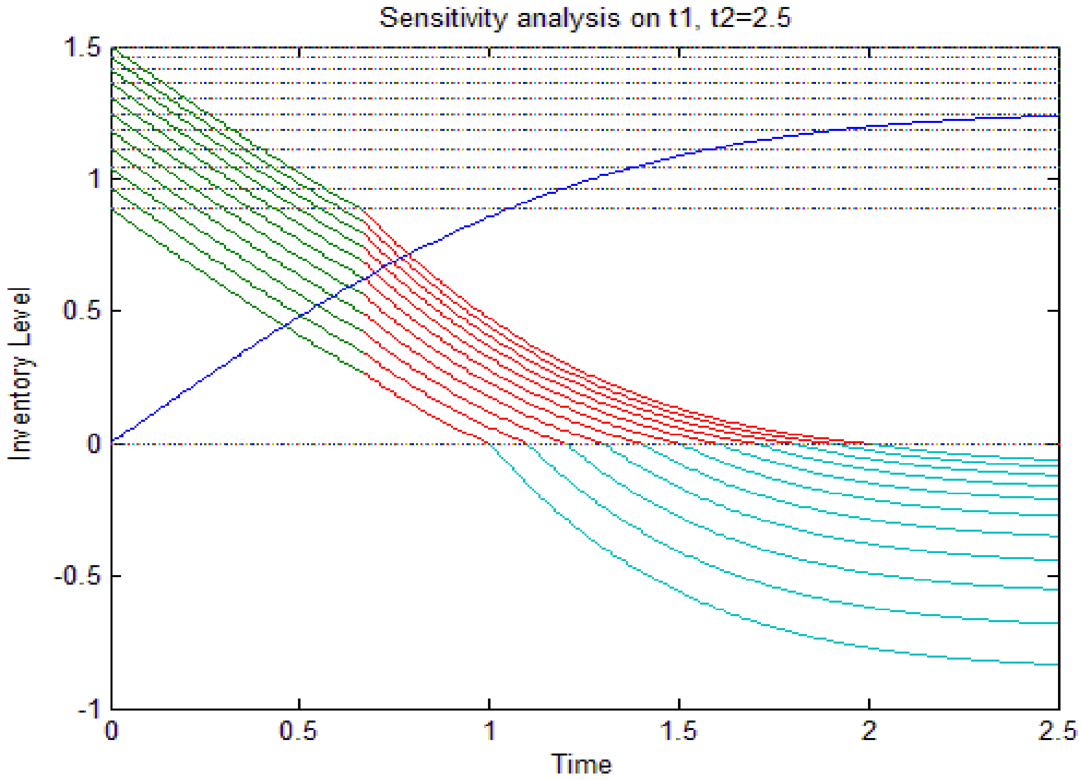


Figure 5.3: Effect of inventory in hand time (t_1)on inventory level

However, the order quantity initially decreases and then increases as t_1 reaches t_2. This is because of the availability of inventory for longer time but at the end of the cycle, total inventory needs to be replenished. The percentage increase in total cost is 16.1% for fixed value of $\theta = 0.79$; $\alpha = 0.5$; and td = 0.67.

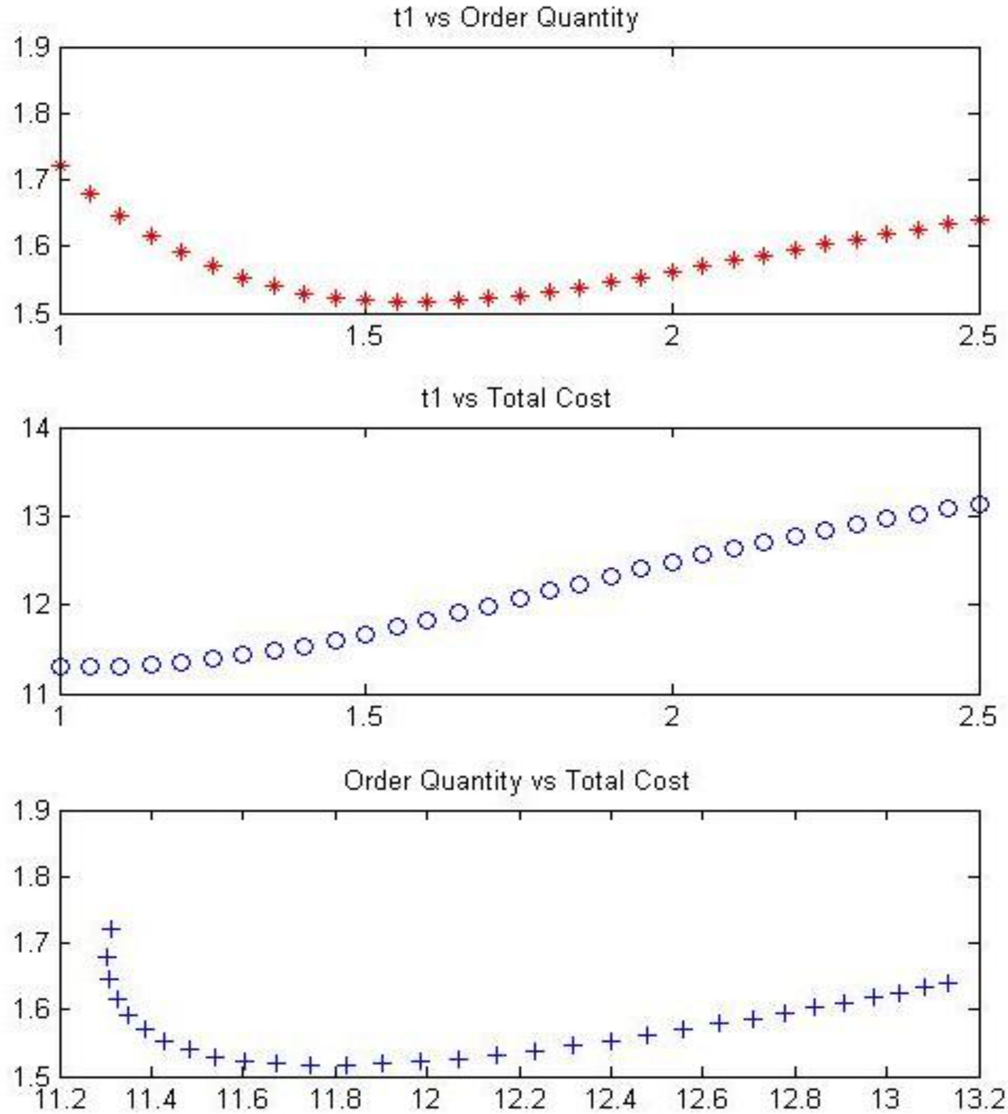


Figure 5.4: Effect of inventory in hand time (t_1)on order quantity and total cost

5.1.1.2 Case with RFID implementation

In this case, keeping all other parameters constant, t_2 is varied from a higher to a lower value as an impact of RFID.

Table 5.2: Impact of RFID on different costs

t_2	S	Q	CH	CD	CS	CQ CO CC	TC
3.0	0.287	1.533	0.411	0.802	0.348	0.2690.034 0.012	11.874
2.9	0.285	1.532	0.411	0.802	0.33	0.2690.031 0.019	11.862
2.8	0.283	1.53	0.411	0.802	0.31	0.270 .029 0.028	11.849
2.7	0.281	1.527	0.411	0.802	0.289	0.2710.026 0.037	11.834
2.6	0.277	1.523	0.411	0.802	0.265	0.271 .023 0.047	11.819
2.5	0.272	1.519	0.411	0.802	0.239	0.271 .021 0.058	11.801
2.4	0.266	1.512	0.411	0.802	0.211	0.2710.018 0.070	11.783
2.3	0.257	1.503	0.411	0.802	0.182	0.2710.015 0.082	11.764
2.2	0.245	1.492	0.411	0.802	0.152	0.271 .012 0.095	11.743
2.1	0.23	1.476	0.411	0.802	0.122	0.2700.010 0.108	11.722
2.0	0.211	1.457	0.411	0.802	0.093	0.268 .007 0.121	11.702
1.9	0.185	1.431	0.411	0.802	0.065	0.2660.005 0.133	11.681
1.8	0.153	1.399	0.411	0.802	0.04	0.2640.003 0.144	11.662
1.7	0.113	1.359	0.411	0.802	0.019	0.2600.001 0.152	11.645
1.6	0.062	1.308	0.411	0.802	0.005	0.2550.000 0.158	11.631
1.5	0.000	1.246	0.411	0.802	0.000	0.2490.000 0.161	11.622

It is observed from the table 5.2, when t_2 varies from a higher value to a lower value for a fixed value of t_1, as an impact of RFID, the replenishment delay is decreasing. The impact of decrease in replenishment delay is observed on many factors including shortages, order quantity, backlogging cost, opportunity cost, crashing cost and ultimately on total cost. The effect of decreased in replenishment delay be well understood from the table and graph shown below.

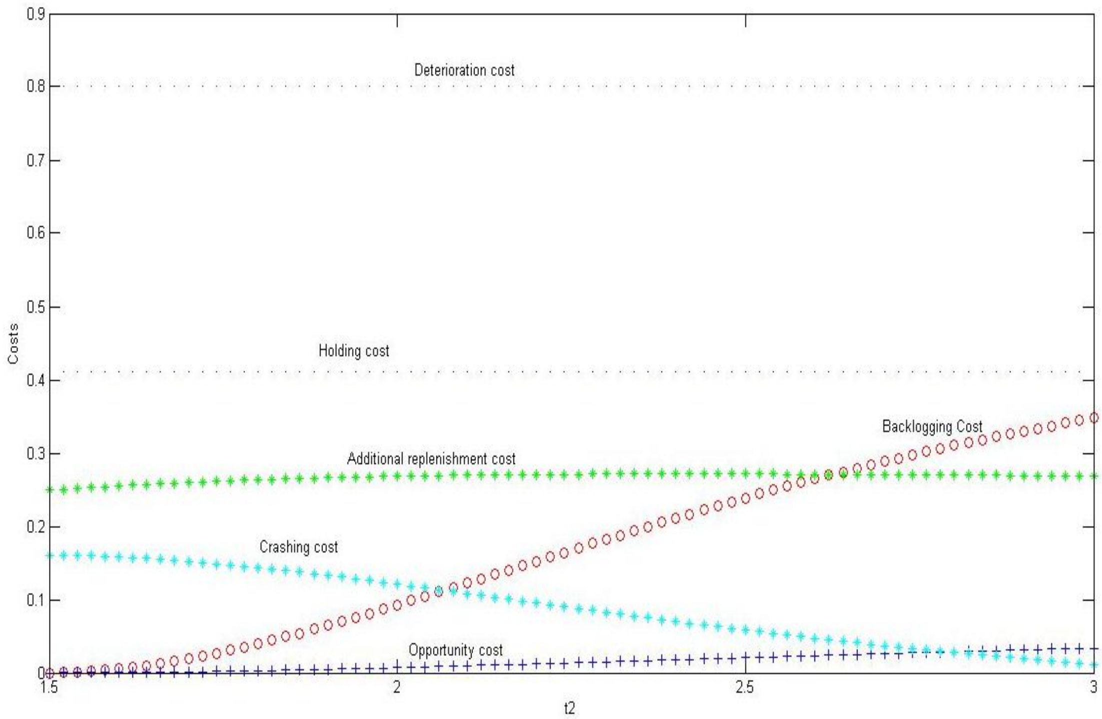


Figure 5.5: The impact of RFID on various supply chain costs

It seen from figure 5.5 that as the t_2 decreased from higher to lower value, it primarily impacts on shortages that need to be backlogged. Due to reduced shortage, shortage cost seen decreased. It has parallel impact on order quantity also. The order quantity also decreases as the delay decreased and it happens because of reduced backlogging required. The opportunity cost and additional replenishment cost is observed to decreasing as an effect of reduced delay. This is true due to the reduced lost sale because of reduced shortage and reduced order quantity respectively. However the reduction in additional replenishment cost is seen slower than the opportunity cost. One can see the impact on crashing cost is negative as compared to the above mention costs. This is because more and more RFID technology and efforts are needed to reduce more and more lead time. Higher the technology incorporated to reduce lead time will lead to higher crashing cost. The holding cost and deterioration costs show no sign of change as during the shortage period no physical inventory is held by the system.

Another point to be observed here is that even crashing cost increases as replenishment delay decrease, the total cost of supply chain seen decreasing continuously. This is because the cumulative effect of decrease in opportunity cost, additional replenishment cost and backlogging cost dominates the effect of rise in cost due to RFID implementation i.e. crashing cost. The percentage reduction in total cost is found out to be 2.12% for the fixed value of; $\theta = 0.79$; $\alpha = 0.5$; td = 0.67 as in above case.

The figure 5.6 and figure 5.7, below indicate the effect of reduced replenishment delay on shortage and total cost.

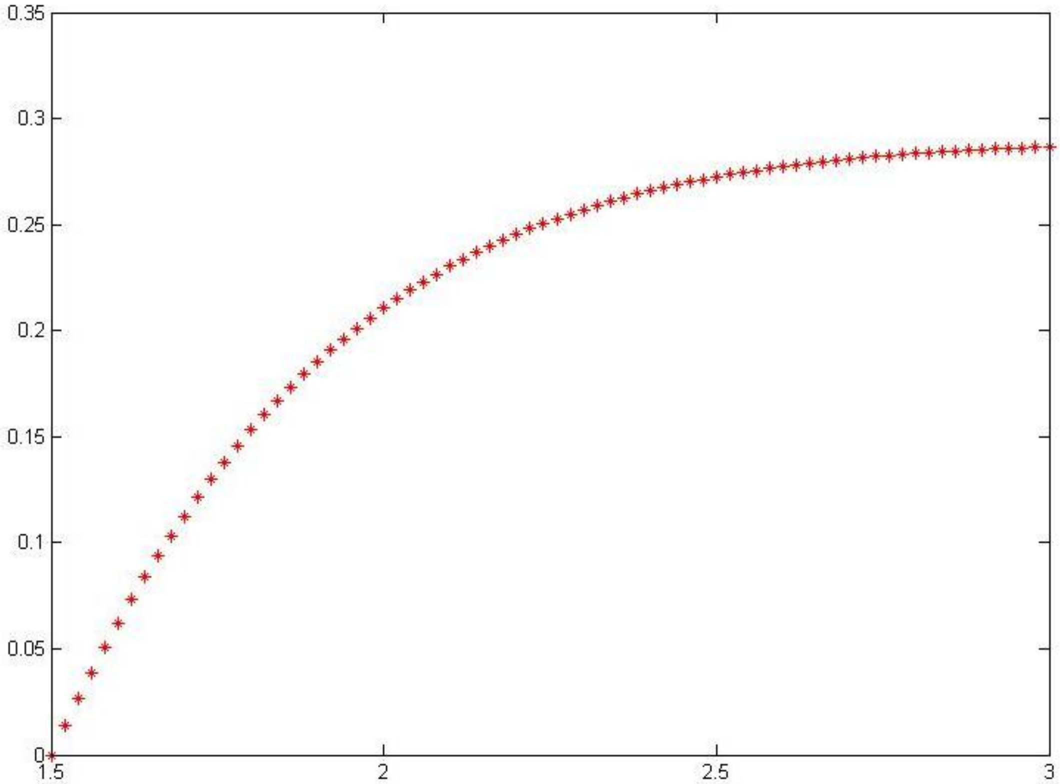


Figure 5.6: Shortage time (t_2) vs Shortage

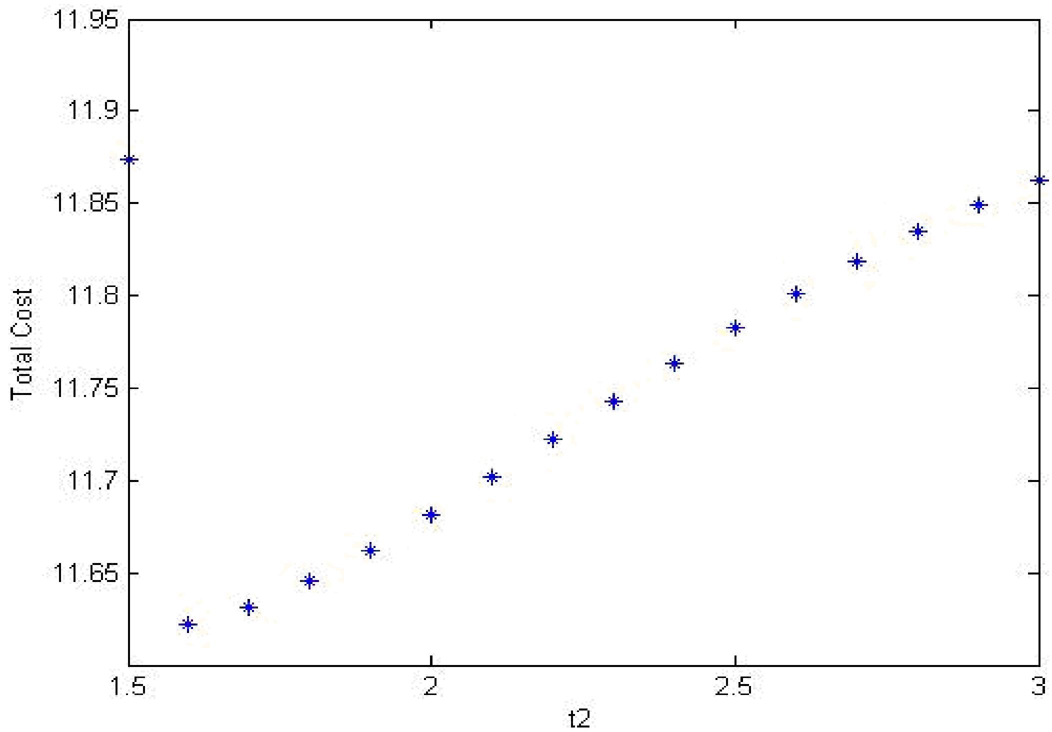


Figure 5.7: Shortage time (t_2) vs Total cost

5.1.1.3 Impact of deterioration rate theta (θ) on total cost and order quantity

In this section the effect of variation of theta (θ) is judged considering t_1 and t_2 constant. The results obtained are shown in the following table 5.3.

Table 5.3: Effect of variation of theta (θ) on shortage and order quantity

Theta	Imax	S	Q
0.200000	1.120435	0.272419	1.392853
0.300000	1.139105	0.272419	1.411524
0.400000	1.158770	0.272419	1.431189
0.500000	1.179493	0.272419	1.451911
0.600000	1.201337	0.272419	1.473756
0.700000	1.224374	0.272419	1.496792
0.800000	1.248677	0.272419	1.521096
0.900000	1.274327	0.272419	1.546746
1.000000	1.301409	0.272419	1.573828

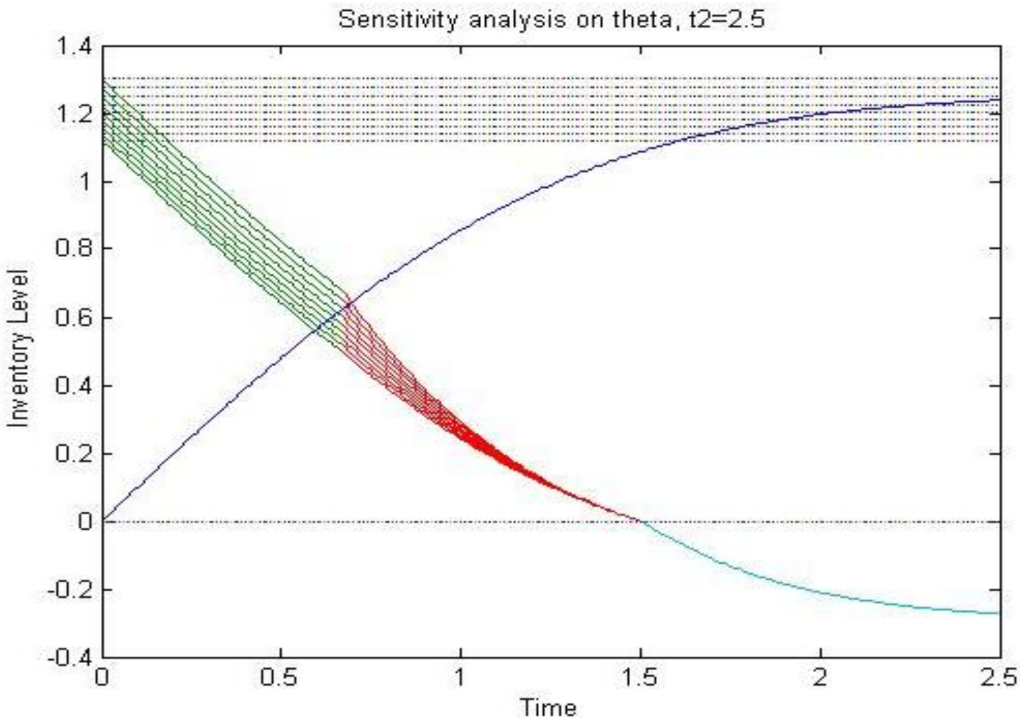


Figure 5.8: Variation of inventory according to (θ)

As seen from the table and the figure 5.8 above, the variation of theta (θ) has a pronounced impact on the maximum inventoried that to be carried at any time and also on the order quantity. As theta increases as an effect of perishability more and more product gets perished and as a consequence more quantity needs to be ordered to fulfil demand. And as more quantity is ordered to counteract effect of perishability, it has no effect on the shortage. Table 4.3 shows order quantity increasing corresponding to the increase in the value of theta.

5.1.1.4 Impact of backlogging parameter alpha (α) on cost and order quantity

Alpha (α) is the parameter that decides the amount of demand backlogged during shortage period. As shown in the table 4.4 below, as the alpha increases from lower to higher values backlogging quantity decreases due to completely backlogging to a partial backlogging. This indicates that with increase in value of alpha (α) the total cost is also decreasing. Refer table 5.4 below.

Table 5.4: Effect of alpha (α) on backlog, order quantity, and total cost

Alpha	Imax	S	Q	Tc
0.100	1.246	0.159	1.405	11.817
0.200	1.246	0.141	1.387	11.786
0.300	1.246	0.125	1.372	11.759
0.400	1.246	0.112	1.358	11.735
0.500	1.246	0.099	1.345	11.713
0.600	1.246	0.088	1.335	11.694
0.700	1.246	0.079	1.325	11.678
0.800	1.246	0.070	1.317	11.663
0.900	1.246	0.063	1.309	11.650
1.000	1.246	0.056	1.302	11.639

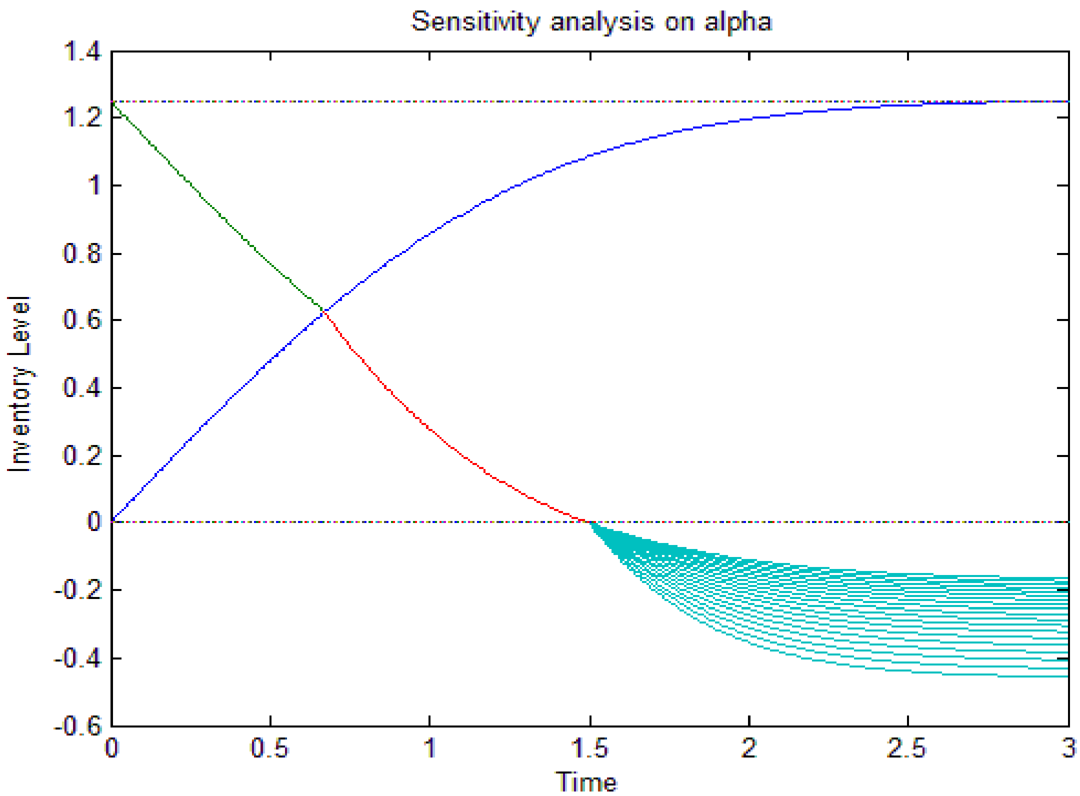


Figure 5.9: Variation of inventory according to alpha (α)

The analysis carried above justifies the positive impact of RFID in perishable product supply chains in terms of reduced total cost of the supply chain. As the total cost of supply chain reduces the chances of better profit margins are diversified. This may lead to better decision making, improved efficiency, and better customer services. Eventually, adopting RFID will lead to improved customer goodwill towards company and the company will progress on the lines of prominent companies such as Walmart, BMW, McDonalds, Daimler Chrysler AG, Boeing, Hyundai, Toyota, McCarran International Airport, US, Virgin Atlantic Airways, and Dell.

5.2 An Optimization of Model

The classical analysis presented in the earlier section provides information only about the effect of individual parameterson the total cost and order quantity. However, neither does it reflect on the hierarchical effectiveness nor does it provide any information about the interactive effectsof the parameter on the said response variables which are total cost and the order quantity. For determining the significance of each parameter and their interactive effects on response variables, the parameters are optimized using Response Surface Methodolgy (RSM) and results are presented in the following section.

5.2.1 Response Surface Methodology (RSM)

Experimental designs enablethe researcherstoidentify the factors that affect the responses. Once the important factors have been identified, the next step is to determine the settings of the factors that results in the optimum value of response. This process is called as optimization. The optimum value of response may either be the maximum or minimum value, depending upon the nature of the product or any process. RSM helps the experimenter reach the objective of optimum response. It is an effective tool for optimizing engineering problems when many factors and interactions affect the desired response (Noordin et al., 2004; Oktem, 2005 and Shi, W. et al. 2014). These methods are extensively used not only for determining the important factors affecting the response but also for examining the relationship between the response and the affecting parameters. Regression models are used for analysis of response, which determines the relationship between the response and affecting parameters rather than identifying the important parameters.

1. The experimenter/researcher needs to move from the present operating conditions to the vicinity of the operating conditions where the response is optimum. This is accomplished using the method of steepest ascent for maximizing the response. The same method can be used to minimize the response and is then referred to as the method of steepest descent.
2. Once in the vicinity of the optimum response the experimenter needs to fit a more elaborate model between the response and factors. Special experiment designs, referred to as RSM designs are used to accomplish this. The fitted model is used to arrive at the best operating conditions that result in either a maximum or minimum response.
3. It is possible that numerous responses may have to be simultaneously optimized. For example, an experimenter may want to maximize strength, while keeping the number of defects to a minimum. The optimum settings for each of the responses in such cases may lead to conflicting settings for the factors. A balanced setting that gives the most appropriate values for all the responses must be determined. Desirability functions are useful in such cases.

5.2.2 Box-Behnken Design

[G. E. P. Box and D. W. Behnken (1960)] introduced similar designs for three-level factors that are widely used in response surface methodology (RSM) to fit second-order models to the response. The designs referred to as the Box–Behnken designswere developed by combining two-level factorial designs with incomplete block designs. The advantages of the Box–Behnken designs are that they all are spherical designs and require factors to be run at only three levels. The designs are also rotatable or nearly rotatable. Some of these designs also provide orthogonal blocking. Thus, if there is a need to separate runs into blocks for the Box–Behnken design, then designs are available, which allow blocks to be used in such a way that the estimation of the regression parameters for the factor effects are not affected by the blocks. In other words, in these designs, the block effects are orthogonal to the other factor effects. Yet another advantage of these designs is that it considers all the three levels, including the outer and central levels. The Box–Behnken design is a response surface methodology (RSM) design that requires only three levels to run an experiment. It is a special 3-level design and is advantageous when the points on the corners of the cube represent level combinations that are prohibitively expensive or impossible to test because of physical process constraints. These designs can sharply reduce the number of experimental sets without decreasing the accuracy of the optimization compared with traditional factorial design methods (Pengpeng et al., 2014).

In the current study, the Box–Behnken design approach (Bahaedin and Morteza, 2011) was used to optimize the parameters and experimental design and statistical analysis was performed step-by-step using the Design-Expert software.

The various factors and their ranges are shown in table 5.5.

Table 5.5: Parameters and their ranges

Parameter	**Range**
Inventory in hand time (t_1)	1–2.5
Shortage time (t_2)	1.5–3
Deterioration rate (θ)	0.2–1
Backlogging parameter (α)	0.1–1

The total cost and order quantity for different set of conditions of variables was calculated. The experimental design is shown in table 5.6.

Table 5.6: Design of experiments

RUN	T_1	T_2	THETA (θ)	ALPHA (α)	R_1 TC	R_2 Q
1	1.75	2.25	0.6	0.55	11.645	1.4438
2	1.75	3	1	0.55	12.6141	1.6345
3	1.75	2.25	0.6	0.55	11.6467	1.4437
4	1.75	1.5	0.6	0.1	11.5844	1.2427
5	2.5	1.5	0.6	0.55	12.5052	1.2241
6	1	2.25	1	0.55	11.2769	1.7773
7	1.75	2.25	0.2	0.1	10.9663	1.2788
8	2.5	2.25	0.6	1	12.4014	1.4846
9	1.75	2.25	0.6	0.55	11.6967	1.4437
10	1.75	2.25	0.6	0.55	11.6467	1.4437
11	1.75	2.25	0.6	0.55	11.6467	1.4437
12	1	3	0.6	0.55	11.3703	1.7958
13	1.75	2.25	0.2	1	10.9876	1.4049
14	2.5	2.25	0.6	0.1	12.4014	1.4846
15	1.75	3	0.6	0.1	11.7646	1.4258
16	1.75	2.25	1	0.1	12.5185	1.552
17	2.5	2.25	0.2	0.55	11.2419	1.2915
18	1	2.25	0.2	0.55	11.1017	1.7439
19	1	1.5	0.6	0.55	10.8283	1.4923
20	1.75	3	0.6	1	11.7261	1.5644
21	2.5	2.25	1	0.55	14.1297	1.7911
22	1	2.25	0.6	0.1	11.2292	1.3085
23	1	2.25	0.6	1	11.2916	2.7196
24	1.75	1.5	1	0.55	12.4535	1.331
25	1.75	1.5	0.2	0.55	10.9013	1.0578
26	1.75	1.5	0.6	1	11.5525	1.0516
27	1.75	2.25	1	1	12.5398	1.674
28	1.75	3	0.2	0.55	11.0618	1.3613
29	2.5	3	0.6	0.55	11.2519	1.3273

With this database, two different test sequential sum of square model summary statistics were performed to check the adequacy of models generated from obtained datathe results are presented in table 5.7

Table 5.7: Adequacy of model tested

Sequential model for total cost						
Source	**Sum of Squares**	**df**	**Mean Square**	**F Value**	**p-value Prob > F**	**Remark**
Mean vs Total	3985.78	1	3985.78			
Linear vs Mean	11.06	4	2.76	18.48	<0.0001	
2FI vs Linear	2.65	6	0.44	8.41	0.0002	Suggested
Quadratic vs 2FI	0.34	4	0.084	1.93	0.1617	
Cubic vs Quadratic	0.44	8	0.055	2.02	0.2042	Aliased
Residual	0.16	6	0.027			
Total	4000.43	29	137.95			
Sequential model for order quantity						
Mean vs Total	64.47	1	64.47			
Linear vs Mean	1.09	4	0.27	4.28	0.0093	
2FI vs Linear	0.59	6	0.098	1.88	0.1405	
Quadratic vs 2FI	0.56	4	0.14	5.05	0.0099	Suggested
Cubic vs Quadratic	0.36	8	0.045	9.71	0.0062	Aliased
Residual	0.028	6	4.606E-003			
Total	67.09	29	2.31			
Statistical summary for total cost model						
Source	**Std. Dev.**	**R-Squared**	**Adjusted R-Squared**	**Predicted R-Squared**	**PRESS**	**Remark**
Linear	0.39	0.7549	0.7140	0.6167	5.61	
2FI	0.23	0.9356	0.8998	0.7899	3.08	Suggested
Quadratic	0.21	0.9585	0.9169	0.7613	3.50	
Cubic	0.17	0.9887	0.9474	-0.6023	23.47	
Statistical summary for order quantity						
Linear	0.25	0.4166	0.3194	0.0879	2.39	
2FI	0.23	0.6411	0.4417	-0.1819	3.10	
Quadratic	0.17	0.8532	0.7063	0.1542	2.22	Suggested
Cubic	0.068	0.9895	0.9509	0.5159	3.98	

The model summary statistical output data shows that the predicted R^2 was the highest for total cost (TC) in comparison withthe other models. Therefore, the 2Fi model was suggested for the further analysis of total cost. The cubic model was discarded because it was aliased. Similarly, for order quantity (Q), a quadratic model was suggested for further analysis. With this information, ANOVA was performed and the results are discussed in the following paragraphs.

5.2.3 Analysis of Variance (ANOVA)

Model adequacy was checked in terms of R^2 values. The effect of individual parameter on the response was determined using ANOVA; the results for both responses are shown in the following tables 5.8 and 5.9.

Table 5.8: ANOVA for TC

ANOVA for Response Surface 2FI model						
Source	**Sum of Squares**	**df**	**Mean Square**	**F Value**	**p-value Prob > F**	**Remark**
Model	13.70	10	1.37	26.14	**<0.0001**	significant
A-II Time(t_1)	3.89	1	3.89	74.24	<0.0001	
B-S Time(t_2)	1.104E-004	1	1.104E-004	2.106E-003	0.9639	
C-Theta (θ)	7.16	1	7.16	136.67	<0.0001	
D-Alpha(α)	9.976E-005	1	9.976E-005	1.903E-003	0.9657	
AB	0.81	1	0.81	15.37	0.0010	
AC	1.84	1	1.84	35.09	<0.0001	
AD	9.734E-004	1	9.734E-004	0.019	0.8931	
BC	2.500E-009	1	2.500E-009	4.769E-008	0.9998	
BD	1.089E-005	1	1.089E-005	2.078E-004	0.9887	
CD	0.000	1	0.000	0.000	1.0000	
Residual	0.94	18	0.052			
Lack of Fit	0.94	14	0.067	132.10	0.0001	significant
Pure Error	2.036E-003	4	5.091E-004			
Cor Total	14.65	28				

There is only 0.11% probabilitythat an F-value this large could occur due to noise. Values of "Probability > F" less than 0.0500 indicate that the model terms are significant. In this case, A, B, C, D, AD, A^2, and B^2 are significant model terms. Values greater than 0.1000 indicate that the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), reduction in number insignificant terms may improve the model.

Table 5.9: ANOVA for order quantity (Q)

ANOVA for Response Surface Quadratic model for Order Quantity						
Source	**Sum of Squares**	**df**	**Mean Square**	**F Value**	**p-value Prob > F**	**Remark**
Model	2.24	14	0.16	5.81	0.0011	significant
A-II Time	0.42	1	0.42	15.11	0.0016	
B-S Time	0.24	1	0.24	8.85	0.0101	
C-Theta(θ)	0.22	1	0.22	7.96	0.0136	
D-Alpha(α)	0.22	1	0.22	7.81	0.0143	
AB	0.010	1	0.010	0.36	0.5558	
AC	0.054	1	0.054	1.97	0.1819	
AD	0.50	1	0.50	18.08	0.0008	
BC	4.441E-016	1	4.441E-016	1.613E-014	1.0000	
BD	0.027	1	0.027	0.99	0.3374	
CD	4.203E-006	1	4.203E-006	1.526E-004	0.9903	
A^2	0.28	1	0.28	10.13	0.0066	
B^2	0.16	1	0.16	5.96	0.0285	
C^2	1.382E-003	1	1.382E-003	0.050	0.8260	
D^2	0.017	1	0.017	0.62	0.4445	
Residual	0.39	14	0.028			
Lack of Fit	0.39	10	0.039	1.928E+007	< 0.0001	Significant
Pure Error	8.000E-009	4	2.000E-009			
Cor Total	2.63	28				

The "Lack of Fit F-value" of 19275396.63 implies that the Lack of Fit is significant. There is only a 0.01% chance that a "Lack of Fit F-value" this large could occur because of noise. Here, A is inventory in hand time, B is shortage time, C is deterioration rate, and D is backlogging parameter.

The above ANOVA table indicates the significance of each individual parameter as well as their interactions on desired responses. Fromtable (TC), the rate of perishability, theta (θ), and the inventory inhand time has pronounced effect on total cost compared with the shortage time and rate of backlogging. The deterioration rate is the most dominating parameter. Another dominating parameter is the inventory in hand time (t_1). Shortage time (t_2), which can be governed by newer technology is observed to be more significant than the rate of backlogging. However, for order quantity (Q), it is observed that the inventory in hand time (t_1) is the most dominating parameter, and shortage time (t_2), deterioration rate theta (θ), and backlogging parameter alpha (α) remain in the decreasing order of significance.

The final equation for total cost, as suggested by the model in terms of actual factors is as follows:

Total Cost (TC)

= 8.42269 + 1.22370* II Time (t_1) + 1.39494* S Time (t_2) - 2.02442* Theta (θ) + 0.098296* Alpha (α)- 0.79791* II Time (t_1) * S Time (t_2) + 2.26050 * II Time (t_1) * Theta (θ) - 0.046222* II Time (t_1) * Alpha (α) + 8.33333E – 005 * S Time (t_2) * Theta (θ) - 4.88889E – 003 * S Time (t_2) * Alpha (α) + 1.73472E – 015 * Theta (θ) * Alpha (α)

And that for order quantity, as suggested by model in terms of actual factors is as

Order Quantity

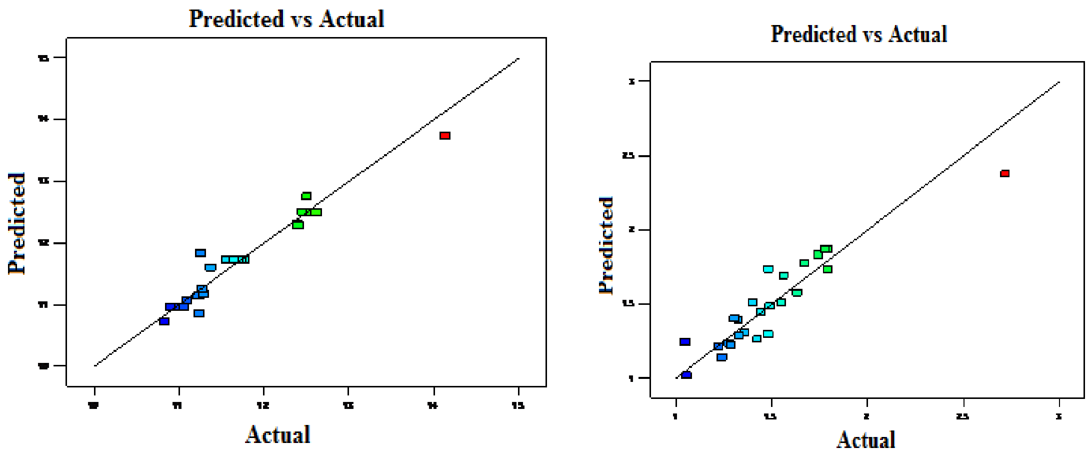
= + 0.24287 - 0.99668 * II Time (t_1) + 1.48417 * S Time (t_2) - 0.44835 * Theta (θ) + 1.30216 * Alpha(α) - 0.089022 * II Time (t_1) * S Time (t_2) + 0.38850 * II Time (t_1) * Theta (θ)- 1.04526 * II Time (t_1) * Alpha + 2.81103E - 016 * S Time (t_2) * Theta (θ)+ 0.24422 * S Time (t_2) * Alpha(α) - 5.69444E - 003 * Theta (θ) * Alpha(α) + 0.36872 * II Time (t_1) ^2 -0.28283 * S Time (t_2)^2 + 0.091214 * Theta (θ) ^2 +0.25318 * Alpha(α)^2

These equations, suggested by the BBD model, are used to predictthe response for the given level of each factor. The predicted values along with the calculated (actual) ones for both the responses are shown in table 5.10.

Table 5.10: Box-Behnken Design and response

Run	Factor Level				Total cost (TC)		Order Quantity (Q)	
					Expt.	Pred.	Expt.	Pred.
1	1.75	2.25	0.6	0.55	11.645	11.72	1.4438	1.44
2	1.75	3	1	0.55	12.6141	12.49	1.6345	1.58
3	1.75	2.25	0.6	0.55	11.6467	11.72	1.4437	1.44
4	1.75	1.5	0.6	0.1	11.5844	11.72	1.2427	1.14
5	2.5	1.5	0.6	0.55	12.5052	12.74	1.2241	1.21
6	1	2.25	1	0.55	11.2769	11.25	1.7773	1.87
7	1.75	2.25	0.2	0.1	10.9663	10.95	1.2788	1.24
8	2.5	2.25	0.6	1	12.4014	12.28	1.4846	1.30
9	1.75	2.25	0.6	0.55	11.6967	11.72	1.4437	1.44
10	1.75	2.25	0.6	0.55	11.6467	11.72	1.4437	1.44
11	1.75	2.25	0.6	0.55	11.6467	11.72	1.4437	1.44
12	1	3	0.6	0.55	11.3703	11.60	1.7958	1.87
13	1.75	2.25	0.2	1	10.9876	10.95	1.4049	1.51
14	2.5	2.25	0.6	0.1	12.4014	12.31	1.4846	1.74
15	1.75	3	0.6	0.1	11.7646	11.72	1.4258	1.26
16	1.75	2.25	1	0.1	12.5185	12.49	1.552	1.51
17	2.5	2.25	0.2	0.55	11.2419	10.84	1.2915	1.23
18	1	2.25	0.2	0.55	11.1017	11.06	1.7439	1.83
19	1	1.5	0.6	0.55	10.8283	10.71	1.4923	1.49
20	1.75	3	0.6	1	11.7261	11.72	1.5644	1.69
21	2.5	2.25	1	0.55	14.1297	13.74	1.7911	1.73
22	1	2.25	0.6	0.1	11.2292	11.14	1.3085	1.40
23	1	2.25	0.6	1	11.2916	11.17	2.7196	2.38
24	1.75	1.5	1	0.55	12.4535	12.50	1.331	1.29
25	1.75	1.5	0.2	0.55	10.9013	10.95	1.0578	1.02
26	1.75	1.5	0.6	1	11.5525	11.73	1.0516	1.24
27	1.75	2.25	1	1	12.5398	12.50	1.674	1.78
28	1.75	3	0.2	0.55	11.0618	10.95	1.3613	1.31
29	2.5	3	0.6	0.55	11.2519	11.84	1.3273	1.40

The linear correlation between the actual values and those predicted by the model are depicted in the following graphs.



(a) Total Cost **(b) Order Quantity**

Figure 5.10: Linear correlation between actual and predicted values

It can be observed from figure 5.10 that the actual values and those predicted by the model are distributed relatively closer to each other. This indicates that the fitted regression equation shows better fit and the BDD is suited for optimization.

5.2.4 Optimum Values of the Parameters

As the RSM model suggests, the parameters were optimized using the numerical optimization approach. During optimization, goals are set by assigningnumerical valuesorranges to the independent and response variables. To obtain the optimum set of conditions, five variables, including order quantity, were set within the range, whereas the total cost was set for minimized condition. The optimum values forparameters were obtained using the desirability function approach and the different parameters were obtained using the desirability ramp as shown in figure 5.11.

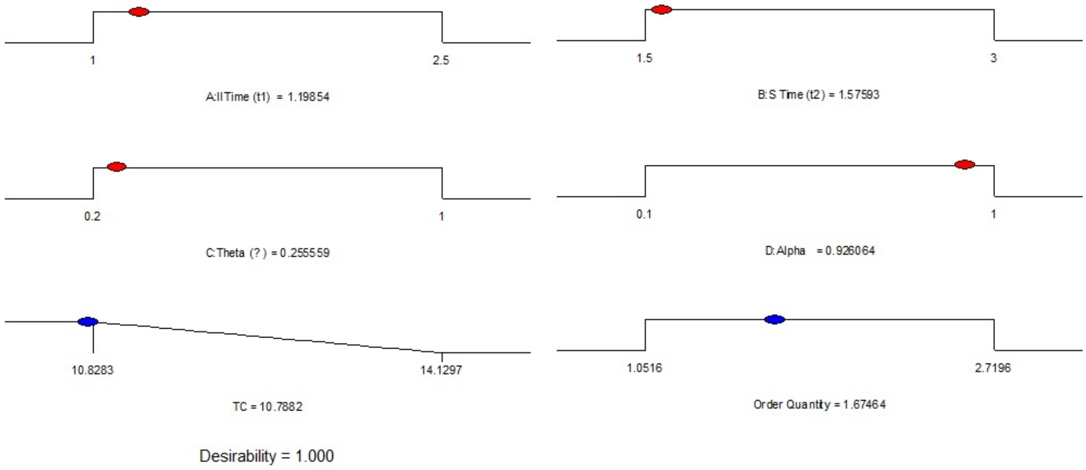


Figure 5.11: Desirability ramp for optimization of total cost and order quantity

Figure 5.11 shows the desirability ramps that were developed for optimum points using numerical optimization. The optimum values of the parameters suggested by this model or methodology are listed in table 5.11.

Table 5.11: The optimum values of the parameters

Response	**Variables**
Total Cost = 10.7882	Inventory in hand time (t_1) = 1.19854
	Shortage time (t_2) = 1.57593
Order Quantity = 1.67464	Theta (θ) = 0.255559
	Alpha (α) = 0.926064

Using these optimum values, the total cost and order quantity were calculated as a part of confirmation of experiment and the values are shown in table 5.12.

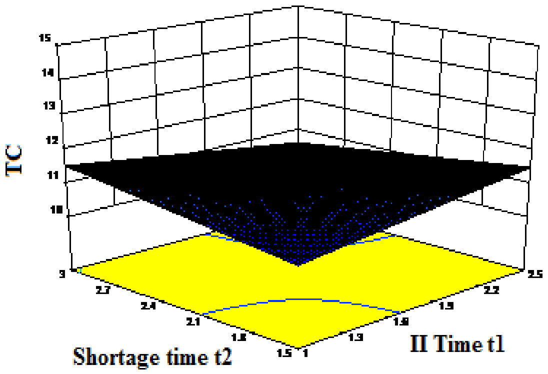
Table 5.12: Comparison of predicted and actual values of TC and order quantity

Optimum Value	**TC Predicted**	**Exp.**	**Relative Error**	**Q predicted**	**Exp.**	**Relative Error**
II Time(t_1) = 1.19854	10.7882	10.79257	0.04%	1.67464	1.64484	1.78%
Sh. Time (t_2) =1.57593						
Theta(θ) =0.255559						
Alpha (α) = 0.926064						

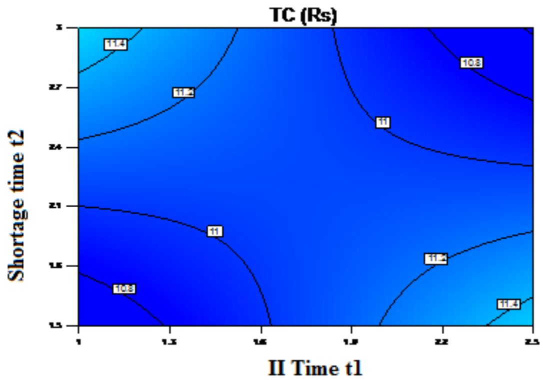
In the next section, the effect of each parameter and their interactions on the main response, that is, the total cost, are presented using the response surface and contour graph.

5.2.5 Effect of Parameters on the Total Cost of Supply Chain

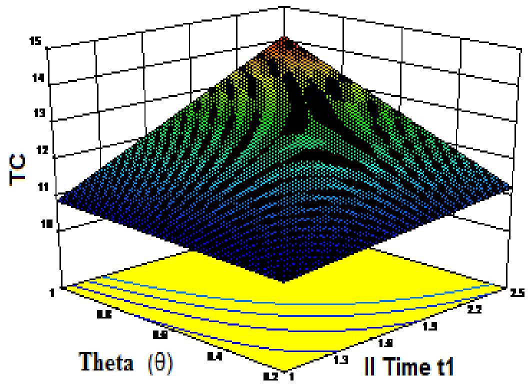
The significance of each parameter is determined by F-test and P-value as shown in table 5.12.The highervalue of F and lower value of P decides the most significant parameter. This has been explained below using response and contour graphs.



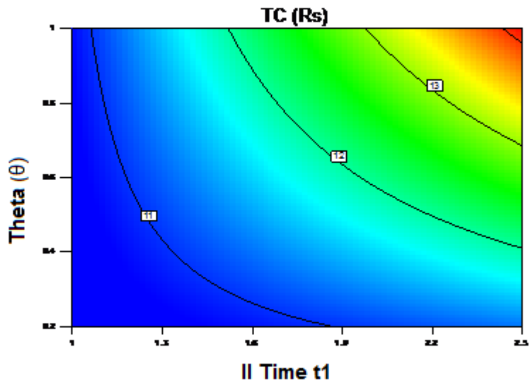
(a)Effect of t_1 and t_2 on TC



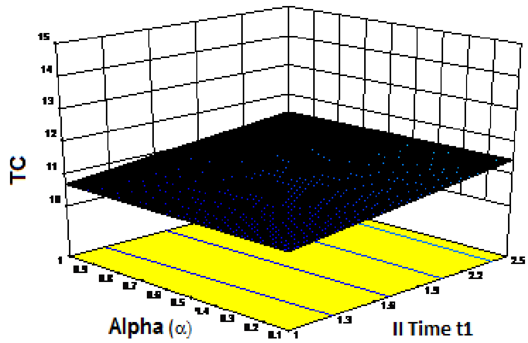
(b)Effect t_1 and t_2 on TC



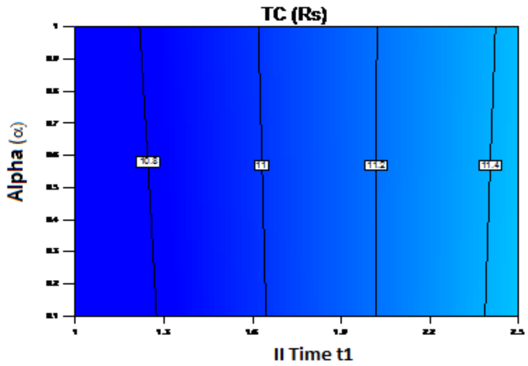
(c)Effect of (θ) and t_1 on TC



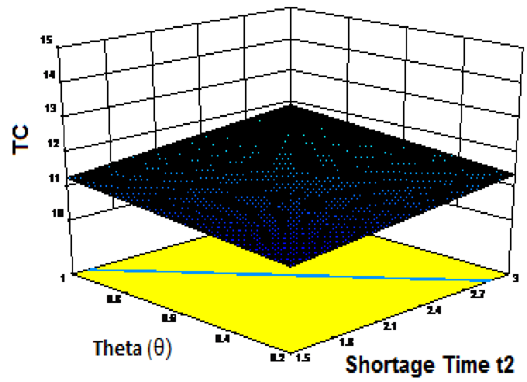
(d) Effect of (θ) and t_1 on TC



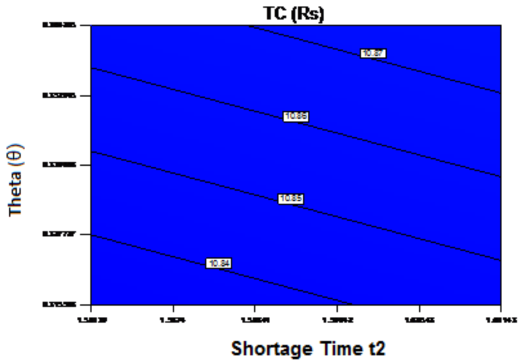
(e)Effect of (α) and t_1 on TC



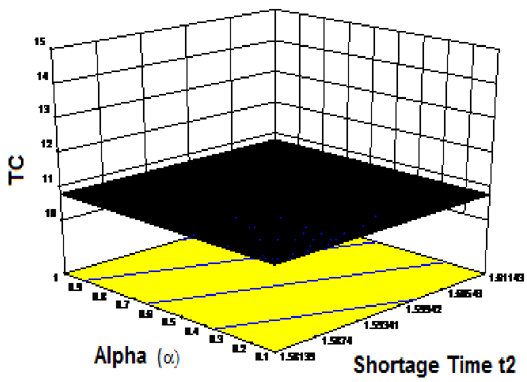
(f)Effect of (α) and t_1 on TC



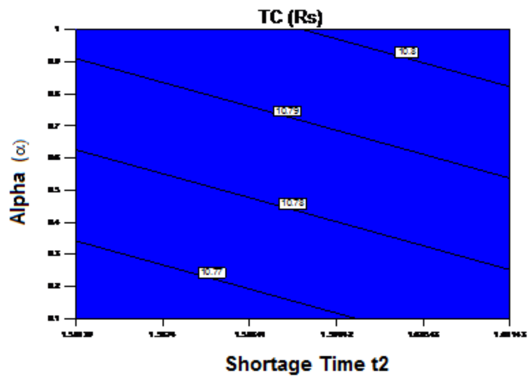
(g) Effect of (θ) and t_2 on TC



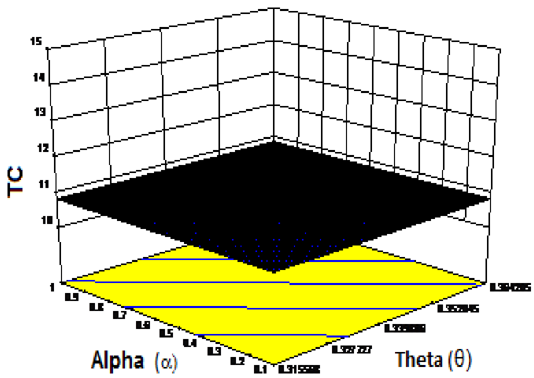
(h) Effect of (θ) and t_2 on TC



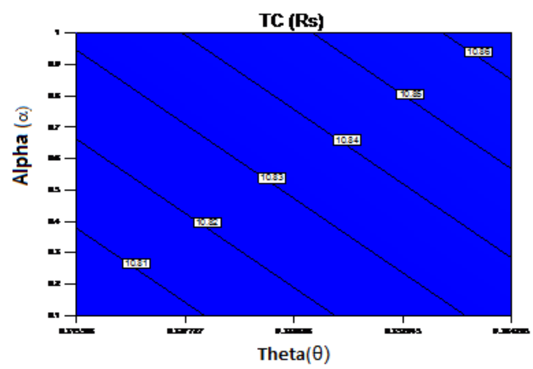
(i)Effect of (α) and t_2 on TC



(j) Effect of (α) and t_2 on TC



(k) Effect of (α) and (θ)



(l)Effect of Effect of (α) and (θ)

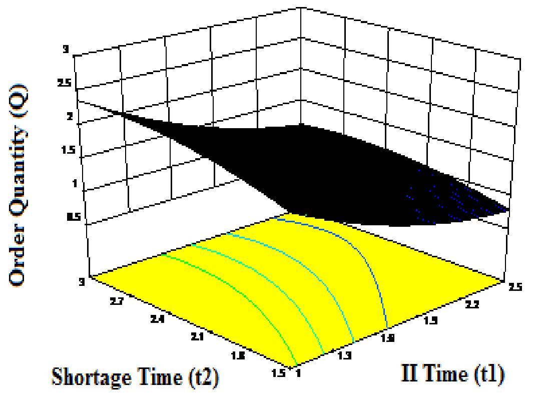
Figure 5.12: Effect of variables on Total Cost (surface and contour plots)

Figure 5.12 indicates that by maintaining the cycle time constant at $t_2 = 3$, and increasing the inventory in hand time t_1, (where inventory reaches to its zero value), from its lower value to higher value, the shortages gets reduced because of the availability of the inventory for a higher time period.However, even shortages and costs related to shortages are reduced overall costs, that is, the total cost of the supply chain increases. This is because of holding a physical inventory for longer time due to which the holding cost superimposes the other shortage related costsand results in an increase in the overall supply chain cost. The deterioration and holding cost collectively increases because of the longer holding time of the physical inventory, which promotes deterioration of the product. This condition is equivalent to the case without RFID in the system.

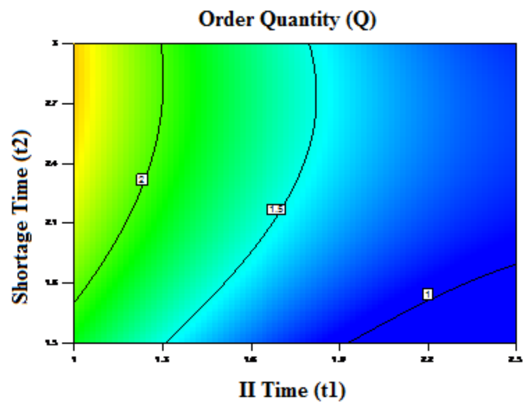
A similar trend, as an impact of RFID, is observed when the shortage time t_2 is varied from a higher to lower value. The replenishment delay decreases. The impact of decrease in the replenishment delay is observed on many factors including shortages, order quantity, backlogging cost, opportunity cost, crashing cost, and ultimately the total cost. The decrease in shortage time t_2 decreases the total cost of supply chain. The contour plots display the regionsin the system that work satisfactorily with desired targeted output. The decision maker has the flexibility to change the input parameters in this range without affecting the output. The minimum totalof supply chain cost can be found determined for certain ranges of input parameters from the contour plots as shown in figure 5.12.

5.2.6 Effect of parameters on order quantity

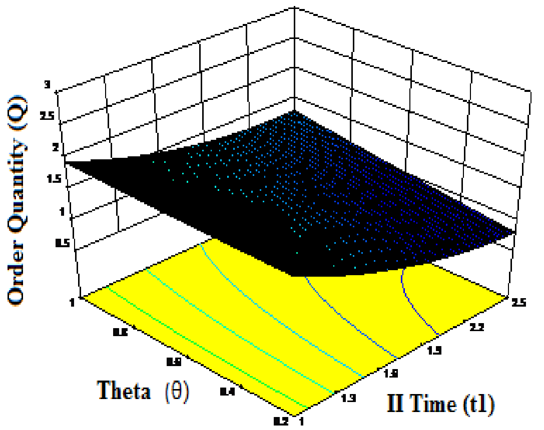
The interactive effects of individual parameters on order quantity are shown in figure 5.13.



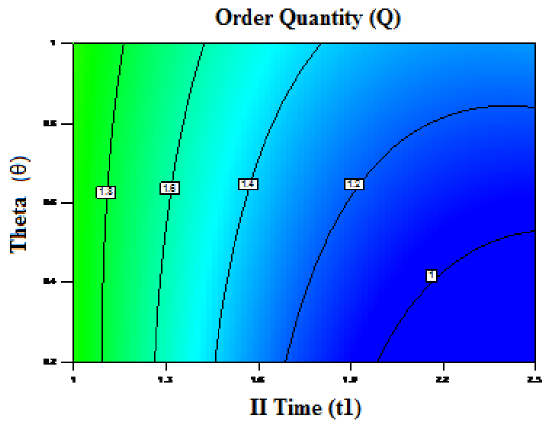
(a) Effect of t_2 and t_1 on Q



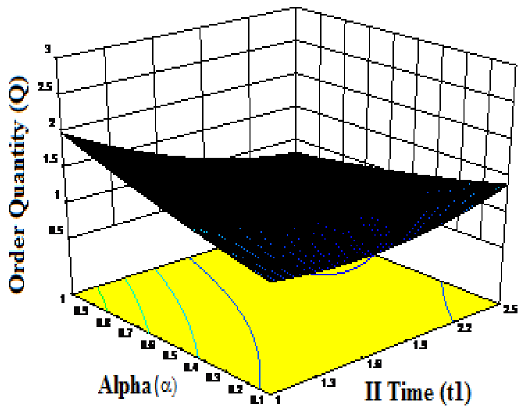
(b)Effect of t_2 and t_1 on Q



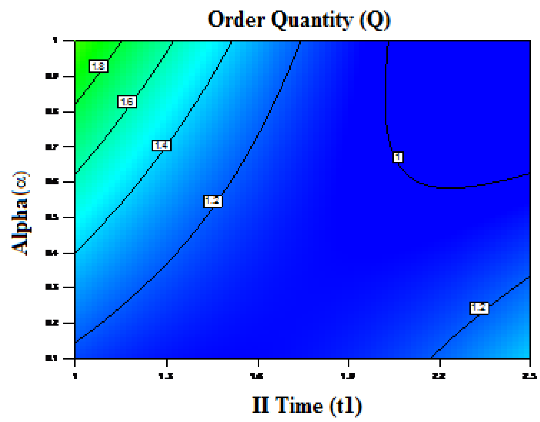
(c)Effect of (θ) and t_1 on Q



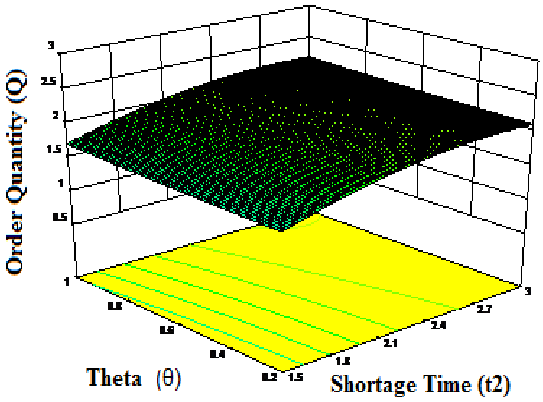
(d)Effect of (θ) and t_1 on Q



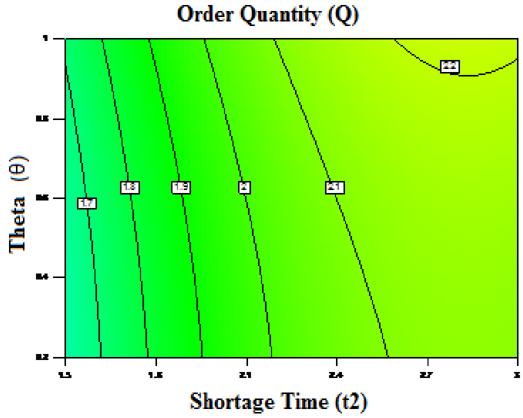
(e) Effect of (α) and t_1 on Q



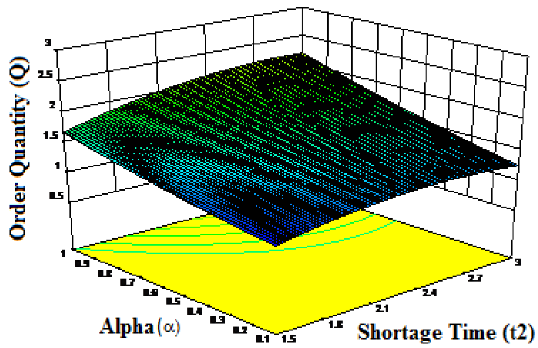
(f)Effect of (α) and t_1 on Q



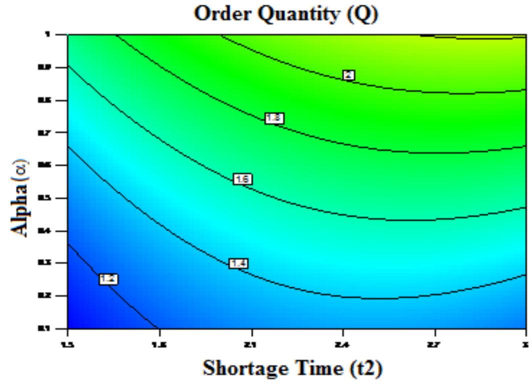
(g) Effect of (θ) and t_2 on Q



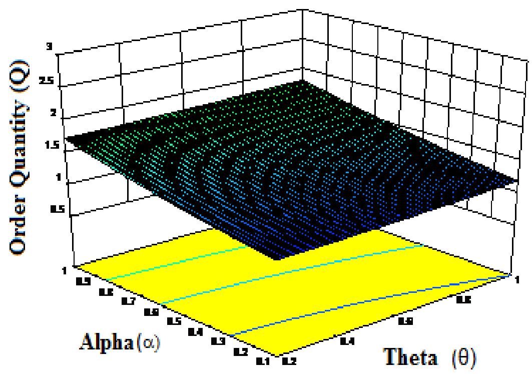
(h) Effect of (θ) and t_2 on Q



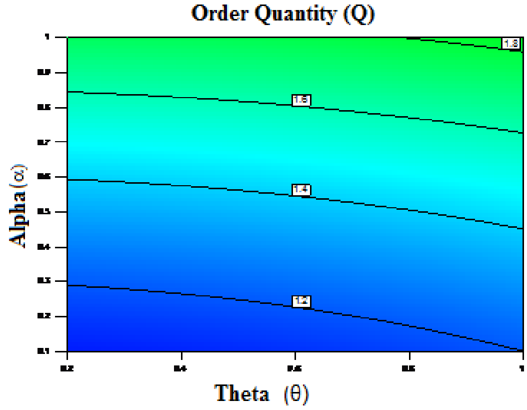
(i) Effect of (α) and t_2 on Q



(j) Effect of (α) and t_2 on Q



(k) Effect of (α) and (θ) on Q



(l) Effect of (α) and (θ) on Q

Figure 5.13: Effect of variables on the Order Quantity (surface and contour plots)

The variation of theta (θ) has a pronounced impact on the maximum inventory that is to be carried at any time and also on the order quantity (figure 5.13). As theta (θ) increases as an effect of perishability, more products perish and consequently more quantity needs to be ordered to fulfil the demand. As more quantity is ordered to counterthe effect of perishability, the backlogged quantity, which depends only upon the decision parameter alpha (α), remains unaffected. Order quantity increases with an increase in the value of theta (θ). However, the backlogging rate has moderate impact on the total cost of supply chain. Alpha is the parameter that decides the amount of demand that is backlogged during shortage period. At the lowest value of alpha (may be during complete backlogging), more quantity is needed to meet the backlogged demand, resulting in higher relevant cost of supply chain. As alpha increases from a low to high value, the rate of backlogging decreases, and the total cost also decreases due to reduced order quantity. The order quantity can be determined from contour plots for certain range of the input parameters as shown in figure 5.13.

The conclusion and the future scope of this study are presented in the following chapter.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE OF RESEARCH

6.1 Summary

In today's era of technological advancements and globalization, customers world wide are exposed to the various products that were not feasible earlier. Customers'demand for high quality and low cost is increasing day-by-day. It is difficult for the PPSCs to easily satisfy customer requirements. Product proliferation, limited market places, inadequate transport facilities, and the product obsolescence create tremendous pressure on managers. Therefore, shortages or price hikes are frequent and because of this many supply chains suffer losses. In the highly competitive atmosphere, resolving the day-to-day problems and challenges is essential.

Many technologies that dilute the above mentioned challenges are available; RFID is one of the best among these technologies. RFID is promising for changing the way of prospering in business. But because of the lack of knowledge of proper methodology of assessing the benefits, managers do not opt of RFID. Many industries are still unaware of this promising technology. Keeping this in view, the present research work was aimed to develope a simple and rational mathematical model that would provide guidance regarding the potential benefits of this technology. The effectiveness of the developed model in providing solutions to resolve day-to-day problems confronted by PPSCs is demonstrated in this study.

An exhaustive literature review was conducted to determine the research gap. During this review, an elaborate framework for the classification of literature was developed and the literature was arranged accordingly for understanding the state-of-art of research in this area of supply chain. The additional benefit is of this classification framework is that it provides guidelines to identify the areas lacking actual and rigorous research in PPSC. Literature review revealed that research on these supply chains is in a preliminary stage and slowly gaining momentum in the right direction. These supply chains suffer huge losses because of inadequate information regarding utilization of newer promising technologies such as RFID. Methods that can be easily applied to formulate the potential benefits for these supply chains in terms of reduced order quantity, reduced shortages, and total cost of supply chain are scarce. In the current study, we attempted to fill this gap through the development of an integrated framework for RFID-based supply chain of perishable products that determines the order quantity and provides solutions for overall cost reduction of the supply chain.

The proposed frame work basically consists of an RFID-interfaced PPSC wherein all partners of supply chains are interfaced through this network. RFID has great impact on the reduction of lead time at all nodesof supply chain. This frame work also provides the base to achieve improved coordination in all activities of supply chains at all nodes. The generic model was developed considering the most realistic situations that prevail at any node of the supply chain. This model was then deduced to suit different set of conditions such as the product with and without instantaneous deterioration, with and without shortage, and partial or full backlog.

The submodels derived from a single generic mode are summarized as follows.

- Model with complete backlogging
- Model with instantaneous deterioration and complete backlogging
- Model with RFID implemented to the full extent
- Model with instantaneous deteriorationand RFID is implemented to the full extent

Overall, the proposed frame work is an attempt to provide an effective tool to every individual of a supply chain to minimize the cost and maximize the profit thereby improving customer service.

For validating the developed model, a case was considered based on data available in the literature. The model was developed considering conditions namely a log-concave varying demand that best suits for a perishable products, perishability effect, and the lead time was considered. These factors diversify the set of realistic situation that prevails at every nod of PPSCs. Considering the different parameter values that were based on a previous research, a step-by-step programming was completed to achieve tabulated and graphic results. Sensitivity analysis for the deterioration and backlogging parameters to verify its effect on the order quantity, shortage and the total cost was performed. The independent variables affecting the total supply chain cost were optimized using RSM. The significance of individual parameter for minimum total cost and order quantity is assessed performing ANOVA. The variables, namely, deterioration rate, in-hand inventory time, shortage time, and the backlogging parameter were in the decreasing order of significance. The surface and contour plots were plotted, which shows the interactive effect of independent variables on response variables, namely, the total cost and order quantity.

6.2 Major research contribution

The major contributions of this research work are summarized below:

- An exhaustive literature review of 302 modeling-based and supporting research paperswas conducted during 2001 to 2014. Aclassical framework to categorize this literature into a broad spectrum of supply chain that include planning, forecasting, coordination, supply chain drivers, network design, performance measures, modeling tools used, product type and product life considerations was developed. This type of a diversified classification framework would provide a road map to prospective researchers for finding the research lacunae and deciding the course of future research.

- Development of RFID-interfaced perishable product supply chain diagram to understand the potential benefits of RFID in a supply chain.
- Development of a mathematical model for perishable product supply chain considering the most realistic conditions prevailing at any node of supply chain. The developed model was used for calculating the order quantity, shortage, maximum cycle inventory and the total cost for all members of supply chain. The peculiarity of this model is that it can be used to calculate the total cost for many sets of conditions as explained above.
- Cost effectiveness of RFID in perishable product supply chain indicates that the incorporation of newer technologies reduces the overall cost of supply chain. This widens the scope of making better decisions and hence improving the efficiency and service level of supply chain.
- The capability of dealing with the effect of stockouts and backlogging in perishable product supply chain are explored in detail.
- The utilization of RFID as a newer and promising technology in supply chain is promoted to form an information hub that will facilitate better decisions in supply chain and will be helpful in reducing the bullwhip effect.

6.3 Future scope and limitations of the research work

Although the current study presents an approach to understand the potential benefits of RFID for improving all major problems into a single framework, the enormity of the task itself renders the framework with many shortcomings that leaves a lot of scope for future research. The existing format as well as the capabilities of the framework can be significantly improved if the current research work is appropriately extended. The following future research directions have been proposed:

- This studyconsiders a single product for modeling and calculations; however, the findings can be extended for multiple products consideration.
- The proposed framework can be extended to consider gradual replenishment and the results may be verified using the findings of the current study wherein instantaneous replenishment has been considered.
- The proposed work can also be extended to consider different demand functions like increasing or linearlog concave and the results may be compared with those of the currentstudy.
- This work can be extended to consider the actual cost of RFID infrastructure and cost analysis may be conducted.

REFERENCE

Agrawal, S., Sengupta R. N. and Shanker K. (2009), “Impact of information on deteriorating items with a linear trend in demand and shortages in all cycles”, *International Journal of Production Economics,* Vol. 49, pp. 205–213.

Alebachew, D. and Kudret, D. (2010), “A genetic approach to two-phase optimization of dynamic supply chain scheduling,” *Computers & Industrial Engineering,* Vol. 58, pp. 411–422.

Alexandre, D. and Mhd-Aly, O. (2002),“A model for supply planning under lead time Uncertainty,” *International Journal of Production Economics,* Vol. 78, pp. 145-152.

Ali, F. G., Atakan Y. and Gokhan A. (2009),“An integrated fuzzy-lp approach for a supplier selection problem in supply chain management,” *Expert Systems with Applications,* Vol.36, pp. 9223–9228.

Altiparmak, F., Gen, M., Lin, L. and Paksoy, T. (2006), “A genetic algorithm approach for multi-objective optimization of supply chain networks,” *Computers & Industrial Engineering,* Vol. 51, pp.196–215.

Amaro, A.C.S. and Barbosa, P.A.P.E. (2009),“The effect of uncertainty on the optimal closed loop supply chain planning under different partnerships structure”, *Computers and Chemical Engineering,* Vol. 33, pp.2144-2158.

Amin A., Ghodsypour, S. H. and Obrien, C. (2009),“Weighted additive fuzzy multi objective model for the supplier selection problem under price breaks in a supply Chain,” *International Journal of Production Economics,* Vol.121, pp.323– 332.

Angerhofer, B. J. and Angelides, M. C. (2006),“A model and a performance measurement system for collaborative supply chains,” *Decision Support Systems,* Vol.42, pp.283– 301.

Arshinder, K., Kanda, A., and Deshmukh S. G. (2009),“A framework for evaluation of coordination by contracts: A case of two-level supply chains,” *Computers & Industrial Engineering,* Vol.56, pp.1177–1191.

Ashley, S. (2004), “Penny-wise smart labels”, *Scientific American,* Vol. 291 No. 2, pp. 30-41.

Atali, A., Lee H.-L. and Ozer O. (2006), “If the inventory manager knew: Value of RFID under imperfect inventory information”, *Technical report, Graduate School of Business,* Stanford University.

Azaron, A., Brown K., Tarim S. and Modarres M. (2008), "A multi-objective stochastic programming approach for supply chain design considering risk," *International Journal of Production Economics,* Vol. 116, pp.129-138.

Badole C. M., Rathore, A.P.S., Jain R. and Nepal, B., (2012)," RFID based supply chain management of perishable products," *International conference on Best Practices in Supply Chain Management*, Bhubaneswar, pp. 62-69.

Bahaedin N. and Morteza Z. (2011), "Optimization of process variables and corrosion properties of a multi layer silica sol gel coating on AZ91D using the Box–Behnken design, Journal of Sol-Gel Science and Technology, vol.59, pp. 640–649.

Bai R., Burke E. K., and Kendall G. (2007),"Heuristic, meta-heuristic and hyper-heuristic approaches for fresh produce inventory control and shelf space allocation," *Journal of the Operational Research Society,* pp. 1-11.

Balakrishnan, A, Geunes, J. and Pangburn, M. S. (2004), "Coordinating Supply Chains by Controlling Upstream Variability Propagation," *Manufacturing and Service Operations Management,* Vol. 6, No. 2, pp. 163–183.

Balan S., Robertde S., Mark G., Stephan M., and Sushmera M., (2010), *"Modeling carbon foot prints across the supply chain, "*International Journal of Production Economics, 10, 1016.

Banerjee, A., Burton, J. and Banerjee, S. (2003),"A simulation study of latteral shipments in single supplier, multiple buyers supply chain networks," *International Journal of Production Economics,* Vol.81, No.82, pp.103–114.

Benkherouf, L. (1995), "On an inventory model with deteriorating items and decreasing time-varying demand and shortages", *European Journal of Operation Research*, Vol.86, pp. 293–299.

Bhunia, A.K. and Maiti, M. (1999), "An inventory model of deteriorating items with lot-size dependent replenishment cost and a linear trend in demand", *Appllied Mathematical Modelling,* Vol. 23, pp. 301–308.

Blackhurst, J., Wu T. and Craighead C.W. (2008),"A systematic approach for supply chain conflict detection with a hierarchical Petri Net extension", *Omega* Vol.36, pp.680-696.

Bogataj, M., and Bogataj, L. (2001),"Supply chain coordination in spatial games," *International Journal of Production Economics,* Vol.71, pp.277-285.

Bojarski, A., Laínez, J., Espuna, A. and Puigjaner, L., (2009),"Incorporating environmental impacts and regulations in a holistic supply chains modeling: An LCA approach," *Computers and Chemical Engineering,* Vol. 33, pp.1747-1759.

Bongju, J., Jung H-S. and Park N-K. (2002), "A computerized causal forecasting system using genetic algorithms in supply chain management", *The Journal of Systems and Software,* Vol. 60, pp. 223–237.

Bottani, E., Montanari, R. and Volpi A., (2010), "The impact of RFID and EPC network on the bullwhip effect in the Italian FMCG supply chain", *International Journal of Production Economics,* Vol. 124, pp. 426–432.

Box, G. E. P. Behnken, D. W. Simplex-Sum Designs: A Class of Second Order Rotatable Designs Derivable From Those of First Order. Ann. Math. Statist. 31 (1960), no. 4, 838-864.

Boyacı, T. and Gallego, G. (2002),"Coordinating pricing and inventory replenishment policies for one wholesaler and one or more geographically dispersed retailers", *International Journal of Production Economics,* Vol.77, pp.95–111.

Bramorski, T. (2007), "Determining Discounts for Perishable Inventory," *EABR (Business) & ETLC (Teaching) Conference Proceedings.*

Brzozowski, C. (2004), "Tags, tickets & labels: new technologies emerge", *Printing News,* Vol. 153 No.3.

Burer, S., Jones, P. C., and Lowe. T. J. (2008),"Coordinating the supply chain in the agricultural seed industry," *European Journal of Operational Research,* Vol.185, pp.354–377.

Cai, J., Wang, L., Han, Y., Zhou, G. and Huang, W., (2010) "*Advance order strategies: Effects on competition structure in a two- echelon supply chain,"* Applied Mathematical Modeling Vol.34, pp.2465–2476.

Cakravastia, A., Toha, I. S., and Nakamura, N. (2002),"A two-stage model for the design of supply chain networks," *International Journal of Production Economics,* Vol. 80, pp. 231-248.

Campuzano, F., Mula, J., and Peidro, D. (2010),"Fuzzy estimations and system dynamics for improving supply chains," *Fuzzy Sets and Systems,* Vol. 161, pp.1530–1542.

Candas, M. F., (2007),"Benefits of considering inventory in service parts logistics network design problems with time-based service constraints," *IIE Transactions,* Vol. 39, No.2, pp.159-176.

Cao, X. and Yao, Z. (2007),“Perishable Products’ Supply Chain Coordination Research with Option Contract under *Two Periods Production Mode,” Proceedings of an International Conference on Automation and Logistics.*

Capkun, V., Hameri, A. P. and Weiss L. (2009), *“On the relationship between inventory and financial performance in manufacturing companies,”* International Journal of Operations & Production Management Vol. 29, No.8, pp.789- 806.

Carlos, J. V. and Marc, G. (2001),“A global supply chain model with transfer pricing and transportation cost allocation,” *European Journal of Operational Research,* Vol.129, pp.134-158.

Caroline, L., Le, G. P. and Auzoux, S., (2008), “A decision support approach for cane supply management within a sugar mill area,” *Computers and Electronics in Agriculture,* Vol. 60, pp.239–249.

Chaharsooghi, S.K., Heydari, J. S. and Zegordi, H. (2008) “A reinforcement learning model for supply chain ordering management: An application to the beer game,” *Decision Support Systems,* Vol. 45, pp. 949–959.

Chakrabarti, T. and Chaudhri, K.S. (1997), “An EOQ model for deteriorating items with a linear trend in demand and shortages in all cycles, International Journal of Production Economics, Vol. 49, pp. 205–213.

Chan, H.K., and Chan, F.T.S. (2010),“Comparative study of adaptability and flexibility in distributed manufacturing supply chains,” *Decision Support Systems,* Vol.48, 331-341.

Chande, A, Dhekane, S, Hemachandra, N and Rangaraj, N. (2005), “Perishable inventory management and dynamic pricing using RFID technology”, *Sadhana,* Vol. 30, Parts 2 and 3, pp. 445–462.

Chang, C. T., Teng, J. T. and Goyal, S. K. (2010), “Optimal replenishment policies for non-instantaneous deteriorating items with stock-dependent demand”, *International Journal of Production Economics,* Vol. 123, pp. 62–68.

Chang, H. J., Teng, J.T. Ouyang L.Y. and Dye Y. (2006),“Retailer’s optimal pricing and lot-sizing policies for deteriorating items with partial backlogging,” *European Journal of Operational Research,* Vol.168, pp.51–64.

Chang, H.-J. and Dye, C.-Y. (1999), “An EOQ model for deteriorating items with time varying demand and partial backlogging”, *Journal of Operational Research Society,* Vol. 50, pp.1176–1182.

Chang, S.L., Wang, R.C. and Wang, S.Y. (2006),“Applying fuzzy linguistic quantifier to select supply chain partners at different phases of product life cycle,” *International Journal of Production Economics,* Vol.100, pp.348–359.

Chang, C. T., Ouyang, L. Y. and Teng, J. T. (2003), “ An EOQ model for deteriorating items under supplier credits linked to ordering quantity,” *Applied Mathematical Modelling,* Vol. 27, pp. 983–996

Chatrfield, D. C., Hayya, J. C. and Harrison, T, P. (2007),“A multi-formalism architecture for agent-based, order-centric supply chain simulation,” *Simulation Modeling Practice and Theory,* Vol.15, pp.153–714.

Che, Z.H., Wang, H.S., Sha, D.Y., (2007),“A multi-criterion interaction-oriented model with proportional rule for designing supply chain networks,” *Expert Systems with Applications,* Vol. 33, pp.1042-1053.

Chen, C.T., Lin, C.T., and Huang, S. F. (2006), “A fuzzy approach for supplier evaluation and selection in supply chain management,” *International Journal of Production Economics,* Vol.102, No.2, pp.289-301.

Chen, F. and Yu, B., (2005), “Quantifying the Value of Lead time Information in a Single-Location Inventory System,” *Manufacturing and Service Operations Management,* Vol. 7, No. 2, pp. 144–151.

Chen, F., Federgruen, A. and Zheng, Y.S. (2001),“Coordination Mechanisms for a Distribution System with One Supplier and Multiple Retailers” *Management Science,* Vol.47, No.5, pp.693-708.

Chen, H., Chen, Y.F., Chiu, C.H., Choi, S.M. and Sethi S. (2010), “Coordination mechanism for the supply chain with lead time consideration and price-dependent demand,”*European Journal of Operational Research* Vol.203, pp.70–80.

Chen, J. M., and Chen, L.T. (2007), “Periodic pricing and replenishment policy for continuously decaying inventory with multivariate demand,” *Applied Mathematical Modeling,* Vol.31, pp.1819–1828.

Chen, K. and Xiao, T. (2009),“Demand disruption and coordination of the supply chain with a dominant retailer,” *European Journal of Operational Research,* Vol. 197, pp.225–234.

Chen, L., and Lee, H., (2009),“Information Sharing and Order Variability Control Under a Generalized Demand Model,” *Management Science,* Vol. 55, No.5, pp.781–797.

Cheung, K. L. and Lee, H. L. (2002),"The Inventory Benefit of Shipment Coordination and Stock Rebalancing in a Supply Chain," *Management Science,* Vol. 48, No.2, pp.300-306.

Cheung, K. L. and Yuan, X.M. (2003),"An infinite horizon inventory model with periodic order Commitment," *European Journal of Operational Research,* Vol. 146, pp.52–66.

Chew, E. P., Lee, C. and Liu, R., (2009), "Joint inventory allocation and pricing decisions for perishable products", *International Journal of Production Economics,* Vol.120, pp. 139–150.

Chiang, W.C., Russell, R., Xu, X., and Zeped, D. (2009),"A simulation / metaheuristic approach to newspaper production and distribution supply chain problems," *International Journal of Production Economics,* Vol.121, pp.752–767.

Chiang, W.K. and Monahan, G. E. (2005),"Managing inventories in a two-echelon dual-channel supply chain," *European Journal of Operational Research,* Vol.162, pp. 325-341.

Choi, T. M., Li, D., and Yan, H. (2008)*,"*Mean variance analysis of a single supplier and retailer supply chain under a returns policy," *European Journal of Operational Research,* Vol.184, pp.356-376.

Choi, T.M., Li D., Yan H. and Chiu, C.H. (2008),"Channel coordination in supply chains with agents having mean-variance objectives," *Omega,* Vol.36, pp.565 -576.

Chong, W. and David, B. (2010),"Formulating partner selection criteria for agile supply chains: A Dempster–Shafer belief acceptability optimization approach", *International Journal of Production Economics,* Vol. 125, pp.284–293.

Chopra, S., Reinhardt, G. and Dada, M. (2004), "The Effect of Lead Time Uncertainty on Safety Stocks,"*Decision Sciences,*Vol. 35 No.1, pp. 1-24.

Choudhary, A. K., Singh, K. A., and Tiwari, M.K., (2006),*"A statistical tolerancing approach for design of synchronized supply chains,"* Robotics and Computer-Integrated Manufacturing, Vol. 22, pp. 315–321.

Chu, W.H.J. and Lee, C.C. (2006),"Strategic information sharing in a supply chain," *European Journal of Operational Research,* Vol.174, pp.1567-1579.

Chung, C.S., Flynn, J., and Stalinski, P. (2007),"A single-period inventory placement problem for a supply chain with the expected profit objective," *European Journal of Operational Research,* Vol. 178, pp.767–781.

Chung, S.-L., Wee, H.-M. and Yang. Po-C. (2008),"Optimal policy for a closed-loop supply chain inventory system with remanufacturing", *Mathematical and Computer Modelling,* Vol. 48 pp.867–881.

Chang, C-T., Teng, J-T. and Goyal, S. K. (2010), Optimal replenishment policies for non-instantaneous deteriorating items with stock-dependent demand," *International Journal of Production Economics,* Vol.123, pp.62–68.

Coppini, M., Strozzi, F., Rossignoli, C. and Rossi, T. (2010), "Bullwhip effect and inventory oscillations analysis using the Beer Game model," *International Journal of Production Research,* Vol.48, No.13, pp.3943-3956.

Corless, R. M., G. H. Gonnet, D. E. G. Hare, D. J. Jeffrey and D. E. Knuth, (1996), "On the Lambert W function," *Advances in Computational Mathematics,* Vol.5, pp.329-359.

Covert, R.P. and Philip, G. C. (1973), "An EOQ model for items with Weibull distribution deterioration," *American Institute of Industrial Engineering Transaction,* vol. 5 pp.323–326.

Croom, S., Romano, P. and Giannakis, M. (2000), "Supply chain management: an analytical framework for critical literature review", *European Journal of Purchasing and Supply Management,* Vol. 6 No. 1, pp. 67–83.

Cruz, J. M., (2009),"The impact of corporate social responsibility in supply chain management: multicriteria decision-making approach,*DecisionSupport Systems,* Vol. 48, 224–326.

Dabbene, F., Gay, P. and Sacco, N. (2008b), "Optimisation of fresh-food supply chains in uncertain environments, Part II: A case study", *Biosystems Engineering,* Vol. 99 No. 3, pp. 360–371.

Darwish, M.A., and Odah, O. M. (2010), "Vendor managed inventory model for single-vendor multi-retailer supply chains," *European Journal of Operational Research,* Vol. 204, pp.473–484.

Das, C. (1975), "Effect of Lead Time on Inventory: A Static Analysis," *Operational Research Quarterly, Pergamon Press,* Vol. 26, 2, i, pp. 273 to 282.

Das, S. K., and Abdel-Malek, L. (2003),"Modeling the flexibility of order quantities and lead-times in supply chains," *International Journal of Production Economics,* Vol. 85, pp.171–181.

Dasci, A., (2003), "Dynamic pricing of perishable assets under competition: A two-period model," Working paper, York University, Toronto, Ontario, Canada.

Datta, T. K. and Pa,l A. K. (1988), "Order level inventory system with power demand pattern for items with variables rate of deterioration," *Indian Journal of Pure Appllied Mathematics,* vol.19, pp. 1043–1053.

Dave, U. and Patel, L. K. (1984), "(T, Si) policy inventory model for deteriorating items with time proportional demand," *Journal of Operation Research Society,* Vol.32, pp. 1013–1019.

David, E.C., and John, R. M. (2009),"Decision-making in the supply chain: Examining problem solving approaches and information availability," *Journal of Operations Management,* Vol.27, pp.220–232.

David, P., Josef, M., Raúl., P. and Verdegay, J. (2009),"Fuzzy optimization for supply chain planning under supply, demand and process uncertainties," *Fuzzy Sets and Systems,* Vol. 160, pp.2640–2657.

De Boeck, L., and Vandaele, N. (2008),"Coordination and synchronization of material flows in supply chains: An analytical approach," *International Journal of Production Economics,* Vol.116, pp.199–207.

Dhumal, P., Sundararaghavan, P. S., and Nandkeolyar, U. (2008),"Cola-Game, An Innovative Approach to Teaching Inventory Management in a Supply Chain," *Decision Sciences Journal of Innovative Education,* Vol.6, No.2, pp.265-285.

Di Pietro, R., and Molva, R. (2010), "Optimal probabilistic solution for information confinement, privacy, and security in RFID systems", *Journal of Network and Computer Applications,* Vol.18, No.5, pp. 839-860.

Ding, D. and Chen, J, (2008), "Coordinating a three level supply chain with flexible return policies," *Omega,* Vol.36, pp. 865 –876.

Disney, S.M. and Towill, D.R. (2003), "On the bullwhip and inventory variance produced by an ordering Policy," *Omega,* Vol. 31, pp. 157 – 167.

Dong, J., Zhang, D., and Nagurney, A. (2004), *"A supply chain network equilibrium model with random demands," European Journal of Operational Research,* Vol.156, pp.194–212.

Dong, M. and Chen, F. F., (2001),"Process modeling and analysis of manufacturing supply chain networks using object-oriented Petri nets," *Robotics and Computer Integrated Manufacturing,* Vol. 17, pp. 21-29.

Drzymalski, J. and Odrey, N. (2008), "Supervisory control of a multi-echelon supply chain: A modular Petri net approach for inter-organizational control," *Robotics and Computer-Integrated Manufacturing,* Vol. 24, PP.728– 734.

Duan, Q.T. and Liao, W. (2013), "A new age-based replenishment policy for supply chain inventory optimization of highly perishable products*," International Journal of Production Economics,* Vol.145, pp. 658–671

Dye, C.Y., Hsieh, T.P. and Ouyang, L.Y. (2007),"Determining optimal selling price and lot size with a varying rate of deterioration and exponential partial backlogging," *European Journal of Operational Research,* Vol. 181, pp.668–678.

Edward, C. R. (2008),"A game-theoretic approach to transfer pricing in a vertically integrated supply chain,"International Journal of Production Economics, Vol.115, pp. 542–552.

Erol, I. and Ferrell, Jr. W.G. (2003),*"A methodology for selection problems with multiple conflicting objectives and both qualitative and quantitative criteria,"* International Journal of Production Economics, Vol.86, pp.187–199.

Ertunga, C. O., Alfred, D., and Teng, S. G. (2008)"Optimizing liquefied natural gas terminal design for effective supply-chain operations," *International Journal of Production Economics,* Vol. 111, pp.529–542.

Esmaeili, M., Aryanezhad, M. and Zeephongsekul P. (2009),"A game theory approach in seller–buyer supply chain," *European Journal of Operational Research,* Vol. 195, pp.442–448.

Estrada-Flores, S., Tanner, D. J. and Amos, N. D. (2002),"Cold chain management during transport of perishable products,*Food Australia,* Vol.54. No.7, pp.268-270.

Fandela, G., and Stamme, M. (2004),"A general model for extended strategic supply chain management with emphasis on product life cycles including development and recycling," *International Journal of Production Economics,* Vol.89, pp.293–308.

Federgruen, A. and Heching, A., (2002),"Multi-location Combined Pricing and Inventory Control," *Manufacturing Service Operations Management,* Vol.4, pp.275-295.

Fengqi, Y., and Ignacio, E. G. (2008),"Design of responsive supply chains under demand Uncertainty" *Computers and Chemical Engineering* ,Vol. 32, pp.3090–3011.

Ferguson, M. and Ketzenberg, M., (2006), "Information sharing to improve retail product freshness of perishables," *Production and Operations Management,* Vol 15, No.1, pp. 57 – 73.

Fernando, D. M., Gonzalo, G., Antonio, E. and Luis, P. (2007),"An agent-based approach for supply chain retrofitting under uncertainty," *Computers and Chemical Engineering,* Vol.31, pp.722–735.

Fleisch, E. and Tellkamp, C. (2005),"Inventory inaccuracy and supply chain performance: a simulation study of a retail supply chain," *International Journal of Production Economics,* Vol.95, pp.373–385.

Franca, R.B., Jones, E.C., Richards, C.N. and Carlson, J.P. (2010),"Multi-objective stochastic supply chain modeling to evaluate tradeoffs between profit and quality," *International Journal of Production Economics,* 10:1016.

Frascatore, M. R. and Mahmoodi, F. (2008),"Long-term and penalty contracts in a two-stage supply chain with stochastic demand," *European Journal of Operational Research,* Vol. 184, pp.147–156.

Fu, Q. and Zhu, K. (2010),"Endogenous information acquisition in supply chain management," *European Journal of Operational Research,* Vol.201, pp.454–462.

Funda, S, and Robinson, Jr E.P. (2005),"Information sharing and coordination in make- to-order supply chains," *Journal of Operations Management,* Vol. 23, pp.579–598.

Gaukler, G., Ozer, O. and Hausman, W. (2005), "RFID and product progress information: Improved emergency ordering policies. *Technical report, Dept. of Management Science and Engineering, Stanford University, Stanford,* CA.

Gaukler, G.M., Seifert, R. W. and Hausman, W. (2007), "Item-level RFID in the retail supply chain", *Production and Operations Management,* Vol.16, pp. 65-76.

Georgiadis, P., and Vlachos, D. and Eleftherios I. (2005),"A system dynamics modeling framework for the strategic supply chain management of food chains," *Journal of Food Engineering,* Vol.70, pp.351–634.

Gerard, P. C., and Robert, S. (2009),"Purchasing, Pricing, and Quick Response in the Presence of Strategic Consumers," *Management Science,* Vol.55, No.3, pp.497–511.

Ghaeli, M., Bahri, P. and Lee, P. (2008), "Scheduling of a mixed batch/continuous sugar milling plant using Petri net", *Computers and Chemical Engineering,* Vol. 32, pp.580–589.

Ghare, P. M. and Shrader, G. F. (1963), "A Model for exponentially decaying inventories," *Journal of Industrial Engineering,* Vol. 14, pp.238–243.

Giannoccaro, I., Pontrandolfo, P., and Scozzi, B. (2003),“A fuzzy echelon approach for inventory management in supply chains,” *European Journal of Operational Research*, Vol. 149, pp.185–196.

Gigler, J.K., Hendrix, E.M.T., Heesen, R.A., van den Hazelkamp V.G.W. and Meerdink G. (2002), “On optimization of agri chains by dynamic programming,” *European Journal of Operational Research*, Vol. 139, pp.613–625.

Gilbert, S. M., and Xi, Y. (2006), “Strategic outsourcing for competing OEMs that face cost reduction opportunities,” *IIE transactions*, Vol.38, No. 11, pp.903-915.

Gjerdrum, J., Shah, N., and“Lazaros, G. P. (2002),“Fair transfer price and inventory holding policies in two-enterprise supply chains,” *European Journal of Operational Research*, Vol. 143, pp.582–599.

Glidden, R. and Bockorick, C. et al. (2004), “Design of ultralow- cost UHF RFID tags for supply chain applications”, *IEEE Communications Magazine*, Vol. 42 No. 8, pp. 140-151.

Gong, Z. (2008),“An economic evaluation model of supply chain flexibility,” *European Journal of Operational Research*, Vol.184, pp.745-758.

Gonzalo, G., Mariana, B., and Luis, P. (2007),“A holistic framework for short- term supply chain management integrating production and corporate financial planning,” *International Journal of Production Economics*, Vol.106, pp. 288–306.

Goswami, A. and Glaudhuri, K. S. (1991), “An EOQ model for deteriorating items with shortages and a linear trend in demand”, *Journal of Operational Research Society*, Vol. 42, pp. 1105–1110.

Grahovac, J., and Chakravarty, A. (2001),“Sharing and Lateral Transshipment of Inventoryin a Supply Chain with Expensive Low-Demand Items,” *Management Science*, Vol.47, No.4, pp. 579-594.

Gross, D. and Soriano, A. (1969),“The Effect Of Reducing Lead time On Inventory Levels-Simulation Analysis,” *Management Science*, Vol. 16, No. 2, pp.61-76.

Gumus, A. T., and Guneri, A.F. (2009),“A multi-echelon inventory management framework for stochastic and fuzzy supply chains,” *Expert Systems with Applications*, Vol.36, pp.5565–5575.

Gumus, A. T., Guneri, A. F., and Selcan, K. (2009),“Supply chain network design using an integrated neuro-fuzzy and MIL approach: A comparative design study,” *Expert Systems with Applications,* Vol. 36, pp. 12570–12577.

Gunasekharan, A., and Kobu, B. (2006) ,“Performance measures and metrics in logistics and supply chain management: a review of recent literature (1995–2004) for research and applications,” *International Journal of Production Research,* pp.1–22.

Gunther, Z., and Michael, W., (2006), *“Warehouse sequencing in the steel supply chain as a generalized job shop model,”* International Journal of Production Economics, Vol. 104, pp.482–501.

Gupta, A., and Maranas, C. D. (2003),“Managing demand uncertainty in supply chain planning,” *Computers and Chemical Engineering,* Vol.27, pp.1219-1227.

Gupta, D., and Weerawat, W. (2006),“Supplier–manufacturer coordination in capacitated two stage supply chains,” *European Journal of Operational Research,* Vol.17, pp.67–89.

Chang, H.-J., Teng J. T.,Ouyang, L. Y. and Dye, C. Y. (2006), “ Retailer’s optimal pricing and lot-sizing policies for deteriorating items with partial backlogging,” *European Journal of Operational Research,* Vol. 168, pp. 51–64.

Hadi, M. B., Rosnah M. Y., Megat M. H., Megat A., and Mohd Rizam A. B. (2009), “Development of a new approach for deterministic supply chain network Design,” *European Journal of Operational Research,*Vol. 198, pp.121–128.

Halati, A. and He Y. (2010),“Analysis of supply chains with quantity based fixed Incentives,” *European Journal of Operational Research,* Vol. 202, pp.214–222.

Hammami, R., Frein Y, and Hadj-Alouane A.B. (2009),“A strategic-tactical model for the supply chain design in the delocalization context: Mathematical formulation and a case study,” *International Journal of Production Economics,* Vol. 122, pp.351–365.

Hammond, D. and Beullens P. (2007),“Closed-loop supply chain network equilibrium under legislation,” *European Journal of Operational Research,* Vol. 183, pp.895–908.

Hariga, M. A., Al-Ahmari A. and Mohamed, A.R.A. (2007),“A joint optimization model for inventory replenishment, product assortment, shelf space and display area allocation decisions” *European Journal of Operational Research,* Vol.181, pp.239–251.

Hariga, M. (1996), "Optimal EOQ models for deteriorating items with time-varying demand, *Journal of Operational Research Society,* Vol.47, pp.1228–1246.

Hariga, M. and Alyan, A. (1997), "A lot sizing heuristic for deteriorating items with shortages in growing and declining markets", *Computers in Operation Research,* Vol. 24, pp.1075–1083.

He, Y., Wang, S.Y. and Lai, K.K. (2010),"An optimal production-inventory model for deteriorating items with multiple-market demand," *European Journal of Operational Research,* Vol. 203, pp.593-600.

Hendricks, K. and Singhal, V. (2009),"Demand-Supply Mismatches and Stock Market Reaction: Evidence from Excess Inventory Announcements," *Manufacturing & Service Operations Management,* Vol. 11,No.3, pp.509–524.

Hennet, J. and Arda, Y. (2008), "Supply chain coordination: A game-theory Approach," *Engineering Applications of Artificial Intelligence,* Vol.21, pp.399–405.

Higgins, L. N. and Cairney, T., (2006), "RFID Opportunities and Risks,"*The Journal of Corporate Accounting and Finance*, pp.51-57.

Hill, J., and Galbreth, M., (2008), "A heuristic for single-warehouse multi retailer supply chains with all-unit transportation cost discounts," *European Journal of Operational Research,* Vol. 187, pp.473–482.

Hsiao, Y.C. (2008),"Integrated logistics and inventory model for a two-stage supply chain controlled by the reorder and shipping points with sharing information" *International Journal of Production Economics,* Vol.115, pp.229-235.

Hsiao, Y.C., Lin Y. and Huang, Y.K. (2010), *"Optimal multi-stage logistic and inventory policies with production bottleneck in a serial supply chain,"* International Journal of Production Economics, Vol.124, pp.408-413.

Hsieh, C.C., and Wu, C.H. (2008),"Capacity allocation, ordering, and pricing decisions in a supply chain with demand and supply uncertainties", *European Journal of Operational Research,* Vol. 184, pp.667–684.

Hsieh, T. P. and Dye, C.Y. (2010b), "Optimal replenishment policy for perishable items with stock-dependent selling rate and capacity constraint", *Computers and Industrial Engineering,* Vol. 59, pp. 251–258.

Hsieh, T.-P and Dye, C.-Y., (2010a), "Optimal replenishment policy for perishable items with stock-dependent selling rate and capacity constraint", *Computers and Industrial Engineering,* Vol.59, No.2, pp.251-258.

Hsu, C.I., Shih, H.H. and Wan, W.C. (2009), "Applying RFID to reduce delay in import cargo customs clearance process," *Computers and Industrial Engineering,* Vol. 57, pp. 506–519.

Huang, H. and Sethi S.P. (2005), "Purchase contract management with demand forecast update," *IIE Transactions,* Vol.37, pp. 775–785.

Hung, W., Nouri, J. and Shah N., (2006) "Object-oriented dynamic supply-chain modeling incorporated with production scheduling," *European Journal of Operational Research,* Vol. 169, pp.1064-1076.

Ivanov, D., Sokolov, B. and Kaeschel, J. (2010),"A multi-structural framework for adaptive supply chain planning and operations control with structure dynamics considerations," *European Journal of Operational Research,* Vol. 200, PP.409–420.

Jack, G.A.J., van der Vorst Adrie J.M. B., and Paul van B., (2000),"Modeling and simulating Multi-echelon food systems," European Journal of Operational Research, Vol. 122, pp.354-366.

Jain, V., Benyoucef, L. and Deshmukh, S.G. (2008),"A new approach for evaluating agility in supply chains using Fuzzy Association Rules Mining," *Engineering Applications of Artificial Intelligence,* Vol. 21, pp.367–385.

Jay, D. S. and Manuel R. (2009), "Control-Relevant Demand Forecasting for Tactical Decision-Making in Semiconductor Manufacturing Supply Chain Management," *IEEE Transactions on Semiconductor Manufacturing,* Vol. 22 No.1, pp.744-753.

Jayaram, J. and Tan, K.C. (2010),"Supply chain integration with third-party logistics Providers," *International Journal of Production Economics,* Vol. 125, pp. 262–271.

Jedermann, R, and Lang, W. (2007), "Semi-passive RFID and beyond: steps towards automated quality tracing in the food chain", *International Journal of RadioFrequency Identification Technology and Applications,* Vol.1, No.3, pp. 247-259.

Jiang, C. and Sheng Z. (2009),"Case-based reinforcement learning for dynamic inventory control in a multi-agent supply-chain system," Expert Systems with Applications, Vol.36, pp.6520–6526.

Jing-Sheng S. (1994), "The Effect of Lead time Uncertainty in a Simple Stochastic Inventory Model," *Management Science,* Vol. 40, No.5, pp. 603-613.

Jones, P., Clarke-Hill, C., Hillie,r D. and Comfort, D. (2005), “The benefits, challenges and impacts of radio frequency identification technology (RFID) for retailers in the UK,” *Marketing Intelligence & Planning,* Vol. 23 No. 4, pp. 395-402.

Jose, B.C. Jr., Raymond R. T., Alvin B. C. and Ballacillo J. (2009), “A dynamic input–output model for nascent bio-energy supply chains,” *Applied Energy,* Vol. 86, pp. 86–94.

Joseph, G. S., Vera, T. and Jiang Z. (2011), “Analytical model of adoption of item level RFID in a two-echelon supply chain with shelf-space and price-dependent demand,” *Decision Support Systems,* Vol. 51, pp. 833–841.

Joshi, Y.V., Information visibility and its effect on supply chain dynamics, **(**2000**),** “Master Thesis,” *Massachusetts Institute of Technology (*MIT), June 2000.

Jung, J.Y., Blau G., Pekny, J.F., Reklaitis, G.V., and Eversdyk, D. (2004),“A simulation based optimization approach to supply chain management under demand uncertainty,”*Computers and Chemical Engineering,* Vol.28, pp.2087–2106.

Jung, J.Y., Blaua, G., Pekny, J.F., Reklaitis, G.V. and Eversdyk, D. (2008),“Integrated safety stock management for multi-stage supply chains under production capacity constraints,” *Computers and Chemical Engineering,* Vol. 32, pp. 2570–2521.

Kaihara, T. (2001),“Supply chain management with market economics”, *International Journal of Production Economics,* Vol.73, pp.5-14.

Kainuma, Y., and Tawar, N. (2006),“A multiple attribute utility theory approach to lean and green supply chain management,” *International Journal of Production Economics,* Vol.101, pp.99-108.

Kaminsky, P., and Kaya, O. (2008)*, “Inventory positioning, scheduling and lead-time quotation in supply chains,”International Journal of Production Economics.* Vol.114, pp. 276–293.

Kaminsky, P., and Kaya, O. (2009),“Combined make-to-order/make-to-stock supply chains,” *IIE Transaction,* Vol. 41, pp. 103–119.

Kang, Y. and Gershwin, S. B. (2004), “Information inaccuracy in inventory systems – stock loss and stock-out, *IIE Transactions,* Vol.37, pp.843-859.

Kannan, G., Sasikumar, P. and Devika, K., (2010),“A genetic algorithm approach for solving a closed loop supply chain model: A case of battery recycling,” *Applied Mathematical Modeling* ,Vol. 34, pp.655–670.

Kazim, S. (2010),“Exploring the impacts of radio frequency identification (RFID) technology on supply chain performance,” *European Journal of Operational Research,* Vol.207, pp. 174–183.

Kheljani, J. G., Ghodsypour, S.H. and Brien, C.O. (2009),“Optimizing whole supply Chain benefit versus buyer’s benefit through supplier selection” *International Journal of Production Economics,* Vol.21, pp.482–493.

Kim, H. S. and Cho, J. H. (2010), “Supply chain formation using agent negotiation,” *Decision Support Systems,* Vol. 49, pp.77–90.

Knights, P.F., Henderson, E. and Daneshmend, L.K. (2004), “Draw point control using radio frequency identification systems”, *CIM Bulletin,* Vol. 89 No. 1003, pp. 53-58.

Kok, A.G. and Shang, H.K. (2007), “Inspection and replenishment policies for systems with inventory record inaccuracy”, *Manufacturing and Service Operations Management,* Vol.9, No.2, pp.185-205.

Kok, A.G., van Donselaar, K.H. and van Woensel, T. (2008), “A break-even analysis of RFID technology for inventory sensitive to shrinkage”, *International Journal of Production Economics,* Vol. 112, pp. 521–531.

Konstantin, K., and Charles, S. T. (2009),“Optimal co-investment in supply chain infrastructure,” *European Journal of Operational Research,* Vol.192, pp.265–276.

Kull, T. and Closs, D., (2008), “The risk of second-tier supplier failures in serial supply chains: Implications for order policies and distributor autonomy,” *European Journal of Operational Research,* pp. 1158–1174.

Kuo, T., and Chang, T. (2008),“Optimal planning strategy for the supply chains of light aromatic compounds in petrochemical industries,” *Computers and Chemical Engineerin* ,Vol.32, pp.1147-1166.

Kurata, H. and Yue, X. (2008),“Trade promotion mode choice and information sharing in fashion retail supply chains”, *International Journal of Production Economics,* Vol.114, pp.507–519.

Lakhal, S., Martel, A., Kettani, O., and Oral, M. (2001),*”On the optimization of supply chain networking decisions,”* European Journal of Operational Research, Vol. 129, pp.259-270.

Lambert, D. M. and Cooper, M. C. (2000), “Issues in supply chain management”, *Industrial Marketing Management*, Vol. 28, pp. 65–83.

Lamothe, J., Khaled H., and Michel, A. (2006),“An optimization model for selecting a product family and designing its supply chain,” *European Journal of Operational Research,* Vol. 169, pp.1030–1047.

Lau, R.S.M., Xie, J., and Zhao, X. (2008),“Effects of inventory policy on supply chain performance: A simulation study of critical decision parameters,” *Computers & Industrial Engineering,* Vol.55, pp.620–633.

Lawrence, S. A., Sivakumar B., and Arivarignan G. (2006),“Perishable Inventory System with Random Supply Quantity and Negative Demands,” *Advanced Modeling and Optimization,* Vol. 8, No.2, pp.151-168.

Lee, C.H. and Rhee, B.D. (2007),“Channel coordination using product returns for a supply chain with stochastic salvage capacity,” *European Journal of Operational Research,* Vol.77, pp.214–238.

Le,e H. L., Padmanabhan, V. andWhang, S. (1997), “Information Distortion in a Supply Chain: The Bullwhip Effect,” *Management Science,* Vol. 43 No.4, pp.546-558.

Lee, I. and Lee, B. (2010),“An investment evaluation of supply chain RFID Technologies: A normative modeling approach,” *International Journal of Production Economics,* Vol.125, pp.313–323.

Lee, J., Edwin, T. C. and Wang, C. S. (2007), “Analysis of postponement strategy for perishable items by EOQ-based models *International Journal of Production Economics,* Vol. 107, pp. 31–38

Lee, Y.M., Cheng, F. and Leung, Y. T. (2004), “Exploring the impact of RFID on supply chain dynamics”, *Winter Simulation Conference, R .G. Ingalls, M. D. Rossetti, J. S. Smith, and B. A. Peters, editors,* pages 1145-1152.

Leslee, N. H. and Tim C. (2006). “RFID Opportunities and Risks,”*The Journal of Corporate Accounting & Finance,* Vol. 17, pp.51-57.

Levin, Y., Mc Gill J. and Nediak N. (2009),“Dynamic Pricing in the Presence of Strategic Consumers and Oligopolistic Competition,” *Management science,* Vol. 55, pp.32-46.

Li, H., Hendry L., and Teunter, R. (2009), “A strategic capacity allocation model for a complex supply chain: Formulation and solution approach comparison,” *International Journal of Production Economics,* Vol.121, pp.505–518.

Li, J, Wang, S. and Cheng, T.C.E. (2010), “Competition and cooperation in a single-retailer two-supplier supply chain with supply disruption”, *International Journal of Production Economics,* Vol. 124,pp.137–150.

Li J., Sheng, Z., and Liu H. (2010),"Multi-agent simulation for the dominant players' behavior in supply chains" *Simulation Modeling Practice and Theory,* Vol.18, pp.850–589.

Li, J. and Mao, J. (2009),"An Inventory Model of Perishable Item With Two Types of Retailers," *Journal of the Chinese Institute of Industrial Engineers,* Vol.26, No.3, pp.176-183.

Li, J., Cheng T.C.E., and Wang S. (2007),"Analysis of postponement strategy for perishable items by EOQ-based models," *International Journal of Production Economics,* Vol.107, pp.31–38.

Li, J., Wang, S., and Cheng, T. C. E. (2010),"Competition and cooperation in a single-retailer two-supplier supply chain with supply disruption," *International Journal of Production Economics,* Vol. 124, pp.137-150.

Li, L., and Liu, L. (2008),"Supply chain coordination with manufacturer's limited reserve capacity an extended newsboy problem," *International Journal of Production Economics,* Vol.112, pp. 860- 868.

Li, S., Zhu, Z., and Huang, L. (2009), *"Supply chain coordination and decision making under consignment contract with revenue sharing," International Journal of Production Economics,* Vol. 120, pp.88–99.

Li, X., and Sridharan, V. (2008),"Characterizing order processes of using (R,nQ) inventory policies in supply chains," *Omega,* Vol. 36, pp.1096-1104.

Liang, T. F. (2008),"Fuzzy multi-objective production/distribution planning decisions with multi-product and multi-time period in a supply chain," *Computers & Industrial Engineering,* Vol. 55, pp.676–694.

Liang, T. F. and Cheng, H. W. (2009),"Application of fuzzy sets to manufacturing/distribution planning decisions with multi product and multi-time period in supply chains," *Expert Systems with Applications,* Vol. 36, pp.3367–3377.

Lin, C., Chow, W.S., Madu, C.N., Kuei, C. H. and Yu, P.P. (2005),"A structural equation model of supply chain quality management and organizational performance," *International Journal of Production Economics,* Vol. 96, pp.355–365.

Lin, P.H., Wong, D.S.H., Jang, S. S., Shieh, S.S. and Chu, J.Z. (2004), "Controller design and reduction of bullwhip for a model supply chain system using z-transform analysis," *Journal of Process Control,* Vol.14, pp, 487–499.

Liu, R., Kumar, A. and vander Aalst, W. (2007), "A formal modeling approach for supply chain event management," *Decision Support Systems,* Vol. 43, PP. 761–778.

Lodree, Jr. E. and Uzochukwu, B. M. (2008),"Production planning for a deteriorating item with stochastic demand and consumer choice," *International Journal of Production Economics,*Vol.116, No.2, pp. 219-232.

Lodree, Jr. E.J., Geiger, C.D. and Ballard K. N. (2010),"Coordinating production and shipment decisions in a two-stage supply chain with time-sensitive demand," *Mathematical and Computer Modeling,*Vol.51, pp.632-648.

Manuel, P., Sivakumar B., and Arivarignan G. (2008),"A perishable inventory system with service facilities and retrial customers," *Computers & Industrial Engineering,* Vol.54, pp.484–501.

Maria, I., Ana P. and Augusto Q. (2010),"Simultaneous design and planning of supply chains with reverse flows: A generic modeling framework," *European Journal of Operational Research,* Vol. 203, pp. 336–349.

Mark, S. and Ki I. (2010),"Managing the order pipeline to reduce supply chain volatility, *European Journal of Operational Research,* Vol.203, pp.380–932.

Mathur, P. P. and Shah, J. (2008), "Supply chain contracts with capacity investment decision: Two-way penalties for coordination," *International Journal of Production Economics,* Vol. 114, pp.56–70.

Matteo, C., Chiara, R., Tommaso, R. and Fernanda, S. (2010),"Bullwhip effect and inventory oscillations analysis using the beer game model," *International Journal of Production Research,* Vol. 48, No. 13, pp.3943–3956.

Mehdi, M., Mohammad R. Y., Vahid F.D. and Seyed R.H. (2009),"Supply chain modeling in uncertain environment with bi-objective approach," *Computers & Industrial Engineering,* Vol. 56, pp.1535–1544.

Mehmet S. N, Jacqueline M. B-R, Rene H, and Jack G.A.J. vander Vorst, (2015), "

Modeling an Inventory Routing Problem for perishable products with environmental considerations and demand uncertainty," *International Journal of Production Economics,* Vol. 164, pp.118–133

Meng, Q., Huang, Y., and Cheu, R.L. (2009),"Competitive facility location on decentralized supply chains," *European Journal of Operational Research,* Vol.196, pp.487–499.

Mickael, C., Pierre, F., and Nikolay, T. (2008),"A combined financial and physical flows evaluation for logistic process and Tactical production planning, Application in a company supply chain," *International Journal of Production Economics*, Vol.112, pp. 77- 95.

Min, H. and Zhou, G. (2002**),** "Supply chain modeling: past, present and future", *Computers and Industrial Engineering,* Vol. 43, pp.239-249.

Minner, S. (2001), "Strategic safety stocks in reverse logistics supply chains," *International Journal of Production Economics,* Vol. 71, pp.417-428.

Mohammad R. And Ali S. N., (2014) Coordination mechanism for a deteriorating item in a two-level supply chain system, *Applied Mathematical Modelling,* Vol. 38, pp. 2884–2900.

Monthatipkul, C. and Yenradee P. (2008), "Inventory/distribution control system in a one warehouse/ multi-retailer supply chain," *International Journal of Production Economics,* Vol. 114, pp.119–133.

Mustafa, O., Theopisti, C. and Melek, A. (2007). "Systems dynamics modeling of a manufacturing supply chain system," *Simulation Modeling Practice and Theory,* Vol. 15, pp.1338–1355.

Muthusamy, G., Srinivasan, R. and Chandrasekharan, R. (2008),"The value of information sharing in a multi-product supply chain with product substitution," *IIE Transactions,* Vol. 40, pp.1124–1140.

Nachiappan, S.P. and Jawahar, N. (2007),"A genetic algorithm for optimal operating parameters of VMI system in a two-echelon supply chain," *European Journal of Operational Research,* Vol. 182, pp.1433–1452.

Nagarajan, M. and Sosic, G. (2008),"Game-theoretic analysis of cooperation among supply chain agents: Review and extensions," *European Journal of Operational Research,* Vol.187, pp.719–745.

Nair, A. and Closs, D. J. (2006),"An examination of the impact of coordinating supply chain policies and price markdowns on short lifecycle product retail performance," *International Journal of Production Economics,* Vol. 102, pp.379–392.

Ng Leon, C.T., Li, Y.O. and Chakhlevitch, K. (2001),"Coordinated replenishments with alternative supply Sources in two-level supply chains," *International Journal of Production Economics,* Vol.73, pp. 227-240.

Nienhaus, J. and Ziegenbein, A. (2006), "How human behaviour amplifies the bullwhip effect: A study based on the beer distribution game online," *Production Planning & Control,* Vol.17, No.6, pp. 547-557.

Nikitin, P.V. and Rao, KVS. (2006),*"Theory and measurement of backscattering from RFID tags,"* IEEE Antennas and Propagation Magazine Vol.48, No.6, pp.212-218.

Nirupam, J., Karimi, I. and Rajagopalan, S. (2002), "Agent-based supply chain management: a refinery application", *Computers and Chemical Engineering,* Vol. 26, pp.1771-1781.

Nystrom, M. A., Lin, T. R. and Yu, H. C. (2006), "Challenges to global. RFID adoption", Technovation, Vol.26, No.12, pp 1317-1323.

Noordin, M. Y., Venkatesh, V. C., Sharif, S.,. Elting, S. and. Abdullah, A. (2004), "Application of response surface methodology in describing the performance of coated carbide tools when turning AISI 1045 steel,"Journal of Materials Processing Technology, vol. 145, no. 1, pp. 46–58.

Odonnell, T., Humphreys, P., McIvor, R. and Maguire, L. (2009),"Reducing the negative effects of sales promotions in supply chains using genetic algorithms," *Expert Systems with Applications*, Vol. 36, pp. 7827–7837.

Oh, S., Ryu, K., Moon, I., Cho, H. and Jung, M. (2010),"Collaborative fractal-based supply chain management based on a trust model for the automotive industry," *Flex Service Manufacturing Journal,* Vol.22, pp.183–213.

Oktem, H., Erzurumlu, T. and Kurtaran, H. (2005), "Application of response surface methodology in the optimization of cutting conditions for surface roughness," Journal of Materials Processing Technology, vol. 170, no. 1-2, pp. 11–16.

Olsson, F. and Tydesjö, P. (2010),"Inventory problems with perishable items: Fixed lifetimes and backlogging,"European Journal of Operational Research, Vol.202, pp.131–137.

Oscar, R. and Adolfo, C. (2003**)**,"Exploring the utilization of a CONWIP system for supply chain management. A comparison with fully integrated supply chains," *International Journal of Production Economics,* Vol. 83, pp.195–215.

Ounnar, F., Pujo P. and Mekaouche, L.(2007),"Customer–supplier relationship management in an intelligent supply chain network," *Production Planning & Control.*Vol. 18, No. 5, pp. 377-387.

Ouyang, L.-Y. and Chuang, B.-R. (2001), "A Periodic Review Inventory Control System with Variable Lead Time," *Information and Management Sciences,* Vol. 12, No. 1, pp.1-13**.**

Paksoy, T., and Chang, C.T. (2010), "Revised multi-choice goal programming for multi-period, multi-stage inventory controlled supply chain model with popup stores in Guerrilla marketing," *Applied Mathematical Modeling,* Vol.34, No.11, pp.3586-3598.

Pan, J. C. H. and Yang, J. S. (2002), "A study of an integrated inventory with controllable lead time", International Journal of Production Research, Vol. 40. No.5, pp. 1263-1273.

Panagiotis, T. and Lazaros, G. P. (2008),"Optimal production allocation and distribution supply chain networks," *International Journal of Production Economics*, Vol.111, pp.468–483.

Papachristos, S. and Skouri, K. (2003), "An inventory model with deteriorating items, quantity discount, pricing and time-dependent partial backlogging", *International Journal of Production Economics,* Vol. 83, pp. 247–256.

Pascal, F., Sophie, D. and Frayret, J. M. (2008),"Multi-behavior agent model for planning in supply chains: An application to the lumber industry," *Robotics and Computer-Integrated Manufacturing,* Vol. 24, pp.664–679.

Paul, G. Ranky, (2006), "An introduction to radio frequency identification (RFID) methods and solution" *Assembly Automation,* vol. 26, no.1 pp.28–33.

Peidro, D., Mula, J., Jimenez, M. M, and Botella, M. M. (2010),"A fuzzy linear programming based approach for tactical supply chain planning in an uncertainty environment," *European Journal of Operational Research,* Vol. 205, pp.65–80.

Pengpeng Q., Mingcan C., Kyounglim K., Beomguk P., Yonggyu S., Eunkyung K., Min J. and 3,Jeehyeong K., (2014), "Application of Box–Behnken design with response surface methodology for modeling and optimizing ultrasonic oxidation of arsenite with H2O2", vol. 12, no.(2), pp. 164-172.

Perea-Lopez E., Ydstie, B. and Grossmann, I. (2003), "A model predictive control strategy for supply chain optimization, *"Computers and Chemical Engineering,*Vol. 27, pp.1201-1218.

Perron, S., Hansen, P., Le Digabel, S. and Mladenovic, N. (2010),"Exact and heuristic solutions of the global supply chain problem with transfer pricing," *European Journal of Operational Research,* Vol.202, pp. 864-879.

Persson, F. and Olhager, J. (2002),"Performance simulation of supply chain designs," *International Journal of Production Economics,* Vol. 77, pp.231-245.

Petrovic, D. (2001),“Simulation of supply chain behavior and performance in an uncertainty Environment,” *International Journal of Production Economics,* Vol. 71, pp.429-438.

Pierreval, H., Bruniaux, R. and Caux, C. (2007),*“A continuous simulation approach for supply chains in the automotive industry,”*Simulation Modeling Practice and Theory, Vol. 15, pp.185-198.

Piplani, R., and Viswanathan, S. (2003), “A model for evaluating supplier-owned inventory strategy,” *International Journal of Production Economics,* Vol. 81, No.82, pp.565–571.

Pitty, S.S., Li, W., Adhitya, A., Srinivasan, R. and Karimi I. A. (2008), “Decision support for integrated refinery supply chains Part 1. Dynamic simulation,” *Computers and Chemical Engineering,* Vol.32, pp.2767–2786.

Pokharel, S. (2008),“A two objective model for decision making in a supply chain,” *International Journal of Production Economics,* Vol. 111, pp.378–388.

Potter, A. and Disney S.M. (2010),“Removing bullwhip from the Tesco supply chain*,” Proceedings of 21st Annual Conference Vancouver,(POMS)* Canada.

Qinglong, G., Liang, L., Zhimin, H. and Chuanyong, X., (2008),“A joint inventory model for an open loop reverse supply chain,” *International Journal of Production Economics,* Vol.11, pp.28–42.

Raghunathan, S. (2003),“Impact of demand correlation on the value of and incentives for information sharing in a supply chain,” *European Journal of Operational Research,* Vol.146, pp.634–649.

Rajurkar, S. and Jain, R. (2010**)**, “Food supply chain management: review, classification and analysis of Literature”, *International Journal of Integrated Supply Management,* Vol. 6, No.1, pp.33-72.

Rajurkar, S. and Jain, R. (2011), “Optimal order quantity model for retailers of perishable products with non-deterministic demand,” *International Journal of Operation Research,* Vol.11, No.3, pp. 262 – 289.

Ranky, P. G. (2006), “An introduction to radio frequency identification (RFID) methods and solution” *Assembly Automation,* Vol. 26, no.1 pp.28–33.

Rao, K, Begum, K. and Murty M. (2007), “Optimal ordering policies of inventory model for deteriorating items having generalized Pareto lifetime,” Current Science, Vol. 93, No.10, pp.1407-1411.

Rau, H., Wu, M.Y. and Wee, H.M. (2003),“Integrated inventory model for deteriorating items under a multi-echelon supply chain environment,” *International Journal of Production Economics,* Vol. 86, pp.155-168.

Reiner, G. (2005),“Customer-oriented improvement and evaluation of supply chain processes supported by simulation models,” *International Journal of Production Economics,* Vol. 96, pp.381-395.

Rekik, Y., Jemai, Z., Sahin, E., and Dallery, Y. (2007a), “Improving the performance of retail stores subject to execution errors: Coordination versus RFID technology”, *Operation Research Spectrum,* Vol.29, pp.597-626.

Rekik, Y., Sahin, E. and Dallery, Y. (2007b), “A comprehensive analysis of the newsvendor model with unreliable supply”, *Operation Research Spectrum,* Vol. 29, pp.207-233.

Reza, Z. F., and Mahsa, E. (2008),“A genetic algorithm to optimize the total cost and service level for just-in-time distribution in a supply chain,” *International Journal of Production Economics,* Vol.111, pp.229–243.

Rob, A. C. M. and van Donselaar K. H. (2007), “A replenishment policy for a perishable inventory system based on estimated aging and retrieval behaviour”, *BETA,* working paper nr. 218.

Robert, S., and Serguei N. (2009), “ Long term contracts under the threat of supplier default”, *Manufacturing and Science Operations Management,* Vol. 11, No.1, pp. 109-127.

Roberto D., Salvatore C. and Jose M. F. (2014), “On bullwhip-limiting strategies in divergent supply chain networks,” *Computers & Industrial Engineering,* Vol. 73, pp. 85–95

Robinson, E., Sahin, F., Gao, L. and Powell E., (2008), “Master production scheduling policy and rolling schedules in a two-stage make-to-order supply chains,” *International Journal of Production Economics,* Vol. 115, pp. 528–541.

Roder, A, and Tibken, B. (2006),“A methodology for modeling inter-company supply chains and for evaluating a method of integrated product and process documentation,” *European Journal of Operational Research,* Vol.169, pp.1010–1029.

Roger, D. H. W. (2004), “An Analytical Investigation of the Bullwhip Effect”,*Production and Operations Management,*Vol. 13, No. 2, pp. 150–160.

Roh, J. J., Kunnathur, A. and Tarafdar, M. (2009), "Classification of RFID adoption: An expected benefits approach", *Information and Management,* Vol. 46 pp. 357–363.

Rong, A., Akkerman, R., and Grunow, M. (2009),"An optimization approach for managing fresh food quality throughout the supply chain," *International Journal of Production Economics,* Vol.131, No.1, pp.421-429.

Rong Y., Shen Z.J.M., and Snyder L.V. (2009),"The Impact of Ordering Behaviour on Order-quantity Variability: A Study of Forward and Reverse Bullwhip Effects," *Flexible Services and Manufacturing Journal,* Vol. 20, No. (1-2), pp. 95-124.

Roy, A., Maiti, M. K., Kar, S and Maiti, M. (2009), "An inventory model for a deteriorating item with displayed stock dependent demand under fuzzy inflation and time discounting over a random planning horizon*," Applied Mathematical Modelling,* Vol. 33, pp. 744–759.

Ru, J. and Wang, Y. (2010),*"*Consignment contracting: Who should control inventory in the supply chain," *European Journal of Operational Research,* Vol. 201, pp.760–769.

Ryu, E. K., and Takagi, T. (2009), "A hybrid approach for privacy-preserving RFID tags", *Computer Standards and Interfaces,* Vol. 31, pp.812–815.

Ryu K., and Yücesan E. (2010),"A fuzzy newsvendor approach to supply chain coordination," *European Journal of Operational Research,* Vol.200, pp.421–438.

Ryu, S.W., and Lee K.K. (2003), "A stochastic inventory model of dual sourced supply chain with lead-time reduction," *International Journal of Production Economics,* Vol. 81, No.82, pp. 513–524.

Saad, N., and Kadirkamanathan, V. (2006),*"*A DES approach for the contextual load modeling of supply chain system for instability analysis,"Simulation Modeling Practice and Theory, Vol.14, pp.541–563.

Sachan, A., and Datta, S. (2005), "*Review of supply chain management and logistics research",*International Journal of Physical Distribution & Logistics Management, Vol.35, No.9, pp.664-705.

Sachan, R. S. (1984), "On (T, Si) inventory policy model for deteriorating items with time proportional demand," *Journal of Operation Research Society,* Vol. 35, pp. 1013–1019.

Sahin, E. (2004), “A qualitative and quantitative analysis of the impact of Auto ID technology on the performance of supply chains,” *PhD thesis, Ecole Centrale Paris.*

Sahin, E., Buzacott, J. and Dallery, Y., (2007), *“Analysis of a newsvendor which has errors in inventory data records”,European Journal of Operational Research,* accepteddoi:10.1016/j.ejor.2007.04.021

Sarac, A., Absi, N. and Dauzere-Peres, S.(2008), “Analyse de l'impact des technologies RFID sur le modele du newsvendor avec des stocks errones”, *In 7e Conference Francophone de MOdelisation et SIMulation - MOSIM'08,* pp. 426-435.

Sarmah S.P., Acharya D. and Goyal S. K. (2008),“Coordination of a single-manufacturer / multi-buyer Supply chain with credit option,” *International Journal of Production Economics,* Vol.111, pp.676–685.

Sérgio M. and José, M. (2004),“A general modeling framework for the operational planning of petroleum supply chains” *Computers and Chemical Engineering,* Vol. 28, 871–986.

Sergio, T. and Sergio, C. (2004), “Simulation in the supply chain context: a survey”,*Computers in Industry,* Vol. 53, pp. 3–16.

Shabnam, R., and Reza, Z. F., (2010),“Strategic design of competing centralized supply chain networks for markets with deterministic demands,” *Advances in Engineering Software,* Vol. 41, pp.810–822.

Shah, Y.K. (1977), “An order-level lot-size inventory for deteriorating items,” *American Institute of Industrial Engineering Transaction,* Vol.9, pp.108–112.

Shaojun, W., Bhaba, R. S. (2006), “Optimal models for a multi-stage supply chain system controlled by kanban under just-in- time philosophy”, *European Journal of Operational Research,* Vol.172, pp. 179–200.

Sheu, J. B. (2005), “A multi-layer demand-responsive logistics control methodology for alleviating the bullwhip effect of supply chains,” *European Journal of Operational Research,* Vol.161, pp.797–811.

Shukla, S. K., Tiwari, M.K., Wan, H. and Ravi, S., (2010), “Optimization of the supply chain network: Simulation, Taguchi, and Psychoclonal algorithm embedded approach,” *Computers & Industrial Engineering,* Vol. 58, pp.29–39.

Shi, W., Shang, J., Liu, Z. and, Zuo, X. (2014), “Optimal design of the auto parts supply chain for JIT operations: Sequential bifurcation factor screening and multi-response surface Methodology," *European Journal of Operational Research,* Vol., 236, pp. 664–676

Silv, C.A., Sous J.M.C., Runkler, T.A. and Sada C. J.M.G. (2009),"Distributed supply chain management using ant colony optimization," *European Journal of Operational Research,* Vol. 199, pp.349–358.

Simchi-Levi, D., Kaminsky, P. and Simchi-Levi, E. (2003), "*Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies*", 2nd Edition, 2003, (Boston: McGraw-Hill).

Skouri, K. and Papachristos, S. (2002),"A continuous review inventory model, with deteriorating items, time-varying demand, linear replenishment cost, partially time-varying backlogging, *Applied Mathematical Modelling,* Vol. 26, pp. 603–617.

Sobhi M. and Radu F. B. (2015), "RFID-wireless sensor networks integration: Decision models and optimization of logistics systems operations," *Journal of Manufacturing Systems,* Vol. 35, pp. 234–245

Sodhi, M. S. and Tang, C.S. (2009),"Modeling supply-chain planning under demand uncertainty using stochastic programming: A survey motivated by asset–liability management," *International Journal of Production Economics.* Vol.121, pp.728–378.

Song, J.-S. (1994), "The Effect of Lead time Uncertainty in a Simple Stochastic Inventory Model,"*Management Science,* Vol. 40, No. 5, pp. 603-613.

Song, H M., Yang, H. and Luo J. Q., (2011), "Optimal Ordering Policy and Coordination Mechanism of a Supply Chain with Controllable Lead-Time-Dependent Demand Forecast," Mathematical Problems in Engineering, vol. 2011, Article ID 985104, 24 pages, doi:10.1155/2011/985104.

Sourirajan, K., Ozsen, L.and Uzsoy R. (2007), "A single-product network design model with lead time and safety stock considerations,"*IIE Transactions,* Vol. 39, pp. 411–424.

Spitter, J.M., Hurkens, C.A.J., de Kok, A.G., Lenstra, J.K. and Negenman E.G. (2005),"Linear programming models with planned lead times for supply chain operations planning," *European Journal of Operational Research,* Vol.163, pp.706–720.

Stephen, C. G., and Sean, P. W. (2008),"Strategic Inventory Placement in Supply Chains: Non- stationary Demand" *Manufacturing & Service Operations Management,* Vol.10, No.2, pp.278–287.

Tadeusz, S. (2009),"Coordinated supply chain scheduling," *International Journal of Production Economics,* Vol. 20, pp.437- 445.

Tan, K. C. (2001**)** "A framework of supply chain management literature", *European Journal of Purchasing & Supply Management*, Vol.7, pp.39-48.

Tellkamp, C. (2006),"The impact of Auto-ID technology on process performance RFID in the FMCG supply chain", *PhD thesis,* the University of St. Gallen.

Tempelmeie, H. (2006),"Supply chain inventory optimization with two customer classes in discrete time," *European Journal of Operational Research,* Vol.174, pp.600–721.

Teng, J.T., Chem M.C., Yang H.L., and Wang Y.J. (1999), "Deterministic lot size inventory models with shortages and deterioration for fluctuating demand", *Operation Research Letters,* Vol. 24, pp. 65–72.

Tzeng S.-F., Chen W.-H., and Pai F.-Y. (2008), "Evaluating the business value of RFID: Evidence from five case studies", *International Journal of Production Economics,*Vol.112, pp.601–613.

Thangam, A., and Uthayakumar, R. (2009),"Two-echelon trade credit financing for perishable items in a supply chain when demand depends on both selling price and credit period," *Computers & Industrial Engineering,* Vol. 57, pp.773–786.

Thonemann, U.W. (2002),*"Improving supplychain performance by sharing advance demand information",* European Journal of Operational Research, Vol.142, pp.81-107.

Tiaojun, X. and Danqin, Y. (2009),"Risk sharing and information revelation mechanism of a one-manufacturer and one-retailer supply chain facing an integrated competitor", *European Journal of Operational Research,* Vol. 196, pp.1076–1085.

Torabi, S.A., Hassini, E., (2008**),** *"An interactive possibilistic programming approach for multiple objective supply chain master planning*," Fuzzy Sets and Systems, Vol.159, pp.193 – 214.

Tsai, C.F. (2006),"An intelligent adaptive system for the optimal variable selections of R&D and quality supply chains," *Expert Systems with Applications*, Vol.31, pp.808–825.

Tsai, C.Y. (2008)“On supply chain cash flow risks,” *Decision Support Systems,* Vol. 44, 1031–1042.

Tsai, J.F. (2007),“An optimization approach for supply chain management models with quantity discount policy,” *European Journal of Operational Research,* Vol.177, pp.982–994.

Tsolakis, N. K., Christos, A. Keramydas, C.A., Agorasti, K., Toka A.K., Aidonis, D.A. and Iakovou E.T.,(2014), “Agrifood supply chain management: A comprehensive hierarchical decision-making framework and a critical taxonomy, *Operations Management,* Vol. 120, PP.47-64

Tullari, S., Vickery S. K., and Narayanan S. (2008),“Optimization models for buyer-supplier negotiations,” *International Journal of Physical Distribution & Logistics Management,* Vol. 38, No.7, pp.551-561.

Tuncel, G. and Alpan G. (2010),“Risk assessment and management for supply chain networks: A case study,” *Computers in Industry,* Vol. 61, pp.250–259.

Twist, D. C. (2005), “The impact of radio frequency identification on supply chain facilities”, Journal of Facilities Management, Vol.3 No.3 pp. 226–239.

Tzeng, S.-F., Chen, W.-H. and Pai, F.-Y. (2008), “Evaluating the business value of RFID: Evidence from five case studies”, *International Journal of Production Economics,* Vol. 112, pp.601–613.

Uster, H. and Keskin, B. B. (2008),“Integrated warehouse location and inventory decisions in a three-tier distribution system,” *IIE Transactions,* Vol. 40, pp.718–732.

Ustundag, A., Mehmet, S. K. and Emre, C. (2010) , “Fuzzy rule-based system for the economic analysis of RFID investments,” *Expert Systems with Applications,* Vol. 37, pp. 5300–5306.

Vaart, T. V. and van Donk D. P. (2008) “A critical review of survey-based research in supply chain integration”, *International Journal of Production Economics,* Vol. 111, pp.42–55.

Vaidyanathan, J. and Anthony, R. (2003), “A simulated annealing methodology to distribution network design and management,” *European Journal of Operational Research*, Vol. 144, pp.629-645.

Wafa, B.E. Al-Othman, Haitham M.S. Lababidi, Imad M. Alatiqi, and Khawla Al-S. (2008),“Supply chain optimization of petroleum organization under uncertainty in market demands and prices”, *European Journal of Operational Research,*Vol.189, pp.822-840.

Wan, X., Pekny J. and Reklaitis, G., (2005), "Simulation-based optimization with surrogate models-Application to supply chain management," *Computers and Chemical Engineering,* Vol. 29, pp. 1317-1328.

Wang, H.S. (2009),"A two-phase ant colony algorithm for multi-echelon defective supply chain network design", *European Journal of Operational Research,* Vol. 192, pp. 243–252.

Wang, J. and Shu, Y. (2005), "Fuzzy decision modeling for supply chain management," *Fuzzy Sets and Systems,* Vol. 150, 107–217.

Wang, J. L. (2009),"A supply chain application of fuzzy set theory to inventory control models DRP system analysis," *Expert Systems with Applications,* Vol.36, pp. 9229–9239.

Wang, J., Zhao R. and Tang W. (2009),"Supply Chain Coordination by Single-Period and Long-Term Contracts with Fuzzy Market Demand," *Tsinghua Science and Technology,* Vol.14, pp.218-224.

Wang, J., Zhao R., and Tang W., (2008),"Fuzzy. Programming Models for Vendor Selection Problem in a Supply Chain," *Tsinghua Science and Technology,* Vol.13, pp.106-111.

Wang, S., Zhou, Y. and Wang, J. (2010), "Coordinating ordering, pricing and advertising policies for a supply chain with random demand and two production modes,*" International Journal of Production Economics,* pp. 1-13.

Wang W., Fung, R.Y.K., and Chai, Y. (2004),"Approach of just-in-time distribution requirements planning for supply chain management," *International Journal of Production Economics,* Vol.91, pp.101–10

Wang, X., and Liu, L. (2007), "Coordination in a retailer-led supply chain through option Contract," *International Journal of Production Economics,* Vol. 110, pp. 115-127.

Wang, X., and Liu, L. (2007),"Coordination in a retailer-led supply chain through option Contract," *International Journal of Production Economics,* Vol. 110, 115-127.

Wang, X., Liu Z., Zheng, C. and, Quan C. (2008),"The Impact of Lead-time on Bullwhip Effect in Supply Chain," *IEEE, Proceedings of the ISECS International Colloquium on Computing, Communication, Control, and Management, 3-4 August 2008, Guangzhou, China.*

Wang, Y. and Yigal, G. (2002),"Supply Chain Contracting and Coordination with Shelf-Space-Dependent Demand," *Management Science,* pp. 137-162.

Warburton R, D. H., (2004), “An Analytical Investigation of the Bullwhip Effect”, Production and Operations Management Vol. 13, No. 2, pp. 150–160.

Webster, S. and Weng Z.K. (2008),“Ordering and pricing policies in a manufacturing and distribution supply chain for fashion products,” *International Journal of Production Economics,* Vol.114, pp.476–486.

Wee, H. M. and Mercan, H.M. (1999), “Exponentially decaying inventory with partial back-ordering”, *Optimum Control in Applied Methematics,* Vol. 20, pp.43–50.

Wee, H. M. (1995), “Deterministic lot size inventory model for deteriorating items with shortages and a declining market”, *Computers in Operation Research,* Vol.22, pp. 345–356.

Wee, H.M. (1999), “Deteriorating inventory model with quantity discount, pri.cing and partial backordering”, *International Journal of Production Economics,* Vol.59, pp. 511–518.

Wee, H. M. and Law S. T. (2001), “Replenishment and pricing policy for deteriorating items taking into account the time-value of money, *International Journal of Production Economics,* Vol. 71, pp. 213-220.

Wei, Y., and Choi, T. M. (2010),“Mean–variance analysis of supply chains under wholesale pricing and profit sharing schemes,” *European Journal of Operational Research,* Vol.204, pp. 255- 262.

Wen, C.Y., Larbani, M., and Liu, C. H. (2010),“Simulation of a supply chain game with multiple fuzzy goals,” *Fuzzy Sets and Systems,* Vol.161, pp.1489–1510.

Venkatadri, U., Srinivasan, A., Montreuil, B. and Saraswat, A., (2006),”Optimization-based decision support for order promising in supply chain networks,” *International Journal of Production Economics,* Vol. 103, pp.117-130.

Vila-Parrish, A.R., Ivy J.S. and King, R.E. (2008),“A simulation-based approach for inventory modeling of perishable pharmaceuticals,” *Proceedings of the Winter Simulation Conference,* pp.1532-1538.

Viswanathan, S. and Piplani, R. (2001),“Coordinating supply chain inventories through common replenishment epochs,” *European Journal of Operational Research,* Vol. 129, pp.277-286.

Wilke, P. and Braunl, T. (2001), “Flexible wireless communication network for mobile robot agents”, Industrial Robot, Vol. 28 No. 3, pp. 220-33.

Wolf, A. S. and Tayur, S., (2009), “Risk sharing in supply chains using order Bands Analytical results and managerial insights,” *International Journal of Production Economics,* Vol. 121, 715–727.

Wong, W.K., Qi, J., and Leung, S.Y.S. (2009),"Coordinating supply chains with sales rebate contracts and vendor-managed inventory," *International Journal of Production Economics,* Vol.120, pp.151-161.

Wu, C. and Barnes, D. (2010), "Formulating partner selection criteria for agile supply chains: A Dempster Shafer belief acceptability optimization approach," *International Journal of Production Economics,* Vol.125, pp.284–293.

Wu, D., and Olson, D. (2008)"Supply chain risk, simulation, and vendor selection," *International Journal of Production Economics,* Vol. 114, pp.646– 655.

Wu, D., Baron, O. and Berman, O. (2009),"Bargaining in competing supply chains with Uncertainty," *European Journal of Operational Research,* Vol.197, pp.548–556.

Wu, K. S., Ouyang, L.Y. and Yang, C.T. (2006), "An optimal replenishment policy for non-instantaneous deteriorating items with stock dependent demand and partial backlogging", *International Journal of Production Economics,* Vol. 101, pp. 369–384.

Wu, N. C., Nystrom, M. A., Lin, T. R. and Yu, H.C. (2005), "Challenges to global RFID adoption", *Technovation,* Vol. 26, pp. 1317-1323.

Wu, Y.N. and Cheng T.C. E. (2008),"The impact of information sharing in a multiple-echelon supply chain," *International Journal of Production Economics,* Vol. 115, pp.1-11.

Xiao, T. and Yang, D. (2008) "Price and service competition of supply chains with risk-averse retailers under demand uncertainty," *International Journal of Production Economics,* Vol.114, pp. 187–200.

Xiao, T., and Yang D. (2009),"Risk sharing and information revelation mechanism of a one manufacturer and one-retailer supply chain facing an integrated competitor." *European Journal of Operational Research,* Vol.196, pp.1076–1085.

Xiao, T., Qi, X. and Yu, G. (2007),"Coordination of supply chain after demand disruptions when retailers compete," *International Journal of Production Economics,* Vol.109, 162–179.

Xiao, T., Shi, T. and Yang, D.(2010),"Coordination of a supply chain with consumer returns under demand uncertainty," *International Journal of Production Economics,* Vol.124, pp.171–180.

Xiao, Y., Chen, J. and Xu, X., (2008), “Fresh Product Supply Chain Coordination under CIF Business Model with Long Distance Transportation”, *Systems Engineering Theory and Practice,* Vol. 28, Issue 2, pp.19–34.

Xiaojing, W., Zhixue, L., Changzheng, Z. and Chunguang Q. (2008), “The Impact of Lead-time on Bullwhip Effect in Supply Chain,” *IEEE Transactions.*

Xie, J, Zhou, D., Wei, J and Zhao, X., (2010) “Price discount based on early order commitment in a single manufacture-multiple retailer supply chain,” *European Journal of Operational Research,* Vol. 200, pp. 368–376.

Xu, H. (2010), “Managing production and procurement through option contracts in supply chains with random yield,” *International Journal of Production Economics,* 10, 1016.

Xu, H. (2010),“Managing production and procurement through option contracts in supply chains with random yield,” *International Journal of Production Economics,* vol. 26, No.2, pp.306-313.

Xu, R. and Zhai X. (2008) ,“Optimal models for single-period supply chain problems with fuzzy demand,” *Information Sciences,* Vol. 178, pp. 3374–3381.

Yanfeng, O., and Carlos, D. (2008),“Robust tests for the bullwhip effect in supply chains with stochastic dynamics,” *European Journal of Operational Research,* Vol. 185, pp.340-353.

Yang, H. L. (2004), “Two-warehouse inventory models for deteriorating items with shortages under inflation,” *European Journal of Operational Research,* Vol. 157 pp.344–356.

Yang, J. and Yang, S. (2007),“The use of a premium-payment scheme in a supply chain involving capacity acquisition,” European Journal of Operational Research, Vol. 181, pp.207–223.

Yang, M. F. (2010),“Supply chain integrated inventory model with present value and dependent crashing cost is polynomial,” Mathematical and Computer Modeling, Vol. 51, pp.802-809.

Yang, S. L. and Zhou Y.W. (2006),“Two-echelon supply chain models: Considering duopolistic retailer’s different competitive behaviors,” *International Journal of Production Economics,* Vol.103, pp.104–116.

Yang T., Wen Y.F. and Wang F.F. (2009),“Evaluation of robustness of supply chain information-sharing strategies using a hybrid Taguchi and multiple criteria decision-making method”, *International Journal of Production Economics,* doi:10.1016/j.ijpe.2009.11.0182011.

Yao, Y, and Dresner, M. (2008),“The inventory value of information sharing, continuous replenishment, and vendor-managed inventory,” *Transportation Research,* Part E, Vol. 44, pp.361–378.

Yasutaka, K., and Nobuhiko, T. (2006), “A multiple attribute utility theory approach to lean and green supply chain management”, *International Journal of Production Economics,* Vol. 101 pp.99–108.

Yin, K., Liu, H. and Yin, G. (2003),“Stochastic models and numerical solutions for production planning with applications to the paper industry,” *Computers and Chemical Engineering,* Vol. 27, 1693-1706.

Yoo, J.S., Hong, S.R. and Kim, C.O. (2009),“Service level management of non-stationary supply chain using direct neural network controller,” *Expert Systems with Applications,* Vol.36, pp.3574–386.

Yossi, A. (2001), “The effect of Collaborative Forecasting on Supply Chain Performance”, *Management Science,* Vol.47, No.10, pp.1326-1343.

Yu, H., Zeng, A. Z. and Zhao L. (2009), “Analyzing the evolutionary stability of the vendor managed inventory supply chains,” *Computers & Industrial Engineering,* Vol.56, pp. 274–282.

Yu, Y., Huang, G. Q. and Liang, L. (2009),“Stackelberg game-theoretic model for optimizing advertising, pricing and inventory policies in vendor managed inventory (VMI) production supply chains,” *Computers & Industrial Engineering,* Vol. 57, pp.368-382.

Zarandi, M.F.H., Pourakbar, M. and Turksen, I. B. (2008), “A Fuzzy agent-based model for reduction of bullwhip effect in supply chain systems,” *Expert Systems with Applications,* Vol. 34, pp.1680–1691.

Zhang, C., Tan, G. W., Robb,, D. J. and Zheng X. (2006), “Sharing shipment quantity information in the supply chain,” *Omega,* Vol.34, pp. 427 – 438.

Zhang, C. and Zhang, C. (2007), “Design and simulation of demand information sharing in a supply chain,” *Simulation Modeling Practice and Theory,* Vol.15, pp.32–46.

Zhang, X., and Huang, G. Q. (2010),“Game-theoretic approach to simultaneous configuration of platform products and supply chains with one manufacturing firm and multiple cooperative suppliers,” *International Journal of Production Economics,* Vol.124, pp.121-136.

Zhao, X., and Shi, C. (2009),"Structuring and contracting in competing supply chains," *International Journal of Production Economics,* Vol.134, No.2, pp. 434-446.

Zhao, X., Deju, X., Zhang, H. and He, Q. (2007), "Modeling and analysis of a Supply assembly–store chain," *European Journal of Operational Research,* Vol.176, pp. 275-294.

Zhou, W. (2009), "RFID and item-level information visibility", *European Journal of Operational Research,* Vol.198, No.1, pp.252-258.

Zhou, Y. and Li, D. H. (2007),*"Coordinating order quantity decisions in the supply chain contract under random demand,"* Applied Mathematical Modeling, Vol. 31, 1029-1038.

Zhu, W., Gavirneni S. and Kapuscinski, R. (2010),"Periodic flexibility, information sharing, and supply chain performance," *IIE Transactions,* Vol.42, pp.173–187.

Zimmer K. (2002),"Supply chain coordination with uncertain just-in-time delivery," *International Journal of Production Economics,* Vol. 77, pp.1–15.

LIST OF PUBLICATIONS

List of International Journal publications

1. Chandrakumar M. Badole, Dr. Rakesh Jain, Dr. A.P.S.Rathore, Dr. Bimal Nepal,(2012) **“**Research and Opportunities in Supply Chain Modeling: A Review,” International journal of Supply Chain Management **Vol. 1 No.3, PP. 63-86.**

List of National Journal publications

1. Chandrakumar M. Badole, Dr. Rakesh Jain, Dr. A.P.S.Rathore, Dr. Bimal Nepal, (2012), “Role of RFID in Supply Chain Management of Perishable Products,” National Journal of Engineering and Technology, GIT, Gandhinagar. **ISSN 2249 – 6157**

List of International Conference publications

1. Chandrakumar M. Badole, Dr. Bimal Nepal,Dr. A.P.S.Rathore, Dr. Rakesh Jain, (2012), “Supply Chain Modeling Scope and Methodology: A Review of Literature in the Last Decade,” Proceedings of the 2011 Industrial Engineering Research Conference, USA.
2. Chandrakumar M. Badole, Dr. A.P.S.Rathore,Dr. Rakesh Jain, Dr. Bimal Nepal, “RFID based supply chain management of perishable products,” International conference on Best Practices in Supply Chain Management, Bhubaneshwar, pp. 62-69, Nov. 2012.
3. Chandrakumar M. Badole, Dr. Bimal NepalDr. A. P. S. Rathore[1],Dr. Rakesh Jain, Dr. Ritu Agrawal (Nov.2013), “RFID and Perishable Product Supply

Chain with Shortages", Proceedings of International Conference on Recent Trends in Engineering Science, ICRTES-13, ELSEVIER, pp. 397- 402

List of National Conference publications

1. Chandrakumar M. Badole, Dr. Rakesh Jain, Dr. A.P.S.Rathore, Dr. Bimal Nepal, (2011) "Impact of RFID on Supply Chain Management of Perishable Products". National convention of Mechanical Engineer and Seminar on Advances in MEMS and Robotics in Manufacturing Industries, Institute of Engineers (India), Jaipur, pp. 4
2. Chandrakumar M. Badole, Dr. Rakesh Jain, Dr. A.P.S.Rathore, Dr. Bimal Nepal, (2012), "RFID and Supply Chain Management of Perishable Products." National Conference on Electic Mechanical Engineering, GIT Jaipur. pp. 147.
3. Chandrakumar M. Badole, Dr. Bimal NepalDr. A. P. S. Rathore[1],Dr. Rakesh Jain, Dr. Ritu Agrawal, (2013) "Methodology for ROI for RFID Based Supply Chain Management of Perishable Product, 28th National Convention on Advancement in Production and Operations Management, Institute of Engineers (India), PP. 323-334.

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