Manufacturing Strategies Integrating Production and Replenishment in a Closed-loop Supply chain

by

Samaneh HAJABEDI

THESIS PRESENTED TO ÉCOLE DE TECHNOLOGIE SUPÉRIEURE IN PARTIAL FULFILMENT OF THE MASTER'S DEGREE WITH THESIS IN SYSTEM ENGINEERING
M. Sc. A.

MONTRÉAL, August 31, 2020

ÉCOLE DE TECHNOLOGIE SUPÉRIEURE
UNIVERSITÉ DU QUÉBEC

BOARD OF EXAMINERS

THIS THESIS HAS BEEN EVALUATED

BY THE FOLLOWING BOARD OF EXAMINERS

Mr. Ali Gharbi, Thesis Supervisor

Department of system engineering, École de technologie supérieure

Mr. Jean-Pierre Kenné, President of the Board of Examiners

Department of mechanical engineering, École de technologie supérieure

Mr. Mustapha Ouhimmou, Member of the Jury

Department of system engineering, École de technologie supérieure

THIS THESIS WAS PRESENTED AND DEFENDED

IN THE PRESENCE OF A BOARD OF EXAMINERS AND THE PUBLIC

AUGUST 18,2020

AT ÉCOLE DE TECHNOLOGIE SUPÉRIEURE

ACKNOWLEDGEMENTS

I would like to emphasize my profound gratitude to the people who help, motivate, and support me during the past two years in order to achieve my purpose.

My sincere gratitude goes to my advisor Professor Ali Gharbi who supports me through the whole program of the master. In addition, he encourages me throughout my research project, gave me confidence and knowledge to go further in this project and being a better researcher.

I would like to express my deep appreciation to my friends and my colleges at our laboratory, Morad, Pedram, Arezou, Siamak, Arash, Farzad.

The last and most important gratitude is for my parents and my siblings who support me and encourage me throughout my whole life to reach my goals. With their absolute love and support, I make my paths easier. Their love is a bridge between everything and me.

Politiques de commande de production intégrant dans la fabrication, la remise à neuf et l'approvisionnement pour une chaîne d'approvisionnement en boucle fermée

Samaneh Hajabedi

RÉSUMÉ

Cette étude traite le problème de planification et de contrôle de la production pour un système de fabrication-remise à neuf où la demande peut être satisfaite soit par la fabrication de nouveaux produits soit par la remise à neuf des produits d'occasion (produits retournés). Il représente un problème commun dans plusieurs industries comme l'électronique, l'aéronautique et l'automobile. Le système étudié, qui produit un seul type de produits finis, est soumis à des pannes et des réparations aléatoires.

Étant donnée la variabilité élevée relative à la prise de décision dans la chaîne d'approvisionnement étudiée, une approche expérimentale basée sur la simulation, les plans d'expériences et la méthodologie de surface de réponse a été utilisée. Cette approche nous a permis de reproduire le comportement dynamique de la chaîne d'approvisionnement, de déterminer les valeurs optimales des paramètres de commande et d'effectuer des analyses de sensibilité approfondies.

Dans la première partie de ce mémoire, nous étudions le cas où la fabrication et la remise à neuf sont dédiées à des installations distinctes. Dans ce cas, le décideur peut appliquer trois différentes stratégies d'inspection de qualité lors de la réception des produits retournés. Une analyse comparative de ces stratégies est ainsi effectuée. L'objectif principal est de déterminer la politique de commande la plus économique, intégrant simultanément la fabrication, la remise à neuf et le contrôle de la qualité des produits retournés. Nos résultats montrent qu'un plan d'échantillonnage est la meilleure stratégie de contrôle de la qualité et garantit une meilleure performance économique de la chaîne d'approvisionnement. Ce travail montre également l'importance de coordonner la décision de contrôle de la qualité à la réception avec les activités de production et d'approvisionnement.

Dans la deuxième partie, nous considérons une installation commune qui partage les activités de fabrication et de remise à neuf. De plus, plusieurs fournisseurs sont considérés pour l'achat des produits retournés. Dans ce système, nous visons à déterminer la meilleure politique de commande de fabrication, de remise à neuf et de sélection du fournisseur en termes de coûts. Ainsi, une approche combinant la simulation et des techniques d'optimisation a été adoptée. Les résultats de l'exemple numérique et de l'analyse de sensibilité considérés montrent qu'une économie de coûts considérable est obtenue lorsque plusieurs fournisseurs sont utilisés par rapport à la situation où un seul fournisseur a le monopole de distribuer les produits retournés.

Cette étude souligne l'importance de coordonner les activités de la fabrication, de la remise à neuf et du contrôle de la qualité des produits retournés ainsi que l'effet de la politique de sélection des fournisseurs afin de réaliser plus d'économies. De plus, elle apporte des contributions intéressantes au domaine du contrôle stochastique des systèmes de fabrication-remise à neuf et permet une meilleure compréhension du comportement de cette classe de systèmes. Des exemples numériques et des analyses de sensibilité approfondies sont considérés dans le but de confirmer la validité des politiques de commande proposées et la robustesse de l'approche de résolution utilisée qui bien adaptée aux besoins des décideurs.

Mots-clés : chaîne d'approvisionnement, plan d'échantillonnage, contrôle optimal stochastique, simulation, méthodologie de surface de réponse, coordination.

Manufacturing Strategies Integrating Production and Replenishment in a closed-loop supply chain

Samaneh Hajabedi

ABSTRACT

This study addresses the production planning and control (PPC) problem within a manufacturing-remanufacturing system, in which demand can be satisfied by either manufacturing of new products or remanufacturing of returned ones. This system can be observed in many industries sectors (e.g. aeronautic and automobile remanufacturing industries). The manufacturing system produces one type of product and is subjected to random failures and repairs.
Given the high variability in decision-making of the considered supply chain, an experimental approach based on simulation modeling, experimental design and response surface methodology has been used. This approach allowed us to reproduce the dynamic behavior of the supply chain, to determine the optimal values of control parameters and carry out deep sensitivity analysis.

In the first part of this thesis, we have studied the case where manufacturing and remanufacturing machines dedicated to the separate facilities, after receiving returned products manufacturer may apply different quality inspections strategies. Each delivered lot of returned products contains a fixed fraction of non-conforming items. The main objective of this system is to determine the best joint integrated control quality combing manufacturing and remanufacturing and control of returned based on the quality. We compare the results related to each strategy. Our results show that a single sampling plan is the best strategy and guarantees a better performance of the supply chain. This work shows the importance of coordinating quality control decision at the reception with the production and supply activities.

In the second part, that is the policy of joint supplier selection, production and replenishment control policies of an unreliable hybrid manufacturing-remanufacturing system, a common facility dedicated to manufacturing and remanufacturing activities, and instead of considering one supplier for buying returned products, we consider multiple suppliers with different characteristics. In this system we are going to determine the best control policy but at this time with consideration of multiple supplier and switching policy. To find an optimal solution, a combination of simulation and optimization techniques has been adopted. The results related to the numerical examples and sensitivity analysis show a considerable cost saving will occur in cases that we have multiple suppliers for selecting compared with the situation that a single supplier has a monopoly in providing the returned products.

Our research contributes the control policy to provide a more effective interaction between manufacturing, remanufacturing, control quality and the effect of supplier selection to make more saving. Moreover, some numerical examples are conducted as illustration, and extensive sensitivity analyses are presented to confirm the robustness of the approach and effectiveness of the resulted control policies. Our approach creates the possibility of having a better viewpoint about the behavior of stochastic manufacturing-remanufacturing systems. In addition, it is straight forward to apply our approach in the operational level.

Keywords: supply chain, acceptance sampling, stochastic optimal control, simulation, response surface methodology, coordination.

Table of Contents

Pages

LIST OF TABLES

Page

LIST OF FIGURES

Page

LIST OF SYMBOLS

θ_i	Raw material ith order instant (time)
δ_R(t)	Random delivery lead-time of returned products order launched at time t
τ_{insp}	Inspection delay per unit (time/unit)
AOQ	Average outgoing quality
AOQL	Average outgoing quality limit
$AOQL_{max}$	Maximum accepted level of the average outgoing quality limit
AOQ_{FP}	The Average Outgoing Quality of Finished products
c	Acceptance Number
C_R^H	Returned products stock holding cost ($/time unit/product)
C_F^H	Finished products stock holding cost ($/time unit/product)
C_B^H	Finished products backlog cost ($/time unit/product)
C_{insp}	Returned products inspection cost ($/unit)
C_{rep}^F	Non-conforming finished products replacement cost ($/Product)
C_{dis}	Disposal cost
C_{Man}	Manufacturing activities cost ($/product)
C_{rem}S1	Remanufacturing operations cost related to Supplier01 ($/product)
C_{rem}S2	Remanufacturing operations cost related to Supplier02 ($/product)
d	Number of non-conforming items in the received lot
dem	Finished product demand rate (units/time)
n	Sample Size
p	Proportion of non-conforming items in the received lot
P_a	Acceptance probability of a lot
$p1$	Proportion of non-conforming items in the received lot related to Supplier01

$p2$	Proportion of non-conforming items in the received lot related to Supplier02
$p^j(.)$	Proportion of non-conforming items produced with remanufacturing activities from supplier *j*
$p^m(.)$	Proportion of non-conforming items produced with manufacturing activities
Q	Returned products lot size
s	Returned products ordering point
U_{man}^{max}	Maximum manufacturing production rate
U_{rem}^{max}	Maximum remanufacturing production rate
U_{man}(t)	Manufacturing rate at time t (Product/time unit)
U_{rem}(t)	Remanufacturing rate at time t (Product/time unit)
$U_{rem}^{max}S1$	Maximum remanufacturing production rate when use returned products of supplier 01 to produce
$U_{rem}^{max}S2$	Maximum remanufacturing production rate when use returned products of supplier 02 to produce
W	Ordering cost
X_F(t)	Inventory level of finished products at time t (product)
X_R(t)	Inventory level of Returned products at time t (product)
X_F(t)	Inventory level of finished products at time t (product)
X_R(t)	Inventory level of Returned products at time t (product)
Z_F	The Finished product hedging level for the production policy

INTRODUCTION

This study focuses primarily on remanufacturing because it has many benefits for the environment, customers, and manufacturers. The key environmental advantages of remanufacturing are that remanufacturing requires less energy than manufacturing. Remanufacturing of the returned product is less costly than the manufacturing of the same product and the profit margin for the company is higher. The resulting products are generally resold "as good as new" in primary markets.

Besides, many available researches assume that suppliers are completely reliable, in other words, assumed a producer will always know how much and when will receive the raw material and when their products can be ready to deliver to the customers. But in the real world, there is some internal and external uncertainty and companies may face to various unpredictable occurrences which causes conflict with their operations. The internal uncertainty included machine failure and repair time, maintenance, capacity, quality issues, etc., and the external uncertainty can be the disruption of supply due to delivery time of raw material or quality of returned products or etc. Considering these uncertainties, companies need careful control of their supply chain to improve their competitiveness and need to consider the potential uncertainties of supply when they design supply chain networks. This issue becomes more complex when the batches of returned products or raw material have some non-conforming items, so in this case, we need a quality inspection at the reception.

To respond to the various kinds of uncertainty, decision-makers need to be flexible. Therefore, manufacturers need to integrate the various management policies (manufacturing, remanufacturing, supply, inspection, etc.) to achieve their objectives. In terms of the importance of integrating and managing various decisions to ensure proper management of a supply chain, the purpose of this thesis is to establish optimal order policies for a closed-loop supply chain when the quality of returned products in the reverse logistics for the remanufacturing activity is not perfect.

Moreover a major issue in hybrid manufacturing-remanufacturing system is whether to perform both manufacturing and remanufacturing operations in a common facility or to devote each production mode in dedicated and separate facilities (Teunter, 2008). two systems consider in this work. In the first system of this work, we consider manufacturing and remanufacturing operation in the separated facility, but in the second system we dedicated both manufacturing and remanufacturing activities reside on a common facility. This kind of system can reduce start-up costs for remanufacturing and lead to more savings in low returns rates situations (Teunter, 2008). A major issue in this context is production planning and control (PPC) within HMRS, which can help a manager to organize and jointly control alternative options of production for effective utilization of production, inventories and resource usage. Furthermore, the cooperation between the production processes when they are carried out in a common facility is especially important in satisfying consumer demand and achieving greater efficiency. Two systems that are considered in this work are quite different and as a result, they require different control policies, so we needed to find the proper control policy separately for each system.

This thesis includes three chapters. The first presents a review of the literature, it also introduces the objectives of our research and the solution approach we are considering in this work. Chapter 2 presents the first policy entitled “Integrated quality strategy in an unreliable manufacturing-remanufacturing system and returned products replenishment in a closed-loop supply chain”, in this chapter we are going to determine the best joint integrated control quality combing manufacturing and remanufacturing and control of returned based on the quality. Chapter 3 presents a second policy entitled “Joint supplier selection, production and replenishment control policies of an unreliable hybrid manufacturing-remanufacturing system”. In the considered supply policy of chapter 03 we are trying to find the best control policy but at this time with consideration of multiple supplier and switching policy between manufacturing and remanufacturing modes of machine.

CHAPTER 1
LITERATURE REVIEW

1.1 Introduction

In this chapter, we will discuss the supply chain function, which is the focus of our research. Afterward, we will concentrate on the main research works relevant to our work. Then we present a review of the literature. During the later step, we will discuss the problem and the research objectives. Finally, the first chapter will conclude with a description of the solution approach implemented in this research project.

1.2 Structure of the supply chain studied

In the following section, we will define certain keywords, to better understand the structure of the considered supply chain.

1.2.1 Definition of key words - Terminology

1.2.1.1 Supply chain

Supply chain is the network of organizations involved in the various processes and activities that generate value in the form of goods or services provided to the ultimate customer across upstream and downstream linkages (Martin, 1992). In other words, a supply chain is made up of several corporations, both upstream (i.e., supply) and downstream (i.e., distribution), and the ultimate customer.

1.2.1.2 Closed-Loop Supply Chain

Closed-loop supply chains (CLSC) are supply chain networks that include the returned processes and the manufacturer has the intent of capturing additional value integrating all supply chain activities (Guide, 2003). The main duties of a closed-loop supply chain are first, it is responsible for value-added procedures to meet customer demand (as before) and second, it tries to collect returned goods from consumers and find the best ways to account for it. (Govindan, 2017)

1.2.1.3. Supply chain management

The purpose of supply chain management is to integrate the customer's requirements with the supplier's material flow to achieve a balance between what is often seen as competing priorities of customer satisfaction, low inventory management, and low unit cost (Graham, 1989). Supply chain management aims at organizing activities and flows from suppliers to end customers (Nakhla, 2009), and enhancing operational performance, company competitiveness, and relationships among the various chain members (Mahnam, 2009). There are some differences between supply chain management and classical control of manufacturing: 1) in the supply chain management the supply chain is seen as a single process. Responsibility for the different chain divisions is not isolated and confined to specific areas such as manufacturing, purchasing, distribution, and sales. 2) Supply chain management relies on strategic decision-making. 3) Supply chain management calls for a different perspective on inventories, which are used as a balancing mechanism of last, not first, resort. 4) A new approach to systems is required, integration rather than interfacing (Houlihan, 1988)

1.2.1.4 Decision making

In a supply chain, there are two forms of decision coordination: centralized or decentralized. The "centralized" decision consists of the fact that in the supply chain there is a single decision-maker whose goal is to reduce (maximize) the overall cost (profit) of the chain. The decision "decentralized" includes many decision-makers who have opposing interests (Jaber, 2010)

1.2.1.5 Stochastic supply chain

A supply chain is said to be stochastic if at least one of its parameters is characterized by the presence of random phenomena (Min, 2002). Such as delivery time (δ), random failure (TTF) of the production machine, or random repair (TTR) of the production machine.

1.2.1.6. Quality control: Single sampling plan by attribute

Quality control of a batch of material (raw, semi-finished, and finished) by a plan aims to recommend its acceptance or rejection (non-acceptance) based on the quality of a sample (Baillargeon, 2013). The single sampling plan by attribute involves randomly picking a number of items in order to verify their compliance with previously defined specifications. If the number of non-conforming items is less than or equal to a predefined acceptance criterion, the batch is accepted. Otherwise, the batch is rejected.

1.2.1.7. Remanufacturing

The purpose of remanufacturing is to bring used products up to quality standards that are as rigorous as those for new products. Remanufacturing can be combined with technological upgrading. Parts for remanufacturing have to fulfill stricter quality standards than parts for refurbishing or repair (Martijn, 1995). Some industries have been remanufacturing since the 1920s (for example, automotive parts have been remanufactured by third parties). The military has routinely remanufactured assets for decades. Research on remanufacturing has increased since the early 1980s (Lund, 1983), with most of the published research appearing since 1990 and focused on operational or engineering issues (Daniel, 2019). Based on the dynamics of the market and the spread of environmental legislation, a growing number of manufacturing companies participate in product recovery activities in their production systems (Atasu, 2008). Moreover, the remanufacturing process is thought to recover the economic and ecological benefits as much as possible due to the increased life of the product and decreased energy and ultimate amounts of waste (Lund, 2003).

1.2.2 Supply chain studied

The system under study can manufacture new products or remanufacture the returned products. The manufacturing and remanufacturing process can be unavailable due to breakdowns and random repairs. The transformation stage produces one final product type and responds to stable market demand. Two types of inventories are involved in this work. The manufactured and remanufactured items are stored in the first inventory. The returned products are collected in the second inventory and then remanufactured or be held on the stock for later remanufacturing. When the manufacturer issues a returned product order, the supplier will deliver it in a lot of size Q. Each lot contains some non-conforming items. All the non-conforming products sold to the customer will be detected by customers and returned to the manufacturer to replace with good ones, which include replacement cost (C_{rep}^{F}). The manufacturer can only produce a single finished product type. The manufacturer turns the raw material and returned products into finished products at a production rate to meet the constant customer demand. The quality of produced parts of the manufacturing operation is equal to produced parts of the remanufacturing operation that is encountered in many industrial sectors (e.g. aeronautic and cartridges remanufacturing industries). System behavior is defined by a continuous component (returned product stock and finished Product stock) and a discrete component (availability of machine). Figure 1.1 is showing the structure of the considered supply chain.

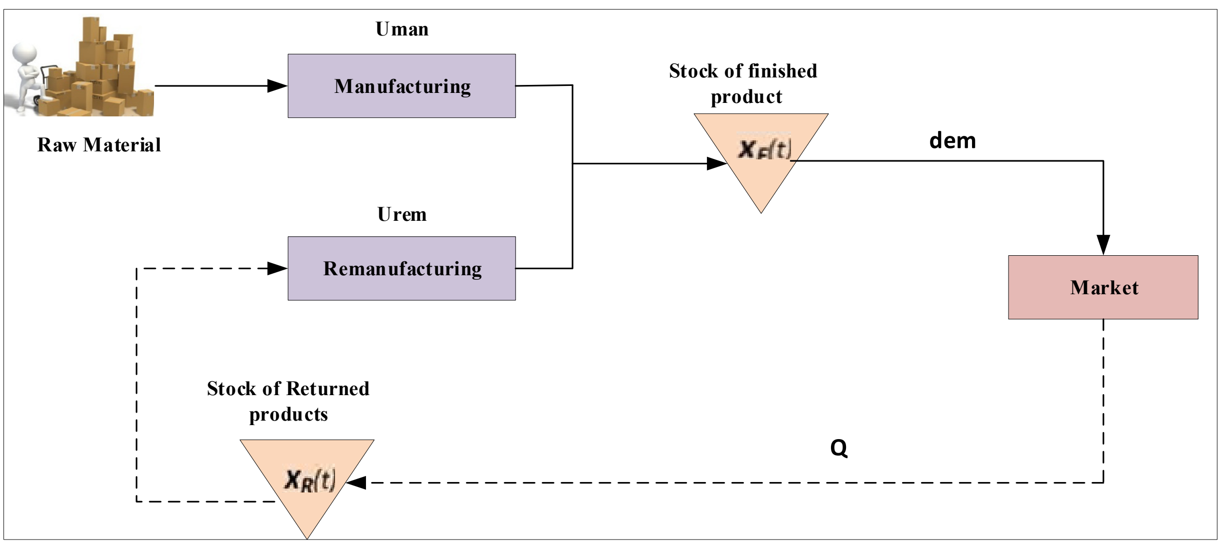


Figure 1.1 Structure of considered supply chain

The returned product held in the manufacturer's return stock incurs a holding cost C_R^H. The manufacturer produces a single type of finished product to respond to the constant demand rate "dem". The Finished product held in the manufacturer's final product stock incurs a holding cost C_F^H. However, if the manufacturer could not respond to the customer demand, a backlog cost C_F^B is considered.

1.2.3 Working hypotheses

The following statement summarizes the general context and main assumptions considered in this system:

1. The raw material for manufacturing operations is always available;
2. Manufacturing operations always produce products with perfect quality;
3. The customer demand is known and described by a constant rate over time;
4. The quality of produced parts of the manufacturing operation is equal to produced parts of the remanufacturing operation. and distributed as new products to meet customer demand;

Assumption 1 and 2 are used to reduce the complexity of the system without the loss of generality of the control problem. Assumption 3 is common in PPC literature, especially at high levels of complexity system, like the system we considered in this work. Assumption 4 is encountered in the literature and many industrial sectors (e.g. aeronautic and cartridges remanufacturing industries).

1.3. State of the art

In this section, we will present the main research works related to our system. We consider the authors who have worked on an unreliable manufacturing system; then, the coordination of manufacturing and remanufacturing in the context of supply chain management, integrating quality into production, and finally integration of supply and production decisions.

1.3.1 Management of unreliable production systems

To determine optimal control policies for an unreliable production systems (subject to breakdowns and repairs), several authors have adopted the theory of stochastic command. This approach allowed them to take into account the different phenomena and the dynamics of their systems.

1.3.1.1 Production control policies

Due to its importance for producers, many approaches have been established in the literature with the objective of an optimal control of stochastic production systems. (Kimemia, 1983) has shown the optimal control policy in their unreliable supply chain called hedging point policy (HPP), according to this policy the machine production rate can take three levels; if the stock level of the finished product is below the threshold level, the machine should product at the maximum rate. If the stock level of the finished product is equal to this threshold, the machine produces at the demand rate, but if the stock level is above this threshold, the machine should be stopped. Following their work (Akella, 1986) considered an analytical solution in a particular case of a single machine, which is producing a single type of product. The machine they considered in their system was subjected to random breakdown and repairs and they showed the well-known hedging point policy (HPP) is optimal. This policy controls the production rate and consists in maintaining the stock level at an optimal threshold when the production system is available in order to avoid shortages during failure periods. Several authors have extended the concept of HPP in order to consider practical aspects. (Sharifnia, 1988), considered a manufacturing system producing a single product with multiple machine failures. The average cost for determining the optimum inventory levels is minimised in his model. His findings are useful for solving the multi product manufacturing systems scenario. (Chan, 2008) assumed that the manufacturing system can produce multiple products, and, other than the original production system, is also possible to use additional production capacity from other machines. This implies cooperative production, since additional capacity can only be used if demand is greater than normal output. They defined the optimal production policy to meet uncertain demands identified with two demand levels for each product type, thus determining a two-level hedging point for each product type. This work is useful in case demand rates follow a general probability distribution rather than a simple Markov process. (Gharbi, 2011) has proven the possibility to use the non-exponential failure and repair time distributions in HPP policy as the optimal production policy. Many authors were trying to develop the optimal control policy of their system in a more complex supply chain that contains manufacturing and remanufacturing operations. For instance, (Ouaret, 2018)considered that the deterioration of the manufacturing facility affects the quality of produced items, which in turn affects the failure process of the remanufacturing facility during its production operation. (Assid, 2019) propose an efficient structure of joint manufacturing and remanufacturing control policy integrating simultaneously the production and disposal activities as well as the procurement of both return and raw material. They showed its advantage in terms of costs compared to several control policies adapted from the literature. More recently, (Assid, 2020)developed a new production control policy for unreliable HMRSs composed of mixed dedicated and shared facilities where the last one can perform both manufacturing and remanufacturing operations.

1.3.2 Integrating manufacturing and remanufacturing operation

In the forward supply chain, there is no responsibility for returned products. However, the reverse supply chain is attempting to consider returned products in the most environmentally friendly manner. The improvement of the supply chains leads to a coordinated new approach that investigates both forward and reverses supply chains simultaneously (Govindan, 2017). Based on the variation of the market and the released environmental legislation, an expanding number of manufacturing companies are undertaking remanufacturing activities into their manufacturing systems (Atasu, 2008). (Van Der Laan, 1997) extended the well-known push and pull control policy to efficiently coordinate manufacturing, remanufacturing, and disposal operations. (Teunter, 2008) discussed that dedicating production lines for manufacturing and remanufacturing can lead to significant reductions in holding costs and increased scheduling flexibility. (Gharbi, 2008) discussed the relationship between manufacturing and remanufacturing. In the same sense, (Francas, 2009) studied a multi-product network design problem and conclude that it is more advantageous to configure a flexible production site if all the products are destined for the same market. The author's work investigated capacity planning and the advantages of the different network configurations for remanufacturing. (Berthaut, 2009) determined the optimal procurement and production of a remanufacturing system. As far as we know, (Kenné, 2012) was the first who investigate the stochastic dynamics of facilities (i.e. subject to random failures and repairs). They used the methodology of stochastic dynamic programming and developed optimal manufacturing and remanufacturing control policy, which minimizes the expected cost including the inventory holding and backlog costs. (Flapper, 2014) studied the optimal scheduling for the hybrid manufacturing-remanufacturing system with negligible setup times and costs using an approach based on the queueing theory. They proposed a production schedule that minimizes the average discounted long-term cost. (Guo, 2015) investigated the optimal production control policy for the hybrid manufacturing-remanufacturing system when the returns rate, the buyback cost, and the remanufacturing cost depend on the quality level. (Tang, 2006) addressed the multi-product economic lot-scheduling problem with returns based on a case study of a company, which manufactures and remanufactures car parts. (Fang, 2017) used five scenarios based on the production capacity and market demand to find the optimal operation strategy maximizing the total profit for a hybrid system with a substitutional relationship between new and remanufactured products. (Kilic, 2018) addressed the stochastic economic lot-sizing problems and proposed two heuristic policies to control manufacturing and remanufacturing operations while integrating service level constraints. Other researchers have been interested in the integration of production with consideration of the quality of raw material or returned product. These works will be presented in more detail in the following paragraphs.

1.3.3. Integrating Quality into the production

Duo to the increasing demands of customers, many authors have been interested in developing more realistic optimal control policies. These models consider an unreliable production system with a significant amount of non-conforming finished product. Many authors were interested to integrate quality into their manufacturing process. Also, many works coordinated quality into the remanufacturing process.

1.3.3.1 Integrating Quality into the manufacturing process

(Rivera-Gómez, 2013) investigated the effect of the deterioration of the manufacturing machine on the quality of finished products. The solution approaches that they considered in their work were numerical and simulation approach based on experimental design and response surface methodology. (Bouslah, 2013) jointly considered the production control policy and a single sampling plan for an unreliable batch manufacturing system. They considered a non-perfect production system. They mentioned in their work that they should also consider the amount of non-conforming products, which is the result of the non-perfect production process in their control policy to support the continuous rate of demand. Following their work, (Hlioui, 2015) also considered a fixed fraction of non-conforming items in the received raw material lot that may pass the inspection and reached the customers. In their production control policy, when the finished product stock reached the threshold level, the production rate should be decreased to the demand rate by taking into account the amount of non-conforming items. In the other work of (Hlioui, 2017), they considered a modified hedging point policy to control the production rate of their system by taking into consideration the proportion of non-conforming raw material items after quality control when the production rate is adjusted the demand rate.

1.3.3.2 Integrating Quality into the remanufacturing

Many works integrated quality of the returned product in their remanufacturing process. (Souza, 2002) proposed different production planning and control strategies for remanufacturing operations. In their work, they considered three different quality categories for returned products; each category needs different remanufacturing processes. (Garg, 2015) combined the notion of vehicle routing problem with CLSC design. Their suggested methods for recovery include repair, decomposition, and disposal. In their work, the rate of return should be determined for remanufacturing activity in advance. Besides, incentive prices should be variable since the returns have different values based on their qualities. (Guo, 2015) investigated the optimal production policy for the hybrid manufacturing-remanufacturing system when the returns rate, the buyback cost, and the remanufacturing cost depend on the quality level. (Jeihoonian, 2017) considered a closed-loop supply chain with different recovery options that are reusing, remanufacturing, recycling. They identified several markets to sell their different kinds of products. They considered the uncertainty in the quality of returned products and modeled it via binary scenarios for each component and module. (Maiti, 2017) used game theory to analyze recovery strategies. They defined minimum quality in their system that was calculated from remanufacturing costs, if the quality of returned products was greater than the minimum, it will be forwarded to remanufacturing; otherwise, it will be sold in the secondary market.

1.3.4 Integration of supply and production decisions

Recent research indicates that short-term procurement is emerging as an effective replenishment strategy, especially in an environment where businesses are developing in a rapidly changing market and unexpected events require a rapid update of supply needs. Being able to identify the optimal conditions in which a decision-maker can choose the best supplier, based overall system state, can help companies improve their productivity and decrease costs (Hlioui, 2017). Many works integrated supplier selection for selecting the raw material for manufacturing operation and some works consider supplier selection for selecting the returned product for remanufacturing operation. These works will be presented in more detail in the following paragraphs.

1.3.4.1 Supplier selection for selecting raw material

(Chen, 2010) proposed a stochastic framework to determine the optimal production control policy and supplier selection procedure for a three-stage supply chain. They proposed an improved analytical hierarchy process (AHP) to select the best supplier, where quality, service, and the total cost under demand disruptions are considered. (Keskin, 2010) developed a simulation-optimization approach to address a multiple-supplier, multiple-warehouse problem. They considered a trade-off between supplier selection and inventory decisions in the presence of stochastic demands. (Hajji, 2011) presented an optimal strategy for an integrated replenishment, supplier selection, and production control problem, where the quality of raw materials and finished products are assumed perfect. (Hajji, 2011) considered a stochastic and dynamic model to determine the optimal order policy. They considered several suppliers in their model. (Naimi Sadigh, 2013) proposed a mathematical model to integrate supplier selection into production and distributor location decisions. (Choudhary, 2013) integrated supplier selection to their system in a dynamic model. (Pazhani, 2016) implemented compartmentalized (Q, R) policies in a serial inventory system with supplier selection. In their analysis, they discussed the benefit of integrating inventory management with supplier selection decisions. (Hlioui, 2017) proposed a control policy, which coordinates supplier selection, replenishment, production, and quality inspection decisions. In their model upon reception of the lot, the manufacturer applies a simple lot-by-lot acceptance-sampling plan with attributes. Based on this inspection plan, if the number of non-conforming items, found in this sample, is equal to or less than the predefined number, the lot will be accepted. Otherwise, the lot will be refused and returned to its original supplier, and then a new order is placed.

1.3.4.2 Integrated Supplier Selection in the reverse logistics

In the following, we will mention the works, which integrated supplier selection in reverse logistics. (Ali, 2016) investigated a closed-loop supply chain, which includes manufacturer, remanufacturer, and third-party logistics provider, which collects used products. They considered multiple suppliers in their work and devoted a certain supplier for collecting each product. (Zouadi, 2018) proposed a lot-sizing problem in the manufacturing-remanufacturing system. In their work, they consider a returned product collection phase from customers that has deterministic returns quantities. They put some emission constraints for manufacturing, remanufacturing, and transportation activities. (Amin, 2012) considered a closed-loop supply chain that includes manufacturer, disassembly, refurbishing, and disposal sites. In their work, they considered supplier selection in the reverse logistics that were categorized based on purchasing cost and timely delivery.

1.4. Literature Review

Over the past decades and in response to the growing awareness of environmental issues, closed-loop supply chain works have grown dramatically. (Teunter, 2008) noticed that when we devoted production lines to manufacturing and remanufacturing, it may cause significant cost saving. (Teunter, 2008) showed that dedicated production lines for manufacturing and remanufacturing could lead to significant reductions in holding costs. Reverse and closed-loop supply chains, including remanufacturing, are not new. Some industries have been remanufacturing since the 1920s (for example, automotive parts have been remanufactured by third parties). The military has routinely remanufactured assets for decades. Research on remanufacturing has increased since the early 1980s (Lund, 1983), with most of the published research appearing since 1990 and focused on operational or engineering issues (Daniel, 2019). Improving supply chains leads to a systematic new strategy that investigates forward and reverses supply chains at the same time (Govindan, 2017). Based on market fluctuations and the published environmental legislation, a growing number of manufacturing companies conduct remanufacturing activities in their production systems (Atasu, 2008). Therefore, because of many advantages that remanufacturing has, the manufacturing industry is witnessing a rising trend in the remanufacturing of used products, and in recent years several models have been published which were integrating the coordination of manufacturing, and remanufacturing and supply management to ensure better management of supply chain.

Companies often import returned products for remanufacturing operations from outside suppliers. The manufacturer may have different reactions regarding the delivered lot of returned products. Many works considered remanufacturing as their main issue, and propose different reactions upon received returned products. (Van Der Laan, 1997) extended the well-known Push and Pull control policy to efficiently coordinate production, remanufacturing, and disposal operations. (Souza, 2002) proposed different production planning and control strategies for remanufacturing facilities. In their work, they considered three different quality categories for returned products; each category needs different remanufacturing processes. (Jeihoonian, 2017) considered a closed-loop supply chain with different recovery options that are reusing, remanufacturing, recycling. They investigated several markets to sell their different kinds of products. They considered the uncertainty in the quality of returned products and modeled it via binary scenarios for each component and module. (Maiti, 2017) used game theory to analyze recovery strategies. They defined minimum quality in their system that was calculated from remanufacturing costs, if the quality of returned products was greater than the minimum, it will be forwarded to remanufacturing; otherwise, it will be sold in the secondary market. Having reviewed the previous works, we found a research gap of taking into account the quality of returned product with single sampling plan in the supply chain in a continuous, dynamic, and stochastic context and the coordination of inspection decisions in the closed-loop supply chain.

Through an integrated supply chain viewpoint, the decision-maker must not be limited to a single possible supplier to better address supply volatility. Because when the system is encountering different uncertain states, the supplier who was the best in a certain condition, may not necessarily be the best in other conditions. Therefore, the selection decision needs to take into account a pool of suppliers, and the decision-maker should select the best supplier according to the whole system state and based on the best offer of potential suppliers. Moreover, an effective supplier assessment and selection process is necessary to improve a company's efficiency and its supply chains (Perona, 2004). Therefore, the supplier selection process and supplier evaluation is a critical issue to be considered in the supply chain management. As we mentioned in the previous section some works coordinated supplier selection process for selecting the returned product for remanufacturing operation in their system but we found some gaps in the previous works of integrating supplier selection with manufacturing and remanufacturing that consider system state, quality of finished products, and supplier parameters simultaneously. Therefore, it will be the objective of the second system of our work.

1.5 Research objectives

This thesis aims to develop optimal control policies for a closed-loop supply chain, considering an unreliable manufacturing system.

In this project, we will develop the following two systems:

1. In the first system, we will study a supply chain producing a single type of product, consisting of a supplier, an unreliable manufacturer, and a final customer where demand can be met via two sources of production that is either manufacturing of new products or remanufacturing of returned ones. Upon reception of the returned products, the producer may execute different quality strategies for the received lot. These strategies will be %100 inspection, no inspection, and a single sampling plan. The main objectives of this model is to determine, the best joint integrated control

quality combing manufacturing and remanufacturing and control of returned based on the quality.

2. The second work will addresses the production planning and control problem within a hybrid manufacturing-remanufacturing system, in which demand can be satisfied by either manufacturing of new products or remanufacturing of returned ones. In the second model, we will propose a new joint production and supply policy composed of multiple suppliers. The manufacturer produces a single type of product in this system. When the amount of returned products in the stock reached zero, the manufacturer should order returned products from the selected supplier. The objective of this work is to determine the best control policy that exists which combine manufacturing, remanufacturing, supplier selection, and switching policy.

1.6 Solution approach

A simulation-based optimization method is adopted in this study. It is a combination of simulation modeling, experimental design, and response surface methodology. The main phases of the proposed control approach are presented in the following figure:

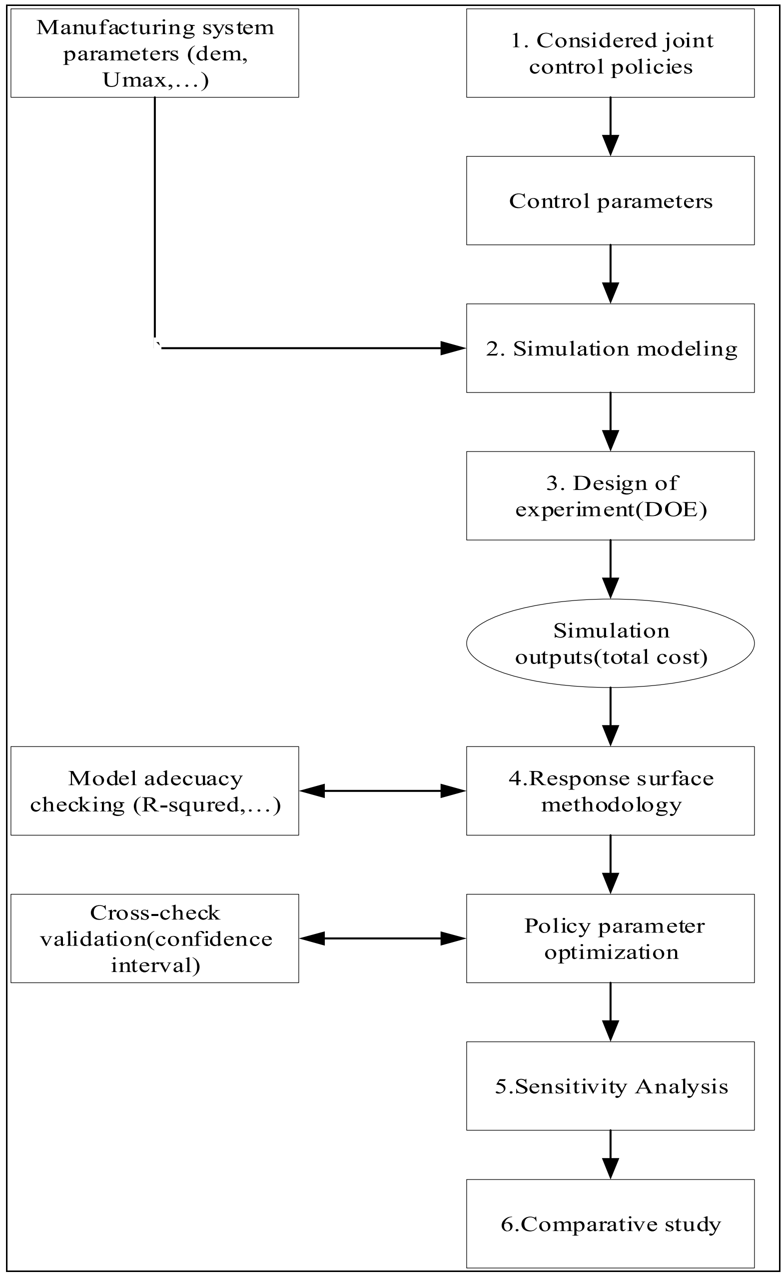


Figure 1.2. Solution approach

Step 1: Control policy

The structure of the control policy and the dynamics and the constraints of the system will be presented at this stage. This step will allow us to define all the control parameters of the system that need to be optimized

Step2: Simulation model

A discrete/continuous simulation model will be developed to represent the dynamics of the considered supply chain. This model will be developed using ARENA software. Indeed, (Lavoie, 2010) have shown that this approach allows representing well the stochastic and dynamic aspects of a system, as well as the reduction of simulation time. During this step, the control parameters defined in the previous step are used as inputs to the simulation model. Following the simulation of the model, the total cost will then be obtained.

Step 3: Design of experiments (DOE)

Using the STATGRAPHICS software, we will work out combinations of the different control parameters in the form of experimental design. Using the simulation model developed in step 2, the total cost incurred for each combination will be determined. An experimental design is developed to distinguish the effects of the main factors, their quadratic effects, and their interactions with the response (the incurred cost).

Step 4: Response surfaces methodology

This method makes it possible to define the relationship between the response (incurred cost) and the main significant factors and/or interactions. From this relation, the optimal value of control parameters and the cost can be determined. Then we checked the model adequacy by R-squared and other factors.

Step 5: Sensitivity analysis

The objective of sensitivity analysis is to present the strength of our solution approach. We analyzed and investigated the optimal values of independent variables regards to changes in the values of each operational parameter.

Step6: Comparative Study

The objective of this section is to conduct an in-depth comparative study in order to determine the best policy in terms of cost.

1.7 Conclusion

In the first section of this chapter, the general structure of the supply chain, which is employed in this work, is illustrated. Next, the state of the art works in this domain are introduced. We discussed a review of various works relating to the determination of an optimal control policy for unreliable manufacturing systems, the integration of manufacturing and remanufacturing operation, and integration quality into production to ensure better management of the supply chain, and the integrating of supply and production decision. In all the cases discussed, the authors were little interested in integrating returned product quality control into a single sampling plan and then consideration of several suppliers in the reverse logistics of a closed-loop supply chain management context. This aspect interests us to get closer to reality. Furthermore, in this chapter, we introduced the research problem and objectives explicitly as well as the solution method applied in this thesis. Thanks to the solution approach, we will develop, in a dynamic and stochastic context, optimal control policies of a supply chain in the presence of an unreliable manufacturing system and sampling plan control process. It will also allow us to show the importance of the interaction of different policies to ensure better performance of the supply chain.

CHAPTER 2

INTEGRATED QUALITY STRATEGY IN AN UNRELAIBLE MANUFACTURING-REMANUFACTURING SYSTEM AND RETURNED PRODUCTS REPLENISHMENT IN A CLOSED-LOOP SUPPLY CHAIN

2.1. Introduction

Reverse and closed-loop supply chains, including remanufacturing, are not new. Some industries have been remanufacturing since the 1920s (for example, automotive parts have been remanufactured by third parties). The military has routinely remanufactured assets for decades. Research on remanufacturing has increased since the early 1980s (Lund, 1983), with most of the published research appearing since 1990 and focused on operational or engineering issues (Daniel, 2019)

There is no liability for returned goods within the forward supply chain. However, the reverse supply chain is attempting to consider returned products in the most environmentally sustainable way. Improving supply chains leads to a systematic new strategy that investigates forward and reverses supply chains at the same time (Govindan, 2017). Based on the market fluctuations and the published environmental legislation, a growing number of manufacturing companies conduct remanufacturing activities in their production systems (Atasu, 2008). The returns processes are used in a closed-loop supply chain and the manufacturer plans to capture the additional value to the supply chain (Daniel, 2019).

Based on the dynamics of the market and the spread of environmental legislation, a growing number of manufacturing companies participate in product recovery activities in their production systems (Atasu, 2008). Moreover, the remanufacturing process is thought to recover the economic and ecological benefits as much as possible due to the increased life of the product and decreased energy and ultimate amounts of waste (Lund, 2003).

In this work, we try to indicate the structure of an unreliable system comprises of manufacturing and remanufacturing integrated quality strategy in a closed-loop supply chain. Moreover, suggest the best way of inspection of the received returned products for remanufacturing operations. In this regard, we will investigate some related works that exist in the literature. Having reviewed the previous works and found the research gap, we will introduce our research problem and its objectives, and thereafter, we will propose our methodology to solve that problem.

The rest of the paper is structured as follows. Section 2 presents a brief overview of previous works related to the problem under study. The system description and problem statement are presented in Section 3. Section 4 presents the problem formulation. Section 5 illustrates the control policies adapted to our context from the literature. In Section 6, we report a solution approach. Section 7 describes the simulation model evaluating the system operation when each control policy is applied. In Section 8, an experimental design is presented. A numerical example is presented in Section 9. Then experimental results represent in Section 10. This is followed by a sensitivity analysis in Section 11. In section 12 a comparative study is conducted. An extensive study presented in section 13, Section 14 presented the other extensive study to our work, and Section 15 concludes the paper.

2.2. Literature Review

Over the past decades and in response to the growing awareness of environmental issues, closed-loop supply chain works have grown dramatically. (Govindan, 2017) reviewed these works in detail. (Teunter, 2008) noticed that when we devoted production lines to manufacturing and remanufacturing, it may cause significant cost saving. (Kenné, 2012) developed optimal manufacturing and remanufacturing control policy, which minimizes the total cost. (Teunter, 2008) showed that dedicated production lines for manufacturing and remanufacturing could lead to significant reductions in holding costs and increased scheduling flexibility. (Kilic, 2018) addressed the stochastic economic lot-sizing problems and proposed two heuristic policies to control manufacturing and remanufacturing operations while integrating service level constraints. (Tang, 2006) addressed the multi-product economic lot-scheduling problem with returns based on a case study of a company that can manufacture and remanufacture car parts.

Based on the variation of the market and the released environmental legislation, an expanding number of manufacturing companies are considering remanufacturing activities in their manufacturing systems (Atasu, 2008). The manufacturing industry is witnessing a rising trend in the remanufacturing of used products. Some industries have been remanufacturing since the 1920s. Research on remanufacturing has been increased since the early 1980s (Lund, 1983), with most of the published research appearing since 1990 and focused on operational or engineering issues (Daniel, 2019). Successful examples include the remanufacturing systems of Mercedes-Benz, IBM, DEC, and Xerox (Atasu, 2008).

Companies often import raw materials from outside suppliers. The manufacturer can have different reactions regarding the delivered lot of raw material. The producer may take into account %100 control of all the parts in the batch obtained. (Salameh, 2000) proposed a new model that applied % 100 inspections for the received lot to examine the quality of the lot, in their model the non-conforming items removed and placed in a single batch and will be sold in a secondary market with a reduced price. They demonstrated that the percentage of items of imperfect quality increases when the size of the economic lot increases. (Gholami-Qadikolaei, 2013) presented a multi-objective and multi-constraint inventory model. They inspected %100 of the received lot. In their work, imperfect items will either be reworked or will be disposed of. (Gorji, 2014) coordinated order allocation, supplier selection, and transportation decisions across a two-level supply chain with one retailer and a collection of suppliers. They took into account the relationship between quality inspection and lot sizing and assumed a %100 inspection process upon reception.

Alternatively, a sampling control plan is adopted to ensure that the supply meets or does not meet the desired standard. (Starbird, 1997) investigated the impact of the single sampling plan by attribute on quality. He showed that the higher the degree of severity of the sampling plan increases, the more pressure on the supplier to improve the quality of its products is increasing. (Peters, 1988) developed an algorithm to jointly determine the batch size to order, the order point, and the optimal parameters of a sampling plan. In (Ben-Daya, 2008) work, a sampling plan with attributes was applied for the quality control of the raw material delivered. They considered two models for the received non-conforming items. The first one is that good quality product will replace the bad items, while the second one is that they will be disposed of with a non-replacement decision. (Al-Salamah, 2011) argued that %100 inspection is not always an affordable option to the manufacturer; instead, the acceptance sampling plan can be a more economical way to inspect the raw material quality. (Moussawi-Haidar, 2013) simultaneously determined the optimal lot size to order, and the parameters of the sampling plan. The authors have shown that the control policy by sampling plan ensures a better result than %100 inspection. (Hlioui, 2015) considered a model that when a lot of raw materials received, a lot-by-lot acceptance sampling plan was applied, and then a decision was taken with regards to a %100 screening or discarding of the sampled lot. In (Hlioui, 2015) work, as soon as the lot received, the manufacturer executes an acceptance sampling plan with a zero non-conforming criterion. If the sample does not contain non-conforming items, the lot is accepted; otherwise, it is rejected. (Hlioui, 2017) proposed a control policy, which coordinates supplier selection, replenishment, production, and quality inspection decisions. In their model, upon reception of the raw material, the manufacturer applies a simple lot-by-lot acceptance-sampling plan with attributes. This plan is characterized by a random sample of size n and an acceptance criterion c. Based on this inspection plan, if the number of non-conforming items, found in this sample, is equal to or less than c, the lot will be accepted. Otherwise, the lot will be refused and returned to its original supplier, and then a new order is placed.

Nevertheless, the other possibility is the raw material forward to the production lines without any inspection (Song, 2013), and (Hajji, 2009).

In this work, we try to compare theses different quality control policies of reverse logistics in a closed-loop supply chain and indicate the best one.

Several types of research considered control theory as one of the most important approaches to solve the problems in a dynamic stochastic context. In the context of the planning problem for unreliable manufacturing systems, several approaches have been developed based on the hedging point policy (HPP) concept (Kenné, 2000).

The HPP policy concept is to create a safety stock in case we encounter any kind of delays in our system related to operation or repair. (Kimemia, 1983) considered the hedging point

Policy (HPP) for their production policy. (Berthaut, 2009) determined a control policy for both supply and remanufacturing activities, composed of a multi-hedging point policy (MHPP) and an (s, Q) policy. (Hajji, 2011)studied a joint production and delayed supply control problem. They showed that the control policy is a combination of (HPP) and (s, Q) policy. (Kenné, 2001) proposed a new control policy combining analytical methods, simulation, and response surface methodology. They have determined the optimal value of the various control parameters of a system composed of several machines and several products. According to the findings of (Hajji, 2011), the raw material inventory and the final product should be maintained at an excess level to face supply operations, maintenance operations, and capacity shortage. However, as some bad quality raw materials may pass inspection, the production policy is controlled by the MHPP policy rather than the HPP policy. (Bouslah, 2013) jointly considered the production control policy and a single sampling plan design for an unreliable batch manufacturing system. By considering an imperfect production system, they showed that a “Modified Hedging Point Policy” (MHPP) controls their production policy. (Hlioui, 2015) considered MHPP for the production control policies, where the supplied lot contains non-conforming items, they considered unreliable manufacturing machine in their system and (s, Q) policy for the supply policy. (Hlioui, 2017), applied the Modified Hedging Point Policy (MHPP) to control the production rate. This policy allows taking into consideration the proportion of non-conforming raw material items after quality control. (Entezaminia, 2020) used Environmental hedging point policies for collaborative unreliable manufacturing systems with variant emitting level technologies.

This section mainly focuses on those Closed-Loop Supply Chain (CLSC) works, which consider remanufacturing as their main issue and propose different quality inspection strategies to reuse the returned products. (Van Der Laan, 1997) extended the well-known Push and Pull control policy to efficiently coordinate production, remanufacturing, and disposal operations. (Souza, 2002) proposed different production planning and control strategies for remanufacturing facilities. In their work, they considered three different quality categories for returned products; each category needs different remanufacturing processes. (Garg, 2015) combine the notion of vehicle routing problem with CLSC design. Their suggested methods for recovery include repair, decomposition, and disposal. In their work, the rate of return should be determined for remanufacturing activity in advance. Besides, incentive prices should be variable since the returns have different values based on their qualities. (Jeihoonian, 2017) considered a closed-loop supply chain with different recovery options that are reusing, remanufacturing, recycling. They had several markets to sell their different kinds of products. They considered the uncertainty in the quality of returned products and modeled it via binary scenarios for each component and module. (Maiti, 2017) used game theory to analyze recovery strategies. They defined minimum quality in their system that was calculated from remanufacturing costs, if the quality of returned products was greater than the minimum, it will be forwarded to remanufacturing; otherwise, it will be sold in the secondary market. (Moshtagh, 2017) presented a model in which the quality of manufactured and remanufactured products is not the same and these products are sold to different markets. The return rate of the returned products is dependent on its quality, which is a random variable. (Fang, 2017) used five scenarios based on the production capacity and market demand to find the optimal operation strategy maximizing the total profit for a hybrid system with a substitutional relationship between new and remanufactured products. (Kilic, 2018) addressed the stochastic economic lot-sizing problems and proposed two heuristic policies to control manufacturing and remanufacturing operations while integrating service level constraints. (Berthaut, 2009) determined the optimal procurement and production of a remanufacturing system.

2.3. Problem formulation

The notations used in this work are defined as follows:

2.3.1. Notations

δ_R(t): Random delivery lead-time of returned products order launched at time t

τ_{insp}: Inspection delay per unit (time/unit)

AOQ: Average outgoing quality

AOQL: Average outgoing quality limit

$AOQL_{max}$: Maximum accepted level of the average outgoing quality limit

$AOQfp(t)$: Average Outgoing Quality of finished products.

c: Acceptance Number

C_R^H : Returned products stock holding cost ($/time unit/product)

C_F^H : Finished products stock holding cost ($/time unit/product)

C_B^H : Finished products backlog cost ($/time unit/product)

C_{insp} : Returned products inspection cost ($/unit)

C_{rep}^F : Non-conforming finished products replacement cost ($/Product)

C_{dis} : Disposal cost

d: Number of non-conforming items in the received lot

dem: Finished product demand rate (units/time)

n: Sample Size

p : Proportion of non-conforming items in the received lot

P_a : Acceptance probability of a lot

$p^r(.)$: Proportion of non-conforming items produced with remanufacturing machine

$p^m(.)$: Proportion of non-conforming items produced with manufacturing machine

Q: Returned products lot size

s: Returned products ordering point

U_{man}^{max}: Maximum manufacturing production rate

U_{rem}^{max}: Maximum remanufacturing production rate

U_{man}(t): Manufacturing rate at time t (Product/time unit)

U_{rem}(t): Remanufacturing rate at time t (Product/time unit)

W: Ordering cost

X_F(t): Inventory level of finished products at time t (product)

X_R(t): Inventory level of returned products at time t (product)

X_F(t): Inventory level of finished products at time t (product)

X_R(t): Inventory level of returned products at time t (product)

Z_F : The Finished product hedging level for the production policy

2.3.2. System description

The system considered in this work is described in Figure 2.1. This system consists of two machines, one for manufacturing operations and one for remanufacturing operations and one supplier. Both machines are subjected to random failures and repairs. The transformation stage produces one final product type and responds to stable market demand. This system can remanufacture their used own brand. The producer orders a batch of returned products from an upstream supplier. The supplier takes an order of returned products for remanufacturing machine with quantity Q and supplies it to the manufacturer after a random shipment delay δ. It is assumed that each delivered lot of returned products contains a fixed fraction of non-conforming items that is donated by p.

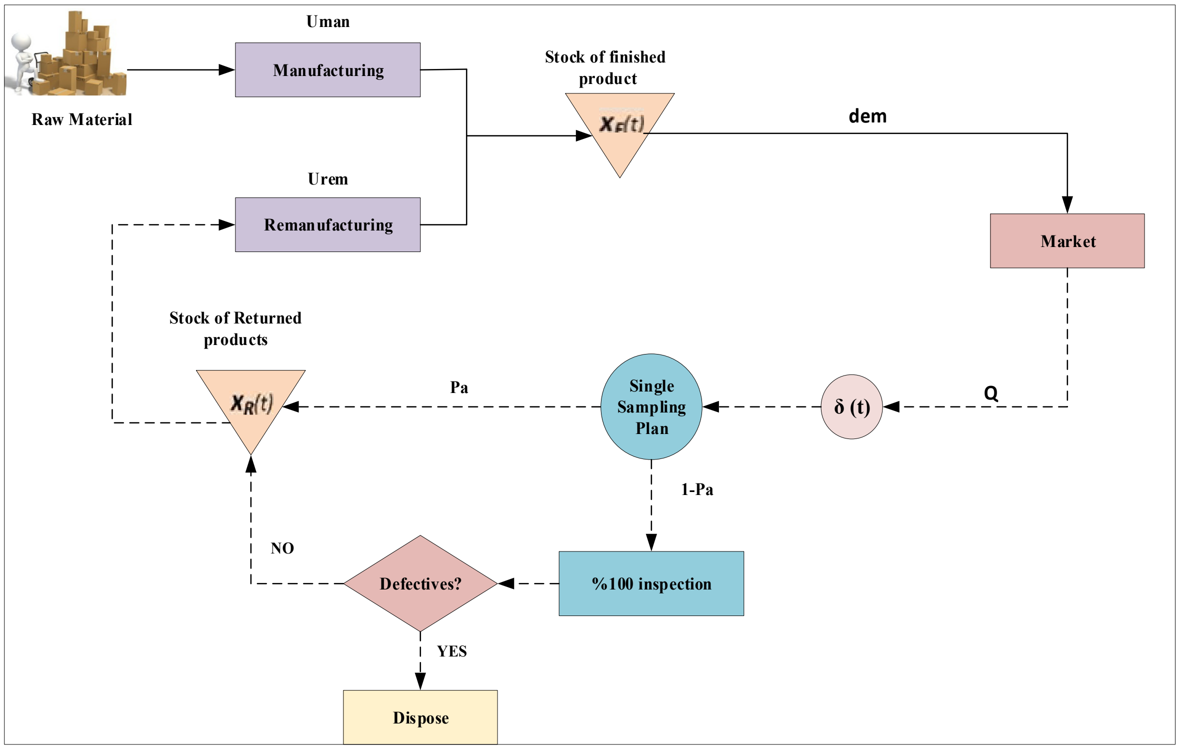


Figure 2.1 System description

Two types of inventories are involved in this work. The manufactured and remanufactured items are stored in the first inventory. The returned products are collected in the second inventory and then remanufactured or be held on the stock for later remanufacturing.

Upon reception of the returned products, the manufacturer inspects its quality using a lot-by-lot acceptance-sampling plan with a zero non-conforming criterion; if the sample does not contain non-conforming items, the lot will be accepted. Otherwise, the manufacturer will perform % 100 inspections for the rejected lot and will dispose of all of the non-conforming items. In a sampling inspection policy, there is the possibility of some non-conforming product pass inspection. These items could be transformed into a finished product, and thus sold to the final customer. We assumed that the customer can detect and return it to be replaced with replacement cost (C_{rep}^{F})per unit cost.

The returned products held in the manufacturer's return stock incur a holding cost C_R^H . The manufacturer produces a single type of finished product to respond to the constant demand rate "dem". The finished product held in the manufacturer's final product stock incurs a holding cost C_F^H. However, if the manufacturer could not respond to the customer demand, a backlog cost C_F^B is considered.

2.3.3. Assumptions

The following statement summarizes the general context and main assumptions considered in this system:

1. The raw material for manufacturing machine is always available;
2. There is a known and available market to buy returned products for the remanufacturing machine;
3. The customer demand is known and described by to a constant rate over time;
4. The quality of produced parts of the manufacturing machine is equal to produced parts of the remanufacturing machine and distributed as new products to meet customer demand;
5. The accepted lot will be placed in the returned product stock immediately;
6. Manufacturing machine always produce good quality products.
7. All the non-conforming products sold to the customer will be detected by customers and returned to the manufacturer to replace with good ones, which include replacement cost (C_{rep}^F).

2.3.4. Problem formulation

The state of the considered manufacturing-remanufacturing system can be described by four components at time t as follows:

- A continuous part X_F(t) which describes the cumulative surplus level of the finished product stock (inventory if positive, backlog if negative);
- A continuous part X_R(t) which describes the cumulative surplus level of the returned products stock that can be positive or zero;
- A discrete-state stochastic process ($\alpha_1(t)$, t≥0) which describes the state of the manufacturing machine. This state can be classified as "manufacturing machine is

available", denoted by $\alpha_1(t)$ =1, or "manufacturing machine is unavailable", denoted by $\alpha_1(t)$ =0;

- A discrete-state stochastic process $(\alpha_2(t)$, t≥0) which describes the state of the remanufacturing machine. This state can be classified as "remanufacturing machine is available", denoted by $\alpha_2(t)$ =1, or "remanufacturing machine is unavailable", denoted by $\alpha_2(t)$ =0.

Thus, the system dynamics may be described by the state variables ($X(t)$, α(t)). The following equations represent the temporal evolution of the system:

$$\dot{X}_F = U_{man}(t) + U_{rem}(t) - \frac{dem}{1-AOQ_{FP}} \qquad X_F(0)=X_F^0 \qquad (2.1)$$

$$\begin{cases} \dot{X}_R = -U_{rem}(t) \\ X_R((\theta_i+\delta_R(\theta_i))^+) = X_R((\theta_i+\delta_R(\theta_i))^-) + Q \end{cases} \qquad X_R(0)= X_R^0 \qquad (2.2)$$

Where X_F^0 and X_R^0 denote the initial stock levels of finished products and returned products respectively, dem denotes finished product demand rate (units/time), $U_{man}(t)$ is manufacturing rate at time t , $U_{rem}(t)$ denotes remanufacturing rate at time t and AOQ_{FP}denotes the Average Outgoing Quality of finished products. That is showing the amount of non-conforming products in the finished products stock, it depends on how much non-conforming products, produced in the manufacturing machine and how much non-conforming products, produced in the remanufacturing machine. Assuming a perfect production process, $AOQ_{FP}(t)$ can be measured as follows:

$$AOQ_{FP}(t)= \frac{\left(\frac{\sum_{i=1/a^i=1}^{N(t)} p^r(Q-n)}{\sum_{i=1}^{N(t)} Q} * U_{rem}(t)\right) + (p^m * U_{man}(t))}{U_{rem}(t) + U_{man}(t)} \qquad (2.3)$$

Where $N(t)$, represents the number of inspected lots at time t, $a^i = 1$, if the ith lot is accepted, and $a^i = 0$ otherwise. n is indicating sample size , Q is lot size.

Two formulas are used to describe the inventory level of returned products (X_R) through a piecewise continuous part. This is particularly useful because X_R faces a continuous downstream remanufacturing process and an impulsive upstream supply when a Q lot of returned products is received at the instant $(\theta_i + \delta_R(\theta_i))$. This order was launched at θ_i. $((\theta_i + \delta_R(\theta_i))^+)$ and $((\theta_i + \delta_R(\theta_i))^-)$ represent the positive and negative boundaries of the ith receipt instant respectively.

The set of admissible control policies *Γ*(.),depends on the stochastic process α(t) is given by:

$$\Gamma(\alpha)=\begin{cases} 0 \leq U_{man}(\mathrm{t}) \leq U_{man}^{max} . I(\alpha_1(\mathrm{t}) = 1) \\ 0 \leq U_{rem}(\mathrm{t}) \leq U_{rem}^{max} . I(\alpha_2(\mathrm{t}) = 1) \end{cases} \quad (2.4)$$

Where *I*(w)=1 if w is true while I(w)= 0 if not.

The supply chain system under consideration in this study is subject to random lead-time and random availability of the production system. A combination of simulation, design of experiments and response surface methodology is used to conduct an in- depth comparative study of the considered control policies. This choice is due to its accuracy and strength while addressing such complex problems. It uses simulation as a powerful tool to describe the dynamics of the system and stochastic aspects. The optimization of the control parameters and the associated total cost, obtained through simulation, is conducted thanks to the design of experiments and the response surface methodology. By comparison, optimizing these control parameters for further comparative study would be too time-consuming to be applicable at the operational level when applying numerical methods, the structure of the control policies are presented in the next section.

2.4. Structure of control policies

The main objective of this section is to present the structure of the control policies for the considered supply policy. We will compare our mentioned policy with the other policies. Therefore, in this work our main objective is to determine the best policy, in order to minimize the total ordering cost, the returns stock holding costs, the finished product stock holding costs, finished products backlog costs, the cost of replacement of non-confirming products, the cost of inspection, and the dispose cost. The production and supply policies are based on the findings of (Hajji, 2011) and (Bouslah, 2013). (Hajji, 2011) illustrated the optimal control policy for a joint production and replenishment problem is defined by a combined hedging point policy (HPP) and (s, Q) policies. (s, Q) policy consists of ordering an economic lot Q of raw material when the volume of upstream inventories reaches s, and The HPP policy is to maintain an extra finished product inventory to be able to meet demand (dem) when the production system is unavailable due to random failure and repair time of machines. (Bouslah, 2013) jointly considered the production control strategy and the implementation of a single sampling plan for an unreliable batch production system. By considering an imperfect production system, they have shown that a "Modified Hedging Point Policy" (MHPP) controls their production policy.

Regarding the quality control policy, we will examine the other possibilities of inspection that is no inspection and %100 inspection for comparative purposes, which will be introduced in the subsequent sections. In this study, our main objective is to determine, the best joint integrated control quality combing manufacturing and remanufacturing and control of returned based on the quality in order to minimize the total expected supply, production, quality inspection, returned products holding, finished products holding/backlog, ordering and the defective finished product replacement cost.

2.4.1 Production policy (MHPP)

Production policy, where the supplied lot contains non-conforming items is proposed in the following equations. As some non-conforming returned products may pass inspection, the production policy is controlled by the MHPP policy rather than the HPP policy.

$$U_{man}:\begin{cases} U_{man}^{max} & X_F < Z_F \ and \ (\alpha 1 = 1) \\ \frac{dem}{1-AOQ_{FP}} - U_{rem} & X_F = Z_F and \ (\alpha 1 = 1) \\ 0 & \text{Otherwise} \end{cases} \quad (2.5)$$

If the stock level of the finished product is below the threshold level ($X_F < Z_F$), and the manufacturing machine is working($\alpha 1 = 1$), the manufacturing machine should product at the maximum rate. As soon as the level of finished products reached to threshold level ($X_F = Z_F$) and the manufacturing machine is working($\alpha 1 = 1$), the manufacturing machine rate change to demand rate by consideration of non-conforming finished products (AOQ_{FP}) as well as the remanufacturing rate. In the other situation that is $(\alpha 1 = 0)$ and/or $(X_F > Z_F)$ the manufacturing machine should be stopped.

$$U_{rem}: \begin{cases} U_{rem}^{max} & X_F \leq Z_F \; and \; X_R > 0 \; and \; (\alpha 2 = 1) \\ 0 & \text{Otherwise} \end{cases} \tag{2.6}$$

Because of many benefits that remanufacturing has, the priority of production is with the remanufacturing operation that always is considered as maximum rate (U_{rem}^{max}). However, if the remanufacturing machine is not working because of failure$(\alpha 2 = 0)$ or when we do not have any returned product in the return stock, the remanufacturing machine should be stopped.

2.4.2. Supply policy

The (s, Q) policy has been applied to control the replenishment decision which is presented in Eq.2.5. (s, Q) policy consists of ordering an economic lot 'Q' of returned product when the volume of upstream inventories reaches 's', Means the returned product inventory should be maintained at an excess level in order to face supply operations or capability shortages.

$$\Omega: \begin{cases} Q & X_R < s \\ 0 & Otherwise \end{cases} \tag{2.7}$$

2.5. Inspection policies:

Upon reception of the returned products, the manufacturer may execute three different policies:

2.5.1. Description of No inspection policy

Figure 2.2 is illustrating the structure of no inspection policy. In this policy, without any quality inspection, the received lot will forward to the returned products stock, the stock in front of the remanufacturing machine. Therefore, we do not have any inspection costs(c_{insp}). In addition, because we do not have any inspection process in this policy, therefore, non-conforming returned product will move through the production line, and it is assumed that all the non-conforming products sold to the customer will be detected by customers and returned to the manufacturer to replace with good ones, which include replacement cost (C_{rep}^{F}).

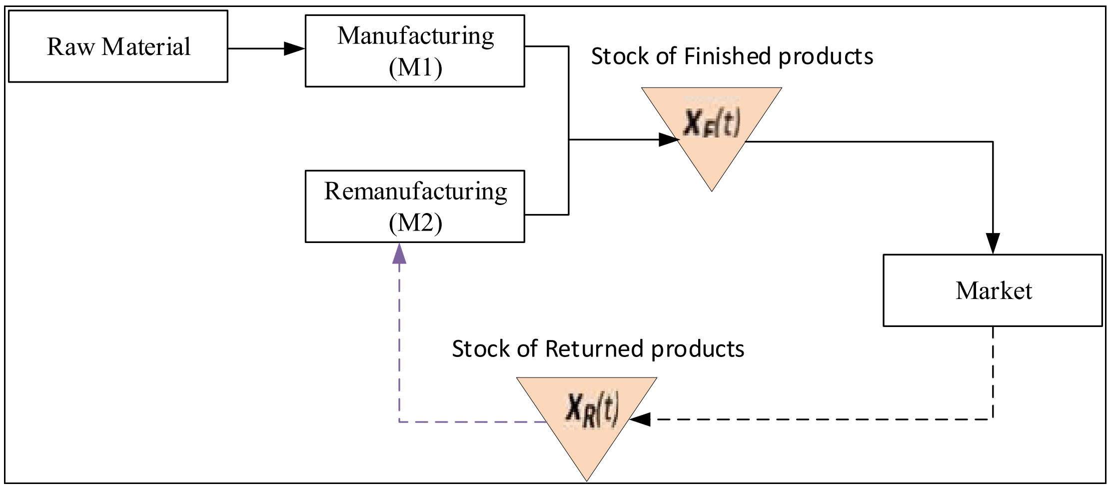


Figure 2.2 No inspection policy

2.5.2. Description of %100 inspection policy

In this policy, the manufacturer will conduct %100 inspection for the received lot. Therefore, the inspection costs are high because we have inspected the entire lot. On the other hand, we will not have any non-conforming items in the stock of finished products because, after %100 inspections, all non-conforming objects will be disposed of. Therefore, customers will not receive any defective products. (Figure 2.3)

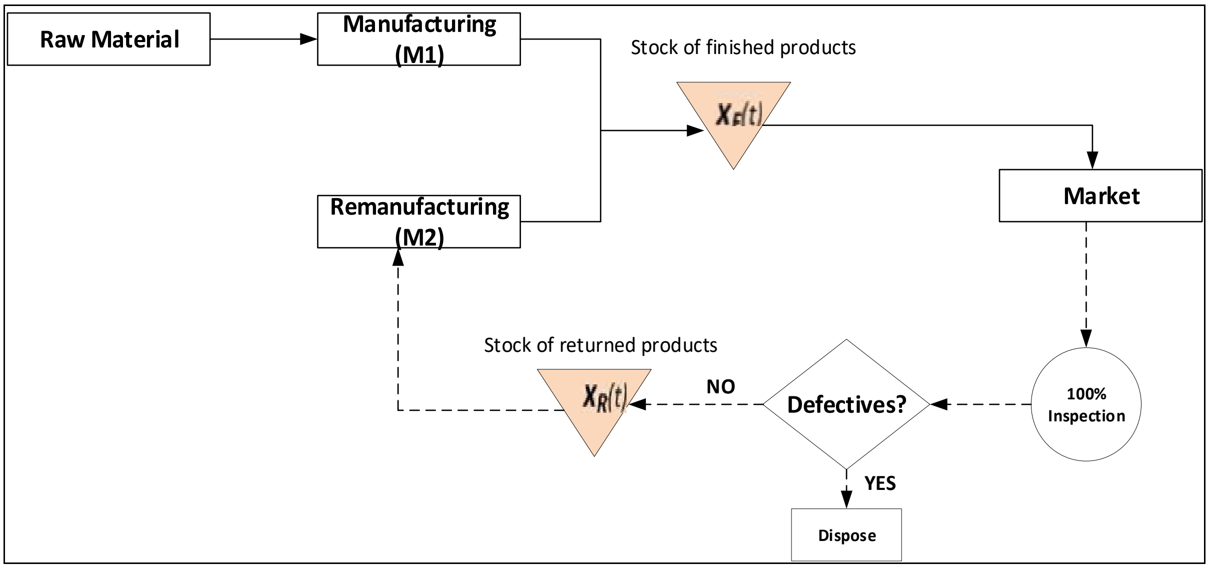


Figure 2.3 %100 inspection policy

2.5.3. Description of acceptance sampling policy with a zero non-conforming criterion

When the lot of returned products is delivered, the manufacturer inspects its quality using a lot-by-lot single acceptance-sampling plan. Upon inspecting a random sample n, if the sample does not contain any non-conforming items(c=0), the lot will immediately place in the returns stock. The probability of acceptance (Pa) of received lot with acceptance sampling strategy is given as follows (Schilling, 2009).

$$P_a=(1-p)^n \qquad (2.8)$$

Where n is sample size, P_a is acceptance probability of the received lot and p is proportion of non-conforming items in the received lot.

Nevertheless, with (1- P_a) percentage, the lot will be refused, and the manufacturer will perform %100 inspection for the rejected lot. In addition, after %100 inspection the non-conforming items will be disposed of (Figure 2.4). When a sampling plan performed, some non-conforming products may pass inspection. Such products could be turned into the stock of a finished product and will be sold to the customer. In this case, it is assumed that the customer can detect and return them to be replaced with a C_{rep}^F per unit cost.

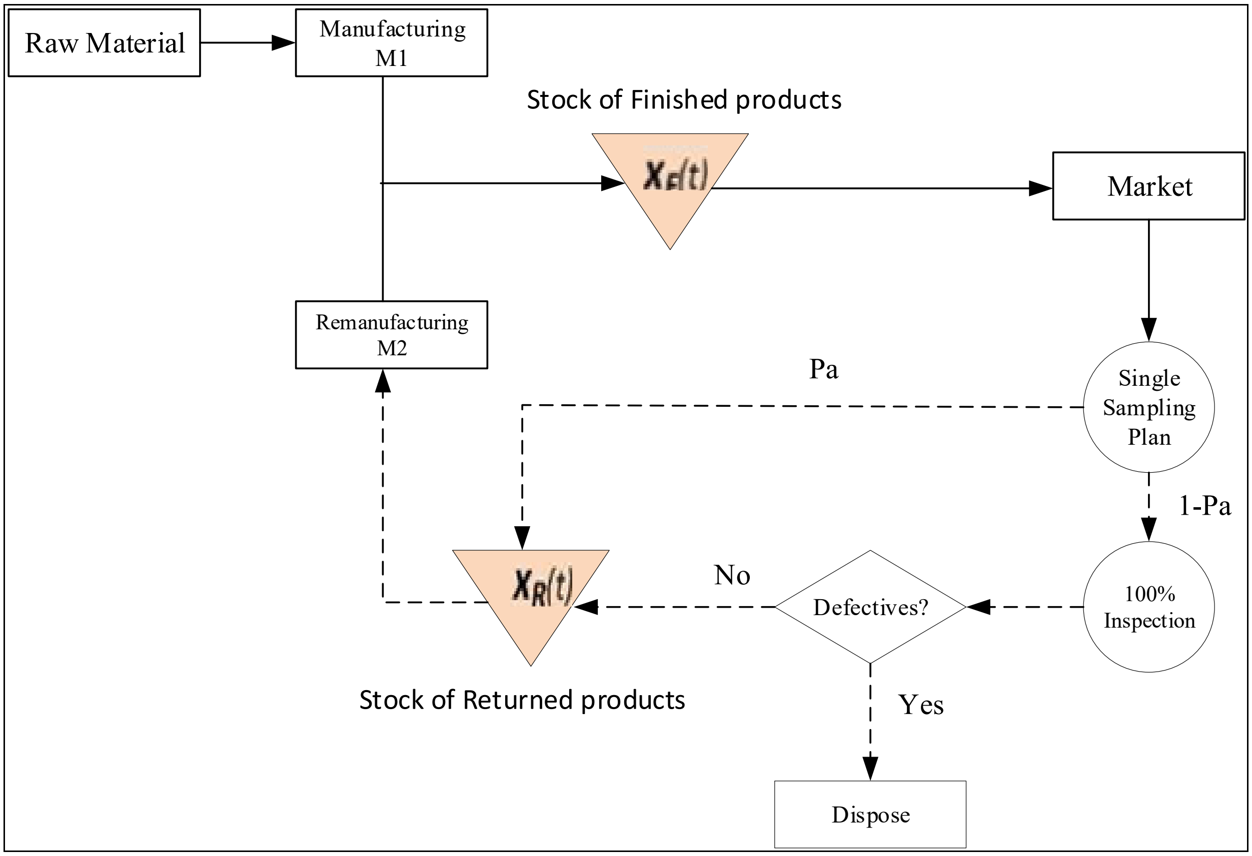


Figure 2.4 Acceptance sampling policy

2.6. Solution approach

The experimental approach considered to solve the mentioned problem is a combination of simulation modeling, experimental design and response surface methodology. The structure of the proposed control approach is as follows and is presented in Figure 2.5.

1. According to the described control policy, a simulation model is developed to describe the dynamics of each integrated production, replenishment and quality problem. Therefore, the total cost of the simulated model is achieved for the defined value of the control policy;
2. An experimental design is developed to distinguish the effects of the main factors, their quadratic effects, and their interactions on the response (the incurred cost);

3. The Response Surface Methodology (RSM) is used to determine the relationship between the incurred cost and the significant main factors and/or interactions. From this estimated relation, the optimal values of the control policy parameters, called ($s*$, $Q*$, $Z*$) and ($s*$, $Q*$, $Z*$, $n*$) and the optimal cost value are determined.

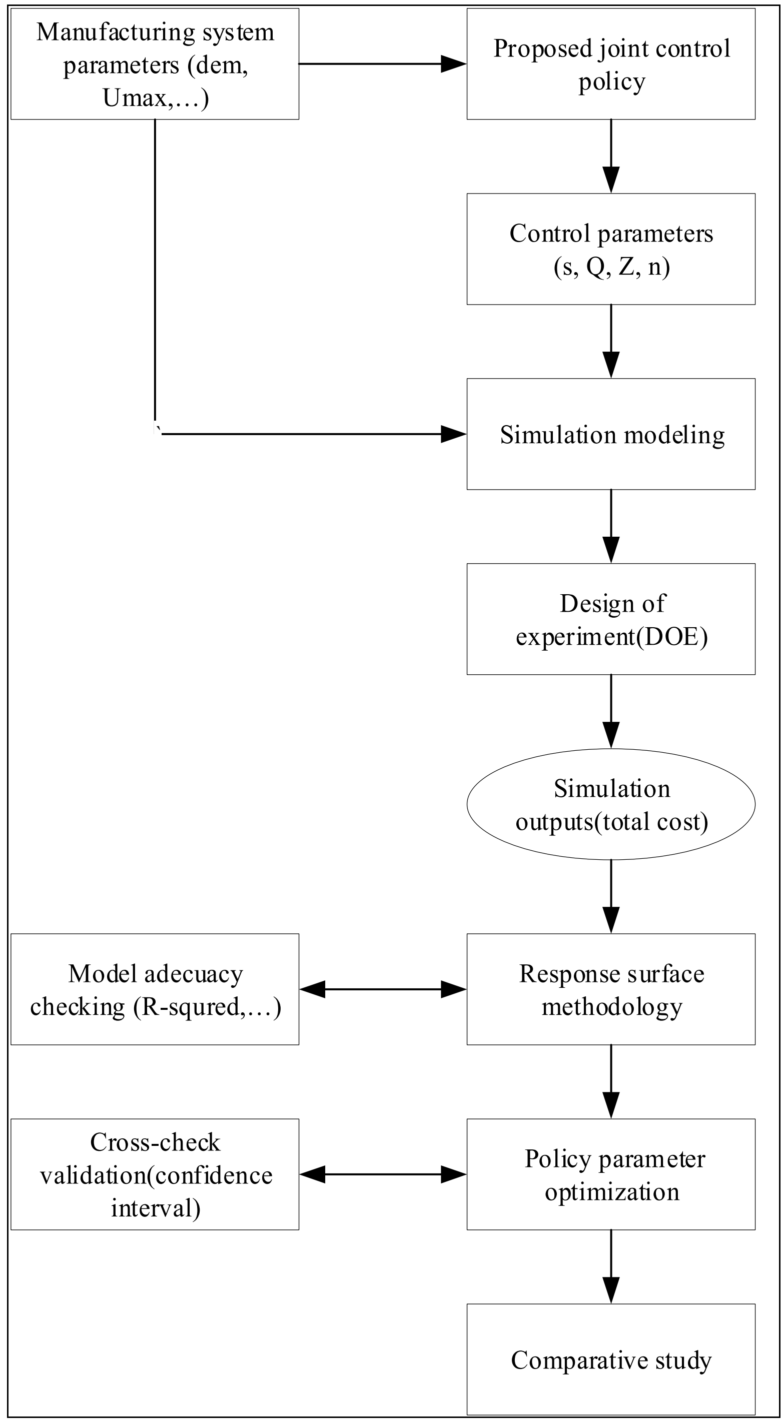


Figure 2.5 Main steps of proposed control approach

2.7. Simulation model

To reproduce the dynamic behavior of the considered supply chain and decision process, three combined discrete/continuous simulation models were developed using the SIMAN simulation language (Pegden, 1995). The models were developed on ARENA simulation software. Using such a combined approach allows a reduction of the execution time and offers more flexibility to integrate the continuous tracking of system parameters (Lavoie, 2010). The first model reproduces the integrated production-replenishment returned products when 'No Inspection' policy is adopted. The second model reproduces the integrated policies when the %100 inspection policy is adopted and the third model reproduces the integrated policies when the 'Single Sampling 'policy is adopted. Fig. 2.6 presents the overall model structure used in each of the three models:

1. The INPUT block 0 initializes the values of the joint production replenishment and quality control policy (s,Q,Z,n) and the problem variables, such as the initial states ($x0$,$y0$), production rates, inspection parameters, the replenishment lead-time;
2. The SUPPLY CONTROL POLICY block 2 sets the order quantities .This block relates to the "Update returned products stock" block 5 in charge of a sensor whenever the returned products stock level crosses the threshold s;
3. The PRODUCTION CONTROL POLICY block 6 sets the production rates. This block relates to the "Update finished products stock" block 7 in charge a sensor whenever the finished products stock level crosses the threshold (Z);
4. The QUALITY CONTROL POLICY block 4 sets the inspection policy. When the lot is delivered after a lead-time block 3, according the selected policy, the decision of the inspector is modelled by a probabilistic BRANCH block of SIMAN, which represents the probability of acceptance Pa. With Pa lots are accepted and with (1-Pa) lots are rejected. Once the quality control is completed, the lot is added to the returned products stock and then the stock level is updated;
5. Finally, when the current time of the simulation reaches T∞ block 8, the simulation is stopped. Once the simulation run is stopped, the system performance (i.e. expected total cost) is calculated.

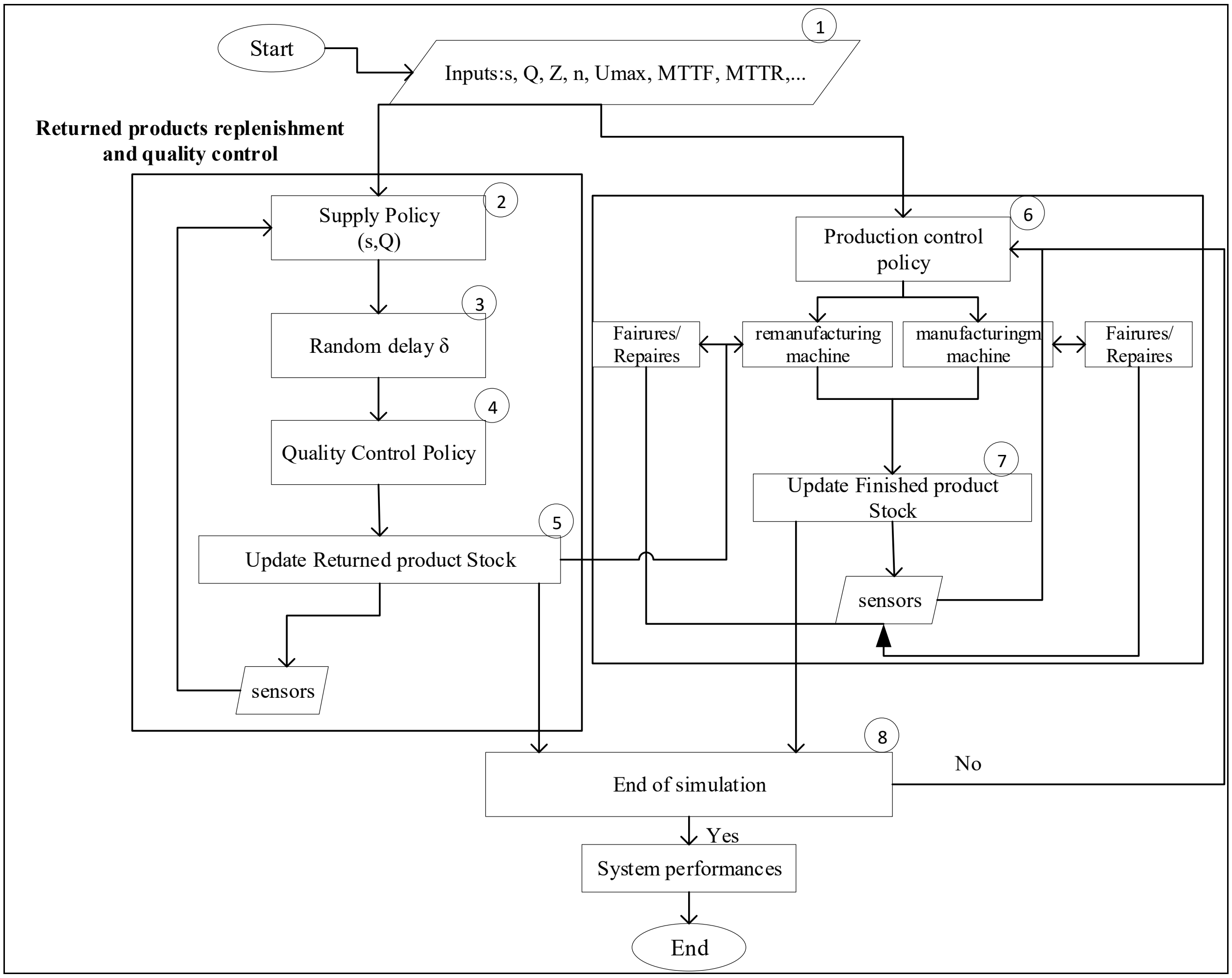


Figure 2.6. Diagram of Simulation

Figure 2.7 shows the dynamics of the returned products and finished products stock levels according to the joint production and supply control policy where the acceptance sampling policy is adopted. Figure 2.7 presents the production process depends on the machine (Fig.2.7.a), the inventory level of the finished products (Fig.2.7.b), and the returned products stock (Fig.2.7.c) and the failure process (Fig.2.7.d). When there is not any returned product in the stock (point. ①.c) , remanufacturing machine cannot work (Point ②.a),but according to our assumption, the raw material for manufacturing process is always available, in this case if the manufacturing system be available , the raw material will transformed to the finished products. Since the inventory level of finished products (X_F) is less than threshold level Z_F(point ③.b), manufacturing machine should produce at maximum rate (point ④.a).

As soon as the level of the finished products stock reached to the threshold Z, (point ⑤.b), manufacturing machine rate change to the demand rate (point ⑥.a). At (point ⑦.c), the returned products stock updated and remanufacturing machine can start to produce at maximum level (point ⑧.a), and manufacturing rate will decrease to demand by consideration of remanufacturing rate (point ⑨.a). A failure occurred in the manufacturing machine (point⑮.d), so manufacturing machine will stopped (point ⑩.a). When the returned products stock crosses the ordering point(s) (point ⑪.c), the manufacturer orders a batch of returned products from the supplier. This lot is delivered after a lead-time δ (point ⑫.c). Once the sample of size n is inspected after S delay, (point ⑬.c). The manufacturer decides to accept or to refuse this lot. If the lot is accepted, it will transferred to the returned products stock. Otherwise, if the lot is refused, the manufacturer performs a full inspection of the lot and dispose all non-confirming items with a Q delay (point ⑭.c).

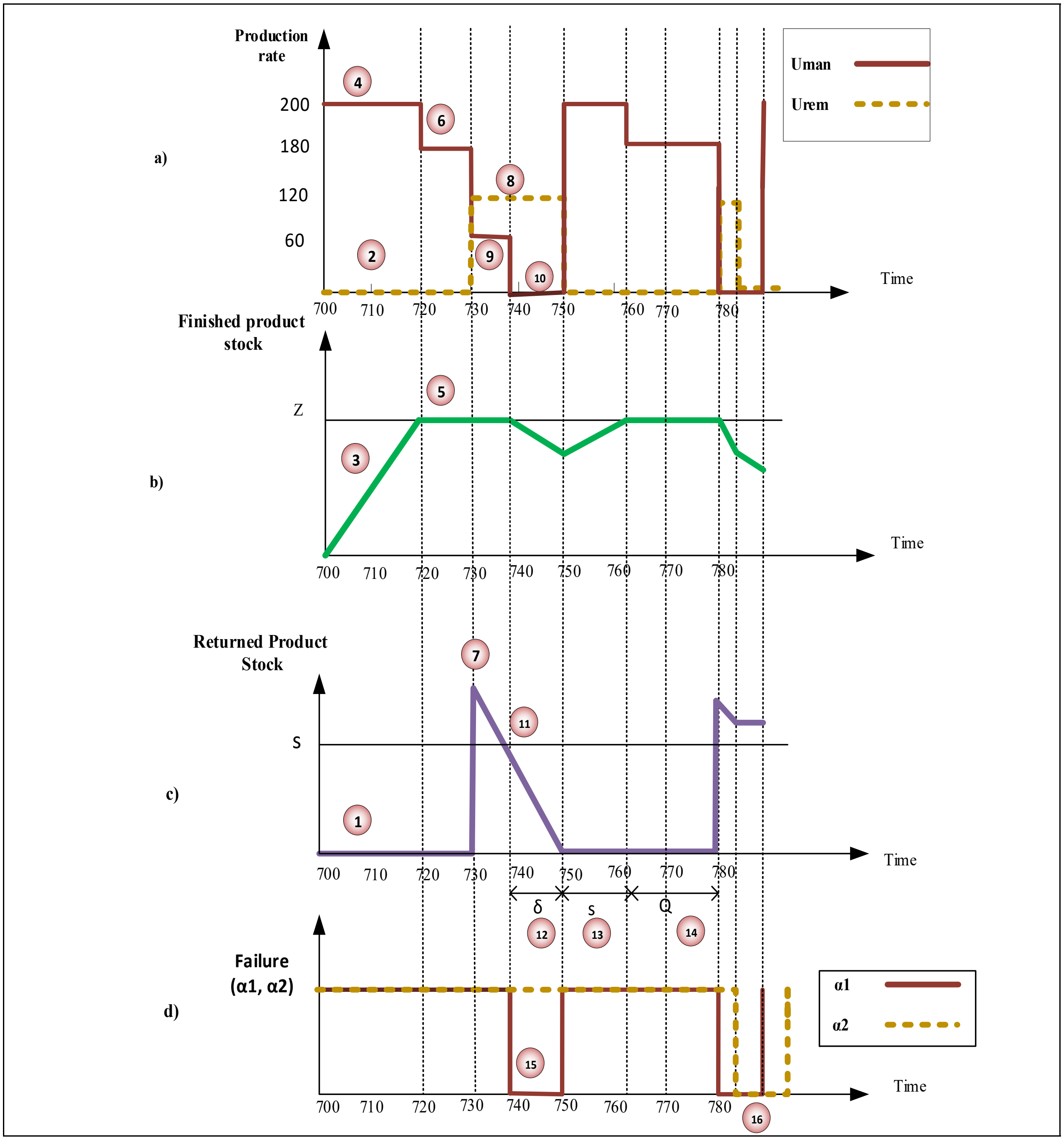


Figure 2.7. Dynamics of the operations

2.8. Experimental design and Response Surface Methodology

In this section, we tried to find out the relationship between the response factor (cost) and significant factors, find the optimal value of three proposed policies (No inspection, %100 inspection and Single sampling plan) and their optimal cost, and finally compare the result of the different policies.

Our decision variables are the final product hedging level Z and the supply parameters (s, Q) for No inspection and 100% Inspection policies. In addition, for sampling plan policy, sample size n will be added and decision variables are (s, Q, Z, n).

2.9. Numerical Examples

We considered the following values of the operational and cost parameters characterizing the supply chain and inspection operations:

Table 2.1 Cost Parameters

Parameters	C_R^H	C_F^H	C_B^H	W	C_{rep}^F	C_{insp}	C_{dis}
Values	3	3	300	0.3	1300	200	50

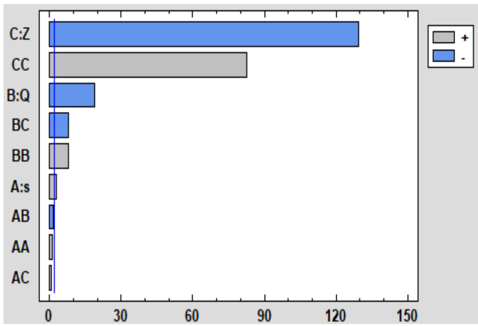
Table2.2 Production Parameters

Parameters	U_{man}^{max}	U_{rem}^{max}	dem	TTF_{man}	TTR_{man}	TTF_{rem}	TTR_{man}	p	δ_R	τ_{insp}
Values	200	120	180	LOGN(60,6)	LOGN(10,5)	LOGN(60,6)	LOGN(10,5)	2.50%	Norm(3,0.33)	0.00032

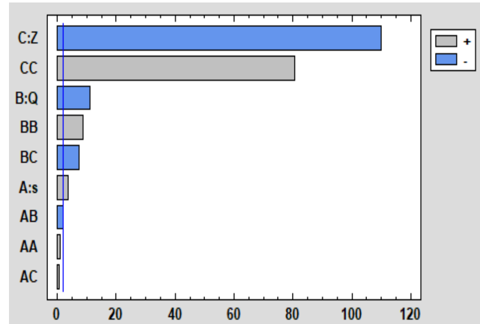
2.10. Experimental results

We used a statistical software application STATGRAPHICS for the experimental design, a multi-factor analysis of the variance (ANOVA) of the simulated data was conducted. This analysis showed the effect of the independent variables (s, Q, Z) or $(s, Q, Z,$ n) and their interactions on the dependent variable (the cost).

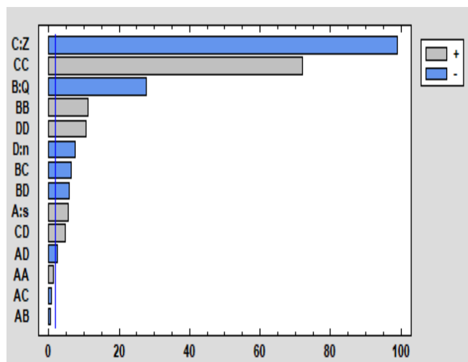
According to the Pareto plot (Fig. 2.8), we noted that all the R_{adj}^2 values are greater than 95% and it means over %95 of total variability is thus explained by the models. (Montgomery, 2013).



$R^2_{ajs} = 99.49\%$ (a): No Inspection



$R^2_{ajs} = 99.36\%$ (b): %100 Inspection



$R^2_{ajs} = 99.29\%$ (c): Single Sampling Plan

Figure 2.8. Standardized Pareto plot for the total cost

From STATSGRAPHICS, the second-order models of the total cost for each inspection policy are given by:

$Cost_{No\ inspection}$ = 97537.5 - 60.2447.s - 8.86689.Q - 24.755.Z + 0.0332654.s^2 - 0.00424881.s.Q + 0.000509267.s.Z + 0.00348878.Q^2 - 0.000969532.Q.Z + 0.00537619.Z^2 (2.9)

$Cost_{\%100}$ = 97389.5 - 43.1826.s - 8.15491.Q - 20.615.Z + 0.0249639. s^2 - 0.0039119.s.Q + 0.000396644.s.Z + 0.00336356. Q^2 - 0.000787575.Q.Z + 0.00459057. Z^2 (2.10)

Cost (s, Q, Z, n) = 80208.1 - 43.6612.s - 8.77275.Q - 20.7325.Z - 1.8344.n + 0.0256547. s^2 - 0.000640285.s.Q - 0.000646591.s.Z - 0.0268175.s.n + 0.0023838*Q^2- 0.000551855.Q.Z - 0.00705913.Q.n + 0.00467165. Z^2 + 0.00304063.Z.n + 0.134638. n^2 (2.11)

Moreover, in order to authenticate the validity of our models, we conducted 30 extra replications and used optimal parameters to make sure the optimal cost of each model is within the confidence interval at 95% using (Eq.2.12).

$$\bar{C}^*(h) \pm t_{\frac{\alpha}{2},h-1} \cdot \sqrt{S^2(h)/_h} \tag{2.12}$$

Where $\bar{C}^*$ is the average obtained cost, S the sample standard deviation, and $(1-\alpha)$ the confidence level.

The optimal solution for each quality strategy is presented in Table 2.3.

Table 2.3. Confidence Interval and Optimal variables and cost results

Policies	Optimal Parameters				Optimal Cost	CI(95%)
	s*	Q*	Z*	n*		
No inspection	1030	2239	2455	_	26202.3	[26195.21, 26292.09]
%100 inpesction	1009	2077	2380	_	42606.3	[42573.47, 42655.73]
Single Sampling Plan	986	2460	2386	143	23022.8	[23009.31, 23079.39]

The results of Table 2.3 illustrate the superiority of the Single Sampling plan policy as compared to the No Inspection and 100% policies, which help ensure a lower total cost. By choosing the Single Sampling Plan policy, we will save the cost up to 45% in comparison to 100% policy %ΔC*= 45%, where %ΔC*=[(C100%*-CSampling∗)/ C100%*] and, we will have up to 12% cost savings in compare to No Inspection policy, %ΔC∗=12%, where %ΔC*=[(CNo Inspection*-CSampling∗)/ C No Inspection∗].

To illustrate the robustness of this solution approach for ranges of systems parameters, a sensitivity analysis will be performed

2.11. Sensitivity analysis

Sensitivity analyses are necessary to ensure a full understanding of the effect of a given parameter variation on the entire system and to make sure that all variations make sense. In this study, we concentrated our efforts on operational parameters judged the most appropriate. The results obtained (Table 2.4) show the impact of this variation on the optimal control parameters ($s*$, Q^*, Z*, n*), when a single sampling policy is considered.

Case 1: Variation of the returned products holding cost c_R^H

When the c_R^H cost increases, we should try to decrease the amount of returned products in the stock, in this case we should order less frequently to have less quantity of returned products in the stock so s* will decrease, also Q* will decrease to reduce the stock level of returned products and avoid the extra cost. In order to have minimum quantity of the returned products in the stock, Z* should increase to accelerate the transformation of returned products to finished product to meet a continuous demand. So in this case to support continuous demand the acceptance decision of a delivered lot should be promotes so n* will decrease. When the c_R^Hcost decreases, the opposite variation of the optimal parameters will be considered.

Case 2: Variation of the finished product holding cost c_H^F

When the c_H^F cost increases, the level Z* decreases to reduce the finished product inventory costs. By reducing the transformation of the raw material and returned products, the system will make more returned products stocks (s* and Q* increase), and with better quality ($n*$ increases), to be used when required. When the c_H^F cost decreases, the opposite variation of the optimal parameters will be considered.

Case 3: variation of the finished product backlog cost c_B^F

When the c_B^F cost increases, the manufacturer increases the Z* in order to ensure enough finished products and meet customer demand. Supply parameters should be increase to reduce the risk of stock-out of returned products because of the lead-time. At the same time we should make sure that we have enough stock in our returned products stock so we should accept more lot , for increasing the number of accepted lot, n* should decrease . We note an opposite variation of the different optimal parameters.

Case 4: Variation of the inspection cost c_{insp}

When the inspection cost c_{insp} increases, the system tends to reduce the total inspection cost, which included sampling, and 100% inspection costs. So n* should be decrease, by decreasing the optimal sample size n*, Pa probability will increase, and leads to an increase in the acceptance frequency for the supplied lot. At the same time, $s*$ and Q* decreases to avoid a high level of returned holding stock. In addition, $Z*$ decreases to avoid returned products stock-out frequently. When the $cinsp$ cost decreases, we note an opposite variation of the optimal parameters.

Case 5: Variation of the disposal cost c_{disp}

Increasing disposal cost results in a tendency to decrease sample lot size, to increase to acceptance probability, so by decreasing n*, the possibility of the accepted lot will increase, returned products stock-out frequency will decrease. In this case s* and Q* decreases to avoid returned product stock cost. Z* will decrease to avoid returned products stock-out frequently.

Case 6: Variation of the finished product replacement cost c_{rep}

When the finished product replacement cost increases, we should try to have a better quality of finished products, in this case n* should increase to guarantee better quality of returned products. Increasing n results in a tendency to increase the lot rejection probability (1- Pa). Consequently, $s*$ and $Q*$ increase in order to ensure that the returned products is available, Z* increases to accelerate transformation of returned products to finished products to avoid extra holding cost with better quality. Decreasing c_{rep} leads to an opposite variation of the optimal parameters.

Case 7: Variation of the ordering cost W

When the ordering cost increases, the decision maker had to order less frequently so s*decreases, and with a larger lot size (Q* increases). By ordering higher quantities, the system keeps a higher level of returned products, Z* increases in order to avoid high returned product holding costs. Moreover, n* should increases to ensure better quality of returned products. When the cost W decreases, we note an opposite variation.

Table 2.4. Sensitivity Analysis

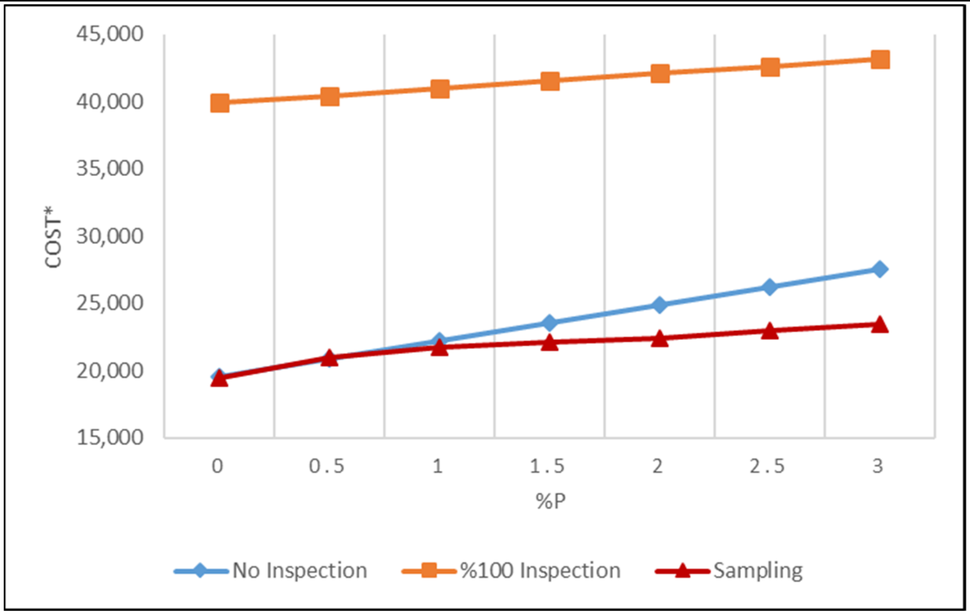
Cases	Parameter	Variation	Optimal Parameters				Cost	Impact on Single Sampling Policy
			s*	Q*	Z*	n*		
Base	_	_	986	2460	2386	143	23023	_
1	C_R^H	2.5	998	2513	2383	145	22115	s*↑, Q*↑, Z*↓,n*↑, Cost*↓
		3.5	980	2408	2389	141	23914	s*↓, Q*↓, Z*↑, n*↓, Cost*↑
2	C_H^F	2.5	985	2454	2440	142	21909	s*↓, Q*↓, Z*↑,n*↓, Cost*↓
		3.5	987	2465	2333	144	24110	s*↑, Q*↑, Z*↓, n*↑, Cost*↑
3	C_B^F	280	982	2458	2363	144	22993	s*↓, Q*↓, Z*↓,n*↑, Cost*↓
		320	990	2462	2406	142	23048	s*↑, Q*↑, Z*↑, n*↓, Cost*↑
4	C_{insp}	150	990	2470	2389	150	22708	s*↑, Q*↑, Z*↑, n*↑, Cost*↓
		250	983	2443	2383	135	23319	s*↓, Q*↓, Z*↓, n*↓, Cost*↑
5	C_{disp}	40	987	2514	2389	144	22437	s*↑, Q*↑, Z*↑, n*↑, Cost*↓
		60	985	2406	2383	142.05	23595	s*↓, Q*↓, Z*↓, n*↓, Cost*↑
6	C_{rep}^F	1200	985	2456	2386	140	23014	s*↓, Q*↓, Z*↓, n*↓, Cost*↓
		1400	987	2464	2387	145	23030	s*↑, Q*↑, Z*↑, n*↑, Cost*↑
7	W	0.25	988	2361	2381	140	21939	s*↑, Q*↓, Z*↓, n*↓, Cost*↓
		0.35	983	2531	2390	144	24074	s*↓, Q*↑, Z*↑, n*↑, Cost*↑

2.12. Comparative study of No Inspection, %100 and Sampling policies

In this section, we compare the No Inspection, %100 and Sampling policies for a system-wide range of parameters, namely, %p,C_{insp} ,C_{rep}, $C_{disp,}$, C_B^F, C_R^H and δ. This variation was conducted under similar conditions (simulation parameters, cost variation and inspection plan).

2.12.1. Effect of the proportion of non-conforming %p variation

When we changed the amount of %p, as can be seen in figure 2.9, for %p≤1%, The difference between the costs of the no inspection and Sampling policies is not significant ($\bar{C}_{No\ Inspection} \simeq \bar{C}_{Sampling}$). However, for %p> 1%, The Sampling policy is the most preferred one given that it offers the least optimal cost. In addition, %100 inspection has the highest cost in all amounts of non- conforming.

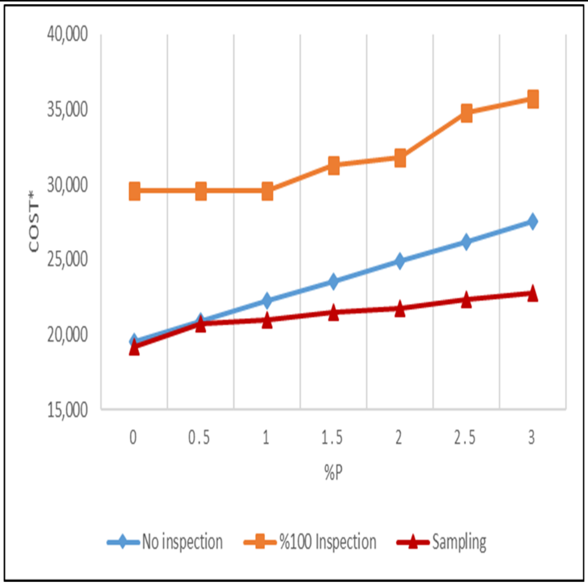


Cost* =f (%p)

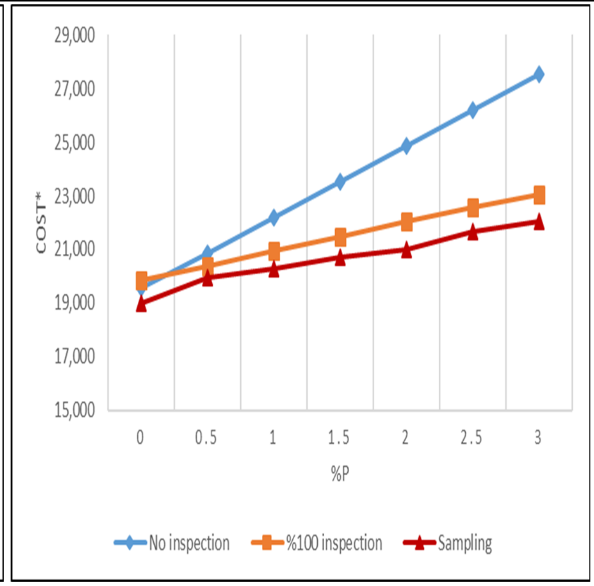
Figure 2.9. .Effect of proportion of non-conforming % p variation

2.12.2 Effect of inspection cost C_{insp}variation

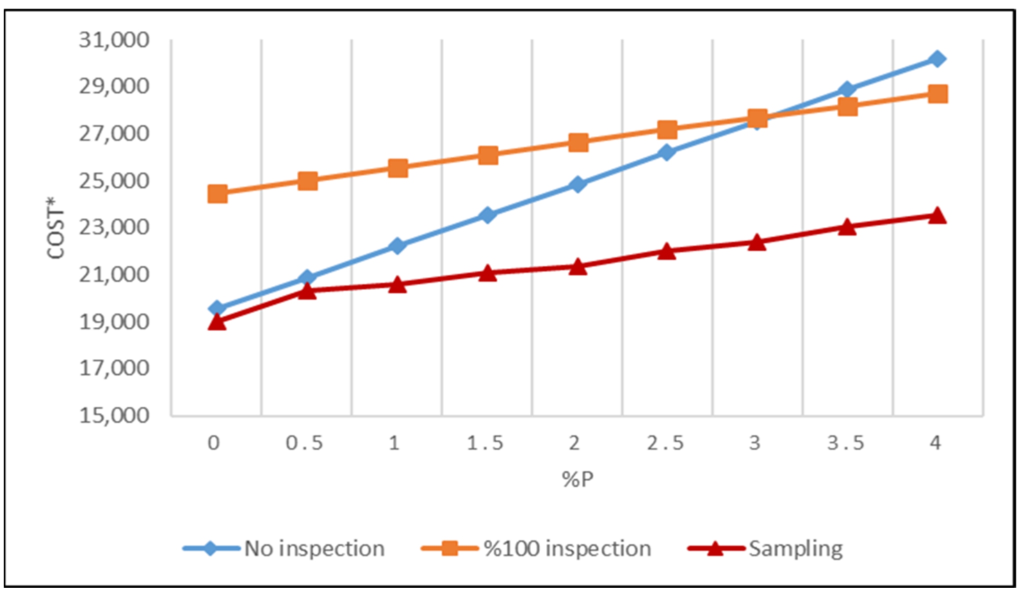
The variation of the inspection cost C_{insp} presented in Fig.2.10.a, Fig.2.10.b and Fig.2.10.c. In figure 2.10.a, the cost curves present two similar variations as those in Fig.2.9. First, for %p ≤0.5%, $\bar{C}_{No\ Inspection} \simeq \bar{C}_{Sampling}$. Second, for %p >0.5%, the Sampling policy is more preferred than the no inspection and %100 inspection. However, when we decrease the inspection cost to C_{insp} = 5 (Fig2.10.b), the cost of the %100 inspection policy decrease significantly and converted to the second selected policy after sampling policy. In figure 2.10.c, we dedicated inspection cost C_{insp} = 50, as we can see from this figure, there is an intersection at point %3 between no inspection and %100 inspection policy. After this point, the second selected policy will be changed from no inspection to %100 inspection.



(a) Cost* =f (%p), c_{insp}=100



(b) Cost* =f (%p), c_{insp}=5

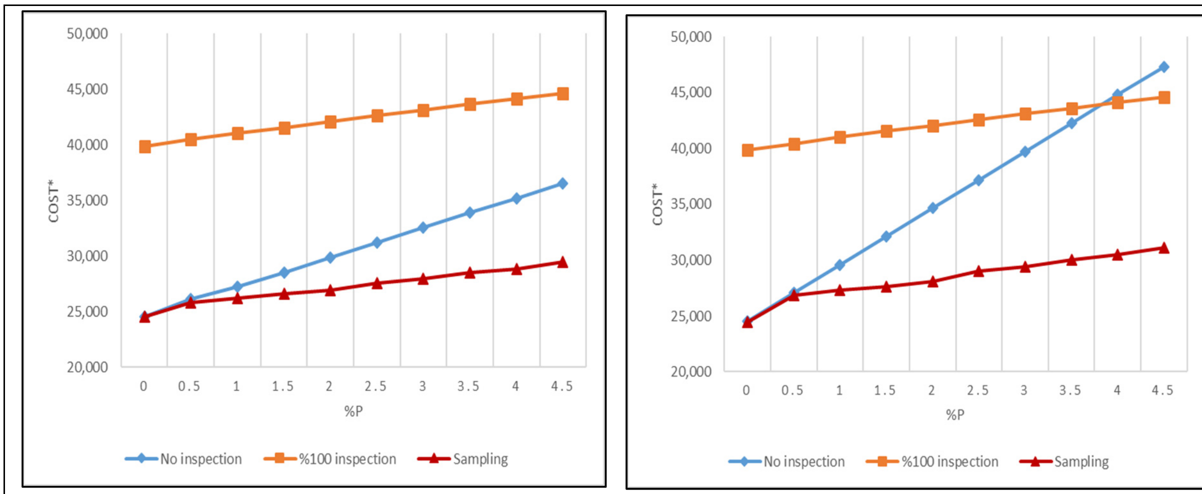


(c) Cost* =f (%p), c_{insp}=50

Figure 2.10. Effect of inspection cost variation

2.12.3. Effect of Finished products replacement cost C_{rep} variation

The variation of the finished product replacement cost C_{rep} presented in Fig.2.11.a and Fig2.11.b. We increased the finished product replacement cost. When we increase the finished products replacement cost, the cost of the % 100 inspection policy will not change (compared to Fig.2.9). Because, in the %100 inspection policy we disposed of all the non-conforming returned products and customers will not receive any non-conforming products. However, the cost of no inspection and sampling policy will increase significantly. As can be seen from figure 2.11, for %p ≤0.5%, $\bar{C}_{No\ Inspection} \simeq \bar{C}_{Sampling}$. However, for %p >0.5%, the Sampling policy is more preferred than the no inspection and %100 inspection. In addition, in Fig 2.11.b at point %4 when we increase the finished product replacement cost to 2500, we can see an intersection between no inspection policy and %100 inspection policy, after this point we should switch the second selected policy from no inspection to %100 inspection policy.



(a) Cost* =f (%p), C_{rep}=1800 (b) Cost* =f (%p), C_{rep}=2500

Figure 2.11. Effect of finished products replacement cost variation

2.12.4. Effect of disposal cost C_{disp} variation

The variation of the disposal cost C_{disp} presented in Fig.2.12. According to the following figure, in different numbers of disposal costs, the sampling policy has the least cost in comparison with no inspection and %100 inspection policies. Therefore, the Sampling policy is more preferred than no inspection and %100 inspection.

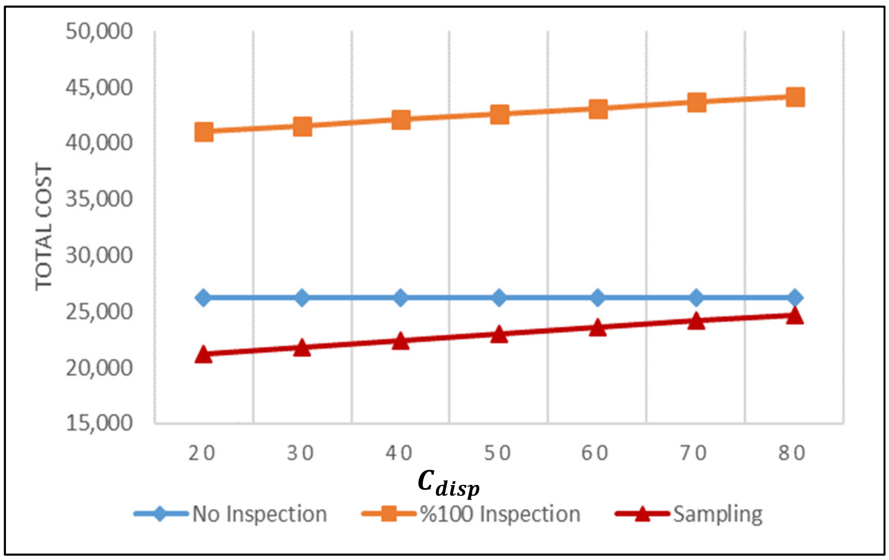


Figure 2.12. Effect of disposal cost C_{disp} variation

2.12.5. Effect of Finished products backlog cost C_B^F variation

The variation of the finished product backlog cost C_B^F presented in Fig.2.13. The results obtained clearly show that the incurred cost under sampling policy is better than that under no inspection and %100 inspection policies. Therefore, the sampling policy is more preferred than no inspection and %100 inspection policies. In addition, %100 inspection has the highest cost in all amount of finished product backlog cost. When the finished product backlog cost increases, the total cost of different policies increased.

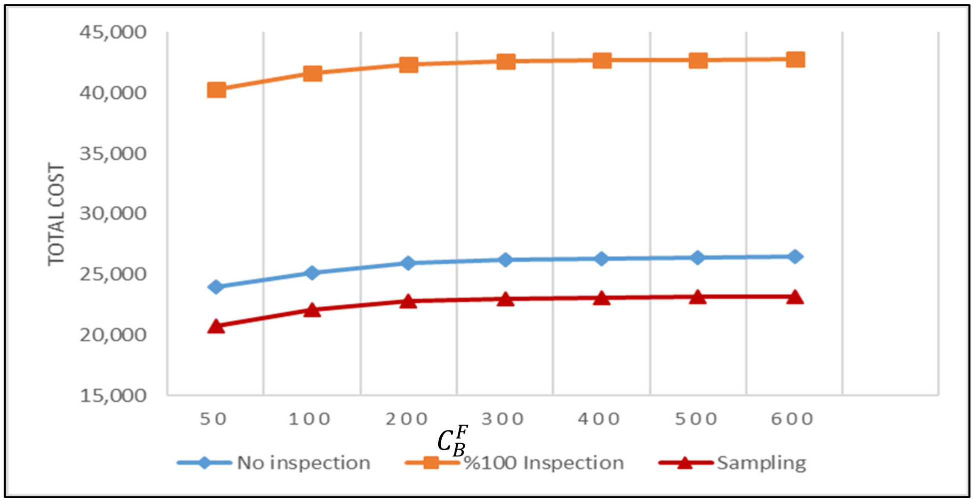


Figure 2.13. Effect of Finished products backlog cost C_B^Fvariation

2.12.6. Effect of returned products holding cost C_R^Hvariation

The variation of the returned products holding cost C_R^H presented in Fig.2.14. As can be seen in Figure 2.14, for all cases Sampling policy is always preferred to the no inspection and %100 inspection policies. The sampling policy has the least cost in comparison with no inspection and % 100 inspection policies. In addition, %100 inspection has the highest cost in all amounts of returned products holding cost. When the returned product holding cost increases, the total cost of different policies increased significantly.

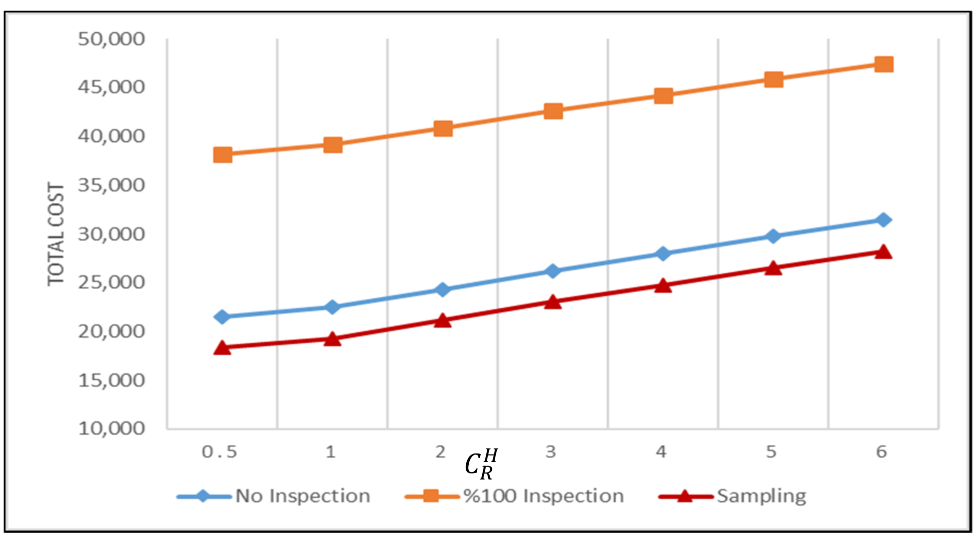
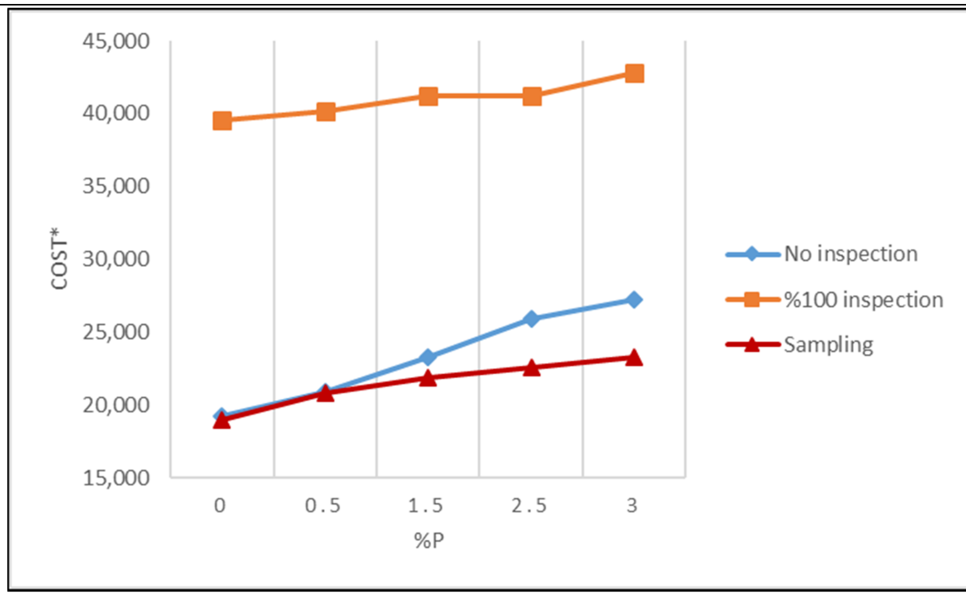


Figure 2.14. Effect of returned products holding cost C_R^Hvariation

2.12.7. Effect of returned product replenishment delay (δ) variation

The variation of the returned product replenishment delay (δ) presented in Fig.2.15. We changed the replenishment delay amount to Norm (4, 0.44) to find the best policy. In this figure, the cost curves present two similar variations as those in Fig.2.9. First, for %p ≤0.5% ,$\bar{C}_{No\ Inspection} \simeq \bar{C}_{Sampling}$. Second, for %p >0.5%, the Sampling policy is more preferred than the no inspection and %100 inspection policies.



Cost* =f (%p), δ =Norm (4, 0.44)

Figure 2.15. Effect of returned products replenishment delay (δ) variation

2.13. Extension to random replenishment delay and random non-conforming items

2.13.1. Effect of random returned products replenishment delay (δ) variation

To reflect the industrial reality we considered different random amounts to replenishment delay to find the best policy. Table 2.5 shows the optimal control parameters and the associated total cost of each policy when the delivery lead-time of returns are random. They are assumed to follow a normal distribution N (μ_d,σ_d) with mean μ_d and standard deviation

σ_d. As can be seen from table 2.5, sampling policy gives the best result in terms of costs in all the studied cases. Table 2.5 also shows that the higher the standard deviation, the more Z*occurs. This is because the system needs higher storage capacities to deal with the delay variability, which causes an increased risk of shortages. By increasing Z*, Q* should increase to ensure that there is enough returned product in the return stock to transform to the finished product. When the standard deviation of lead-time increases, n* should decrease. When the n* decreases, the probability of acceptance of lot increases to accept more lot and avoid the lack of returned products and backlog costs.

Table 2.5. Effect of random replenishment delay (δ) variation

Policies	Delay	s	Q	Z	n	Total Cost
No inspection	Norm (3,0.55)	1030	2238	2455	_	26200.3
	Norm (3,0.66)	1030	2238	2455	_	26200.4
	Norm (3,0.77)	1030	2239	2456		26200.9
	Norm (3,0.88)	1030	2239	2456	_	26201.2
	Norm (3,0.99)	1030	2239	2456	_	26201.6
	Norm (3,1)	1030	2239	2456	_	26201.8
%100 Inspection	Norm (3,0.55)	1012	2149	2388	_	41552.6
	Norm (3,0.66)	1012	2149	2388	_	41552.6
	Norm (3,0.77)	1012	2149	2389	_	41553.2
	Norm (3,0.88)	1012	2150	2390	_	41553.5
	Norm (3,0.99)	1012	2150	2390	_	41553.8
	Norm (3,1)	1012	2150	2390	_	41554
Sampling	Norm (3,0.55)	986	2451	2396	143	22918.1
	Norm (3,0.66)	986	2510	2397	145	22926.4
	Norm (3,0.77)	986	2512	2398	146	22960
	Norm (3,0.88)	986	2514	2398	147	23006.1
	Norm (3,0.99)	986	2514	2400	148	23048.3
	Norm (3,1)	986	2518	2414	148	23077

2.13.2. Effect of random non-conforming items (%p) variation

Table 2.6 shows the optimal control parameters and the associated total cost of each policy when the amount of non-conforming items in the received lot is random. They are assumed to follow a normal distribution N (μ_d,σ_d) with mean $\mu_d$and standard deviation σ_d. As can be seen from table 2.6, sampling policy gives the best result in terms of costs in all the studied cases. Table 2.6 also shows when the standard deviation increases, the Z* increases too. Because by increasing variability, the probability of acceptance of the lot will decrease and therefore the probability of rejection will increase, in this case, the probability of %100 inspection of the lot will increase so, we will have a delay for inspection and risk of the backlog will be increased. Therefore Z* increases because the system needs higher storage capacities to deal with %p variability. Also Q* will increase to ensure there is enough returned products in the stock to decrease the risk of backlog cost. When the standard deviation of %p increases, n* should decrease to accept more lot and avoid the lack of returned products and backlog costs.

Table 2.6. Effect of random non-conforming items (%p) variation

Policies	Delay	s	Q	Z	n	Total cost
No inspection	Norm(2.5, 0.5)	996	2292	2463	_	26135.9
	Norm(2.5, 1)	995	2294	2469	_	26161.3
	Norm(2.5, 1.5)	995	2295	2477	_	26190.7
	Norm(2.5, 2)	994	2297	2478	_	26195.8
%100 Inspection	Norm(2.5, 0.5)	995	2025	2372	_	41730.2
	Norm(2.5, 1)	995	2037	2375	_	42172
	Norm(2.5, 1.5)	995	2055	2378	_	42465.9
	Norm(2.5, 2)	995	2065	2379	_	42668
Sampling	Norm(2.5, 0.5)	983	2361	2444	50	23523.2
	Norm(2.5, 1)	982	2399	2445	51	23768.3
	Norm(2.5, 1.5)	980	2454	2454	52	23805.9
	Norm(2.5, 2)	980	2468	2455	52	24160

2.14. Extension to the influence of the AOQL constraint on the optimal control policy

In this section, we will assess the influence of the AOQL restriction on the optimal control policy. We focus on the case where a single sampling plan is implemented to ensure a certain average of outgoing quality limit $AOQL_{max}$, required by customers. The proposed quality control policy implies that a sampling amount of returned products is inspected before being transferred to the inventory stock. Once defective items are identified upon inspection, they are disposed of prior to moving them to the inventory stock. To meet customer requirements, the optimization problem is subject to a specified constraint on the average outgoing quality limit (AOQL). The optimal integrated solution should minimize the total incurred cost while meeting a defined restriction on the average outgoing quality limit (AOQL).

2.14.1. Optimization problem

The optimization problem should provide the optimal value of the control parameters (s*, Q*, Z*, n*) that minimize the total cost, and at the same time satisfy the $AOQL$ constraint required by customers. The optimization problem is to solve the following non-linear constrained stochastic model:

Min Cost (s,Q,Z,n)

Subject to (2.13)

$AOQL \leq AOQLmax$

2.14.2. Optimization method

From STATSGRAPHICS results, the regression models of the total cost and AOQ is obtained according to the following equation:

Cost (s, Q, Z, n) = 80208.1 - 43.6612.s - 8.77275.Q - 20.7325.Z - 1.8344.n + 0.0256547. s^2 - 0.000640285.s.Q - 0.000646591.s.Z - 0.0268175.s.n + 0.0023838*Q^2- 0.000551855.Q.Z - 0.00705913.Q.n + 0.00467165. Z^2 + 0.00304063.Z.n + 0.134638. n^2 (2.14)

AOQ (s, Q, Z, n) = 0.0150271 - 0.00000332691.s + 3.29279. 10^{-7}.Q + 1.44155. 10^{-7}.Z - 0.00015855.n + 1.71111. 10^{-9}. s^2 - 1.2492410^{-10}.s. Z + 9.47457. 10^{-10}.s. n - 3.92327. 10^{-10}. Q. n + 4.5119. 10^{-7}. n^2 (2.15)

At considering Equation (2.14) and (2.15), the optimization problem is presented as follows:

Min Equation (2.14)

Subject to (2.16)

$Equation$ (2.15)$\leq AOQLmax$

Model (2.16) determines the best values (s*, Q*, Z*, n*) which minimize average total cost and at the same time satisfy the $AOQL$ constraint.

The cost function (2.14) is minimized with non-linear programming methods in the MATLAB software to define the optimal values of the control parameters that satisfy the $AOQL$ constraint (2.15).

2.14.3. Optimal results

In table 2.7, we present the optimal cost of the proposed policy for different levels of the $AOQL$ restriction. From the obtained results, we can observe for the values of $AOQL_{max}$ from 0.1% to 3.4%, the $AOQL$ constraint is active. However, for all values of $AOQL_{max}$> 3.4%, the $AOQL$ constraint is inactive as the optimal solution obtained at $AOQL_{max}$=3.4% realizes the minimum possible cost (23013 $). Furthermore, it is evident that the total expected cost increases as the $AOQLmax$ decreases. While it remains the same for $AOQL_{max}$> 3.4%. Mainly because when $AOQL$ decreases, we want, a better quality of products so we should inspect more samples and dispose of more non-conforming items. Because of the expensive inspection and disposal cost, we will have more cost.

Table 2.7. Optimal cost related to the different value of AOQL

AOQL	Cost	s*	Q*	Z*	n*
0.1	23152	1000	2381	2401	172
0.5	23092	1000	2450	2389	168
1	23060	998	2468	2386	163
1.5	23042	996	2471	2385	159
1.8	23035	995	2472	2385	157
2.2	23027	994	2472	2385	155
3	23017	991	2487	2385	151
≥3.4	23013	990	2489	2385	150

2.14.4. Sensitivity analysis of AOQL

2.14.4.1. Effect of variation of Inspection Cost C_{insp} on n*

The effect of variation of inspection cost on n*can be observed from Figure 2.16. Two results can be clearly seen from the following figure.

1. As the customer quality requirements become more strict, then n* increases progressively. The reason behind this result is that more inspection inclined to more sampling lot and intends to eliminate more defectives items. So when AOQL increase, n* should be decreases

2. Secondly, as can be seen from figure 2.16, the indicator of n*, is higher for all values of $AOQLmax$, when the inspection cost is reduced to $\boldsymbol{C_{insp}}$=150, this is because, more inspection can be conducted at reducing $\boldsymbol{C_{insp}}$. However, when the inspection cost increases to Cins=250, we clearly observe that the n* indicator is always less than the previous case leading to conduct less inspection for any $AOQLmax$ value. This reduction in n* is because at increasing $\boldsymbol{C_{insp}}$, inspection activities are more penalized and thus less conducted.

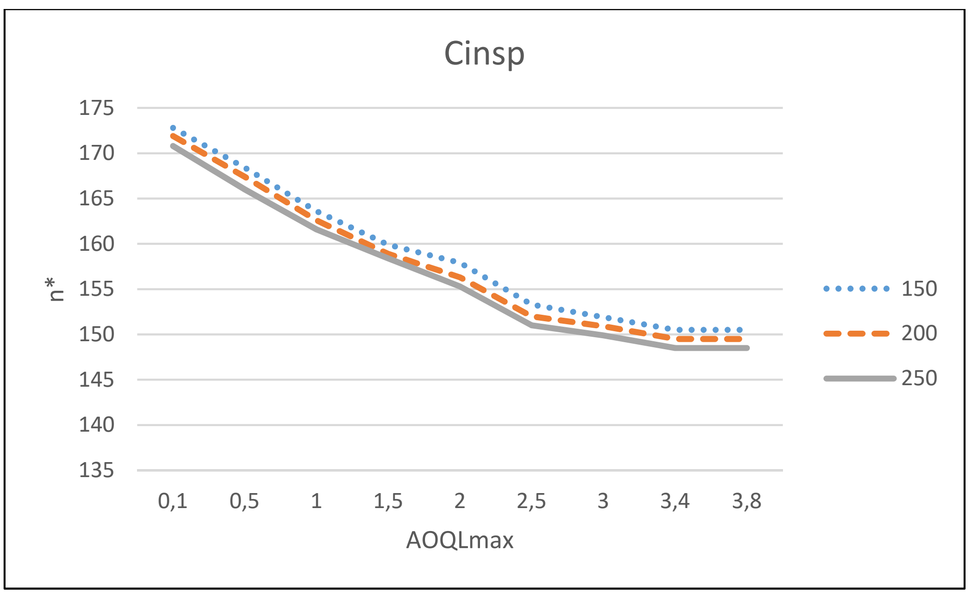


Figure 2.16. variation of Inspection cost on n*

2.14.4.2. Effect of variation of Finished products replacement cost C_{rep} on n*

The effect of variation of finished product replacement cost C_{rep} cost on n*can be observed from Figure 2.17. Two results can be clearly seen from the following figure.

1. Firstly, as can be seen from figure 2.17, the indicator of n*, is higher for all values of $AOQLmax$, when the finished products replacement cost is increased to C_{rep} = 1800, this is because; more inspection can be conducted at increasingC_{rep}. However, when the replacement cost decrease to C_{rep} =800, we clearly observe that the n* indicator is always less than the previous case leading to conduct less inspection for any $AOQLmax$ value. This reduction in n* is because at increasingC_{rep}, we need to increase the quality of the products, so we should inspect more lot, in this case n* will increase when C_{rep} increases.

2. Secondly, when we need better quality of finished products, then n* increases progressively. The reason behind this result is that more inspection inclined to more sampling lot and intends to eliminate more defectives items. So when AOQL increase, n* should be decreases.

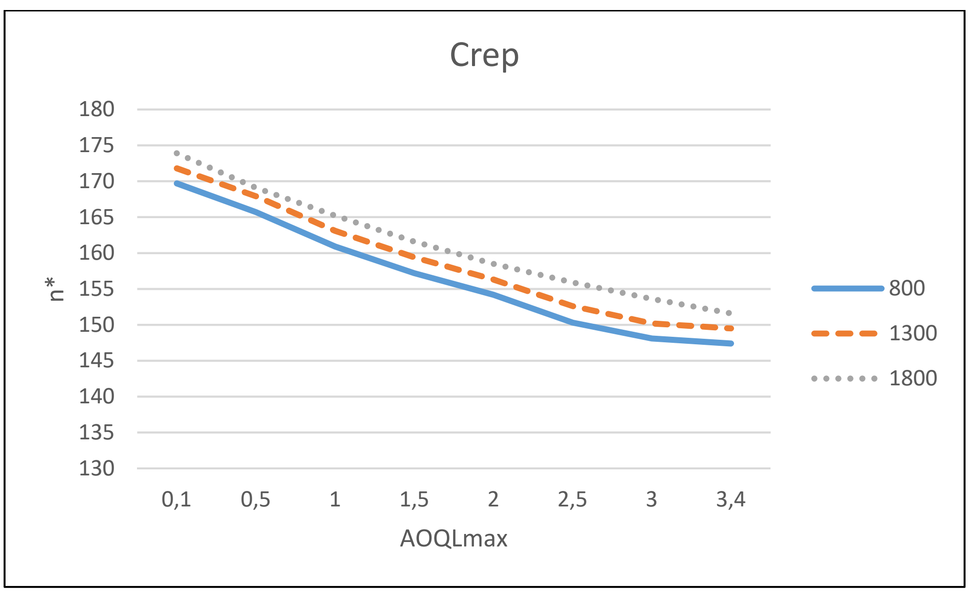


Figure 2.17. Effect of variation of finished products Replacement cost C_{rep} on n*

2.14.4.3. Effect of variation of returned products stock holding cost C_R^H on Q*

Two results can be observed from figure 2.18 which is indicating the effect of variation of returned product stock holding cost C_R^H on Q*.

1. As the customer quality requirements become less strict, n* decreases and less inspection inclined to less sampling lot, so the possibility of accepting lot will increases therefore then Q* increases progressively. So when AOQL increase, Q* should be increases.

2. Secondly, as can be seen from figure 2.18, the indicator of Q*, is higher for all values of $AOQLmax$, when the returned product holding cost is decreases to C_R^H= 2.5. However, when the returned products holding cost increases to C_R^H= 3.5, we clearly observe that the Q* indicator is always less than the previous case. Because when the c_R^H cost increases, we should try to decrease the amount of returned products in the stock, in this case Q* will decrease to reduce the stock level of returned products and avoid the extra cost.

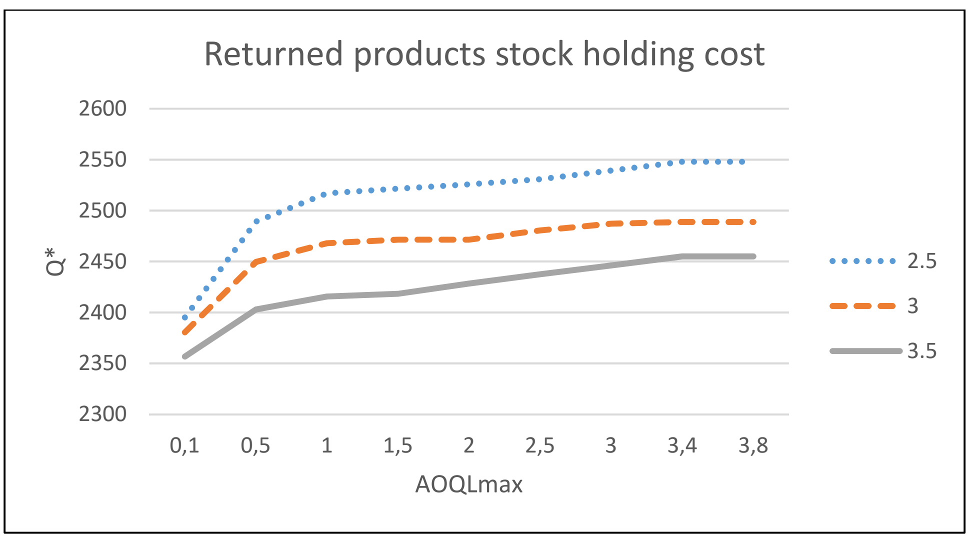


Figure 2.18. Effect of variation of returned products stock holding cost C_R^H on Q*

2.14.4.4. Effect of variation of return stock holding cost on s*

The effect of variation of return stock holding cost $\boldsymbol{C_R^H}$ cost on s*can be observed from Figure 2.19. Two results can be clearly seen from the following figure.

1. Firstly, as can be seen from figure 2.19, the indicator of s*, is higher for all values of $AOQLmax$, when the return stock holding cost is reduced to C_R^H= 2.5. Because when the c_R^H cost increases, we should try to decrease the amount of returned products in the stock, in this case we should order less frequently to have less quantity of returned products in the stock so s* will decrease. However, when the returned products holding cost increases to C_R^H= 3.5, we clearly observe that the s* indicator is always less than the previous case leading to conduct less inventory cost for any $AOQLmax$ value.
2. Secondly, as the customer quality requirements become less strict, then s* decrease progressively. The reason behind this result is that when the quality requirements by customers becomes less important we inspect less lot , so n* will decrease and the possibility of accepting lot will increases , in this case we should order less frequently to have less quantity of returned products in the stock to avoid extra inventory cost so s* will decrease. Therefore when AOQL increase, s* should be decreases.

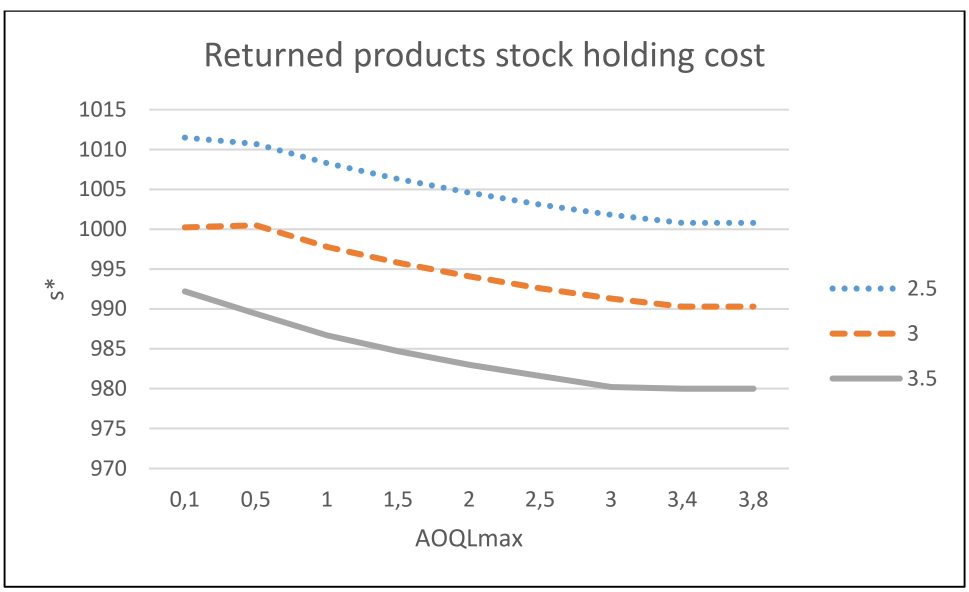


Figure 2.19. Effect of variation of returned products stock holding cost on s*

2.15. Conclusion

In this study, we have developed, in a stochastic dynamic context, an integrated production, replenishment, and quality inspection control policy to minimize the total cost of a closed-loop supply chain with an unreliable manufacturer and imperfect quality of returned products. Production, replenishment, and inspection decisions are all made at the manufacturer stage. When a lot of returned product is received, the manufacturer may conduct three different inspection policies for the receipt lot. A lot-by-lot acceptance sampling plan, %100 inspection, or the third possibility is to forward the returned products to the remanufacturing line without any inspection. Due to the variability of the inspection decisions, we have used a combined approach based on the simulation model and response surface methodology to optimize the control parameters of the three policies.

In this paper, a comparative study between the three inspection decisions has shown that a single sampling plan is more advantageous than the two other quality control policies (100% inspection and No inspection) in terms of the total cost. In reality, such a policy allows the decision-maker to decrease the total costs, depending on the entire supply chain.

Then we extended our work to when we have a constraint on the quality of the finished products by customer. We noticed, as the customer quality requirements become stricter, then the amount of sampling lot will increase progressively. We try to eliminate more non-conforming items, so more inspection inclined to more sampling lot and intends to eliminate more defectives items. Therefore, the total cost will increase.

The current work can be developed in different directions. One may consider other sampling policies, such as double and sequential sampling plans. Moreover, an alternative extension could be considering various acceptance number for the sampling lot and increase the degree of severity of the sampling lot with the optimization of the sampling plan parameters. Furthermore, we can consolidate our work with the presence of several suppliers where we can switch from one supplier to another based on our supply chain state.

CHAPTER 3

JOINT SUPPLIER SELECTION, PRODUCTION AND REPLENISHMENT CONTROL POLICIES OF AN UNRELIABLE HYBRID MANUFACTURING-REMANUFACTURING SYSTEM

3.1. Introduction

In the forward supply chain, there is no responsibility for returned products. However, the reverse supply chain is attempting to consider returned products in the most environmentally friendly manner. The improvement of the supply chains leads to a coordinated new approach that investigates both forward and reverses supply chains simultaneously (Govindan K., 2017) . Based on the variation of the market and the released environmental legislation, an expanding number of manufacturing companies are undertaking remanufacturing activities into their manufacturing systems (Atasu, 2008).

Remanufacturing has emerged as an important research field in recent years, which focuses on value-added recovery. This has been used in several different areas, such as vehicles, telecommunications, electrical devices, machinery, etc. Besides economic profitability, there is legislation that assigns liability to the producers for the returned products (Zanoni S., 2006).

In the advanced manufacturing market, hybrid manufacturing-remanufacturing systems (HMRS) have become an important subject (Esmaeilian B, 2016).Indeed, the remanufacturing is considered to recover the economic and ecological benefit as much as possible due to the extended life of the product and decreased energy and ultimate amounts of waste (Lund, 2003). The most challenging part in HMRS is deciding to dedicate the manufacturing and remanufacturing operations in a common facility or separated facilities (Teunter, 2008).In this work, we consider both manufacturing and remanufacturing operations in a common facility. This will reduce remanufacturing start-up costs (Teunter, 2008).

In this work, we propose a dynamic supplier selection policy coordinated by production and replenishment in reverse logistics. Through an integrated supply chain viewpoint, the decision-maker must not be limited to a single possible supplier to better address supply volatility. Because when the system is encountering different uncertain states, the supplier who was the best in a certain condition, may not necessarily be the best in other conditions. Therefore, the selection decision needs to take into account a pool of suppliers and decision-maker should select the best supplier according to the whole system state and based on the best offer of potential suppliers.

To bring our problem closer to reality, we allocate a stochastic amount to the quality of the suppliers. It could result from an inadequate quality control procedure or even damage that may be occurring through transportation (Hlioui, 2017). At any given time, the decision-maker will select the supplier having the best offering, depending on the supplier parameters and the system state. When faced to low quality of the final products, it is recommended to order from the supplier with the highest quality. Otherwise, if the quality of the final products is comfortable, it will be better to order from the supplier with the lowest cost.

To the best of the authors' knowledge, no existing work integrates all these aspects in a common framework. All decisions are assumed to occur at the manufacturer stage, and made by a single decision-maker who aims to minimize the total cost.

The rest of this paper is organized as follows. Section 2 presents a brief overview of previous works related to the problem under study. Section 3 presents the notation and problem statement. Section 4 reports the problem formulation. Section 5 reports the control policy. Section 6 illustrates the solution approach. The simulation model is presented in section 7. The experimental design and Response Surface Methodology presented in section 8. A numerical example is delivered in section 9 to outline the usefulness of the proposed control policy. Section 10 reports the experimental results. Sensitivity analyses are discussed in section 11. In section 12, we illustrate an extensive comparative study between different selection policies. In section 13, an extensive study is discussed. Finally, the conclusion is given in section 14.

3.2. Literature review

The works on the closed-loop supply chain have become vast and multifaceted over the past decades and there is much attention to remanufacturing in response to the growing awareness of environmental issues. (Govindan, 2017) investigated these works in detail. However, this section mainly concentrates on those closed-loop supply chains that consider both manufacturing and remanufacturing in the common facility.

To reduce start-up costs, we allocate both manufacturing and remanufacturing operations in a common facility. This attitude can be observed in many industries to increase productivity and reduce costs. (Teunter, 2008) noticed that when we devoted production lines to manufacturing and remanufacturing, it may cause significant cost saving. Most of the works in the literature concentrated on the systems in which manufacturing and remanufacturing are dedicated to the separated facilities. (Kenné, 2012) developed optimal manufacturing and remanufacturing control policy, which minimize the total cost. (Guo, 2015) concluded that in the hybrid manufacturing-remanufacturing system, remanufacturing costs rely on the quality level of the raw material. (Assid, 2019) elaborated a policy in a hybrid manufacturing-remanufacturing which the manufacturer should decide to manufacture new products or remanufacture returned products to gain cost saving.

In the forward supply chain, there is no responsibility for returned products. However, the reverse supply chain is attempting to consider returned products in the most environmentally friendly manner. The improvement of the supply chains leads to a coordinated new approach that investigates both forward and reverses supply chains simultaneously (Govindan K., 2017). Some industries have been remanufacturing since the 1920s. Research on remanufacturing has been increased since the early 1980s (Lund, 1983), with most of the published research appearing since 1990 and focused on operational or engineering issues (Daniel, 2019). Based on the variation of the market and the released environmental legislation, an expanding number of manufacturing companies are considering remanufacturing activities in their manufacturing systems (Atasu, 2008). (Van Der Laan, 1997) extended the well-known Push and Pull control policy to coordinate production, remanufacturing and disposal operations. (Teunter, 2008) showed that dedicated production lines for manufacturing and remanufacturing can lead to significant reductions in holding costs and increased scheduling flexibility. In the same sense, (Francas, 2009) studied a multi-product network design problem and conclude that, it is more advantageous to configure a single flexible production site if all the products are destined for the same market. The author's work investigated capacity planning and the advantages of the different network configurations for remanufacturing. (Berthaut, 2009) determined the optimal procurement and production of a remanufacturing system. (Flapper, 2014)studied the optimal scheduling for HMRS with negligible setup times and costs using an approach based on the queueing theory. They proposed a production schedule that minimizes the average discounted long-term cost. (Guo, 2015) investigated the optimal production policy for the hybrid manufacturing-remanufacturing system when the returns rate, the buyback cost, and the remanufacturing cost depend on the quality level. (Polotski V, 2015) presented an optimal control model for a hybrid manufacturing-remanufacturing system. (Fang, 2017) used five scenarios based on the production capacity and market demand to find the optimal operation strategy maximizing the total profit for a hybrid system with a substitutional relationship between new and remanufactured products. (Kilic, 2018) addressed the stochastic economic lot-sizing problems and proposed two heuristic policies to control manufacturing and remanufacturing operations while integrating service level constraints.

For a decision-maker, one of the most important decisions to make is choosing the best source of suppliers to provide raw material or returned products for the production process. An effective supplier assessment and selection process is necessary to improve a company's efficiency and its supply chains (Perona, 2004). Therefore, supplier selection process and supplier evaluation is a critical issue to be considered in supply chain management. (Wu D., 2008) investigated three types of supplier selection methodologies in their work that contains concurrent constrained programming (CCP), data envelopment analysis (DEA) and multi-objective programming (MOP) models. (Wu D., 2008) worked on a complex multi-objective programming model for selecting suppliers when considering risk factors. (Chen, 2010) considered supplier characteristics by price, service and total cost under the disturbance of demand. The model they proposed is stochastic to determine the optimal production control policy and the selection method for suppliers. They worked on a stochastic method to decide the optimum quality control policy and the selection of suppliers in their supply chain. (Choudhary, 2013) developed a model that considered carrier selection, supplier selection, and inventory decisions, at the same time in a dynamic model. (Naimi Sadigh, 2013) proposed a model combing supplier selection and production and distributor location together. (Gorji, 2014) integrated order allocation, supplier selection, and transport decisions via a supply chain with one retailer and a pool of suppliers. They applied a %100 inspection policy for the received lot in their work.

We considered supplier selection for providing returned products in the reverse logistics in our work. In the following, we will mention the works, which integrated supplier selection in reverse logistics. (Ali, 2016) investigated a closed-loop supply chain, which includes manufacturer, remanufacturer, and third-party logistics provider, which collects used products. They considered multiple suppliers in their work and devoted a certain supplier for collecting each product. (Zouadi, 2018) proposed a lot-sizing problem in the manufacturing-remanufacturing system. In their work, they consider a returned product collection phase from customers that has deterministic returns quantities. They put some emission constraints for manufacturing, remanufacturing and transportation activities. (Amin, 2012) considered a closed-loop supply chain that includes manufacturer, disassembly, refurbishing, and disposal sites. In their work, they considered supplier selection in the reverse logistics that were categorized based on purchasing cost and timely delivery.

3.3. Notation and Problem Statement

3.3.1. Notation

The notations used in this work are defined as follows:

θ_i: Raw material ith order instant (time)

AOQ_{FP} : The Average Outgoing Quality of finished products

C_R^H : Returned products stock holding cost ($/time unit/product)

C_F^H : Finished products stock holding cost ($/time unit/product)

C_B^H : Finished products stock backlog cost ($/time unit/product)

C_{rep}^{F}: Non-conforming finished product replacement cost ($/product)

C_{Man}: Manufacturing operations cost ($/product)

C_{rem}S1: Remanufacturing operations cost when we use returned products of supplier 01 to produce ($/product)

C_{rem}S2: Remanufacturing operations cost when we use returned products of supplier 02 to produce ($/product)

dem : Finished product demand rate (units/time)

$p1$: Proportion of non-conforming items in the received lot related to supplier01

$p2$: Proportion of non-conforming items in the received lot related to supplier02

AOQ_R: Proportion of non-conforming items produced with remanufacturing operations

AOQ_m: Proportion of non-conforming items produced with manufacturing operations

Q: Returned products lot size

U_{man}^{max}: Maximum manufacturing production rate

$U_{rem}^{max}S1$: Maximum remanufacturing production rate when use returned products of supplier 01 to produce

$U_{rem}^{max}S2$: Maximum remanufacturing production rate when use returned products of supplier 02 to produce

U_{man}(t): Manufacturing rate at time t (product/time unit)

U_{rem}(t): Remanufacturing rate at time t (product/time unit)

X_F(t): Inventory level of finished products at time t (product)

X_R(t): Inventory level of returned products at time t (product)

Z_F : The Finished product hedging level for the production policy

S_R : Remanufacturing mode of machine

3.3.2. System description

The structure of the considered hybrid manufacturing-remanufacturing system is presented in Figure 3.1. This system consists of one facility that can either manufacture new products (manufacturing mode) or remanufacture returned products (remanufacturing mode). Moreover, is subjected to random failures and repairs.

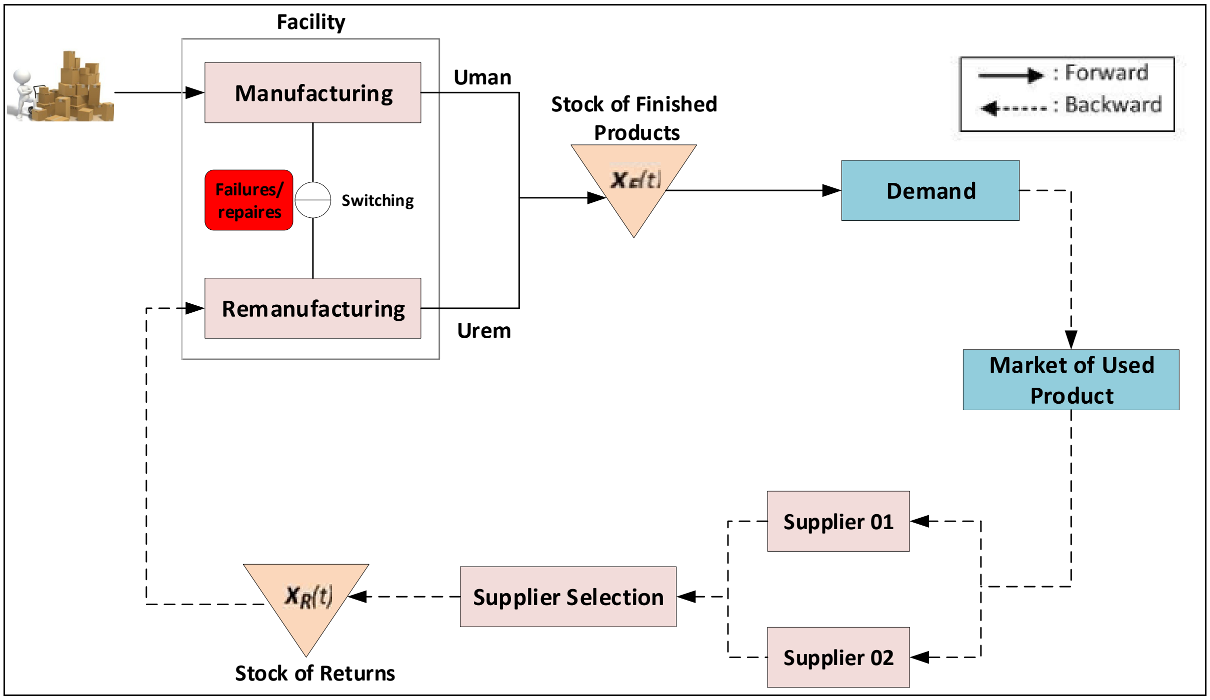


Figure 3.1. System Structure

Two stocks are considered in this work. The first one is related to the finished products that can be fulfilled with manufacturing or remanufacturing activities. The second stock belongs to the returned products. The main assumptions considered in this work are:

- The quality of products produced in the manufacturing mode is the same as the ones produced in the remanufacturing mode and distributed as new products to meet customer demand;
- The customer demand rate is constant;
- To reduce the complexity of the considered system we assumed the switching time from manufacturing to remanufacturing modes and vice versa is negligible;
- The raw material for manufacturing operation is always available;
- Manufacturing operation always produce products with perfect quality;
- The replenishment delay for ordering returned products from suppliers is negligible
- Production cost in remanufacturing mode is less than production cost in manufacturing mode;

- The maximum remanufacturing rate when we are using the returned products of the supplier with better quality is greater than the supplier with the worst quality;
- All the non-conforming products sold to the customer will be detected by customers and returned to the manufacturer to replace with good ones, which include replacement cost (C_{rep}^{F}).

At each order for remanufacturing operation, the manufacturer receives the returned products from a selected supplier in a lot of size Q. Each supplier is characterized by two parameters, a deterministic returned product purchasing cost, and a stochastic proportion of non-conforming items that follows a general probability distribution.

Finished product stock can be fulfilled with the products, which are produced with manufacturing or remanufacturing operations to respond to the constant demand rate of customers. Raw materials are transformed at the manufacturing rate U_{man}(t) to the finished products. The manufacturing rate can take a value between zero and U_{man}^{max}, where U_{man}^{max} denotes the maximum manufacturing rate. Returned products are transformed at the remanufacturing rate U_{rem}(t) to the finished product. The remanufacturing rate can take a value between zero and $U_{rem}^{max}S1$, if the returned products of supplier01 is used for remanufacturing operations or, zero to $U_{rem}^{max}S2$ if the returned products of the supplier 02 is used for remanufacturing operations.

The objective of this work is to determine the effective joint production and supply control policy for the integrated hybrid manufacturing-remanufacturing system, replenishment and supplier selection that minimizes the incurred total cost.

3.4. Problem formulation

The state of the hybrid manufacturing-remanufacturing system can be described by three components at time t as follows:

1. A discrete-state stochastic process (α (t), t ≥0), which describes the operational mode of the facility. (α(t) =1), if the facility is available for production at time t and (α(t)=0), if the facility is not available and operational;
2. A continuous part(X_F), which describes the cumulative surplus of the finished product stock. This part can be positive for an inventory or negative for a backlog;

3. A continuous part(X_R), which describes the cumulative surplus level of the returned product stock. This part can be positive for inventory or zero;

Thus, the system dynamics may be described by the state variables (X(t), α(t)). The following equations represent the temporal evolution of the system:

$$\dot{X}_F = U_{man}(t) + U_{rem}(t) - \frac{dem}{1-AOQ_{FP}(t)} \qquad X_F(0)=X_F^0 \qquad (3.1)$$

$$\begin{cases} \dot{X}_R = -U_{rem}(t) \\ X_R((\theta_i)^+) = \left(X_R((\theta_i)^-)\right) + Q \end{cases} \qquad X_R(0)= X_R^0 \qquad (3.2)$$

With X_F^0 and X_R^0 respectively define the initial stock levels of finished products and returns. Two formulas are used to express the inventory level of returned products (X_R) through a piecewise continuous part. This is particularly useful because X_R faces a continuous downstream remanufacturing process and an impulsive upstream supply when a Q lot of returned products is received at the instant θ_i. This order was launched at θ_i. $(\theta_i)^+$ and $(\theta_i)^-$ represent the positive and negative boundaries of the ith receipt instant respectively.

AOQ_{FP} denotes the Average Outgoing Quality of finished products. That is showing the amount of non-conforming products in the finished products stock.

$$AOQ_{FP}(t)= \frac{(p1* I(S_R=1)*U_{rem}(t))+(p2* I(S_R=0)*U_{rem}(t))+ p^m* U_{man}(t))}{(U_{rem}(t)+ U_{man}(t))} \qquad (3.3)$$

Where *I*(w)=1 if w is true while I(w)= 0 if not, $p1$ indicate the proportion of non-conforming items produced with remanufacturing operations from supplier *01*, $p2$ indicate the proportion of non-conforming items produced with remanufacturing operations from supplier *02* and p^m is showing the proportion of non-conforming items produced with manufacturing operations.

Knowing that the facility cannot be in two different production modes at the same time, the following equations must be valid:

$$U_{man}(t).\ U_{rem}(t) = 0 \qquad (3.4)$$

The set of admissible control policies *Γ*(.), depends on the stochastic process α(t) and S_R that is indicating the remanufacturing mode with the selected supplier is given by:

$$S_R \begin{cases} 1 & \text{if the system is in remanufacturing mode and returned product of supplier 01 is used} \\ 0 & \text{if the system is in remanufacturing mode and returned product of supplier 02 is used} \end{cases} \quad (3.5)$$

$$\Gamma(\alpha) = \begin{cases} 0 \leq U_{man}(\mathrm{t}) \leq U_{man}^{max} . I(\alpha(\mathrm{t}) = 1) \\ 0 \leq U_{rem}(\mathrm{t}) \leq U_{rem}^{max} \mathrm{S1}.\ I(\alpha(\mathrm{t}) = 1).\ I(S_R = 1) \\ 0 \leq U_{rem}(\mathrm{t}) \leq U_{rem}^{max} \mathrm{S2}.\ I(\alpha(\mathrm{t}) = 1). I(S_R = 0) \\ U_{man}(\mathrm{t}). U_{rem}(\mathrm{t}) = 0 \end{cases} \quad (3.6)$$

Where I(w)=1 if w is true while I(w)= 0 if not.

The supply chain system under consideration in this study is subject to random availability of the production system. A combination of simulation, design of experiments and response surface methodology is used to conduct an in- depth comparative study of the considered control policies. This choice is due to its accuracy and strength while addressing such complex problems. It uses simulation as a powerful tool to describe the dynamics of the system and stochastic aspects. The optimization of the control parameters and the associated total cost, obtained through simulation, is conducted by design of experiments and the response surface methodology. By comparison, optimizing these control parameters for further comparative study would be too time-consuming to be applicable at the operational level when applying numerical methods, the structure of the control policies are presented in the next section.

3.5. Structure of control policies

The main purpose of this section is to illustrate the structure of the control policies for the described system. Moreover, we will compare our mentioned policy with the other policies. Therefore, in this work our main objective is to determine the best policy, in order to minimize the total manufacturing, remanufacturing, returned stock holding, finished products holding/backlog cost, and the defective finished product replacement cost. We are going to model and describe six policies as the following:

1. In the first model, only one mode of production has been considered which is manufacturing. There is no remanufacturing in this model;

2. The second model considers only the remanufacturing mode of the machine when we are using the returned products, which is provided by supplier 01 to produce. There is no manufacturing in this model;
3. The third model considers only the remanufacturing mode of the machine when we are using the returned products, which is provided by supplier 02 to produce. There is no manufacturing in this model;
4. The fourth model considered supplier 01 as a permanent supplier for providing returned products when we have both manufacturing and remanufacturing modes to produce;
5. The fifth model considered supplier 02 as a permanent supplier for providing returned products when we have both manufacturing and remanufacturing modes to produce;
6. This model, which is our proposed system, considered both suppliers as potential and both modes of machines (manufacturing and remanufacturing) are considered in the production stage.

3.5.1. Production rate policy

The production policy is illustrated in the table 3.1 for each policy separately. The production policy that is considered in this work are based on the findings of Hajji et al. (2011) and Bouslah et al. (2013). Hajji et al. (2011) showed that the optimal control policy for a joint production and replenishment problem is defined by a Hedging Point Policy (HPP). Based on Hajji et al. (2011) work, the final product inventory should be maintained an extra inventory to be able to meet demand (dem) when the production system is unavailable due to machine failures. Bouslah et al. (2013) by considering an imperfect production system have shown that a "Modified Hedging Point Policy" (MHPP) controls their production policy. In our work, by considering the effect of average total quality of the finished products AOQ_{FP} on the real demand rate, a modified HPP may be more appropriate to illustrate our production policy.

Table 3.1. Considered control policies

Control Policy	Production	Procurement
#1	$U_{man}: \begin{cases} U_{man}^{max} & X_F < Z_F \\ dem & X_F = Z_F \\ 0 & \text{Otherwise} \end{cases}$ (3.7)	-
#2	$U_{rem}: \begin{cases} U_{rem}^{max} S1 & X_F < Z_F \\ \frac{dem}{1-AOQ_{FP}} & X_F = Z_F \\ 0 & \text{Otherwise} \end{cases}$ (3.8)	$\begin{cases} Q_{S1} & X_R = 0 \\ 0 & Otherwise \end{cases}$ (3.13)
#3	$U_{rem}: \begin{cases} U_{rem}^{max} S2 & X_F < Z_F \\ \frac{dem}{1-AOQ_{FP}} & X_F = Z_F \\ 0 & \text{Otherwise} \end{cases}$ (3.9)	$\begin{cases} Q_{S2} & X_R = 0 \\ 0 & ise \end{cases}$ (3.14)
#4	$U_{man}: \begin{cases} U_{man}^{max} & X_F < Z_F \\ \frac{dem}{1-AOQ_{FP}} & X_F = Z_F \\ 0 & \text{Otherwise} \end{cases}$ (3.10) $U_{rem}: \begin{cases} U_{rem}^{max} S1 & X_F < Z_F \\ \frac{dem}{1-AOQ_{FP}} & X_F = Z_F \\ 0 & \text{Otherwise} \end{cases}$	$\begin{cases} Q_{S1} & X_R = 0 \\ 0 & Otherwise \end{cases}$ (3.15)
#5	$U_{man}: \begin{cases} U_{man}^{max} & X_F < Z_F \\ \frac{dem}{1-AOQ_{FP}} & X_F = Z_F \\ 0 & \text{Otherwise} \end{cases}$ (3.11) $U_{rem}: \begin{cases} U_{rem}^{max} S2 & X_F < Z_F \\ \frac{dem}{1-AOQ_{FP}} & X_F = Z_F \\ 0 & \text{Otherwise} \end{cases}$	$\begin{cases} Q_{S2} & X_R = 0 \\ 0 & Otherwise \end{cases}$ (3.16)
#6	$U_{man}: \begin{cases} U_{man}^{max} & X_F < Z_F \\ \frac{dem}{1-AOQ_{FP}} & X_F = Z_F \\ 0 & \text{Otherwise} \end{cases}$ (3.12) $U_{rem}: \begin{cases} U_{rem}^{max} S1.\mathrm{I}(S_R = 1) & X_F < Z_F \\ U_{rem}^{max} S2.\mathrm{I}(S_R = 0) & X_F < Z_F \\ \frac{dem}{1-AOQ_{FP}}.\mathrm{I}(S_R = 1) & X_F = Z_F \\ \frac{dem}{1-AOQ_{FP}}.\mathrm{I}(S_R = 0) & X_F = Z_F \\ 0 & \text{Otherwise} \end{cases}$	$\begin{cases} Q & X_R = 0 \\ 0 & Otherwise \end{cases}$ (3.17) $\begin{cases} Min(\%p1, \%p2) & AOQ_{FP} \geq AOQ03 \\ Min(c1, c2) & Otherwise \end{cases}$

Where U_{man}^{max} is the maximum manufacturing production rate, $U_{rem}^{max}S1$ is the maximum remanufacturing production rate when the returned products of supplier 01 is used to produce, $U_{rem}^{max}S2$ is the maximum remanufacturing production rate when the returned products of supplier 02 is used to produce. AOQ_{FP} is the average outgoing quality of finished product, Z_F denotes the Finished product hedging level for the production policy. Q_{S1} is returned products lot size, when we are ordering from supplier 01. $Q_{S2}$is returned products lot size, when we are ordering from supplier 02.

3.5.2. Switching policy

In Policy #1, #2, and #3, there is only one mode of the machine; therefore, it does not need to consider switching between modes of the machine in these policies. However, in policy #4, #5, and #6, we consider both modes of the machine, which is manufacturing and remanufacturing. In order to present the system production modes in these policies (manufacturing or remanufacturing), we identify two levels for the Average Outgoing Quality of finished product (AOQ_{FP}) which is presented in Figure 3.2. These levels are an indicator for switching from manufacturing mode to remanufacturing mode or vice versa. AOQ01 is believed to be larger than AOQ02. When the AOQ_{FP} reached the first level that is AOQ01(Fig.3.2. point①), it means the average quality of the finished products is not good enough and we need to improve the quality of the finished products, so we should switch from remanufacturing mode to manufacturing mode to have a better quality of the finished products. In this situation when we start producing with manufacturing mode that is supposed to produce only good quality, the AOQ_{FP} will constantly decrease. When the average quality of finished product reached the second level, which is AOQ02 (Fig.3.2. point ②), it means we have good enough quality of finished products in our stock, so we can turn into the less costly remanufacturing mode.

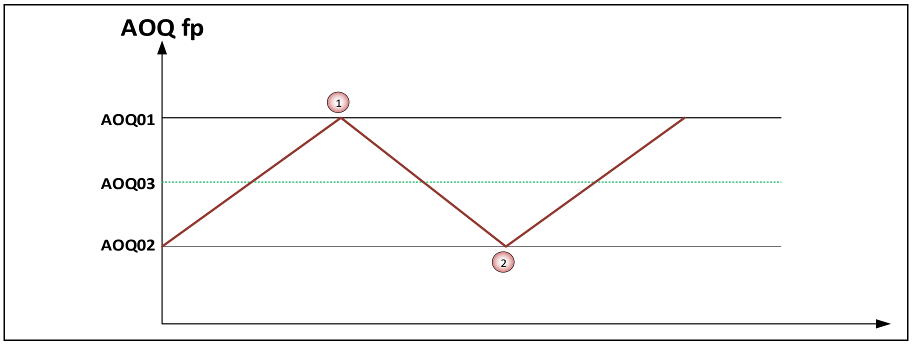


Figure 3.2 Switching policy

3.5.3. Procurement policy

The procurement policy is also illustrated in table 3.1. As explained earlier, we believed the raw materials are always available for manufacturing activities. However, we should order returned products for remanufacturing activities. Therefore, in policy #1, which contains only the manufacturing mode of the machine, does not need to order raw material. For policy #2, #3, #4, #5, and #6, when the quantity of returned products in the return stock approaches zero, we need to order a lot of Q from the selected supplier. In policy #2 and #4, we consider supplier 01 as the permanent supplier, therefore when the quantity of returned products in the return stock approaches zero, we need to order a lot of Q from supplier 01. In policy #3 and #5, we consider supplier 02 as the permanent supplier, therefore when the quantity of returned products in the return stock approaches zero, we need to order a lot of Q from supplier 02. In policy #6, which is our proposed policy, we considered two suppliers that characterized by different qualities and different prices, the supplier with better quality has a higher cost and the supplier with the worst quality has a lower cost. In this policy, the average quality of final products is an important indicator in helping the decision-maker selects the best supplier. Let AOQ03 denote the hedging level for the quality of finished products.

- If the average quality of the finished product is above threshold AOQ03, it means we do not have good quality products in the stock of finished products; the decision-maker needs to focus on the supplier that offers the better quality.
- If the average quality of the finished product is low (under the threshold AOQ03), the decision-maker considers that there is a comfortable quality of final products. Then, it

is better to reduce the total purchasing costs, so the decision-maker should order from suppliers that cost less for us. Figure 3.3 is presenting the supplier selection process.

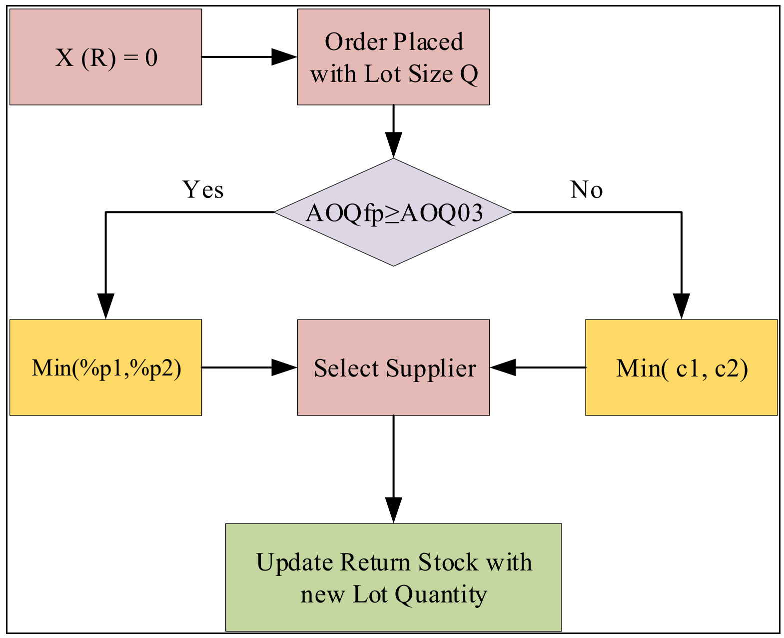


Figure 3.3 Supplier Selection process in our proposed policy

3.6. Solution approach

A simulation-based optimization method is adopted in this study. It is a combination of simulation modeling, experimental design and response surface methodology. The fundamental phases of the proposed control approach are according to the following steps that are also presented in Figure 3.4:

1. A simulation model is developed to describe the dynamics of the simultaneous production planning and replenishment problem by considering the control policy;
2. An experimental design is developed in order to distinguish the effects of the main factors, their quadratic effects and their interactions on the response (the incurred cost);
3. The Response Surface Methodology (RSM) is used to define the relationship between the response (incurred cost) and the main significant factors and/or interactions. In

this work, the optimal values of the control policy parameters, called (Q*, Z*, AOQ01*, AOQ02*, AOQ03*) and the optimal cost value are determined.

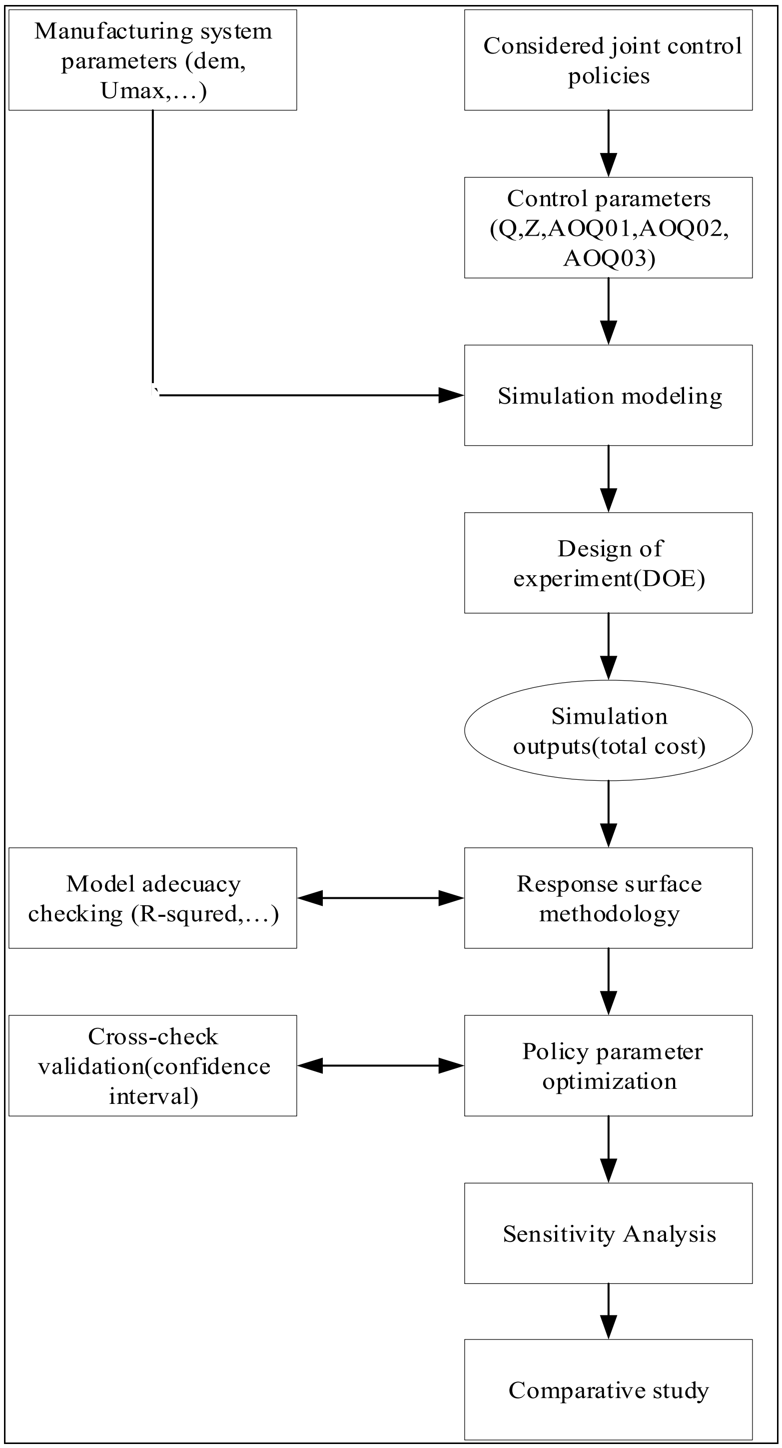


Figure 3.4 Main steps of proposed control approach

3.7. Simulation model

To illustrate the dynamic behavior of the considered supply chain and decision process, six combined discrete/continuous models related to the mentioned six policies were developed using the SIMAN simulation language (Pegden, 1995). The models were developed by ARENA simulation software. Using such a combined approach allows a reduction of the execution time and offers more flexibility to integrate the continuous tracking of system parameters (Lavoie, 2010).

Figure 3.5 presents the production process of our proposed policy depends on the machine mode (Fig.3.5.a), the inventory level of the finished products $X_F(.)$ (Fig.3.5.b), the Average Outgoing Quality of finished product AOQ_{FP} (Fig.3.5.c), the Facility's state α (.) (Fig.3.5.d), and the availability of stored returns (Fig.3.5.e). This is determined by the variance of both manufacturing and remanufacturing rates, recognizing that at the same time the production facility cannot be in two different production modes. As shown by point ①.a, the manufacturing rate is zero while the remanufacturing rate is at the maximum rate (U_{rem}^{max}S1=250 products / time unit) while we are ordering from Supplier01. Since the inventory level of finished products (X_F) is less than threshold Level Z_F(point ②.b) and average outgoing quality of the finished product is at level 2 (AOQ02) (point ⑤.c), machine mode should be in remanufacturing mode with the maximum rate (point ①.a). As soon as the stock of finished products reached to threshold level Z_F (point ③.b), the remanufacturing rate will decrease to demand rate (point ④.a). Thanks to the availability of returns in stock (point ⑥.e), as soon as the average quality of finished product reached the AOQ01 (point ⑦.c), we should switch to manufacturing mode (point ⑧.a), because the level of finished product is equal to Z_F(point ⑨.b). The manufacturing rate will be at demand rate (point ⑧.a), the production facility will be unavailable duo to failure (point ⑩.d); production should be stopped with both modes (point ⑪.a). After repairing, manufacturing activities will be continued at maximum rate (point ⑫.a) because the level of finished product is less than threshold level (point ⑬.b). When the level of finished product reached Z_F(point ⑭.b). In addition, the average quality of the finished products reached the

AOQ02 (point ⑰.c) so we should switch to remanufacturing mode with demand rate (point ⑮.a). When the amount of return stock reaches zero we order new lot with negligible replenishment delay (point ⑯.e). At (point. ⑱c) the average quality of the finished product is low (under the threshold AOQ03), so the decision-maker considers that there is a comfortable quality of final products. Then, it is better to reduce the total purchasing costs, so the decision-maker should order from suppliers that cost less for us.

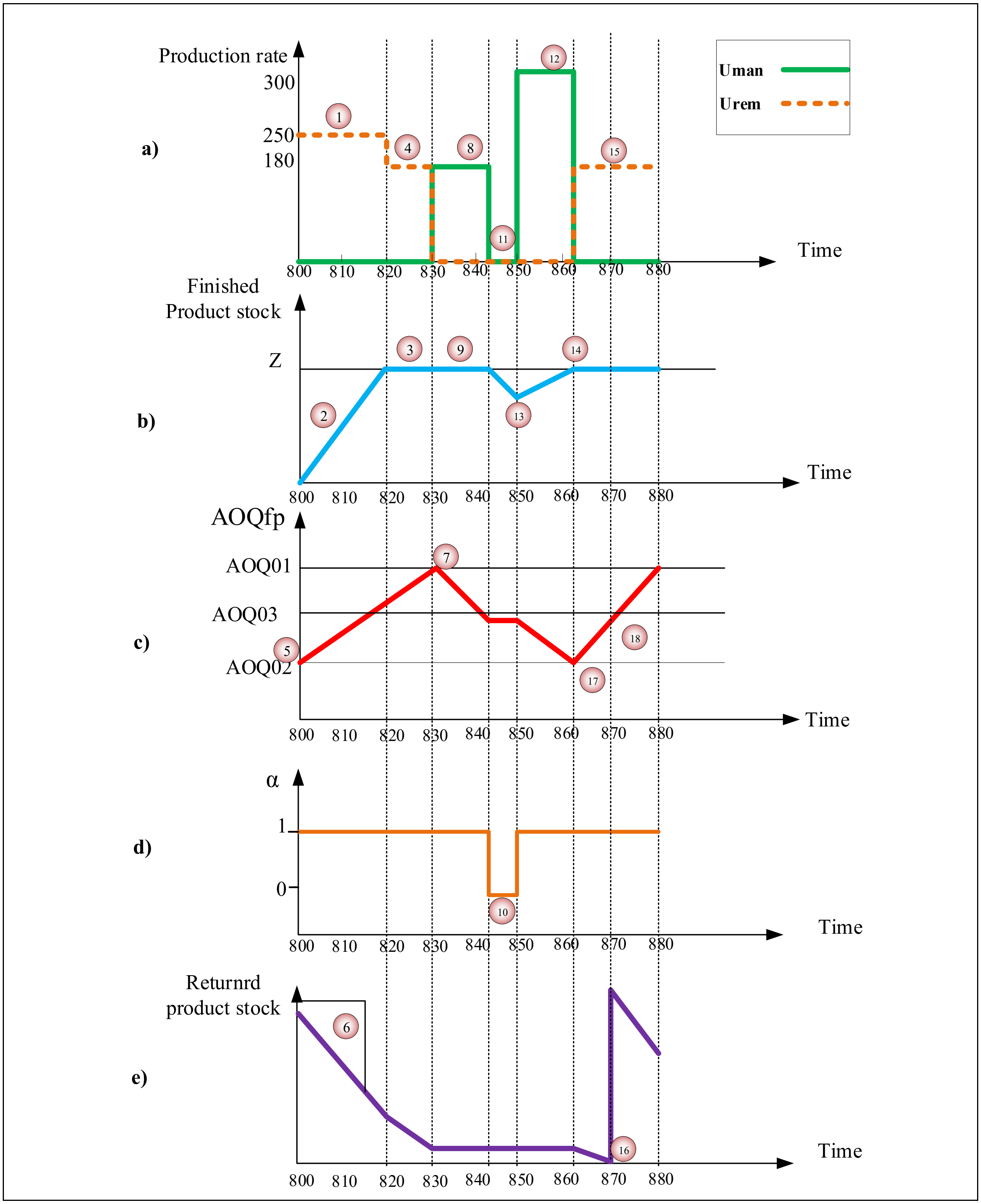


Figure 3.5 Dynamic of operation during the simulation run

3.8. Experimental design and Response Surface Methodology

The purpose of this section is first, find out if the input parameters that are (Q, Z, AOQ01, AOQ02, AOQ03) affect the response (the cost) or not and develop a regression equation. Secondly, the optimal parameter values of the six mentioned policies and the optimal expected cost are distinguished. Thirdly, a sensitivity analysis is applied to show the robustness of the selected policy and highlight important features.

3.9. Numerical examples

In this section, firstly a numerical example is conducted to indicate the experimental approach and the provided control policies. Then, we conduct a sensitivity analysis to highlight the robustness of our approach. For this purpose, we considered two suppliers. The cost, production and supplier parameters are presented in Table 3.2, 3.3, and 3.4, respectively. In this example, 'MM' represents the integrated control policy where only manufacturing mode is used to produce (Policy#1). 'RM-SU01' represents the integrated control policy where only remanufacturing mode is used to produce, and we used returned products of supplier 01 for the remanufacturing operations (Policy#2). 'RM-SU02' represents the integrated control policy where only remanufacturing mode is used to produce and we used returned products of supplier 02 for the remanufacturing operations (Policy#3). 'SU(01)' represents the integrated control policy where only supplier 1 is selected and both manufacturing and remanufacturing operations has been considered (Policy#4). 'SU(02)' represents the integrated control policy where only supplier 2 is selected and both manufacturing and remanufacturing operations has been considered (Policy#5). SS(1,2) represents the policy where both suppliers 1 and 2 are considered using the dynamic supplier selection policy and both manufacturing and remanufacturing operation have been considered (Policy#6).

Table 3.2. Cost Parameters

Parameters	c_R^H	c_F^H	c_B^H	c_{Rep}^F	c_{man}	c_{rem}S1	c_{rem}S2
Values	7.8	7.8	220	800	300	220	240

Table 3.3 Production parameters

Parameters	U_{man}^{max}	U_{rem}^{max}S1	U_{rem}^{max}S2	dem	TTF	TTR
Values	300	250	280	180	LOGN(95,6)	LOGN(10,5)

Table 3.4 Supplier parameters

Parameter	%p	C
Supplier 01	UNIF (8%, 8.9%)	0.5
Supplier 02	UNIF (0.5%, 2.5%)	1.5

3.10 Reduction of a control parameter

The true usefulness of our simulation-optimization endeavor is illustrated with a numerical example. We note that we can simplify the procedure to determine the optimal value of the control parameters (Q, Z, AOQ01, AOQ02, AOQ03). According to the following experiment we concluded, the AOQ03 optimal value is very close to the average of AOQ01 and AOQ02. We used a statistical software application ‘STATGRAPHICS ‘to statistical analysis of the simulated data. Based on statistical analysis, the second-order models of the total cost for is given by:

Cost = 572502. - 54.1071.Z - 109.33.Q - 4.54575E6.AOQ01 - 3.02289E6.AOQ03 - 2.81685E6.AOQ02 + 0.00570842. Z^2 - 0.00161459.Z.Q + 203.535.Z.AOQ01 + 126.89.Z.AOQ03 + 320.755.Z.AOQ02 + 0.0373687. Q^2 - 558.73.Q.AOQ01 - 262.013.Q.AOQ03 + 214.554.Q.AOQ02 + 2.95965E7. . $AOQ01^2$ + 1.16969E7.AOQ01.AOQ03 + 1.66246E7.AOQ01.AOQ02 + 2.40482E7. $AOQ03^2$+ 8.32448E6.AOQ03.AOQ02 + 3.96725E6. $AOQ02^2$ (3.18)

Fig. 3.6 is showing the scheme of the cost response surfaces on different two-dimensional plan.

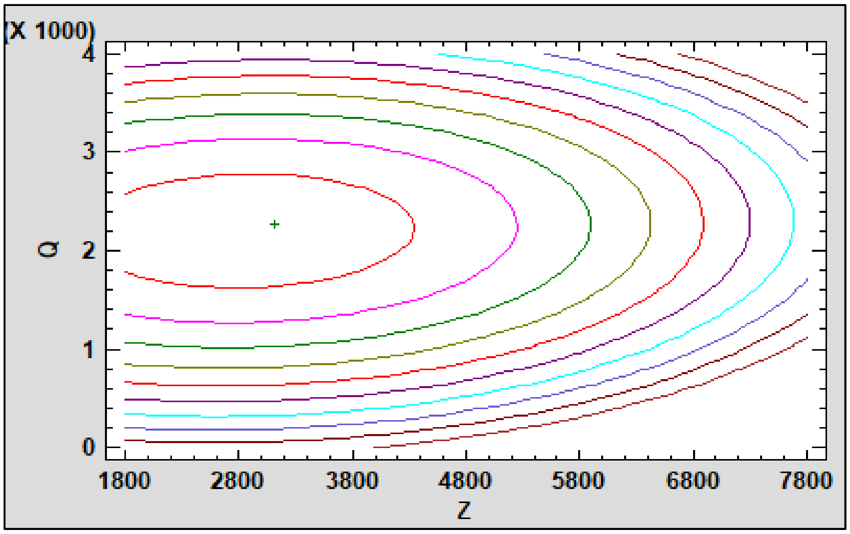


Figure 3.6 Contours of estimated response surface

the optimal control parameters corresponding to the minimum total cost is according to the following:

Z*= 3113, Q*= 2277, AOQ01*= 7.80%, AOQ03*= 4.7%, AOQ02*= 0.20%, Cost*=113221

So it can clearly be seen that the AOQ03 optimal value is very close to the average of AOQ01 and AOQ02, in this case to simplify our policy and avoid the complexity of our system we approximate the value of AOQ03 by taking the average of AOQ01 and AOQ02. Based on this consideration, the number of control parameters is reduced to (Q, Z, AOQ01, AOQ02).

3.11. Experimental results

We used a statistical software application ‘STATGRAPHICS ‘to statistical analysis of the simulated data. It helped to quantify the effects of the independent variables (Q, Z, AOQ01, and AOQ02) on the dependent variable (Cost).

Based on statistical analysis, the second-order models of the total cost for each policy are given by:

$$\boldsymbol{Cost_{MM}(Z)} = 155536. - 27.1575.Z + 0.00516099.\, Z^2 \qquad (3.19)$$

$$\boldsymbol{Cost_{RM-SU01}(Z,Q)} = 197365. - 11.7565.Z - 33.2074.Q + 0.00269391.\, Z^2 - 0.000451872.Z.Q + 0.00454545.\, Q^2 \qquad (3.20)$$

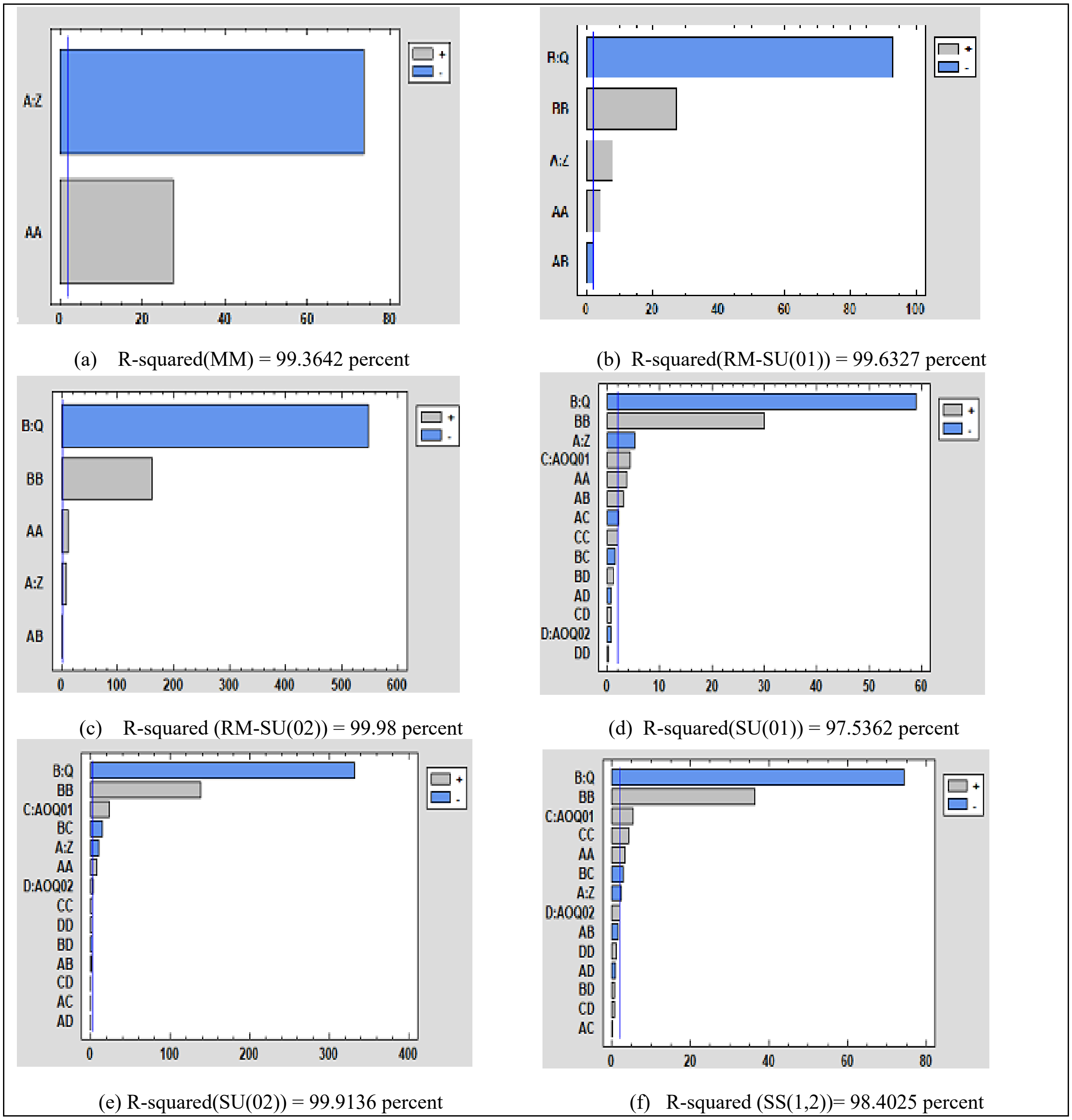
$\boldsymbol{Cost}_{\boldsymbol{RM-SU02}}(\boldsymbol{Z},\boldsymbol{Q})$= 516799. - 17.2491.Z - 322.749.Q + 0.00349232. Z^2 - 0.00026647.Z.Q + 0.0725642. Q^2 (3.21)

$\boldsymbol{Cost}_{\boldsymbol{SU01}}$**(Z,Q,AOQ01,AOQ02)=** 326113-13.445.Z- 121.812.Q- 1.61355E6.AOQ01–1.34341E6.AOQ02+ 0.00478484. Z^2+0.00396471.Z.Q-275.888.Z.AOQ01–215.632.Z.AOQ02+0.0283594. Q^2-166.625.Q.AOQ01 +294.575.Q.AOQ02+1.85492E7. $AOQ01^2$+ 1.70488E7.AOQ01.AOQ02+ 9.65625E6. $AOQ02^2$ (3.22)

$\boldsymbol{Cost}_{\boldsymbol{SU02}}$**(Z, Q, AOQ01, AOQ02)** = 435452. - 24.5795.Z - 298.967.Q + 1.65084E6.AOQ01 - 3778.57.AOQ02 + 0.00484696. Z^2 - 0.000387111.Z.Q - 11.7333.Z.AOQ01 - 9.3.Z.AOQ02 + 0.0928808. Q^2- 2316.25.Q.AOQ01-285.183.Q.AOQ02+7.82585E7. $AOQ01^2$+4.82857E6.AOQ01.AOQ02+ 4.65292E7. $AOQ02^2$ (3.23)

$\boldsymbol{Cost}_{\boldsymbol{SS(1,2)}}$ **(Z, Q, AOQ01, AOQ02)**= 503402. - 20.0893.Z - 135.851.Q - 5.63292E6.AOQ01 - 325823.AOQ02 + 0.00482624. Z^2 - 0.00204882.Z.Q - 40.4765.Z.AOQ01 - 111.51.Z.AOQ02 + 0.0382509. Q^2- (3.24) 352.845.Q.AOQ01 + 73.275.Q.AOQ02 + 4.37258E7.$AOQ01^2$+ 5.89E6.AOQ01.AOQ02 + 7.22801E6. $AOQ02^2$

According to the Pareto plot (Fig. 3.6), We noted that all the R^2_{adj} values are greater than 95% and it means over 95 %of total variability is thus explained by the models. (Montgomery, 2013)



(a) R-squared(MM) = 99.3642 percent

(b) R-squared(RM-SU(01)) = 99.6327 percent

(c) R-squared (RM-SU(02)) = 99.98 percent

(d) R-squared(SU(01)) = 97.5362 percent

(e) R-squared(SU(02)) = 99.9136 percent

(f) R-squared (SS(1,2))= 98.4025 percent

Figure 3.7 Pareto plot of different policies

Fig. 3.7 is showing the scheme of the cost response surfaces on different two-dimensional plan and also illustrating the parameter corresponding to the minimum total cost respectively for the RM-SU01, RM-SU02, SU(01), SU(02) and SS(1,2) models:

MM: Z*=2631, Cost*= 119810

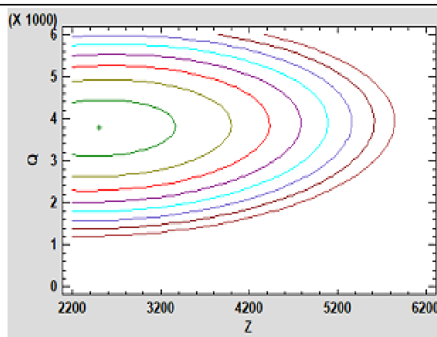
RM-SU01: Z*=2499, Q*=3777, Cost*= 119963 (Fig.3.8. (a));

RM-SU02: Z*=2549, Q*= 2237, Cost* 135131(Fig.3.8. (b));

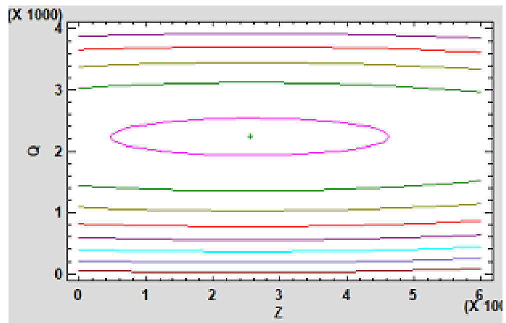
SU(01):Z*=2640,Q*=2156,AOQ01*=%7.0and AOQ02*=0.3 % , Cost* 117338 (Fig.3.8.(c));

SU(02):Z*=2633,Q*=1829,AOQ01*=%1.65,AOQ02*=0.9%,Cost*=143316; (Fig.3.8.(d)),:

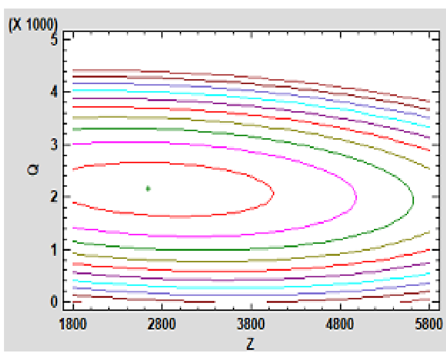
SS(1,2):Z*=2898,Q*=2193, AOQ01*= %7.44, AOQ02*= %0.4, Cost*=115297 (Fig.3.8.(e)).



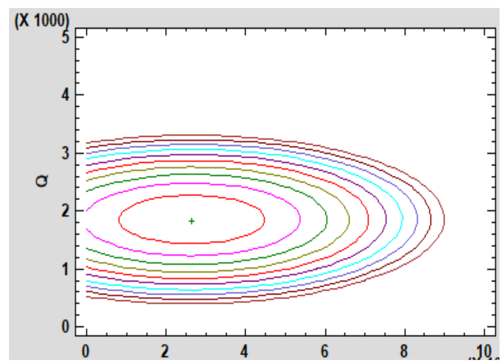
(a)RM-SU(01)



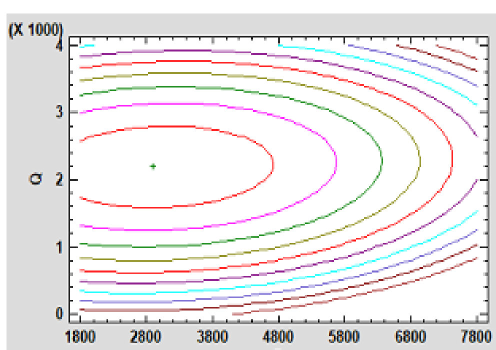
(b)RM-SU(02)



(c)SU(01)



(d) SU(02)



(e) SS(1,2)

Figure 3.8 Contours of estimated response surface

Moreover, in order to authenticate the validity of our models, we conducted 30 extra replications and used optimal parameters to make sure the optimal cost of each model is within the confidence interval at 95% using (Eq.3.24).

$$\bar{C}^*(h) \pm t_{\frac{\alpha}{2},h-1} \cdot \sqrt{S^2(h)/h} \tag{3.25}$$

Where $\bar{C}^*$ is the average obtained cost, S the sample standard deviation, and $(1-\alpha)$ the confidence level.

Table 3.5 Confidence interval and optimal variables and cost results

Policies	Optimal Parameters				Optimal Cost	CI(95%)
	Z*	Q*	AOQ01*	AOQ02*		
MM	2631	-	-	-	119,810	[119745 , 120164.2]
RM-SU01	2499	3777	-	-	119,963	[119600.6 , 120008.3]
RM-SU02	2555	2229	-	-	135,131	[134949.9 , 135682.3]
SU(01)	2640	2156	7.00%	0.30%	117,338	[117007 , 117346.5]
SU(02)	2633	1829	1.65%	0.90%	143,316	[143028.97 , 143712.07]
SS(1,2)	2899	2193	7.44%	0.40%	115,297	[115216 , 115756]

We can conclude three results from table 3.5:

1. According to the results, if the decision-maker wants to choose between supplier 01 and supplier 02, he should select supplier 01;
2. If we are producing with remanufacturing mode only, it is more economical for us to order returned products from supplier01;
3. Table 3.5 also indicates Supplier Selection Policy (SS(1,2)) is the best one in comparison to other policies. Thanks to the flexibility of the Supplier Selection policy, the decision-maker can select suppliers at any time according to the system state and supplier parameters.

To illustrate the robustness of this solution approach for ranges of system parameters, a sensitivity analysis will be performed.

3.12. Sensitivity analysis

The objective of sensitivity analysis is to present the strength of our solution approach. We changed one operational parameter at a time, and analyze the effect of this variation on optimal independent variables (Q*, Z*, AOQ01*, AOQ02*) and incurred cost (Cost*).The following analysis presents the results of this sensitivity analysis compared to the basic case, when a SS(1,2) policy is considered.

Case 1. Effect of variation of Finished Product holding Cost

When the c_H^F cost increases, the level Z* decreases to reduce the finished product inventory costs and Q* also decreases with reducing the transformation of returned products to the finished products as you can see in the following table 3.6. Decreasing c_H^F leads to an opposite variation of the Z*and Q* and Cost*.

Case 2. Effect of Variation of Finished product backlog Cost

According to the following table, When the c_B^F cost increases, the manufacturer increases the Z* in order to ensure enough finished product to meet continuous customer demand. Also Q* should be increase to reduce the risk of stock-out of returned products. Decreasing c_B^F leads to an opposite variation of the Z*and Q* and Cost*.

Case 3. Effect of Variation of Returned Product Stock holding Cost

When the c_R^H cost increases, we should reduce the stock level of returned product and avoid the extra cost so Q* will decrease. In addition, Z* increase to accelerate the transformation of returned products to finished products. Decreasing c_R^H leads to an opposite variation of the Q*and Z* and Cost*.

Case 4. Effect of variation of Finished Product Replacement cost

Increasing c_{Rep}^{F}results in a tendency to increase the quality of final products to avoid further finished product replacement costs. So for increasing final product quality we should increase using manufacturing activities instead of remanufacturing activities, because in manufacturing mode , always good quality will produce, Consequently the system decrease the AOQ01* level and increase AOQ02* level to accelerate using manufacturing mode. By decreasing the remanufacturing mode of machine Q*will also decrease. Decreasing c_{Rep}^{F} leads to an opposite variation of the AOQ01* and AOQ02*.

Case 5. Effect of Variation of Manufacturing Cost

Increasing c_{man} results in a tendency to use remanufacturing mode instead of manufacturing mode, consequently AOQ1* will increase and AOQ02* level will decrease to accelerate using remanufacturing mode of machine. By increasing the remanufacturing mode of machine Q*will also increase. Decreasing c_{man} leads to an opposite variation of the AOQ01* and AOQ02*.

Case 6. Effect of Variation of Remanufacturing Cost Supplier 01

Increasing $c_{rem}\,S1$ results in a tendency to use manufacturing mode instead of remanufacturing mode, consequently AOQ1* level will decrease and AOQ02* will increase to accelerate using manufacturing mode machine. By decreasing the remanufacturing mode of machine Q*will also decrease. Decreasing $c_{rem}\,S1$ leads to an opposite variation of the optimal parameters.

Case 7. Effect of Variation of Remanufacturing Cost Supplier 02 on AOQ01*

Increasing $c_{rem}\,S2$ results in a tendency to use manufacturing mode instead of remanufacturing mode, consequently AOQ1* level will decrease and AOQ02* will increase to accelerate using manufacturing mode machine. By decreasing the remanufacturing mode of machine Q*will also decrease. Decreasing $c_{rem}\,S2$ leads to an opposite variation of the optimal parameters.

Table 3.6 Sensitivity Analysis

Cases	Parameter	Variation	Optimal Parameters				Cost	Impact on Supplier Selection Policy
			Z*	Q*	AOQ01*	AOQ02*		
Base	_	_	2899	2193	7.43%	0.348%	115,297	-
1	C_H^F	7.3	2954	2194	7.43%	0.34%	114,003	Z*↑, Q*↑, AOQ01*- , AOQ02*- , Cost*↓
		8.3	2844	2192	7.43%	0.34%	116,564	Z*↓, Q*↓, AOQ01*- , AOQ02*- , Cost*↑
2	C_B^F	200	2828	2192	7.43%	0.34%	114,747	Z*↓, Q*↓, AOQ01*- , AOQ02*-, Cost*↓
		240	2959	2194	7.43%	0.34%	115,809	Z*↑, Q*↑, AOQ01*- , AOQ02*-, Cost*↑
3	C_R^H	7.3	2900	2196	7.43%	0.34%	114,748	Z*↑, Q*↑, AOQ01*- , AOQ02*- , Cost*↓
		8.3	2898	2190	7.43%	0.34%	115,845	Z*↓, Q*↓, AOQ01*- , AOQ02*- , Cost*↑
4	C_{rep}^F	700	2877	2194	7.44%	0.20%	114,747	Z*↓, Q*↑ , AOQ01↑-, AOQ02↓-, Cost*↓
		900	2918	2192	7.42%	0.40%	115,809	Z*↑, Q*↓ , AOQ01*↓, AOQ02↑-, Cost*↑
5	C_{man}	200	2900	2188	7.30%	0.40%	108,877	Z*↑, Q*↓ , AOQ01↓-, AOQ02↑-, Cost*↓
		400	2897	2202	7.60%	0.20%	121,588	Z*↓, Q*↑ , AOQ01*↑, AOQ02↓-, Cost*↑
6	C_{rem}S1	200	2899	2194	7.44%	0.346%	113,720	Z*- , Q*↑ , AOQ01↑-, AOQ02↓-, Cost*↓
		240	2899	2192	7.42%	0.350%	116,873	Z*- , Q*↓ , AOQ01*↓, AOQ02↑-, Cost*↑
7	C_{rem}S2	220	2899	2194	7.45%	0.338%	113,892	Z*-, Q*↑ , AOQ01↑-, AOQ02↓-, Cost*↓
		260	2899	2192	7.44%	0.358%	116,701	Z*-, Q*↓ , AOQ01*↓, AOQ02↑-, Cost*↑

3.13. Comparative study

We conducted additional experiments to show the robustness of our suggested policy.

3.13.1. Effect of non-conforming proportion variation

In this case, we change the parameters of one supplier at a time to show which policy has the minimum cost. Figure 3.8 is illustrating the result of the variation of %p related to the supplier01 and the variation of the optimal total cost. We can see from Figure 3.8, Supplier Selection policy is always more preferable and is the best policy because of the lowest optimal cost that this policy has in all the time. Moreover, we note that the decision-maker may select the different policy, depending on the supply chain parameters. There are five switching points in this figure that after that decision-maker should change his decision from the selected policy.

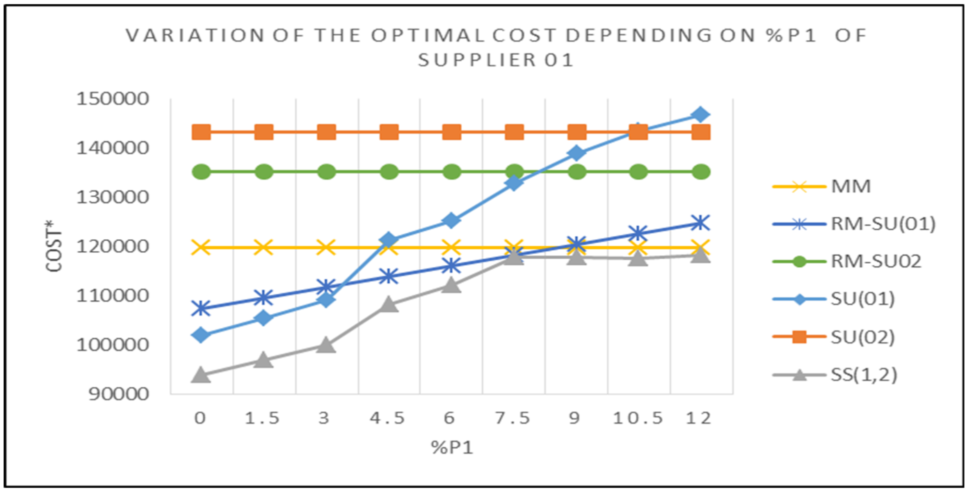


Figure 3.9 Effect of non-conforming proportion variation

3.13.2 Effect of finished products holding cost C_H^F variation

In this case, Figure 3.9 is illustrating the result of the variation of finished products holding C_H^F cost and the variation of the optimal total cost. We can see from Figure 3.9, Supplier Selection policy is always more preferable and is the best policy because of the lowest optimal cost that this policy has in all the time. Moreover, we note that the second choice can be the SU(01) policy, which includes both manufacturing and remanufacturing operation and choose supplier one as a permanent one. Also, the highest cost is related to the SU(02) policy, which allocated supplier 02 as a permanent one. In addition, we can see from the following figure, the cost related to the RM-SU01 and MM policies is approximately the same.

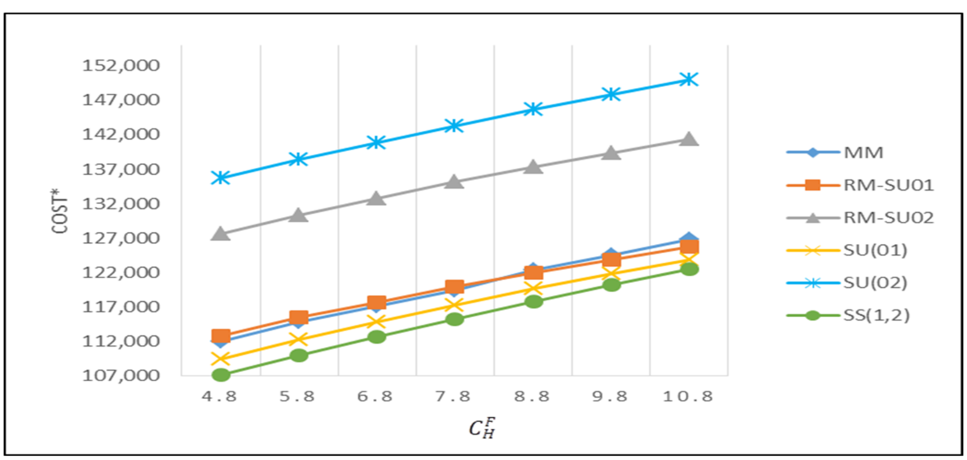


Figure 3.10 Effect of finished products holding cost C_H^F variation

3.13.3. Effect of Finished products backlog cost C_B^F variation

Figure 3.10 is showing the result of the variation of finished products backlog cost C_B^F and the variation of the optimal total cost. Figure 3.10 is clearly indicating the Supplier Selection policy is always preferred because of the lowest possible cost this approach has in all time. Moreover, we note that when we dedicated supplier 02 as a permanent one in our system, we will encounter with highest cost, this issue is clearly can be seen in the following figure by SU(02) and RM-SU(02) policies.

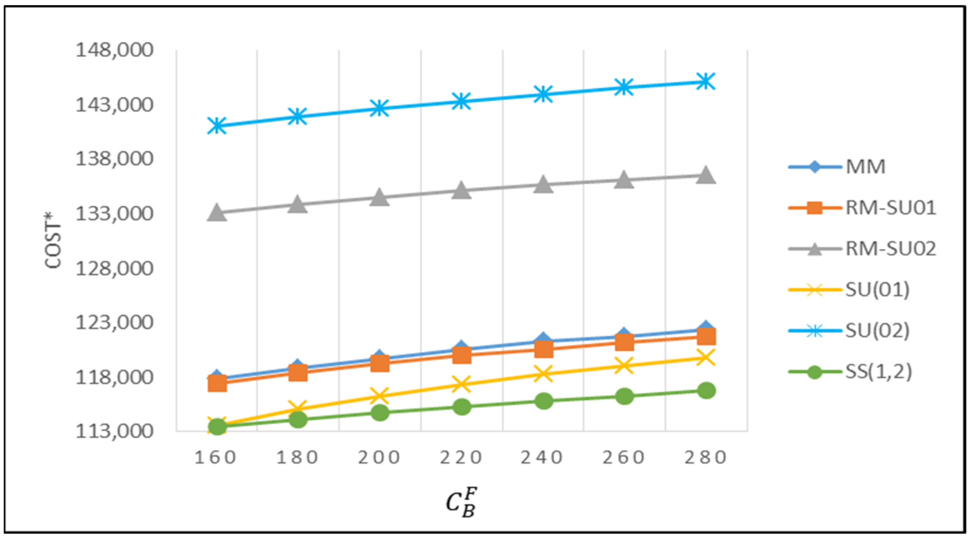


Figure 3.11 Effect of Finished products backlog cost C_B^F variation

3.13.4. Effect of Returned products holding cost C_R^H variation

In this case, we change the returned products holding cost C_R^H to show which policy has the minimum cost. Figure 3.11 is illustrating the result of the variation of returned products holding cost and the variation of the optimal total cost. We can see from Figure 3.11, Supplier Selection policy is always more preferable and is the best policy because of the lowest optimal cost that this policy has in all the time.

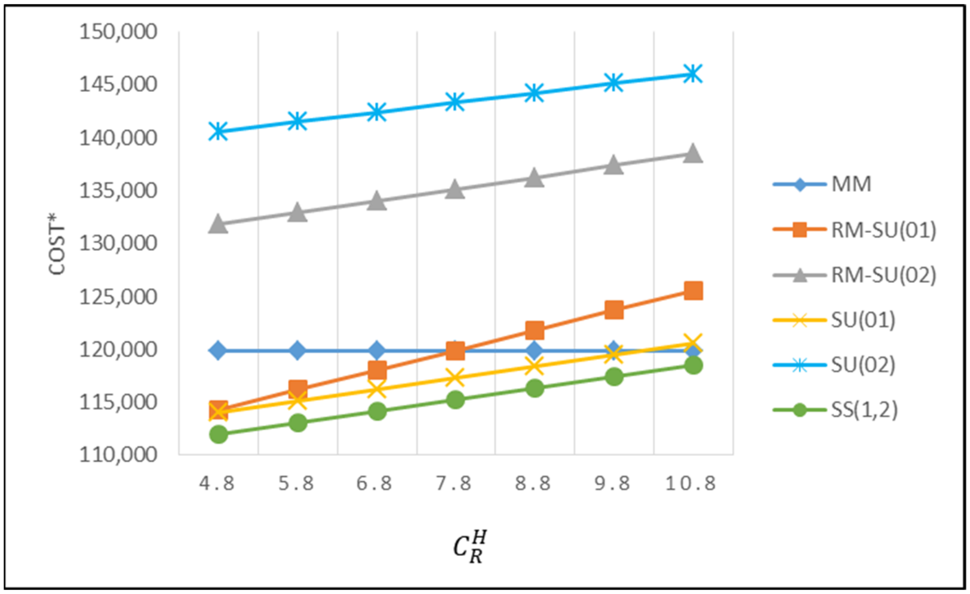


Figure 3.12 Effect of Returned products holding cost $\boldsymbol{C_R^H}$ variation

3.13.5. Effect of Finished products replacement cost C_{rep} variation

Figure 3.12 is illustrating the result of the variation of finished product replacement cost $\boldsymbol{C_{rep}}$ and the variation of the optimal total cost. Figure 3.12 is showing clearly the superiority of the Supplier Selection policy in comparison to other policies because of the lowest possible cost this approach has in all time. Moreover, as can be clearly observed from the following figure, the optimal cost of the policies that consider supplier one as a permeant supplier, (RM-SU(01) and SU(01)) increase significantly by increasing replacement cost. Because supplier one has a greater amount of non-conforming items. Moreover, when we use the returned products which provided by supplier one to produce, the amount of non- conforming products which customer receive will be increased, so we will encounter with more replacement cost in our system.

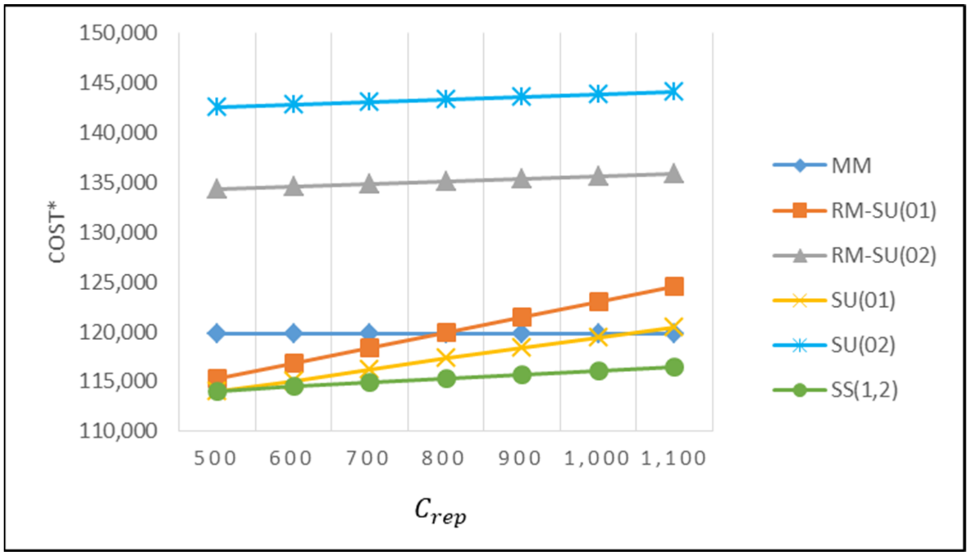


Figure 3.13 Effect of Finished products replacement cost C_{rep} variation

3.14. Extension to effect of random non-conforming proportion variation

To reflect the industrial reality we considered different random amounts to %p to find the best policy. In this case, we change the parameters of one supplier at a time to show which policy has the minimum cost. Table 3.7 shows the optimal control parameters and the associated total cost of each policy when we allocated random non-conforming items for supplier 01. We can see from Table 3.7 Supplier Selection policy (SS(1,2)) is always more preferable and is the best policy because of the lowest optimal cost that this policy has in all the time. Table 3.7 also shows that the higher the standard deviation, the more Z* increase. This is because the system needs higher storage capacities to deal with the %p variability, and needs to protect variability. The highlighted parts of this table are showing the policies that when we changed %p of supplier 01, it has no effect on these policies, that is MM, RM-SU(02), and SU(02) policies.

Table 3.7 Effect of random non-conforming proportion variation

Polcies	%p1	Z	Q	AOQ01	AOQ02	Total cost
MM	UNIF (%7.5,%9.4)	2631	-	-	-	119,810
	UNIF (%7,%9.9)	2631	-	-	-	119,810
	UNIF (%6.5,%10.4)	2631	-	-	-	119,810
	UNIF (%6,%10.9)	2631	-	-	-	119,810
RM-SU(01)	UNIF (%7.5,%9.4)	2480	2225	-	-	119,505
	UNIF (%7,%9.9)	2538	2219	-	-	119,837
	UNIF (%6.5,%10.4)	2557	2214	-	-	119,896
	UNIF (%6,%10.9)	2633	2211	-	-	119,953
RM-SU02	UNIF (%7.5,%9.4)	2555	2229	-	-	135,131
	UNIF (%7,%9.9)	2555	2229	-	-	135,131
	UNIF (%6.5,%10.4)	2555	2229	-	-	135,131
	UNIF (%6,%10.9)	2555	2229	-	-	135,131
SU(01)	UNIF (%7.5,%9.4)	3433	2221	7.10%	0.10%	121,851
	UNIF (%7,%9.9)	3452	2219	7.20%	0.11%	122,223
	UNIF (%6.5,%10.4)	3482	2196	7.30%	0.40%	123,324
	UNIF (%6,%10.9)	3487	2195	7.40%	0.90%	124,151
SU(02)	UNIF (%7.5,%9.4)	2633	1829	1.65%	0.90%	143,316
	UNIF (%7,%9.9)	2633	1829	1.65%	0.90%	143,316
	UNIF (%6.5,%10.4)	2633	1829	1.65%	0.90%	143,316
	UNIF (%6,%10.9)	2633	1829	1.65%	0.90%	143,316
SS(1,2)	UNIF (%7.5,%9.4)	2887	2287	7.30%	0.87%	116,785
	UNIF (%7,%9.9)	2960	2214	7.40%	0.90%	116,989
	UNIF (%6.5,%10.4)	3079	2197	7.45%	1.10%	117,609
	UNIF (%6,%10.9)	3184	2177	7.50%	1.10%	118,771

3.15. Conclusion

In this study, we have developed, in a stochastic and dynamic context, an integrated production, replenishment, and supplier selection to minimize the total cost of a hybrid system under an unreliable production system and stochastic supplier parameters.

A new supplier selection strategy is being proposed and contrasted with a traditional selection decision (selecting and retaining the same supplier). This new policy is characterized by a flexible supplier selection decision depending on the parameters of the suppliers and the state of the system. A combination of, simulation modeling, statistical analysis, and surface response methodology was adopted to solve this problem and optimize the control parameters.

Furthermore, a new production mode policy was suggested for switching between modes of machine. It depends on the average quality of the finished products. When the average quality of the finished product is low, we need to improve the quality of our products so we should switch to the manufacturing mode that is supposed to produce only good products. When the average quality of products is good, we can turn into the remanufacturing mode that is supposed to cost less.

The comparison of outcomes between the different policies demonstrates the significant cost savings that the proposed policy (supplier selection) will achieve.

This work can be extended further, considering multiple suppliers where we can switch from one supplier to another based on quality, price, and the system state. Moreover, an important extension to this paper may be the optimal number of suppliers to consider. In addition, the supplier parameters can vary to other characteristics.

CONCLUSION

In this work, we addressed the production planning and control problem within a manufacturing-remanufacturing system, in which demand can be satisfied by either manufacturing of new products or remanufacturing of returned ones. The manufacturing system produces one type of product and is subjected to random failure and repair time.
To solve the various problems presented in this work, an approach of the experimental solution was adopted. It is a combination of simulations and optimization techniques. The simulation models were modeled by combination discrete and continuous events to reduce the computation time compared to modeling by discrete events (Lavoie, 2010). These were developed with ARENA software from Rockwell Automation. This allowed us to better present the supply chain dynamics, in the stochastic context. For optimization, we used STATGRAPHICS software. To validate the robustness and the effectiveness of this approach, sensitivity analyzes were carried out.
In the first chapter, we discussed the supply chain function which is the focus of our research. Afterward, we concentrated on the main research works relevant to our work. Then, we presented a review of the literature. This literature review allowed showing the originality of our work compared to all the old works.

In the second chapter, we proposed to jointly integrate, and coordinate production, replenishment and quality inspection decisions in an unreliable manufacturing system where demand can be met via two sources of production that is either manufacturing of new products or remanufacturing of returned ones. After receiving returned products, the manufacturer may apply three different quality inspections strategies. We did a comparative study of three control policies that are no inspection, % 100 inspections, and single sampling plan. The results obtained showed the advantage of single sampling plan policy in comparison to the other policies in the context of supply chain management. This work showed the importance of coordinating quality control decision at the reception with the production and supply activities.

The third chapter addressed the production planning and control problem within a hybrid manufacturing-remanufacturing system, in which demand can be satisfied by either manufacturing of new products or remanufacturing of returned ones. This work proposed a new joint production and supply policy composed of multiple suppliers. Based on the quality of the final products, the decision-maker decides to order returned products from which supplier for remanufacturing operations. We did a comparative study of six control policies. The results related to the numerical examples and sensitivity analysis show a considerable cost saving, will occur in cases that we have multiple suppliers for selecting and both manufacturing and remanufacturing considered in our production stage compared with the situation that a single supplier has a monopoly in providing the returned products or when we have only manufacturing or remanufacturing in our system.

The research work adopted in this thesis proposes stochastic models which integrate the influence of quality aspects on the control policy of production. The developed models can be applied to industries that are subject to random disruption and uncertainties that can lead to significant productivity declines. Our models can be used by decision-makers to establish effective control actions involving manufacturing, remanufacturing and quality control of returns. The present work might be extended in several directions. We can extend the obtained control policies to analyze more complex manufacturing systems, by consideration multi-type products. The simulation optimization approach can be useful in this respect. One may consider other sampling policies, such as double and sequential sampling plans. An alternative extension might be consideration of imperfect inspection process. In addition an important extension of this work can be consideration of the other characteristics of the supplier parameters such as delay, quality, and price. Also the deterioration of the machine following the consumption of non-conforming returned products can be considered in the future works.

BIBLIOGRAPHY

Akella, R.,Kumar, P. "Optimal control of production rate in a failure prone manufacturing system." *Automatic Control, IEEE Transactions on* 31 (1986): 116-126.

Al-Salamah, M. "Economic order quantity with imperfect quality, destructive testing acceptance sampling, and inspection errors." *Advances in Management & Applied Economics* 1 (2011): 59-75.

Amin, S. H., & Zhang, G. "An integrated model for closed-loop supply chain configuration and supplier selection: Multi-objective approach." *Expert Systems with Applications* 39(8) (2012): 6782-6791.

Assid, M., Gharbi, A., & Hajji, A. "Production and setup control policy for unreliable hybrid manufacturing-remanufacturing systems." *Journal of Manufacturing Systems* 50 (2019): 103-118.

Assid, M., Gharbi, A., & Hajji, A. "Production planning of an unreliable hybrid manufacturing–remanufacturing system under uncertainties and supply constraints. Computers & Industrial Engineering,." *Computers & Industrial Engineering* 136 (2019): 31-45.

Assid, M., Gharbi, A., Hajji, A.,. "Production control of failure-prone manufacturing-remanufacturing systems using mixed dedicated and shared facilitie." *International Journal of Production Economics* 224 (2020): 107549.

Atasu, A., Sarvary, M., & Van Wassenhove, L. N. "Remanufacturing as a marketing strategy." *Management science*, 2008: 1731-1746.

Baillargeon, G. *Plans d'échantillonnage en contrôle de la qualité* . 5e. Vol. XV. Trois-Rivières: Contrôle par attributs, 2013.

Ben-Daya, M., Noman, S. M. "Integrated inventory and inspection policies for stochastic demand." *European Journal of Operational Research* 185 (2008): 159-169.

Berthaut, F., Pellerin, R., & Gharbi, A. "Optimisation of the control policy for a stochastic remanufacturing system with an unreliable replacement parts supply." *International Journal of Simulation and Process Modelling*, 2009: 205.

Boukas E. K., et Haurie, A. "Manufacturing flow control and preventing maintenance: a stochastic control approach." *Automatic Control, IEEE Transactions on* 35 (1990): 1024-1031.

Bouslah, B., Gharbi, A. et Pellerin. "Joint optimal lot sizing and production control policy in an unreliable and imperfect manufacturing system." *International Journal of Production Economics* 144 (2013): 143-156.

Chan, F.T.S., Z. Wang, J. Zhang and S. Wadhwa. " Two-level hedging point control of a manufacturing system with multiple product-types and uncertain demands ." *International Journal of Production Research* 46 (2008): 3259-3295.

Chen, X., Zhang, J. "Production control and supplier selection under demand disruptions." *Journal of Industrial Engineering and Management*, 2010: 421-446.

Choudhary, D., Shankar, R. "Joint decision of procurement lot-size, supplier selection, and carrier selection." *Journal of Purchasing and Supply Management* 19 (2013): 16-26.

Daniel, V., Guide R., Terry P. Harrison, Luk N. Van Wassenhove,. "The Challenge of Closed-Loop Supply Chains." *Journal on Applied Analytics*, 2019.

Entezaminia, A., Gharbi A., Ouhimmou, M. "Environmental hedging point policies for collaborative unreliable manufacturing systems with variant emitting level technologies." *Journal of Cleaner Production*, 2020.

Esmaeilian B, Behdad S, Wang B. "The evolution and future of manufacturing." *Manufacturing Systems*, 2016: 79-100.

Fang, CC, Lai MH, Huang YS. "Production planning of new and remanufacturing products in hybrid production systems." *Comput Ind Eng*, 2017: 88–99.

Flapper, SD, Gayon JP, Lim LL. "On the optimal control of manufacturing and remanufacturing activities with a single shared server." *Eur J Oper Res*, 2014: 86–98.

Francas, D, Minner S. "Manufacturing network configuration in supply chains with product recovery." *Omega*, 2009: 757-769.

Garg, K., Kannan, D., Diabat, A., Jha, P.C. "A multi-criteria optimization approach to manage environmental issues in closed loop supply chain network design." 2015.

Gharbi, A., A. Hajji and K. Dhouib. "Production rate control of an unreliable manufacturing cell with adjustable capacity." *International Journal of Production Research* 49 (2011): 6539-6557.

Gharbi, A., Pellerin, R. et Sadr, J. "Production rate control for stochastic remanufacturing systems." *International Journal of Production Economics, vol. 112, no 1, p. 37-47.*, 2008: 37-47.

Gholami-Qadikolaei, A., Mirzazadeh, A. et Tavakkoli-Moghaddam, R. "A stochastic multiobjective multiconstraint inventory model under inflationary condition and different inspection scenarios." *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture* 227 (2013): 1057-1074.

Gorji, M.H., Setak, M., Karimi, H. *Optimizing inventory decisions in a two-level supply chain with order quantity constraints.* Applied Mathematical Modelling, 2014.

Govindan K., Soleimani H. "A review of reverse logistics and closed-loop supply chains." *Journal of Cleaner Prodcution*, 2017: 371-384.

Govindan, K., Soleimani, H. "A review of reverse logistics and closed-loop supply chains: a Journal of Cleaner Production focus." *Journal of Cleaner Production* 142 (2017): 371-384.

Graham, Stevens. "Integrating the Supply Chains," International Journal of Physical Distribution and Materials Management,." 8 (1989): 3-8.

Guide, V. D. R., Harrison, T. P., Van, Wassenhove, L. N. *The challenge of closed-loop supply chains.* -: Interfaces, 2003.

Guo, J, Ya G. "Optimal strategies for manufacturing/remanufacturing system with the consideration of recycled products." *Comput Ind Eng*, 2015: 226–234.

Hajji, A, Gharbi A, Kenne JP. "Joint replenishment and manufacturing activities control in a two stage unreliable supply chain." *International Journal of Production Research*, 2009: 3231-3251.

Hajji, A., Gharbi, A. , Artiba, A. "Impact of random delay on Replenishment and production control strategies." *Logistics International Conference*, 2011: 341-348..

Hajji, A., Gharbi, A., Kenne, J. P., Pellerin. "Production control and replenishment strategy with multiple suppliers." *European Journal of Operational Research* 208 (2011): 67-74.

Heizer, J. *Operations Management with MyOMLab.* Global Edition: Pearson Education, 2011.

Hlioui, R., Gharbi A. , Hajji A. "Joint supplier selection, production and replenishment of an unreliable manufacturing-oriented supply chain." *International Journal of Production Economics, 187, 53-67.*, 2017: 53-67.

Hlioui, R., Gharbi A., Hajji A. "Replenishment, production and quality control strategies in three-stage supply chain." *International Journal of Production Economics* 166 (2015): 90 -102.

Hlioui, R., Gharbi, A., Hajji, A. "Integrated quality strategy in production and raw material replenishment in a manufacturing-oriented supply chain." *International Journal of Advanced Manufacturing Technology*, 2015: 1-14.

Houlihan, John B. "International Supply Chains: A New Approach," Management Decision." 26 (1988): 13-19.

Jaber, M. Y., Bonney, M. et Guiffrida, A. L. "Coordinating a three-level supply chain with learning-based continuous improvement." *International Journal of Production Economics* 127 (2010): 27-38.

Jeihoonian, M., Zanjani, M.K., Gendreau, M. "Closed-loop supply chain network design under uncertain quality status: case of durable products." *Int. J. Prod. Econ*, 2017.

Kenné, J. P., Gharbi, A. "Production planning problem in manufacturing systems with general failure and repair time distribution." *Production Planning and Control* 11 (2000): 581-588.

Kenné, J., Gharbi, A. "A simulation optimization approach in production planning of failure prone manufacturing systems." *Journal of Intelligent Manufracturing* 12 (2001): 421-431.

Kenné, JP, Dejax P, Gharbi A. "Production planning of a hybrid manufacturing-remanufacturing system under uncertainty within a closed-loop supply chain." *Int J Prod Econ*, 2012: 81-93.

Keskin, B.B., Melouk, S.H., Meyer, I. "A simulation-optimization approach for integrated sourcing and inventory decisions." *Computers & Operations Research* 37 (2010): 1648-1661.

Kilic, OA., Tunc H, Tarim SA. "Heuristic policies for the stochastic economic lot sizing problem with remanufacturing under service level constraints." *Eur J Oper Res*, 2018: 1102–1109.

Kim E, Saghafian S, Van Oyen MP. "Joint control of production, remanufacturing, and disposal activities in a hybrid manufacturing-remanufacturing system." *Eur J Oper Res*, 2013: 337-348.

Kimemia, J. et Gershwin, S. B. "An algorithm for the computer control of a flexible manufacturing system." *AIIE Transactions* 15 (1983): 353-362.

Lavoie, P., Gharbi, A. , Kenné, J. P. "A comparative study of pull control mechanisms for unreliable homogenous transfer lines." *International Journal of Production Economics* 124 (2010): 241-251.

Lund, R.,. *1983. Remanufacturing: United States Experience and Implications for Developing Nations.* Washington, DC.: World Bank, 1983.

Lund, R., Hauser, W. *The remanufacturing industry: Anatomy of a giant.* Dep Manuf Eng Bost, 2003.

Mahnam, M., Yadollahpour, M. R., Famil-Dardashti, V. et Hejazi, S. R. "Supply chain modeling in uncertain ev=nvironment with bi-objective approach." *Computers & Industrial Engineering* 56 (2009): 1535-1544.

Maiti, T., Giri, B.C. "Two-way product recovery in a closed-loop supply chain with variable markup under price and quality dependent demand." *Int. J. Prod. Econ*, 2017.

Martijn, Thierry, Marc Salomon , Jo Van Nunen Luk,Van Wassenhove. "Strategic Issues in ptoduct recovery management." *California Management Review* 37 (1995).

Martin, Christopher. *Logistics and Supply Chain Management, London: Pitman Publishing.* 1992.

Min, H., et Zhou, G. "Supply chain modeling: past, present and future." *Computers & Industrial Engineering* 43 (2002): 231-249.

Montgomery, D. C. *Design and analysis of experiments, 8th ed.. Hoboken, NJ: John Wiley & Sons, Inc., 1 ressource en ligne. p.* 2013.

Moshtagh, M.S., Taleizadeh, A. "Stochastic integrated manufacturing and remanufacturing model with shortage, rework and quality based return rate in a closed loop supply chain." *J. Clean. Prod*, 2017: 1548-1573.

Moussawi-Haidar, L., Salameh, M. K. et Nasr, W. "An instantaneous replenishment model under the effect of a sampling policy for defective items." *Applied Mathematical Modelling*, no. 37 (2013): 719-727.

Naimi Sadigh, A., Fallah, H., Nahavandi, N. "A multi-objective supply chain model integrated with location of distribution centers and supplier selection decisions." *International Journal of Advanced Manufacturing Technology* 69 (2013): 225-235.

Nakhla, M. *L'essentiel du management industriel : maîtriser les systèmes : production, logistique, qualité, supply chain.* 2eme. Paris: Dunod/L'Usine nouvelle, 2009.

Ouaret, S., Kenné, J.P., Gharbi, A.,. "Stochastic optimal control of random quality deteriorating hybrid manufacturing/remanufacturing systems." *Journal of Manufacturing Systems* 49 (2018): 172-185.

Pazhani, S., Ventura, J.A., Mendoza, A. "A serial inventory system with supplier selection and order quantity allocation considering transportation costs." *Applied Mathematical Modelling* 40 (2016): 612-634.

Pegden, C. D. *Introduction to Simulation using SIMAN.* 2nd ed. New York: McGraw-Hill, 1995.

Perona, M., Miragliotta, G. "Complexity management and supply chain performance assessment. A field study and a conceptual framework." *International journal of production economics* 90(1) (2004): 103-115.

Peters, M. H., Schneider, H. et Tang, K. "Joint determination of optimal inventory and quality control policy." *Manage. Sci.* 34 (1988): 991-1004.

Polotski V, Kenne JP, Gharbi A. "Optimal production scheduling for hybrid manufacturing remanufacturing systems with setups." *J Manuf Syst*, 2015: 703-714.

Rezaei, J., & Davoodi, M. *A deterministic, multi-item inventory model with supplier selection and imperfect quality.* Applied Mathematical Modelling, 2008.

Rivera-Gómez, H., Gharbi, A. et Kenné, J. P. "Joint production and major maintenance planning policy of a manufacturing system with deteriorating quality." *International Journal of Production Economics* 146 (2013): 575-587.

Salameh, M. K., et Jaber, M. Y. "Economic production quantity model for items with imperfect quality stems with variant emitting level technologies. Journal of Cleaner Prod." *International Journal of Production Economics* 64 (2000): 59-64.

Schilling, E. G., et Neubauer, D. V. "Acceptance sampling in quality control (2009)." *2nd ed. Boca Raton: CRC Press, 1 texte électronique (xxxvii, 683 p.) p.*, 2009.

Sharifnia, A. "Production Control of a Manufacturing System with multiple machine states." *IEEE Transactions on Automatic Control* 33 (1988): 620-625.

Song, D.P. *(2013) Optimal Control and Optimization of Stochastic Supply Chain Systems.* London: Springer London, 2013.

Souza, G.C., Ketzenberg, M.E. and Guide, Jr., V.D.R. "Capacitated remanufacturing with service level constraints." *Production and Operations Management*, 2002: 231–248.

Starbird, S.A. "Acceptance sampling, imperfect production, and the optimality of zero defects." *Naval Research Logistics (NRL)* 44 (1997): 515-530.

Tang, O., Teunter R. "Economic lot scheduling problem with returns." *Prod Oper Manag*, 2006: 488.

Teunter, R., Kaparis K., Tang O. "Multi-product economic lot scheduling problem with separate production lines for manufacturing and remanufacturing." *Eur J Oper Res*, 2008: 1241-1253.

Van Der Laan, E., Salomon M. "Production planning and inventory control with remanufacturing and disposal." *Eur J Oper Res*, 1997: 264-278.

Vercraene S, Gayon JP, Flapper SD. "Coordination of manufacturing, remanufacturing and returns acceptance in hybrid manufacturing/remanufacturing systems." *Int J Prod Econ*, 2014: 62–70.

Wan, H., Xu, X. et Ni, T. "The incentive effect of acceptance sampling plans in a supply chain with endogenous product quality." *Naval Research Logistics (NRL)* 60 (2013): 111-124.

Wu D., & Olson, D. L. "Supply chain risk, simulation, and vendor selection." *International journal of production economics* 114(2) (2008): 646-655.

Zanoni S., Ferretti, I., & Tang, O. "Cost performance and bullwhip effect in a hybrid manufacturing and remanufacturing system with different control policies." *International Journal of Production Research*, 2006: 3847-3862.

Zouadi, T., Yalaoui, A., & Reghioui, M. "Hybrid manufacturing/remanufacturing lot-sizing and supplier selection with returns, under carbon emission constraint." *International Journal of Production Research* 56(3) (2018): 1233-1248.