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Quality-Driven Logistics: Reverse Logistics Process Reengineering, Improving Customer Service Quality

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Abstract: **To succeed in the modern global economy, it is critical to build a Logistics network that is information-rich, highly flexible, cost effective, and defined by both customer needs and internal corporate strategy. Organizations must constantly reinvent the Logistics network to allow business growth and change. Yet, the superiority in Logistics operations is anything but enough to achieve competitive advantage. The proper handling of Reverse Logistics is currently perceived as the leading distinction edge among organizations. From another perspective, high operational efficiency is dependent on quick, accurate, and continuous exchange of information within an organization. Such ability is achieved through the use of modern Information Technology and computer automation. As organizations cannot move into the highly competitive environment by adapting old management methods, Process Reengineering might be the solution. In this research, the concepts of Reverse Logistics, Information Technology, and Process Reengineering are spotlighted. A reengineering of the current maintenance process of a major Egyptian Healthcare Medical Equipment Provider is proposed in order to enhance the Customer Service Quality and the Operational Efficiency. Computer simulation modeling is used to evaluate the proposed model.**

Keywords: **Business Process Reengineering, Computer Simulation, Customer Service Quality, Cycle Time, Healthcare, Operational Efficiency, Reverse Logistics.**

I. INTRODUCTION

The process of planning, implementing, and controlling the effective and efficient flow of products and services from the point of origin to the point of consumption is commonly referred to as "Logistics". Oppositely, "Reverse Logistics" (RL) is a newer concept that encompasses all of these activities as they operate in reverse direction, from the consumption point back to the origin, and that more than ever, is seen as vital for nowadays industries. The management of machine repairs of previous purchases, a common type of reverse logistics, is considered an important frontier of competitive advantage. Successful retailers understand that managing reverse logistics effectively will have a positive impact on their bottom line and competitive advantage. Another cutting edge enabler is the use of modern Information Technology, as rapid developments in IT increase the availability of information, and also the opportunities to transfer information between different inter and intra-organizational units. Here potential avenues are explored to reengineer Reverse Logistics processes, through the use of IT, with the aim of seeking enhancement in terms of customer service quality, operational costs and cycle time.

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II. PROBLEM STATEMENT

While the concept of Logistics and its related activities have been thoroughly studied, modelled, analyzed, and optimized, the concept of Reverse Logistics, on the other hand, still lacks a lot of research effort. Most logistics systems are not well equipped to manage product movement in a reverse channel, and returned products often cannot be transported, stored and handled in the same manner as in a forward channel. The costs associated with Reverse Logistics are nine times higher than those associated with forward Logistics. As failure in Reverse Logistics impacts negatively on customer satisfaction, and causes market share loss, industries that have not spent much time and energy addressing Reverse Logistics issues are now trying to make major improvements and reengineer their business processes.

III. MOTIVATION, OBJECTIVES & CONTRIBUTION

The first application of Reverse Logistics Reengineering was conducted in 1997, however, from the investigated previous studies tabulated in Appendix 1, there is no specific study that covers a complete Reverse Logistics Reengineering project or indicates the best simulation application to be used. There is also no specific trend to measure the performance of the Reverse Logistics or to reengineer it. This research is essentially motivated by the Reverse Logistics problems in general and specifically by the fact that there are limited researches conducted in applying the Reverse Logistics Process Reengineering in the HealthCare field, especially in Egypt. The main contribution of this research is to conduct an in-depth analysis, a Reverse Logistics process modification and simulation for the purpose of improving the Customer Service Quality and increasing the Operational Efficiency in the Egyptian Healthcare Equipment field. The main objective of this research is to investigate avenues to reengineer a current reverse logistics process with a primary objective of enhancing Customer Service Quality and a secondary objective of exploring opportunities for increasing the Operational Efficiency.

IV. METHODOLOGY

The methodology adopted in this research is a mixed process methodology aiming at devising a transformation process to map the analysis results acquired from RL process of a major HealthCare Medical Equipment Provider (HCMEP), towards the obtention of a modified RL process framework in a systematic and automated way through the use of computer simulation modelling. The main data gathering techniques used are Interviews, Documentation, Reports and Observations.

V. LITERATURE REVIEW

The specific research question to be answered is: How can the Customer Service Quality be improved and the Operational Efficiency be increased in terms of Cycle Time & Full Time Equivalents in the Reverse Logistics process of an organization?

The relation between each of the variables contained in the hypotheses will be highlighted in the proposed hypotheses as follows:

H1: There is a relation between Customer Service Quality (CSQ) and Cycle Time (CT).

H2: There is a relation between Operational Efficiency (OE) and Full Time Equivalents (FTEs).

H3: There is a relation between Customer Service Quality (CSQ) and Operational Efficiency (OE).

The following Table 1 summarizes the reviewed literature and the relations between each variable of the hypotheses:

Table 1: Summary of Literature Review

H1, relation between CSQ & CT	
Author(s)	**Conclusion**
(Jacobson, 1997)	Customer Service is improved when Cycle Times are reduced.
(Andersen, 1999)	Reducing Cycle Times, save cost, time & Satisfy Customers

(Papouras, 1999)	Reduced Cycle Time increases Customer Satisfaction.
(Habibbhai & Deshpande, 2014)	Short Cycle Times are essential to provide Customer Satisfaction.
H2, relation between OE & FTEs	
Author(s)	**Conclusion**
(Cox, 2006)	Sales per full time equivalent is a measure of operational efficiency
(Horta et. al., 2010)	Full time equivalent is a major KPI of operational efficiency.
(Mizrahi, 2011)	Full time equivalent is a productivity measure to determine efficiency.
H3, relation between CSQ & OE	
Author(s)	**Conclusion**
(Amini & Retzlaff-Roberts, 1999)	There is a positive relation between Operational Efficiency & Customer Service Quality through reducing full time equivalent & cycle times.
(Scheraga, 2004)	Focused expenditure on customer value based activities has a positive impact on operational efficiency.
(Auramo et. al., 2004)	Offering value added services to customer provides more visibility about customer demand, which helps the supplier plan its own operations effectively. Hence, it is a CSQ-OE loop.
(Coelli et. al., 2005)	Customer Service Quality is an output of Operational Efficiency and such output should be measured to provide an actual indicator.
(Reinwald, 2013)	Strong positive correlation between operational efficiency & customer satisfaction based on service quality.

(Own, 2015)

From the previously summarized literature review, the following theories can be concluded:

From H1: Reducing Cycle Time (CT) increases Customer Service Quality (CSQ).

From H2: Reducing Cost per Full Time Equivalents (FTEs) increases Operational Efficiency (OE).

Increasing Units per Full Time Equivalents (FTEs) increases Operational Efficiency (OE).

From H3: Increasing Operational Efficiency (OE), increases Customer Service Quality (CSQ).

VI. CONCEPTUAL MODEL

A business process reengineering is implemented to address the main issues of a company's RL Maintenance Process, and proposing a modified maintenance process applied to a case study concerning one of the Egyptian Healthcare Medical Equipment Providers (HCMEP), representing around 15 international product lines. For confidentiality reasons, the name of the company will not be mentioned and will be referred to as HCMEP. It is a private partnership company, established in 1986 for marketing and distributing Medical Equipment in the whole of Egypt.

Upon the preliminary interview with the Service Team, the main problems faced by HCMEP in its maintenance process are; the complexity of the healthcare equipment that is limiting the on-site repairing process, as in 50% of service cases it is a must to withdraw the machine from the customer's site back to the service center. In addition, the climate nature (temperature and humidity) in Egypt and other infrastructure problems such electric current volatility and road humps (upon transportation) jeopardize the machines for defects, even after the repair process, upon returning back the machine to the client.

The in-depth analysis conducted to the HCMEP's current maintenance process (CMP), revealed the existence of two main problems; A lot of customer complaints have been reported concerning the lengthy repairs which impacts negatively on the customer service quality. The total income of the service department has decreased signaling the existence of some operational deficiencies.

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The literature review, previous studies, together with the listed hypotheses has provided insights for handling these problems by following these directions; Increasing the customer service quality (CSQ), which can be obtained through reducing the maintenance cycle time (CT) (Based on H1).

Increasing the operational efficiency (OE) which can be obtained through increasing the number of units per full time equivalent (FTE) and/ or decreasing the cost per full time equivalent (FTE) (Based on H2).

The HCMEP's Current Maintenance Process (CMP) needs to be redesigned in order to simplify it, minimize the steps, eliminate redundancy and optimize the efficiency.

Using a computer software program to generate all the available information needed once the service call is received. The program is to generate the following;

- Machine serial number, history of defects / repairs / upgrades and warranty conditions; Defect report including all details of the defect, symptoms, error messages;
- Client / site name, address, contact details;
- Client history and recommendations of handling from previous experiences;
- Assigning the qualified service engineer familiar with such defects and who received a previous training on such machines;
- Recommendation of handling such defect from previous experiences, which may facilitate the repair onsite process; Approximate service cost for repairing such defects;
- Upon investigation onsite, in case the defect differs from the reported defect in the service call, the service engineer can access the system to identify all recommendations and troubleshooting steps necessary to eliminate such defect and repair the machine onsite;
- In both cases, either to repair onsite or to repair in the service center, the system can provide an estimated service quotation for the client approval;
- The computer software is to provide the ability of predicting the needed spare parts to be available in stock based on the previous maintenance operations, which will save the import time in many maintenance cases.
- The cost of the computer program is estimated to be EGP 30,000, which will be depreciated on 2 fiscal years (15,000 EGP / each of the initial 2 years of using the software).

The Proposed Maintenance Process (PMP) was modified and the main differences between the current & the proposed RL processes can be summarized as follows:

Table 2: Main Differences between CMP & PMP

	CMP	**PMP**
IT Process automation	Not available	Available
Number of process steps	30	19
Machine maintenance cycle time range (hours)	82 - 224	62 - 213
Defected machine history	Not available unless manually investigated	Issued automatically early in the service order
Warranty conditions	Explored manually lately in the repair process	Issued automatically early in the service order
Engineer assignment	An available engineer is assigned	Assigning a qualified engineer trained on the reported defect(s) or familiar with machine type.

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Estimate repair quotation	Not available	Issued automatically early in the service order
Spare parts availability	May or may not be available in stock	Higher probability for spare parts availability due to software prediction
Failure in repair testing attempt	Machine treated as new order and submitted to assigning new engineer in a whole repeated service cycle (time consuming)	Machine submitted only to repair/ replace and retesting cycle with same engineer (time saving)

(Own, 2015)

VII. COMPUTER SIMULATION MODELLING

Using Arena® simulation software V.14.70.04, the following steps were applied;

Step 1: Mapping the current and proposed maintenance process diagrams into Arena simulation flow chart modules, consisting of entities, processes, decision points, disposal points and end points as shown in Appendix 2.

Step 2: Defining model data associated with each module, setting time distribution constraints in addition to decision point probability conditions.

Step 3: Allocating the case study resources and defining associated parameters.

Step 4: Specifying the same replication length, duration, working hours.

Step 5: Running the Simulation and viewing the category overview reports.

CMP Simulation Results:

- After running the simulated CMP model with [OP-SC1], the following results were obtained from the Arena Category Overview Report.
- The number of maintained and delivered equipment at the end of the simulated period is 654 devices out of 700. The average total time for a medical equipment maintenance cycle is 275 hours in which only 43 hours spent as value added time and 232 hours spent as wait time.
- The average total (Manpower) cost for a single medical equipment maintenance is 560 EGP.
- The total maintenance resources (Manpower) cost during 300 days simulation period is 408,277 EGP (in which the busy cost is 397,701 EGP and the idle cost is 10,575 EGP).
- After running the simulated PMP model with [OP-SC1], the following results were obtained from the Arena Category Overview Report.
- The number of maintained and delivered equipment at the end of the simulated period is 695 devices out of 700.
- The average total time for a medical equipment maintenance cycle is 89 hours in which 25 hours are spent as value added time, and 64 hours spent as wait time.
- The average total cost for a single medical equipment maintenance is 313 EGP.
- The total maintenance resources cost (Manpower) during 300 days simulation period is 409,354 EGP (in which the busy cost is 218,282 EGP and the idle cost is 191,072 EGP). Plus the 15,000 EGP annual cost of the specialized maintenance computer program (as computer software is usually depreciated on 2 fiscal years) = 424,354 EGP.

PMP First Simulation Results:

- After running the simulated PMP model with [OP-SC1], the following results were obtained from the Arena Category Overview Report.

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- The number of maintained and delivered equipment at the end of the simulated period is 695 devices out of 700.
- The average total time for a medical equipment maintenance cycle is 89 hours in which 25 hours are spent as value added time, and 64 hours spent as wait time.
- The average total cost for a single medical equipment maintenance is 313 EGP.
- The total maintenance resources cost (Manpower) during 300 days simulation period is 409,354 EGP (in which the busy cost is 218,282 EGP and the idle cost is 191,072 EGP). Plus the 15,000 EGP annual cost of the specialized maintenance computer program (as computer software is usually depreciated on 2 fiscal years) = 424,354 EGP.

PMP Second Simulation Results:

The results of the first PMP simulation run revealed a high idle cost suggesting a recommended reduction in manpower. For this specific reason, the first operational scenario [OP-SC1] is adjusted into the second operational scenario [OP-SC2] which is then tried to assess the effect of excess Manpower reduction on cost and efficiency. The following results were obtained from the Arena Category Overview Report.

The number of maintained and delivered equipment at the end of the simulation period is 700 devices out of 700.

- The average total time for a medical equipment maintenance cycle is 97 hours in which 25 hours are spent as value added time, and 72 hours spent as wait time.
- The average total cost for a single medical equipment maintenance is 317 EGP.
- The total maintenance resources cost (Manpower) during the 300 days simulation period is 300,300 EGP (in which the busy cost is 221,901 EGP and the idle cost is 78,399 EGP). Plus the 15,000 EGP annual cost of the specialized maintenance computer program (as computer software is usually depreciated on 2 fiscal years) = 315,300 EGP.

VIII. ANALYSIS & SUMMARY

The results acquired from the Simulation Reports for the three simulation runs CMP [OP-SC1], PMP [OP-SC1] and PMP [OP-SC2] are summarized in the following Table 3.

Table 3: Summary of simulation results

<table>
<tr><th></th><th colspan="2">CMP [OP-SC1]</th><th colspan="2">PMP [OP-SC1]</th><th colspan="2">PMP [OP-SC2]</th></tr>
<tr><td>Number of maintained devices (number out)</td><td colspan="2">654</td><td colspan="2">695</td><td colspan="2">700</td></tr>
<tr><td>Number of units per Manpower</td><td colspan="2">44</td><td colspan="2">46</td><td colspan="2">64</td></tr>
<tr><td rowspan="3">Average Cycle Time per machine (hours)</td><td colspan="2">275</td><td colspan="2">89</td><td colspan="2">97</td></tr>
<tr><td>Value-added time</td><td>wait time</td><td>Value-added time</td><td>wait time</td><td>Value-added time</td><td>wait time</td></tr>
<tr><td>43</td><td>232</td><td>25</td><td>64</td><td>25</td><td>72</td></tr>
<tr><td>Average cost per machine (EGP)</td><td colspan="2">560</td><td colspan="2">313</td><td colspan="2">317</td></tr>
<tr><td rowspan="4">Total resources Manpower cost

(for 300 operational days) (EGP)</td><td colspan="2" rowspan="2">408,277</td><td colspan="2">Without computer SW cost 409,354</td><td colspan="2">Without computer SW cost 300,300</td></tr>
<tr><td>Busy cost</td><td>Idle cost</td><td>Busy cost</td><td>Idle cost</td></tr>
<tr><td>Busy cost</td><td>Idle cost</td><td>218,282</td><td>191,072</td><td>221,901</td><td>78,399</td></tr>
<tr><td>397,701</td><td>10,575</td><td colspan="2">With computer SW cost 424,000</td><td colspan="2">With computer SW cost 315,300</td></tr>
</table>

(Own, 2015)

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Time Analysis:

The average Cycle Time (CT) for each single machine is a key comparison aspect and a major factor when considering which process to adopt, as it is a pointer towards customer service quality (as demonstrated in H1).

The examination of the comparison of the CMP [OP-SC1], PMP [OP-SC1], and PMP [OP-SC2] concerning the average cycle time attribute reveals the following information:

- The average cycle time in the Current Maintenance Process CMP is quite high; 275 hours =~ one and a half month, which rationalizes the customer complaints about the repair delays.
- The fact that the majority of the cycle time is wasted as wait time reveals the presence of a problem and the urge for process reengineering.
- The most time accumulating process activities, according to the category overview report, are the "Testing" process followed by the "Assign Qualified Engineer" process. These processes are Manpower-dependent, showing that the available 15 engineers and technicians are not sufficient to handle the defective machines efficiently given the current maintenance process configuration.
- The average cycle time in the Proposed Maintenance Process PMP [OP-SC1] has dramatically improved; 89 hours =~ 12 days, which would definitely stop any delay complaints.
- The wait time has noticeably decreased proving the significance of process reengineering.
- In the redesigned proposed process, the 15 engineers and technicians are fairly enough to handle the defective machine.
- The average cycle time in the Proposed Maintenance Process PMP [OP-SC2] has also dramatically improved; 97 hours =~14 days, though it is slightly longer than PMP [OP-SC1].
- The wait time is very acceptable regarding the fact that the number of Manpower has decreased from 15 to 11 engineers and technicians, but still the handling of repairs is adequate.

Cost Analysis:

Cost is a major factor to consider when comparing processes. There are three categories of costs to analyze; average maintenance cost per machine, total resources cost, and busy versus idle costs.

- From the examination of the comparison of the CMP [OP-SC1], PMP [OP-SC1], and PMP [OP-SC2] concerning the average maintenance cost per machine, the Current Maintenance Process (CMP) exhibits the highest cost per machine whereas the Proposed Maintenance Process (PMP) in both scenarios shows a significant cost decrease.
- Although the total resources cost of the Proposed Maintenance Process (PMP) in [OP-SC1] seems to be slightly higher than the Current Maintenance Process (CMP), this is a deceiving increase as the total number of maintained machine in PMP is more than CMP.
- The second scenario application to the Proposed Maintenance Process (PMP) proves to be the best concerning the total resources cost (least cost and most maintained machines).
- In the Current Maintenance Process CMP, the idle cost is very small in comparison to the busy cost. This is usually a good efficiency indicator; all Manpower working and little money spent on rest. But again this is misleading because the wait time for the machines in CMP is very big; meaning that the Manpower available is not enough to handle the maintenance.
- In the Proposed Maintenance Process PMP [OP-SC1], the idle cost is relatively high, meaning that the workforce exceeds than the workload. This is because the reengineering effort in PMP and the use of IT organized the process and made it less Manpower-dependent.
- This big idle cost in the PMP [OP-SC1] was the reason in the first place for the introduction of the second operational scenario [OP-SC2], in which the Manpower is reduced in order to decrease the idle cost.

- In the Proposed Maintenance Process PMP [OP-SC2], the idle cost has decreased in comparison to [OP-SC1] as a result to Manpower reduction, and even though the number of maintained machines has increased showing that PMP [OP-SC2], at this point, exhibits the best results.

Output Analysis:

The comparison of the CMP [OP-SC1], PMP [OP-SC1], and PMP [OP-SC2] concerning the total number of maintained and delivered machines at the end of the 300 simulation run period, revealed the following:

- The Proposed Maintenance Process PMP [OP-SC2] demonstrates the best results concerning the number out (all machines are maintained and delivered) in comparison to both CMP and PMP [OP-SC1].
- The number of units per Full Time Equivalent (FTE) and the cost per Full Time Equivalent (FTE) are chief comparison factors as they are indicators to Operational Efficiency (OE).
- Increasing Operational Efficiency (OE) can be realized in many ways, some of which include, as demonstrated in H2, the increase in the number of units per Full Time Equivalent (FTE) and/ or the decrease in the cost per Full Time Equivalent (FTE).
- In the Proposed Maintenance Process PMP, in both scenarios, no decrease in cost per FTE was realized. This is partially due to the cost of computer software that adds to the total resources cost. However, no visible increase in the cost / FTE in both scenarios of PMP is manifested.
- On the other hand, the number of units per FTE in both scenarios of the Proposed Maintenance Process PMP, and especially in [OP-SC2], shows a raise and an improvement comparing to CMP.

Analysis Summary:

The Proposed Maintenance Process PMP, in both scenarios, dramatically improved the average machine Cycle Time (CT). This is a major contributor to increasing Customer Service Quality (CSQ) which is one of the HCMEP intended objectives. The Proposed Maintenance Process PMP, in both scenarios, significantly reduced the average machine maintenance cost, which counts as a positive signal for both the customer and the company. The total number of maintained and delivered machines by the Proposed Maintenance Process (PMP), in both scenarios, were augmented. The number of units per Full Time Equivalent (FTE) in the Proposed Maintenance Process PMP, in both scenarios and particularly in [OP-SC2], has radically increased. This indicates an enhancement to the Operational Efficiency (OE) which is another HCMEP intended objective. Although the cost per FTE hasn't decreased, the benefits realized by the Proposed Maintenance Process PMP, for either scenario, compensate the slight cost increase required to adopt it. Thus, the Proposed Maintenance Process PMP proved to be a success and managed to accomplish the required objectives.

IX. CONCLUSION

Successful organizations constantly rethink how they do their work in order to improve customer service, cut operational costs, and become world-class competitors. Reverse Logistics, a field that has formerly been overlooked, can play an important part in the growth of an organization, and whom when properly handled, leads to minimizing costs, increasing customer service and gaining customer loyalty. A Reverse Logistics process reengineering effort, all the way through restructuring the process design, optimizing sub processes, and incorporating IT and computer automation, can lead to achieving the mentioned objectives. In this study, the notions of Reverse Logistics, Business Process Reengineering, and Information Technology were the focal points guiding the research effort. A Reverse Logistics maintenance process reengineering model was proposed, to target the deficiency occurring in the current maintenance process of a case study. The proposed model was tested and evaluated using computer simulation modelling. The Arena simulation software used allowed the comparison of multiple scenarios for both case study's current and proposed maintenance processes, and the analysis of the results confirmed the worth and significance of the proposed process. There is a demonstrated inversely proportional relationship between Cycle Time & Customer Service Quality, an inversely proportional relationship between Operational Efficiency & cost per Full Time Equivalent, a direct proportional relationship between Operational Efficiency & units per Full Time Equivalent, and a direct proportional relationship between Customer Service Quality & Operational Efficiency as deduced from the literature review and the previous studies. The thorough analysis of the current maintenance process of the HCMEP case study revealed multiple flaws and lack of efficiency which were the drive to engage in the reengineering effort. Process streamlining, Information Technology and automation, and redundancy elimination were included in the reengineered proposed maintenance process model with the aim of enhancing Customer Service Quality and improving Operational Efficiency. Simulation modelling was conducted to both current and proposed maintenance processes so as to evaluate and provide a comparative basis upon which, the decision making concerning process adoption could be facilitated. The simulation findings' analysis confirmed the merit of the proposed maintenance process and verified its ability to accomplish the desired objectives.

X. LIMITATIONS OF THE STUDY

The focus on one industry only, the Healthcare Equipment industry, represents a limitation to the generalization of the findings to other industries in the Egyptian market. This research considers a retailer's viewpoint but do not consider other stakeholders, such as manufacturers. Other studies consider a manufacturer point of view more specifically. Thus, this research is considered to be complementary to other studies. The chosen case study company has knowledge about Reverse Logistics (judgmental sampling), which may not agree with true sample population. Time is another limitation, as it prevented the actual application and implementation of the proposed reengineered maintenance process.

XI. RECOMMENDATIONS FOR FUTURE WORK

The main recommendation is to apply the proposed maintenance process in the real world, as it was a limitation to apply it over a 1 year period to measure the validated virtual results of the simulation against reality. In addition, it is highly recommended that future studies to cover in addition, the reengineering of reverse logistics channels, back to the other side of the supply chain, from the distributor to the manufacturer, as this is perceived to save also time and cost for the ultimate end-user.

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APPENDICES

Appendix 1: Summary of the Previous Studies.

Approach	Date	Application Field	Basic Concept	Contribution	Benefits	Drawbacks / Limitations	Simulation
Kims Approach	1997	Hospital	Process Redesign	Dynamic process modeling (DPM) method to support firms interested in redesigning their business processes.	The DPM method reduces the risk of BPR by providing a better understanding of the target business process from the customer's viewpoint.	Focusing on CS and overlooking the cost issue.	SIMPRO-CESS
Clendenin Approach	1997	Empirical / Xerox (Photocopying)	Evaluation & Mapping	Xerox Business Process Architecture is used to determine process linkages, dependencies and measurements. As well as to map and document the returns process for equipment.	Determination of tactical productivity opportunities and breakthrough projects.	Should have focused on disposition / recycling as the trade-in rates are very high in Photocopying industry.	VISIO / I-Think
Amini Approach	1999	Apparel Retailing	New Function	Sizeable reductions in Full Time Equivalents (FTEs)	Net reduction in FTEs is about 85% to 90% of current levels	Creation of a new job type that decreases the FTEs net reduction	Arena
Goldsby Approach	2000	Beverage Retailing (Several Firms in Michigan)	New job function	Utilizing a third party to gather and transport containers collected at stores utilizing reverse vending machines for recycling.	Reducing wages and times of collection activities and reducing the used spaces in distribution warehouses.	Additional cost of the new job function (third party collection)	N/A
Ritchie	2000	Pharmaceutical	Recycling for	Enabling management &	Reducing waste and	Limitation of recycling	N/A

Approach	Date	Application Field	Basic Concept	Contribution	Benefits	Drawbacks / Limitations	Simulation
Approach		Stock (Industry-wide / 28 hospitals)	later reuse.	pharmacy staffs to understand how the process was mapped and how the problem is identified and process redesign.	reducing stock level.	in pharmaceutical field.	
Knemeyer Approach	2002	Computers Recycling / Refurbishing (Qualitative Examination)	Designing a Reverse Logistics system to recycle / refurbish computers.	Mapping & Analyzing the economic viability of an overall system designed to reach and refurbish EOL (End Of Life) computers.	Recycling / Refurbishing adds more value & give the computers longer useful lives increased profits for demanufacturing / recycling companies.	The study didn't consider the importance of disposition as a procedure for environmental Reverse Logistics practices.	N/A
Chan & Chan Approach	2008	Mobile phone industry	Pilot Questionnaire Survey	The study results approaches critical factors in designing reverse logistics systems for the mobile phone industry as a short life cycle product.	Emphasizing on the importance of the reverse logistics awareness in the mobile phone industry, which is considered a major barrier in this industry.	The limitation is that the size of the surveyed companies is not large and they are limited to Hong Kong based companies. Both factors may affect the generalization of the study.	N/A.
Lau Approach	2009	Empirical Study Electronics industry in China	Comparison of the RL theories & models in China	Concluding the common barriers for RL implementation in China	The study reveals the problems encountered in the implementation of reverse logistics in China and proposes measures to expedite the development.	The complex nature of China's transitional economy and political considerations may influence the perspectives and practices of small manufacturers in the management of environmental issues are limiting the generalizability of the findings.	N/A
Hsu Approach	2009	Major retailing department store.	Mapping the current RL process and identifying the possible development areas.	Providing the detailed description of the business process in the Reverse Logistics in the retailing business.	Inventory can be more efficiently managed. Improved returns management can significantly reduce costs and provide valuable information to a retailer's planning cycles.	The study didn't provide a clear solution for the time required for managing damages when no return authorization is forthcoming from the vendor. In this instance, vendors are unwilling to commit to something because they don't know how much it will cost them.	N/A.
Zhang Approach	2010	Semiconductor Manufacturing	Integration and Coordination	Reengineer the order fulfillment process (OFP) by capitalizing on integration and coordination across the entire supply chain	Improvements on selected KPIs (Order fulfillment, Order processing, Fabrication time, Delivery performance, Productivity & Operating hours)	N/A except for the implementation time (eight months)	ProModel
Chan Approach	2010	Generic / Empirical Study	People Involvement	Proposing an activity-based framework for RL practitioners	Designing a new reverse logistics system from the process reengineering perspective	Compromising between cost and technical performance.	Not specified
Ming Approach	2010	Generic / Empirical Study	Process Redesign	New information process of logistics system is formed cored by Logistics Information Processor through information process reengineering.	Logistics Information Processor improved a lot in the efficiency, range, and amount of information dissemination.	Non-reflective of customer satisfaction and more oriented to the products itself (number, types, weight).	Not specified
Cempel	2010	Decorative	New process	Remarkable increase in	Significant growth in	Future concern of	IDEF0

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Approach	Date	Application Field	Basic Concept	Contribution	Benefits	Drawbacks / Limitations	Simulation
Approach		Wholesale Retailing	modeling	customer satisfaction	several KPIs	autocratic influential management	
De la Fuente Approach	2010	Metal-mechanic manufacturing capital equipment	Enterprise modeling case study	New enterprise modeling methodology applicable to supply chain reverse and forward engineering and integration.	The proposed methodology allows for the study and analysis of the business processes used by the company to manage its supply chain, as well as the definition of a reverse logistics system (for later implementation).	Given the fact that the company did not perform any residue recovery or recycling processes, despite being aware of standing environmental legislation.	N/A.
Bienstock Approach	2011	Direct Retailing	New Process	Redesigning the product return process.	Reduce the time for customers to receive credit or exchange products. Reducing the returns processing center-staffing requirements	Could replace customer's phone call before return, with a prior email notification, which would save the necessity of a dedicated employee to answer the phone call.	Arena
Oluyemisi Approach	2012	Aircraft Field	New Tool	Radio Frequency Identification (RFID) tag memory and database for end-of-life aircraft Reverse Logistics network.	RFID technology has greater capacity to reduce running costs of the end-of-life aircraft Reverse Logistics network.	Huge initial investment cost of RFID technology.	Arena
Groznik Approach	2012	Petroleum Distribution	Process Improvement	Improving effectiveness in distribution network	Significant decrease in average lead-time, average work, average wait & average costs.	Focusing on the distribution phase only.	iGrafx Process
Bernon Approach	2013	Empirical Case Study (OEM & retailing)	Exploring supply chain integration (SCI) enabling practices, their benefits and barriers in a retail product returns process context.	One of the first works that systematically and empirically explores SCI in reverse supply chain processes, as opposed to forward supply chain processes.	Illustrates the value of SCI initiatives in product returns processes and informs managers' decision making in the planning and execution of similar SCI implementations in product returns processes	A single case research strategy provides a limited opportunity for external generalization of the research findings.	N/A.
Insanic Approach	2014	Product recovery in the PC industry	Qualitative case study	Applies a new perspective on product recovery. The analytical framework and qualitative approach complement mainstream approaches, based on three dimensions of business reality: activities, resources and actors.	The study offers companies broader perspective on their product recovery operations by illustrating how they are related to a wider network.	Focused on the economic dimension of sustainable product recovery, without taking environmental and societal concerns into consideration.	N/A.
Lütjen Approach	2014	Conceptual Modeling	Model transformation; system analysis	Developed the concept of model-driven logistics engineering by analyzing the domains of production and logistics.	Defining the essentials of model-driven logistics engineering and promising approaches of the field of model-driven engineering are presented.	Lack of framework for model-driven engineering, which allows to apply different modeling and simulation techniques in order to plan and evaluate logistics systems in an efficient way.	N/A.

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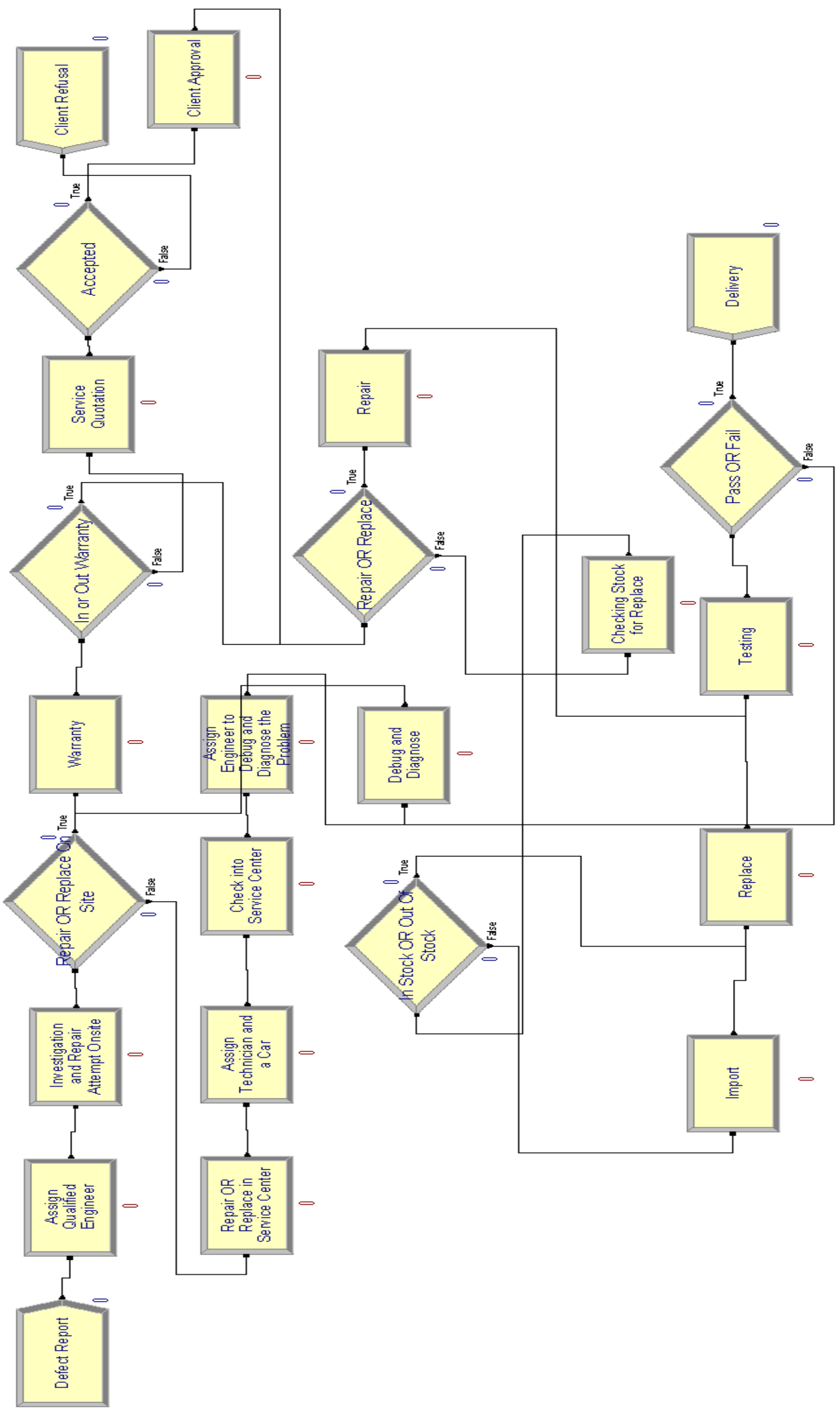
Appendix 2: CMP & PMP Simulation Flowchart Maps.



(CMP Simulation flowchart Map)
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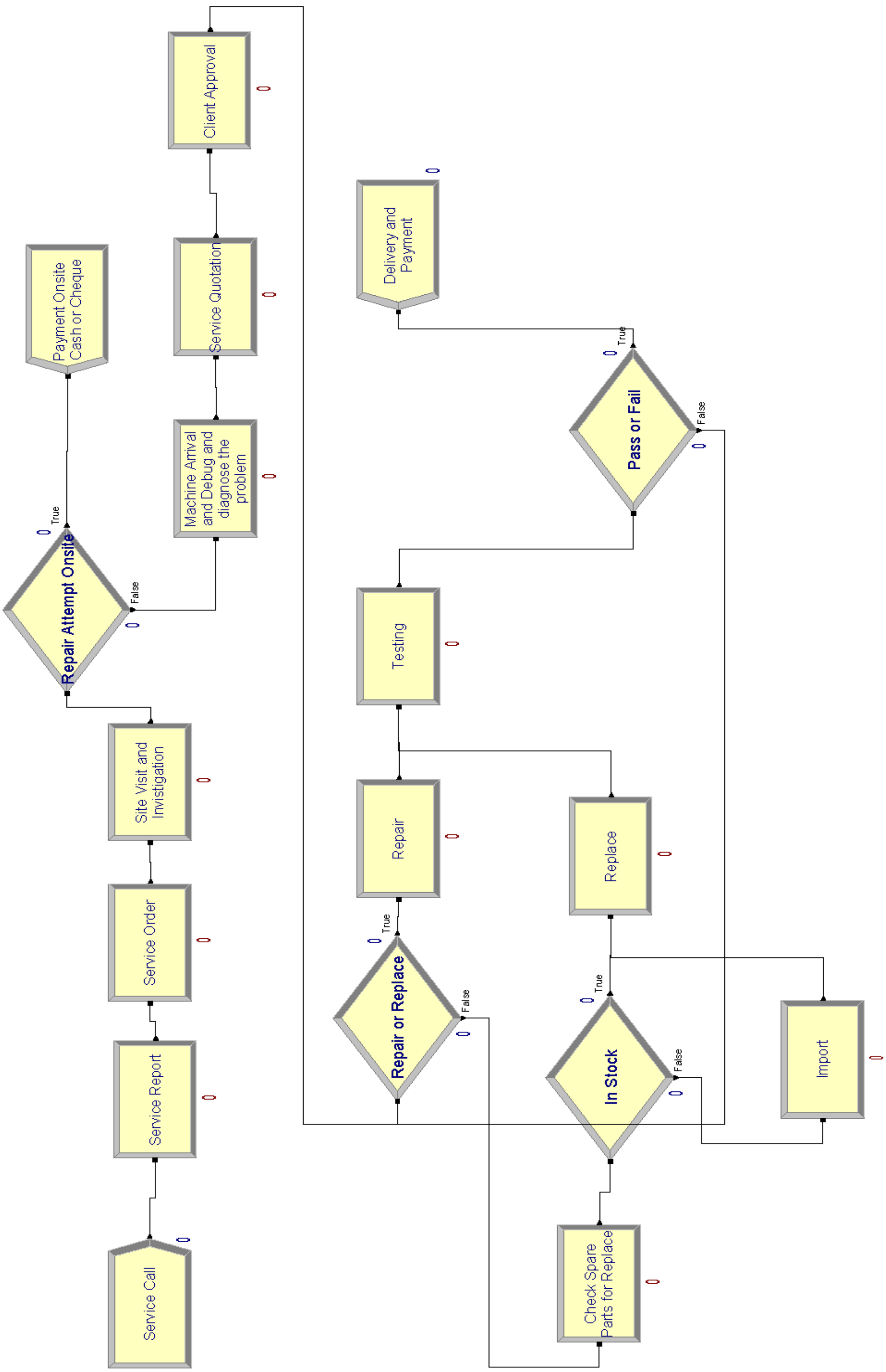

(PMP Simulation flowchart Map)
(Own, 2015)