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PROPOSITION OF A METHODOLOGY TO EVALUATE THE PERFORMANCE OF THE PRODUCTION PROCESS VIA PERFORMANCE INDICATORS OF BOTH THE PRODUCTION PROCESS AND REVERSE CHAIN PROCESS

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ABSTRACT

The production process represents the core of every industrial company. And each company strives to improve the critical process of production. The purpose of this work is to propose a methodology to evaluate the performance of the production process via performance indicators of both the production and the reverse chain process. The first part of the article presents the problems studied. The second part describes the literature review of reverse logistics and performance indicators. The third part highlights the interest of this study in the industrial field. The fourth part shows the different steps of the proposed methodology and the proposed performance indicators and its application to a case study followed by an analysis of the results obtained. The last chapter represents the conclusion and the research opportunities of this paper.

Keywords: reverse logistics, production processes, performance indicators, supply chain, automotive wiring.

1. INTRODUCTION

Returned goods are uncontrollable and unpredictable hence the difficulty of having a precise forecast system in order to plan the return logistics. Also, when returning a product, there are different types of returned products. We distinguish three categories:

- Convertible product into raw material: product that can be converted into raw materials for future reuse in the industry;
- Products for reparation: product can be repaired into the final product after processing or reparation;
- Product inconvertible: product recovered without any benefit to the industry, rejected.

On a previous study, we have founded out that returned products for reparation represent the most beneficial type of returns in the global chain. That is why we chose to focus our work on the impact of the returns on the production process and specially retuned products for reparation. Our study will focus on the relation between the production process and returned products specially the “products for reparation” [12]

In this work, our aim is to propose a methodology to evaluate the performance of the production process via performance indicators of both the production process and the reverse chain process and apply it to an industrial case: A company producing automotive wiring.

The first part describes the literature review of reverse logistics and performance indicators. The second part highlights the interest of this study in the industrial field. The third part shows the different steps of the proposed methodology and the proposed performance indicators and its application to a case study followed by an analysis of the results obtained. The last chapter represent the conclusion and the research opportunities of this paper.

2. LITERATURE REVIEW

2.1 Definition of reverse logistics

The term reverse logistics is the most commonly encountered in the literature when it comes to return management and processing of recovered products. This name is suggestive of the fact that it allows to refer to the related logistics activities of an organization, but in an opposite direction, as opposed to the regular activities of the supply chain. Given the emergence of the concepts of reverse logistics in the last ten years, it is not surprising that the use of a relatively varied and sketchy terminology. Reverse logistics is often treated in the literature in a given context: specifically address activities or disassembly of products in electronic commerce, or refers often to a definite case study focusing on a particular type return. [25].

Thierry *et al.* (1995) discuss the reverse logistics under the name of managing the recovery (Product recovery management), as:

"The management of products, components and materials used or disposed of that are the responsibility of the manufacturing company. The objective of product recovery’s management is to obtain the maximum economic and environmental value reasonably possible, while reducing the ultimate amount of waste. "[27]

For their part, Beaulieu *et al.* (1999), Beaulieu (2000) have presented reverse logistics, this time under the term reverse logistics, as:

"A set of management activities to reintroduce non-core assets in sectors with added value." [3]; [4]

In the Kocabasoglu *et al.* (2007) study, top manager’s risk propensity towards involvement with the reverse supply chain was directly related to the reconditioning process, an aspect of product recovery. [20]

In the recent studies, the reverse logistics also known as the Closed Loop Supply Chain (CLSC) [17]; [22], [23] designed to manage the recycling and recovery process of end-of-life [8]; [18]. A Closed loop supply chain generally involves a manufacturer taking care for the reverse logistics process. The goods are returned and recovered directly by the original manufacturer or through indirect channels [2]. All the returned goods are resold in primary or secondary market after necessary disposition [28]. Essentially, a CLSC extends the normal forward SC by including reverse SC channels for product return, recycling/recovery, remanufacturing, and resale [19].

In the last decade, studying CLSC has become a major area of SC management literature and increasing attention has been devoted to the understanding, management, and improvement of this type of SC structure [1];[19].

2.2 Production process and the reverse logistics

The production process is the main process in the company. For the reverse logistic, its liaison with the production lies in the remanufacturing process. Indeed, the remanufacturing process is generally concerned with material recovery from high value products [5]. In most of the cases, remanufacturing is carried out by the manufacturers because of their knowledge of products. Products are remanufactured by utilizing existing facilities that forms a closed loop supply chain network [14]. Uncertainty in terms quality, quantity and timing of product returns are important factor for the success of remanufacturing network [24]. Since this network works as intermediary between the collection and redistribution, they form a fairly complex multi-level structure [16] [20] conducted a survey empirically for assessing the linkages between supply chain investments, organizational willingness to take risk and business uncertainty, and found that ongoing investment in the forward supply chain was more inclined toward recycling and waste management, but not in remanufacturing. Wilcox et al. (2011) stated that the firms must manage uncertain cash flow problems due to the erratic and unpredictable cash transactions associated with uncertain product returns. [29] In our study, we propose to propose performance indicators to monitor the production process with the inclusion of the reverse chain and specially the remanufacturing process being the main process that has a direct impact on the reverse chain.

A recent study has showed that reverse logistics also influence the maintenance process which is a crucial part to maintain a steady production process. [11]

3. INTEREST OF THE STUDY

The advantage of reverse logistics' integration is mainly customer satisfaction. Indeed, there a son for this satisfaction is varied according to Rogers (2001) [24] and Carter and Ellram (1998) [6] Langnau (2001) [21] and Dowlatshashi (2000) [9]. But the main reasons are the laws in some countries centred on customer service, Marketing aspect or interest of some consumers for healthy products to the environment in addition to the economical aspect of returns for recycling material and ecological and environmental aspects.

Furthermore, previous study has shown that reverse logistics has a big impact not only on the cost but also on delay that impact the production process and also on the stocks management [10].

3.1 Legislation aspect

Some countries require companies to integrate reverse logistics. The primary example is the European Community Directive on packaging material which states that a customer may leave the package at the retailer and it must ensure their recycling. [15]

3.2 Marketing aspect

On the one hand, the companies are trying to solid if the loyalty of their customers by offering a guarantee on products. On the other hand, customers are more interested in ecological and healthy products to the environment. That is why companies are becoming more aware of the reverse logistics. In Transportation and Distribution in 1993, it is mentioned that 80% of respondents in their survey would be willing to buy a more expensive product if it had a low environmental impact. [7]

3.3 Economical aspect

Generally, companies treat reverse logistics as a constraint consider in it as an economic burden. Instead, reverse logistics has a very attractive investment return.

Despite the importance of reverse logistics' integration in the direct supply chain, it takes up a large part of the overall cost of direct chain. Indeed, the importance of calculating the break-even point of reverse logistics remains an important factor in determining the limit of investment in product returns. Similarly, it allows businesses to predict their potential gain. And allow them to define their investment thresholds in reverse logistics and extreme cases to avoid additional expenses. [26]

On another note, studies has shown that reverse logistics can be very beneficial at low rates of returns specially in companies producing automotive wiring [13]

4. METHODOLOGY

The proposed methodology will have for goal to define and specify the performance indicators and there inter relation.

Our methodology is as follow:

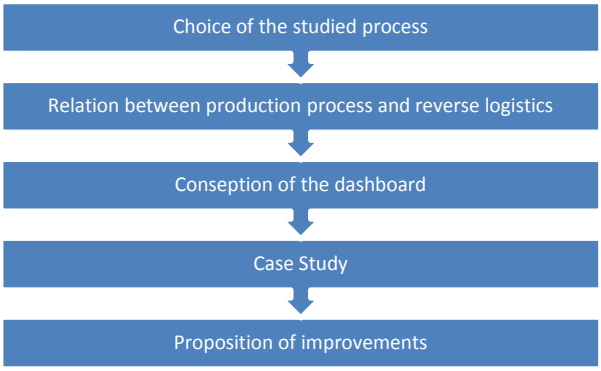

Figure-1. Proposed methodology.

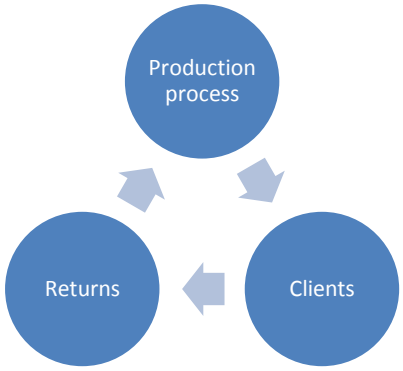

Figure-2. Study model.

Our case study was conducted in a manufacturing automotive cable. Indeed, our methodology will help better understand the liaisons between, different performance indicators and better understand and survey the production process and the reverse chain.

4.1 Choice of the studied process

In this first step, we determine the chosen process for our study. We chose the production process due to its crucial role in the company. Previous study has shown the impact of the reverse supply chain on the production being on the delay caused by the returned products and there remanufacturing process on the production process. That is why we desire to connect the reverse supply chain to the production process. We propose to take into consideration when studying the production process the following process:

Even though our study focuses on the production process, we will also study the relation between these three units:

- **Production process:** main study purpose;
- **Clients:** Delivery of finished products and satisfaction;
- **Return:** Sorting and reintroduction of returns.

4.2 Conception of the dashboard

This step represents the core of our study. Indeed, the conception of the dashboard and the specification of the performance indicators will be the basis of the analyses of the production process.

In our study, we will focus on the tactical level for both the production process and the reverse supply chain:

For the production process, we propose the Table-1:

Table-1. Production process' performance indicators.

Performance indicator	Definition	Measures
Rates of delays	Emphasise on the rates of the global delays in the production process	$\frac{Delays\ due\ to\ returns}{Total\ work\ time}$
Rates of remanufacturing cost per returned product	Emphasise on the average costs for each type of products per day	$\frac{Product's\ remanufacturing\ cost}{Total\ remanufacturing\ cost}$
Rates of reclamations from clients	Emphasise on the rate of reclamations from clients	$\frac{Reclamation\ clients}{Total\ Clients}$
Cost of delay	Indirect cost due to production halts due to breakdown	$\frac{\text{Delay cost}}{\text{Total delay cost}}$
Rates of returns	Rate of returned products to the company	$\frac{\text{Returned products}}{\text{Delivred products}}$

We will use these performance indicators to survey the production intern process.

In order to measure these performance indicators, we propose the following mathematical model:

Input data
Index i: Represents months
Index j: Represents Products
CRP_j: Average remanufacturing costs for returned products from product j
QRP_{ij}: Quantity returned from product j on month i.
QP_{ij}: Quantity produced from product j on month i.
D_{ij}: Delay caused by returns on month i on the process of manufacturing for products j
P_j: Productions' rate for the product j
PN_{ij}: Penalties on delays for product j in month i
S_j: Cost of product j on the market

4.3 Data outputs

Remanufacturing cost for product j on month i

$$CRP_j * QRP_{ij}$$
(1)

Cost of delay time on month i for products j

$$D_{ij} * P_j * S_j + D_{ij} * PN_{ij}$$
(2)

Rates of returns on month i for products j

$$\frac{SRP_{ij}}{SP_{ij}}$$
(3)

4.4 Case study

Our case study focuses on the study of the production process of an automotive wiring company on the tactical level. To better monitor and study the production process, we use the proposed performance indicators of both the reverse chain and the production process.

For six month, we will evaluate the production process for the company for each product:

We obtained the following results:

For the performance indicators performance "rates of delays"

Figure-3. Performance indicators "rates of delay" for all products.

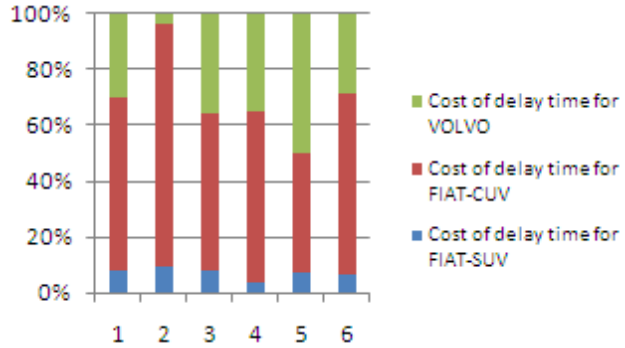

Figure-4. Performance indicators "Cost of delay time" for all products.

On the one hand, we can see the product Fiat-CUV has the highest rate of delay being the product that has the highest product returns and then products remanufacturing which consumes a lot of resources and a lot of time.

On the other hand, the product FIAT-SUV having the lowest production rate and the lowest price in the market leads to the cost of delay time for the product FIAT-SUV having the lowest rate in contradiction to VOLVO who has a bigger production rate and bigger market price which leads to bigger rate cost of delay with lesser rate of delay time

For the performance indicators performance "Rates of clients reclamations"

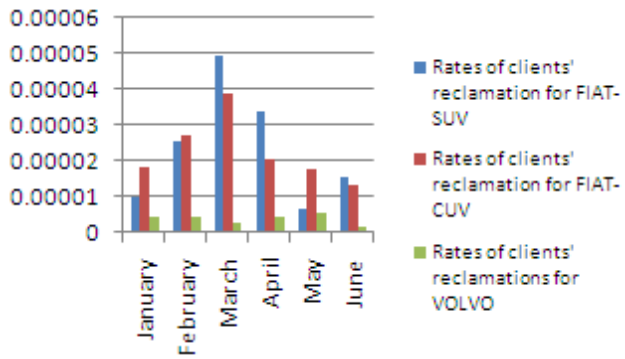

Figure-5. Performance indicators "Rates of clients' reclamation" for all products.

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As we can notice from the chart, the product "FIAT-CUV" due to being the most expensive product and needs to meet high quality standards.

For the performance indicators performance "Rates of remanufacturing cost per returned product"

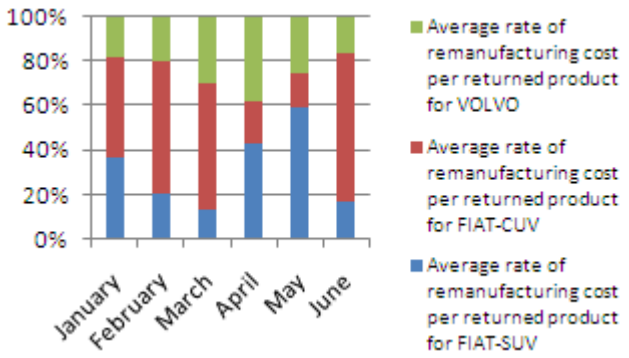

Figure-6. Performance indicators "Average Rates of remanufacturing cost per returned product" for all products.

As expected from the previous graphs, the product labelled as "FIAT-CUV" has the highest average costs due to having the second most returned products and the highest delays. Indeed, the high standards of the products makes the average remanufacturing costs high and the more low quality returned product from the clients the higher the remanufacturing cost becomes.

4.5 Proposition of improvements

In this part, we aim to improve the production process by proposing improvement to reduce "remanufacturing costs", "Clients reclamation" and reduce "rate of delay". We proposed these improvements to the company in the next 6 months:

- Improve Formation quality and sensitize the operators for the importance of quality;
- Introduce a sorting process for return products;

After improvement, we obtained the following results:

For the performance indicators performance "rates of delays"

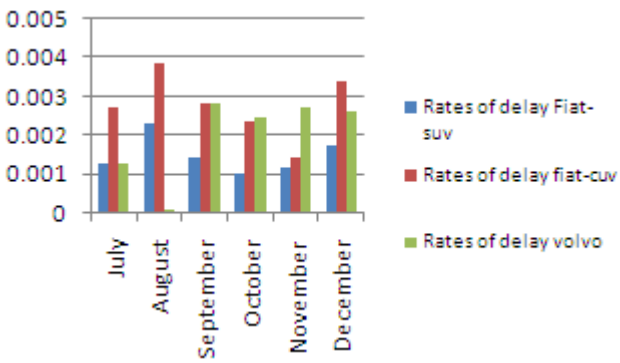

Figure-7. Performance indicators "rates of delay" for all products after improvements.

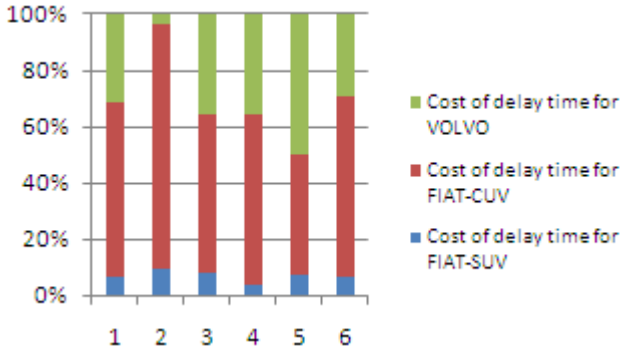

Figure-8. Performance indicators "Cost of delay time" for all products after improvements.

On the one hand, we see a reduction in the rate of delays. Thanks to the sorting process. Indeed, the sorting process has enabled a great time economy in the remanufacturing process since it allows a better categorisation of the returned products.

On the other hand, due to the improvement, we have now less overall delay time.

For the performance indicators performance "Rates of clients reclamations"

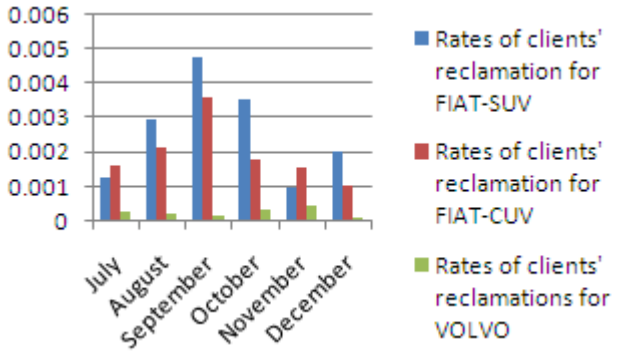

Figure-9. Performance indicators "Rates of clients' reclamation" for all products after improvements.

We gained a slight reduction in the rates of clients' reclamation. The reduction is caused by the improvement and emphasise on the quality of products: Less returned products by quality control.

For the performance indicators performance "Rates of remanufacturing cost per returned product"

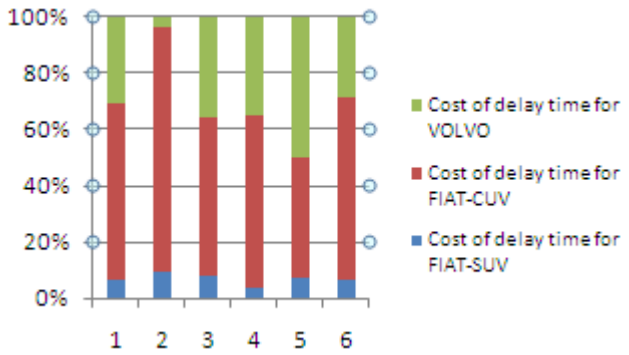

Figure- 10. Performance indicators "Average rates of remanufacturing cost per returned product" for all products after improvements.

Even though the introduction of sorting process helped us reduce the delay on production process and the improvement in quality reduced the rate of reclamations from clients the average remanufacturing cost remains high.

5. RESULTS ANALYSIS

We noticed that overall, the improvement done to the production process has improved the production process. Indeed, we have now less returns and reclamation from clients due to the improvement and the emphasis on the quality to meet the clients' standards and needs. Furthermore, the company gained not only on the rates of returns but also in the reduction of the delay in the production process. The sorting process helps the company better organise the remanufacturing returned products and so reduce the delay caused by the remanufacturing process on the production process.

Our proposed methodology main goal is to propose a monitoring tool to better analyse and understand the core behaviour of the company and allow the monitor of both the reverse chain and its influence on the production process on both the remanufacturing process part and the direct production process.

6. CONCLUSIONS

Our study propose a methodology to better measure and monitor the production process including the impact and the effects of the reverse chain on the main companies' process the production process. We found out in our study that the proposed impact factors can be used to monitor the production process and the impact of the reverse chain and also study the impact of the quality increase and the introduction of sorting process in the production process on the reverse chain.

Even though, the proposed performance indicators may seem global and stay on a tactical level they are sufficient to study the production process. We can improve the proposed dashboard by including more specific performance indicators.

The proposed model can be used in general in many production processes for different companies.

Reverse logistics still remains a double-edged sword. As it could increase the benefice or reduce it.

It is for this reason that our model provides a monitoring tool for the production process to better apprehend the reverse chain.

As perspective of working for this article, we aim to extend our studies to the rest of the main process in the direct supply chain.

Finally, our objective is to propose a global dashboard to better monitor the supply chain both direct and reversed.

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