MATERIALS HANDLING MANAGEMENT: A CASE STUDY

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ABSTRACT: The highly competitive environment, linked to the globalization phenomena, demands from companies more agility, better performance and the constant search for cost reduction. The present study focused on improvements in internal materials handling management, approaching the case of a large company in the automotive industry. Materials handling is intrinsically associated with production flow. Because of this, it has direct influence on transit time, resources usage, and service levels. The objective was to evaluate, in a systematic way, the impact of implemented changes in materials handling management on the internal customers' perceptions of cost, safety in service, service reliability, agility and overall satisfaction. A literature review preceded a case study in the company's manufacturing unit and the questionnaires were completed by 26 employees directly involved in the process. Analyzing the answers, it was possible to suggest that internal customers understood that the new materials handling management system enlarged service agility and reliability and reduced costs, which caused an improvement in overall satisfaction.

Key words: *internal handling, material flow, materials management, material handling management, service level.*

1. INTRODUCTION

There is a strong concern to adjust the supply system in a company (Machline, 2008) to achieve a higher service level internally and to the outside customers. This brings to a higher operational level and even a possible differential when compared with the other competitors (Milan, Paiva & Pretto, 2006; Paiva, Carvalho Jr. & Fensterseifer, 2004).

Materials handling management is among many factors that contribute to improve a company's performance. The Materials Handling Industry of America [MHIA] defines materials handling management as "Material Handling is the movement, storage, control and protection of material, goods, and products throughout the process of manufacturing, distribution, consumption and disposal. The focus is on the methods, mechanical equipment, systems and related controls used to achieve these functions" (mhia.org/learning/glossary). Then it is observed that handling is broader than simple materials movement, although both terms are sometimes used as synonyms.

The relevance of materials handling stems from the intrinsic relationship that it has with production flow. When it presents an imbalance, there is formation of extra stock or rupture in supply. When the flow does not have enough velocity, transit time is long and the system is not capable of serving the customers when they need it.

It is well understood that material handling improvement may have positive effects over production. However, it is not only production, but the way the employees see the new situation. When the perception is favorable, the benefits are possible; if not, behavioral issues can emerge. Evaluations are important when interventions into the work environment are implemented. The present work is specifically related to materials handling management. By means of effective materials handling management, the company's operational performance may improve (Chopra & Meindl, 2001; Rosenbloom, 2003) aiming to satisfy the customers or meet their expectations in terms of their needs, desires and demands (Oliver, 2010; Stock & Lambert, 2001).

The case study related in this work was performed in an automotive industry located in the northeastern part of Rio Grande do Sul State of Brazil. It was founded more than 50 years ago and is classified as a large-sized company since it has more than 2000 employees. This region contains a cluster of industries of metal-mechanic, automotive and metallurgical sectors that in its majority belong to production chains which demand a high internal performance level from their partners.

The company in question, after analyzing production flow as a whole, identified that among other measures it would be necessary to improve materials handling management in the manufacturing process. This was motivated by the observed delay in forklifts service and their high maintenance cost. Forklifts were used both for parts handling and transportation and to assist in tooling changes, which many times resulted in excessive setup time leading to production delays. Changes were made in the materials handling process to address these concerns.

The main objective of this case study was to evaluate internal customers' satisfaction levels after the change. In order to do this, it was necessary to identify the factors that explain overall satisfaction; to do it, open-ended questionnaires were applied. The respondents – 26 people directly linked to daily materials flow – were requested to identify the attributes and unfold them into sub-factors which represented the internal process in more details. The identified attributes were cost, safety in service, service reliability and agility. After this step, a second questionnaire with close-ended questions was applied to the same respondents in order to evaluate performance satisfaction at each factor and sub-factor and also overall satisfaction. The questions requested the respondent perception about the improvement – perceived or not – after the interventions.

The collected data were analyzed with multiple regressions. Data analysis indicated that the factors agility, service reliability and cost are able to explain overall satisfaction. In addition to that the satisfaction level of most of internal customers with the new materials handling management system is equal or even superior when compared to the previous one.

2. LITERATURE REVIEW

2.1 Material Flow

Materials handling makes production flow possible, as it gives dynamism to static elements such as materials, products, equipments, layout and human resources (Stock & Lambert, 2001; Chopra & Meindl, 2001). Groover (2001) highlights that despite its importance, materials handling is a topic that frequently is treated superficially by the companies. However, other authors have perceived its relevance. During the period in which Shingo (1996) contributed to the development of the Toyota Production System, he developed the Production Function Mechanism that proposes to explain how the production phenomenon happens.

Shingo (1996) indicated that, in the West, production was treated as a process of a sequence of operations. In the Production Function Mechanism, the concepts are directly related to a production analysis focus. A process analysis consists of an observation of the production flows that turn raw materials into final products. From this concept, the author highlights that the main analysis is the one associated with the process, because it follows the production object. The analysis of the operations comes later because it focuses on production subjects (operators and machines). When making this distinction, it is possible to perceive the relevance of materials handling.

Beyond the basic function of movement, it is also relevant to cite the functions of storage and information transfer, which occurs simultaneously and has both strategic and operational dimensions. Organizations are relying on information systems using tools like Electronic Data Interchange (EDI), or similar information technology resources, to gain in precision and reliability, in the interchange, and availability of information (Lambert & Stock, 2001; Laudon & Laudon, 2006, Milan, Basso & Pretto, 2007).

According to Asef-Vaziri & Laporte (2005) an important proportion of manufacturing expenses can be attributed to material handling and the most critical material handling decisions in this area are the arrangement and design of material flow patterns. This idea is shared by Ioannou (2002), which argues that an important aspect of any production system is the design of a material handling system (MHS) which integrates the production operations

The relevance also occurs in another context. Ballou (1993) states that the storage and handling of goods are essential among the set of logistics activities, and their costs can absorb 12% to 40% of its costs. In addition, the MHIA estimates that 20% to 25% of manufacturing costs are associated to handling (Groover, 2001, p. 281). According to Sule (1994) apud Sujono & Lashkari (2006), material handling accounts for 30–75% of the total cost of a product along the production chain, and efficient material handling can be responsible for reducing the manufacturing system operations cost by 15–30%.

For Bowersox and Closs (1996), the main logistic responsibility in manufacturing is to formulate a master-program for the timely provision of materials, components and work-in-process. Stevenson (2001) understands that logistics (including materials and goods flowing in and out of a production facility as well as its internal handling) has become very important to an organization to acquire competitive advantages, as the companies struggle to deliver the right product at the correct place and time. The main challenge is to promote, with low cost, a flow whose velocity allows the execution of manufacturing process with the expected satisfaction level.

2.2 Elements and Characteristics of a Material Handling System

Materials handling study requires that several elements are considered. The first is a handling system project, which covers activities of sequencing, velocity, layout and routing (Groover, 2001). In order to complete the analysis, Groover (2001) recommends analyzing the material itself (or object) to be transported. Therefore, it suggests the classification of Muther and Hagan (apud Groover, 2001), which considers: (i) physical state (solid, liquid, gas); (ii) size (volume, length, width, height); (iii) weight; (iv) condition (hot, cold, dry, dirty, sticky, adhesive); (v) risk of damage (weak or strong); and (vi) safety hazards (explosive, flammable, toxic, corrosive, etc.).

Additionally, the issue of equipment and devices must be examined. Dias (1993) adopts the term "moving" to describe what, in this article, is called management (handling) to adopt the terminology of Groover (2001). When dealing with equipment, Dias (1993) presents a broad classification that covers five categories: (i) transporters (belts, chains, rollers, etc.); (ii) cranes, hoists and lifts; (iii) industrial vehicles (carts, tractors, pallet transporters, forklifts); (iv) positioning equipment, weighing and control (ramps, transfer equipment); and (v) stents and support structures (pallets, holders, reels).

According to Chan, Ip & Lau (1999), a key factor in material handling system design process is the selection and configuration of equipment for material transportation. This is directly related to this study.

According to Gurgel (1996), the equipment should be selected based on some preliminary considerations: take into account the utilization of the factory floor and its load capacity; examine the dimensions of doors and corridors; pay close attention to ceiling height, identify the environmental conditions and their nature, avoid the use of combustion engines traction equipments in storage of food products, meet all safety standards to protect humans and to eliminate the possibility of incurring criminal and civil liabilities arising from accidents, and examine all kinds of available energy options and their capacity to supply required movements.

The right choice of equipment and location of work-in-process is fundamental for the optimization of a company's manufacturing capacity. Bowersox and Closs (1996) state that a critical factor in positioning stocks in process is a balance between convenience and consolidation to create efficiencies when the stock flows along the value chain.

The importance of layout, which defines the placement of equipment and, consequently, restricts possible routes and sequencing, can be perceived by the prominence that the subject is treated in production management literature. The analysis of the relationship between layout studies and material handling, however, does not receive much attention in the same literature. This lack of attention can be seen in works like Gaither and Frazier (2002), Chase, Jacobs and Aquilano (2006) and Slack, Chambers, Harland, Harrison and Johnston (1997).

Finally, the systems and information technology constitute essential factors for materials handling management. Stair and Reynolds (2006), Laudon and Laudon (2006) and O'Brien and Marakas (2007) support the study of fundamentals and general principles of information systems.

In order to improve the performance of distribution operations and, in this specific case, the internal material handling process, it is important to consider both human and technical factors (Chakravorty, 2008). In this sense, this study assesses the internal customers' perception of a material handling process improvement.

With regard to the attributes to be considered in a material handling system, according to Kulak (2005), effective use of labor, providing system flexibility, increasing productivity, decreasing lead times and costs are some of the most important factors influencing selection of material handling equipment. These factors are directly related to some attributes found in the present study.

The determination of a material handling system involves both the selection of suitable material handling equipment and the assignment of material handling operations to each individual piece of equipment (Sujono & Lashkari, 2006). Hence, according to Sujono & Lashkari (2006) material handling system selection can be defined as the selection of material handling equipment to perform material handling operations within a working area considering all aspects of the products to be handled. In this context it is important to mention that, in this study, only the selection of the material handling equipment was considered.

3. PROBLEM AND INTERVENTION DESCRIPTION

The first sub-section describes the situation prior to the intervention, identifying the problems that were found. The second describes the factors that motivated the change. The third describes the changes and the situation after its completion. Besides variables and sub-variables, customers' overall satisfaction regarding the implemented changes was also evaluated.

3.1 Situation Prior to the Intervention

This study was conducted in the manufacturing sector of an automotive company. The manufacturing sector is responsible for almost all of the supply of assembly lines, including the components that go through a pre-assembly process before proceeding to final product assembly. In this sector are concentrated cutting and bending tools and dies required for components manufacturing to assembly lines. The whole process runs with the aid of forklifts. Often, the setup time is equal to or higher than the time needed for parts manufacturing. This situation, coupled with the cost of downtime, demonstrates the importance of the tooling exchange process.

Besides helping in the execution of setups and carrying out internal transport managed by an electronic scoreboard installed in the factory roof, forklifts also performed activities for transporting materials between pavilions. When executing this last activity, the forklifts often travelled on uneven roads, which caused great bouncing, burdening maintenance cost for equipment wear or premature breakage.

Often, when a forklift leaves its workplace to transport a container between pavilions, delays in machines' setups are generated, causing unnecessary costs and stress on the forklift operator. The operator could do little besides feel forced to increase the speed during the route, creating risks of accidents with personal injury and / or materials damage. This activity as well as the studied process relate to Goldratt's Theory of Constraints (TOC) to seek bottlenecks and reduce or eliminate them (Goldratt; Cox, 2004).

Although there were enough forklifts to meet the demand from the manufacturing sector, many times it was not possible to meet immediately the manufacturing needs due to reasons like long distances to travel and frequent maintenance due to excessive use of the equipment. This directly affected internal customers' satisfaction.

The presented problem was: how to increase internal customer satisfaction, while stabilizing or decreasing forklifts' maintenance cost?

3.2 Change Motivators

Due to development of new markets, manufacturing demands for a large variety of components and final product assemblies increased. This demand growth led to speed increases and changes in how materials and tools were being handled and transported in order to monitor manufacturing requirements.

With these changes and demands for manufacturing to attain the company's goals, there was also pressure for growth and lack of tolerance with forklift operators, since the work did not always run quickly and with quality. Additionally, forklift maintenance costs were increasing, demanding sometimes excessive spending that jeopardized the budget. The dissatisfaction and demotivation of forklift operators was notorious, and an increase was also noticed in the number of collisions between the equipments. Finally, boxes and containers were unsatisfactorily stored in the hallways together with the machines to attempt to reduce production interruptions.

3.3 The Changes and the Situation after the Implementation

One suggested solution was to rent two forklifts as a way to solve the problem. But this only served to soften it, and brought a larger cost to the company. It was realized then that it was not the quantity of equipments that was going to solve the problem but the way material handling was being executed in relation to the necessity of the presented changes.

From this observation, processes and material flows were mapped and separated in two ways: (i) vertical movements which make greater efforts and little ground movement; and (ii) horizontal movements that rely on traction to travel longer distances, including transport out of the work units.

Another proposed solution was to use a tractor towing small "wagons", forming a kind of train. Ballou (1993) states that this approach is more economical for larger volumes that must be moved over long distances along the same route.

Several cargo (pallets) units were constructed with special wheels, fitted with suspension coupled to support the material weight and traverse the gaps between the pavilions. Afterwards, several "cages" were made to be used for holding the parts that go through the processes of bath and painting. More robust containers for heavier and less delicate parts storage were also constructed.

The next step was to create spaces (pit stops) for pallets with their mobile parts on each workstation. In order to the truck driver to know when he could transport material, it was necessary to create an identification system. It was decided that every time that the operator finished the process in his station, he would put on the packaging a green sign indicating that the container would be ready to be transported to the next production step. The truck driver, when removing a filled container, should replace it with an empty one in the vacant post.

Tests were conducted with a timetable for the train passage, but this alternative did not meet the need for flexibility in case of emergencies (pieces to technical assistance and replacement of damaged materials in the assembly process).

It was then decided to set a path that would follow the manufacturing process sequence. To inform the train operator of some urgency, a mobile phone was given to him. Thus, the supervisor could communicate with the operator instantly when there were critical parts and / or components to be collected.

After the changes were completed, it was necessary to evaluate their impacts. This study evaluated internal customers' satisfaction level with the new materials handling and transporting configuration.

4. RESEARCH METHODOLOGY

4.1 Company Characterization

The studied company, Marcopolo S/A., is one of the main bus body producers in the world. Founded in 1949, in Caxias do Sul, the company is divided into four business units: (i) bus, with bodies of Marcopolo and Ciferal brands; (ii) LCV, with complete minibus under the Volare brand; (iii) plastic products, with MVC brand; and (iv) parts and components, with service parts for the company brands and parts for other segments of the Syncroparts brand.

The company maintains a technology transfer contract with the Iveco SPA. The transferred technology from the lines Midi bus, Low Entry and High Decker was made in the factory of CBC-Iveco in China. Currently, Marcopolo has a representative office called Marcopolo Changzhou Office at Changzhou and has also been developing a joint venture agreement with Tata Motors in India. This study took place only at the Brazilian facility.

4.2 Objectives

The present study had as its objective to evaluate, in a systematic way, the impact of the implemented changes in materials handling management on the internal customers' perceptions at the manufacturing department in Marcopolo S/A. unit located in Caxias do Sul – RS.

To reach this objective, the following specific objectives were established: (i) describe the changes in material handling processes at the company; (ii) evaluate internal material handling flow in manufacturing, verifying the improvements; and (iii) analyze internal customers' satisfaction levels relative to the new system.

4.3 Data Collection

The sample was the people directly involved with the daily flow of materials, selected intentionally. The respondents held positions as leaders, supervisors, forklift drivers and warehouse operators, enabling a comprehensive view of the problem. Data collection for the satisfaction survey was divided into two stages. The first step was an open-ended question survey (Appendix 1). Respondents were asked about their perceptions regarding the changes in materials handling emphasizing evidence of the improvements, problems still identified after change implementation and suggestions for the relevant attributes in question. Two criteria were used to define factors and sub-factors from the obtained answers: i) the factor must be cited by respondents of all positions (leaders, supervisors, forklift drivers and warehouse operators); ii) the number of times that the criterion has been cited by the 26 respondents. Table 1 shows the evaluated factors, their definitions and the associated sub-factors.

Table 1 – Factors and sub-factors of satisfaction survey

N.	Factors	Factors Description	Sub-factors
1	**Cost**	Monetary value available to maintain the operation: expenditures with periodic maintenance linked to forklifts use	Mechanical shutdowns Electrical shutdowns Corrective painting
2	**Safety in Service**	Identifies forklifts operator's conduct on new handling and internal transport way	Safety in handling Tooling storage Efficient routing
3	**Service Reliability**	Identifies manufacturing satisfaction level in terms of reliability	Operator's autonomy Operator's performance and availability
4	**Agility**	Identifies the time spent with tool exchange coupled handling (discounting the times associated with the machine, such as loose and/ or fix arrays or tools)	Setup agility Material handling quickness Tooling handling quickness

Performance improvements (current state vs. status quo) were measured using the following scale: 1 = much worse, 2 = worse, 3 = same, 4 = better and 5 = much better. For instance, the employee was asked: "Comparing previous and current procedures for handling and internal transport, how do you assess the costs related to mechanical downtime?" To answer the question, the options of the scale mentioned above were offered. At this point it is important to highlight that the study was evaluating the respondents' perception, starting from the assumption that they had knowledge enough (even empirical) because they are directly involved in the process.

5. DATA ANALYSIS AND RESULTS

Once the new situation was established, data collection started followed by analysis and presentation of the results. The data were tabulated in order to obtain an average percentage and standard deviation of overall satisfaction in relation to the factors and sub factors presented during sampling. Table 2 shows the results.

Table 2 – Internal satisfaction survey

ATTRIBUTE	Average	S	Sat.>=4	Sat.=3	Sat.<=2
COST	3,58	0,69	69,2%	26,9%	3,8%
Mechanical Shutdowns	3,74	0,93	73,1%	19,2%	7,7%
Electrical Shutdowns	4,05	0,78	80,8%	19,2%	0,0%
Corrective Painting	3,74	0,81	65,4%	34,6%	0,0%
SAFETY IN SERVICE	3,88	0,65	80,8%	15,4%	3,8%
Safety in Handling	3,92	0,84	80,8%	15,4%	3,8%
Tooling Storage	3,73	0,68	80,8%	15,4%	3,8%
RELIABILITY OF THE SERVICE	3,35	0,75	38,5%	57,7%	3,8%
Safety in Handling	3,23	0,65	30,8%	65,4%	3,8%
Operator`s Autonomy	3,81	0,90	69,2%	26,9%	3,8%
Operator`s Performance and Availability	3,73	0,78	53,8%	46,2%	0,0%
AGILITY	3,50	0,58	46,2%	53,8%	0,0%
Setup Time	3,36	0,58	26,9%	73,1%	0,0%
Material Handling Quickness	3,81	0,85	53,8%	46,2%	0,0%
Tooling Handling Quickness	3,48	0,67	34,6%	65,4%	0,0%
OVERALL SATISFACTION	**3,54**	**0,58**	**50,0%**	**50,0%**	**0,0%**

Considering satisfaction levels equal to or higher than 4 in Table 2, it is identified that the overall satisfaction percentage shows that 50% of the respondents noticed improvements in the process after its implementation (answers ≥ 4 in the scale that was used).

The data were analyzed with the aid of multiple linear regressions for each of the studied factors, as well as for general satisfaction. The results are shown as follows.

5.1 Cost Analysis

Regression analysis for the cost sought to understand how much it was influenced by each of its sub-factors. Regarding factor and sub-factors relationships, corrective painting was not statistically significant. The satisfaction in relation to the cost factor was considered as the dependent variable and the ratings of each of the other two remaining sub-factors were treated as independent variables. Expression 1 was obtained. The value of $R^2 = 0.63$ indicates that expression 1 is able to explain 63% of the variability in cost assessments.

Cost = 0.36 x electrical shutdowns + 0.31 x mechanical shutdowns (**1**)

The p-values found for the terms were less than 0.19. This should be considered as an exploratory result related to the significance of the sub-factors.

5.2 Safety in Service Analysis

Regression analysis for safety in service tried to understand how it was influenced by each of its sub-factors. For this factor, tooling storage was not statistically significant. Then, the satisfaction in relation to the safety in service factor was considered the dependent variable and the rating of safety in handling was treated as the independent variable and the expression 2 was obtained. The value of $R^2 = 0.73$ can state that the second expression is able to explain 73% of the variability in safety in service evaluations.

Safety in Service = 0.66 x safety in handling (**2**)

The p-value found for the term was less than 0.0001, which allows us to assert that it is significant with a probability of at least 99.9%.

5.3 Service Reliability Analysis

Regression analysis for service reliability attempted to understand how it was influenced by each of its sub-factors. For this factor, efficient routing, operator's performance and availability did not show significance, so the only sub-factor that was considered as an independent variable was operator's autonomy according to expression 3, where we can see service reliability as the dependent variable. The value of $R^2 = 0.68$ can state that expression 3 is able to explain

68% of the variability in service reliability's assessments.

Service Reliability = 0.69 x Operator's autonomy (**3**)

The p-value for the term was less than 0.0001, which allows us to assert that it is significant with a probability of at least 99.9%.

5.4 Agility Analysis

Regression analysis for agility aimed to understand how this was influenced by each of its sub-factors. In this factor all sub-factors presented statistical significance and were treated as independent variables in expression 4 where we observe agility as the dependent variable. The value of $R^2 = 0.89$ can state that expression 4 is able to explain 89% of variability in assessments of agility.

Agility = 0.40 x tooling handling quickness + 0.31 x setup agility + 0.19 x material handling quickness (**4**)

The p-values found for the terms were less than 0.17, so the results should be considered exploratory.

5.5 Overall Satisfaction Analysis

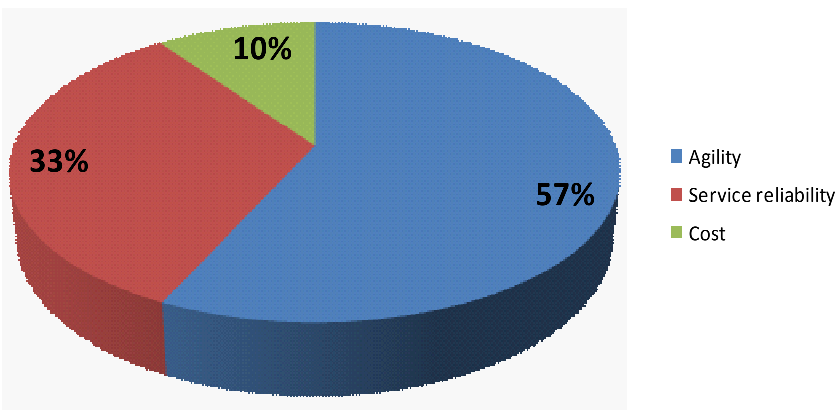
The regression analysis for overall satisfaction aimed to understand how this was influenced by every factor. Analyzing the relation among the factors and overall satisfaction, safety in service was not statistically significant, so it was not considered as an independent variable in expression 5, where it is possible to observe that the three remaining factors are the independent variables and overall satisfaction is the dependent variable. The value of $R^2 = 0.89$ shows that the expression 5 is able to explain 89% of the variability in overall satisfaction ratings.

Overall Satisfaction = 0.65 x agility + 0.38 x service reliability – 0.12 x cost (**5**)

The p-values found for the terms were less than 0.17, so the results should be considered exploratory.

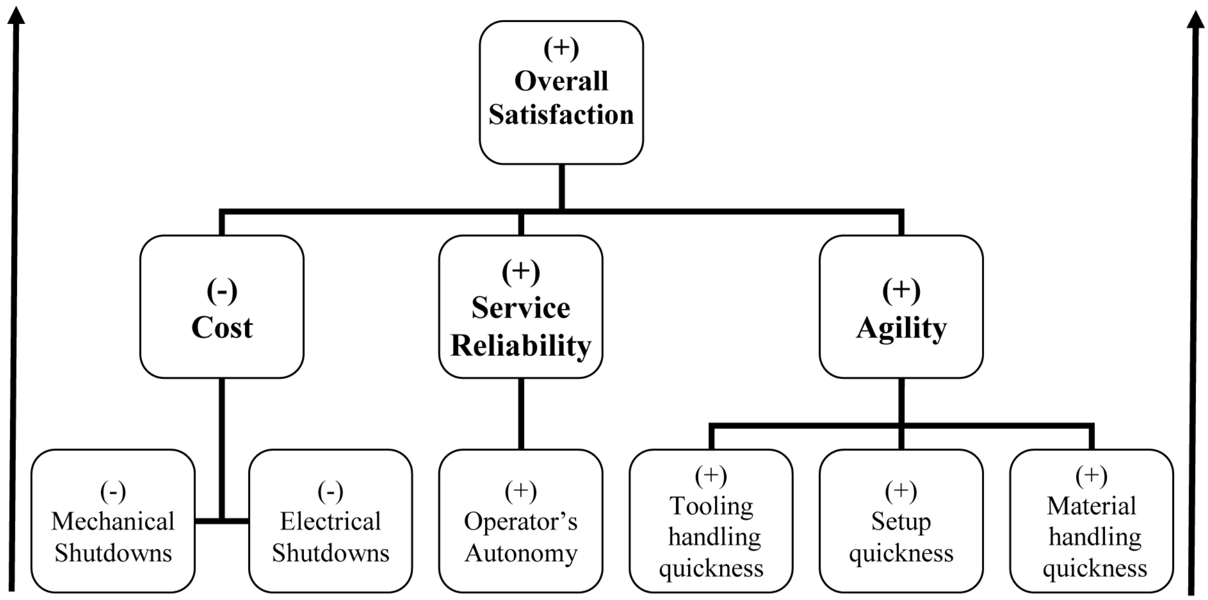
According to Malhotra (2006), the weights of each attribute can be calculated from an expression obtained in Multiple Regression. To calculate the relative weight of each attribute, it is necessary to get an overall satisfaction value when it assumes its maximum (=5) and the others are at the minimum value (=1). After that, the values found with the attribute in maximum and minimum must be subtracted. This procedure was used to transform the regression model's coefficients in the percentages shown in Figure 1.

Figure 1 – Factors that affect overall satisfaction



By these results, it was possible to develop a model of the perceived satisfaction with internal material handling process redesign (activities). The model is presented in Figure 2 and it has as its base the factors and sub-factors that presented statistical significance.

Figure 2 – Model of satisfaction of the implemented improvements



6. CONCLUSION

Due to constant complaints because of failures in service and also low speed in material transport, the company was motivated to innovate and/or improve internal processes that could increase the efficiency of services to manufacturing. The basis of the implanted system was the concept of stock on wheels, practicing materials transport with the aid of a tug internally named "train". The tug pulls the wagons with more load than forklifts (previous system), maximizing travels and loads through a specific route.

With the new system implementation the need to assess its real impact in relation to the expected improvements emerged. From internal customers' evaluation there was an increase in overall satisfaction. This increase can be explained by a greater agility (57%), greater reliability in service (33%) and lower cost (10%). The results identified the significant subfactors and their impacts on the described factors.

Besides internal customer satisfaction improvement, which was evidenced by the present study, there was an effective improvement in the internal material handling. The improvement in material flow caused by the use of the proposed vehicle increased the accuracy of materials delivery time inside the company. Operations became safer. The system used was able to evaluate the perceptions of the implemented changes, as well as to identify factors and sub-factors that influenced satisfaction increase. These improvements in the company operations resulted in new subsidies to perform similar studies.

In relation to specific established objectives, changes in material handling processes at the company were described (first specific objective); internal material handling flow in manufacturing was evaluated and improvements were made (second specific objective); and internal customers' satisfaction levels related to the new system were analyzed (third specific objective).

This way, the present work's general objective was attained: to evaluate, in a systematic way, the impact of the implemented changes in materials handling management through internal customers' perceptions, evidencing a relevant contribution to the company and to the studied area.

It is important to highlight that there were no losses of jobs although some employees were reallocated. One operator from the central warehouse was transferred to vehicle driving and his previous job was divided between two other people from the same department. Regarding inventories, there was a reduction in work-in-process; however there were no changes in raw material and finished goods stocks because the purchasing policy and customer delivery time were not modified.

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APPENDIX 1: OPEN-ENDED QUESTIONNAIRE

1 - What is your general perception in relation to material handling process after the changes?

2 - What are the main evidences of the improvements?

3 - What problems are still identified after the implementation of the change?

4 - What are the main factors affected?

5 - What are the main issues identified in each factor?

APPENDIX 2: CLOSE-ENDED QUESTIONNAIRE

How do you evaluate material handling system at the company after the established changes?

Please, use the scale below to answer the following questions:

1 = much worse
2 = worse
3 = equal
4 = better
5 = much better

1. How do you evaluate the cost of operations?

1 2 3 4 5

1.1 How do you assess the occurrence of mechanical shutdowns?

1 2 3 4 5

1.2 How do you assess the occurrence of electrical shutdowns?

1 2 3 4 5

1.3 How do you evaluate the need for corrective painting?

1 2 3 4 5

2. How do you rate safety in service?

1 2 3 4 5

2.1 How do you assess the safety in handling?

1 2 3 4 5

2.2 How would you rate tooling storage?

1 2 3 4 5

3. How would you rate the reliability of the service?

1 2 3 4 5

3.1 How do you assess route efficiency?

1 2 3 4 5

3.2 How do you assess the operator's autonomy?

1 2 3 4 5

3.3 How do you assess operators' performance and availability?

1 2 3 4 5

4. How do you assess the agility of operations?

1 2 3 4 5

4.1 How do you evaluate the setup time?

1 2 3 4 5

4.2 How do you assess material handling quickness?

1 2 3 4 5

4.3 How would you rate the tooling handling quickness?

1 2 3 4 5

5. What is your overall assessment of the situation after the changes?

1 2 3 4 5

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