Performance of Operations in Distribution Centers

Case Study of Collaborative Logistics MixMove & 3M

Hugo Bernardo Mateus

Department of Engineering and Management, Instituto Superior Técnico

Abstract

The efficiency of market supply, both in terms of quantity and quality, has been a persistent goal for all companies. Cooperation and coordination between companies, technological advances, the development of internal strategies and the critical sense of the results obtained are crucial factors for the acquisition of an optimized, competent, and objective logistics process.

This concern with the obtained performance has become persistent and the search for internal solutions and for indicators that better express the state of the company have become a priority in the strategy of these companies. This paper addresses the collaboration developed by two companies, 3M and MixMove, which interact in the logistics process. This complementarity exists because 3M is responsible for the internal operations at its hubs and MixMove for providing a management and logistics planning software. In this paper, the performance of 3M hubs will be evaluated with the application of the software granted by MixMove, through the development of systematic and theoretical methodologies associated with the measurement of performance indicators and the creation of new indicators that improve the operational analysis of the company's results.

Keywords: Supply Chain Management, Warehouse Operations, Performance Measurements, Performance Measurements in Supply Chains

1. Introduction

Supply chains are included in a very dynamic environment. The quantity of products handled, the demand of the markets and the concern with operational costs are some factors that lead the companies to rethink their internal structures and their tactical and strategic decisions when approaching the markets. 3M is a multinational company that, in terms of distribution, has several distribution centers of its own or subcontractors dealing with different products on a daily basis, most of which come from different business areas, which enables it to adapt to challenging markets.

The significant increase in computational power and the introduction of modeling software made the resolution of optimization problems and decision-making processes simpler and easier, obtaining solutions close to optimum (Bartolacci et al., 2012). MixMove, through its MixMove Match software, allows the management and planning of operations in distribution networks to be simplified, but, above all, it allows to obtain the performance improvement in the activities.

2. Case study

The partnership between these two companies arose from the need presented by 3M to reduce transport costs and increase the efficiency of the storage of cargo in their vehicles. The adoption of intermediate supply points in the supply chain allowed for proximity with consumers however, throughout operations, some hubs began to lack space due to the high number of products received.

The MixMove Match software, with the help of information systems, allows to monitor all internal operations from the distribution center organizing the construction of pallets and subsequent operations to the delivery to the consumer. These operations are Planning, Reception, Separation, Construction, Documentation and Labelling, and Loading and Shipping and will be detailed throughout this section.

In this paper, in addition to the operations performed in the hubs, the focus will be on adapting the chosen performance measurement system (SMART pyramid) in the context of hubs, on measuring the performance of the operations of certain 3M hubs and creating indicators that complement the performance analysis, and on associating all the chosen indicators with the internal activities performed in 3M hubs.

2.1. Planning

The planning operation carried out is based on waves of goods that indicate the number of pallets that will be transported, by one or more trucks, to the reconstruction hub at a given date and time. This process allows you to know exactly how many products have been collected, in what quantity and at what time they will be shipped and where they are destined to go. This planning considers not only the information acquired via EDI (Electronic Data Interchange) but also the existing restrictions on the type of reconstruction that will be carried out as well as the internal scheme that the distribution centers present.

2.2. Reception

In the reception, all logistics units are unloaded by the operators, and then identified by scanning their SSCC (Serial Shipping Container Code) numbers from the RFID (Radio Frequency Identification) devices available at the arrival doors. These unloaded pallets will then go to a sorting area where they will be divided according to their destination.

2.3. Separation

The sorting of goods is aimed at the management of individual parcels and/or pallets per customer. This sorting process can be done either directly or through a pre-sorting. In the direct sorting operators place the disorganized pallets in specific locations for subsequent correspondence with the consumer. In the pre-sorting, the flows of products and pallets go to specific areas of the hub for a first sorting process and then they will undergo a final sorting operation where they will go to other specific areas of the hub and start their construction and subsequent shipping.

2.4. Construction

The construction of pallets is a simple process and can have two variants, one is parcel by parcel, where the SSCC of the parcel is read by the scanner and then the SSCC of any parcel that is already on the pallet is also read, indicating the system that those two parcels will belong to it. The other variant, faster construction, where the first parcel of the pallet is read and then the remaining parcels are read one by one and placed on it.

2.5. Documentation and Labelling

In this operation, the pallets go for another scanner procedure and STILL (Standard Transport and International Logistics Label) number will be generated by the information system. This number must be compatible with the GS1 standards and must contain in addition to the information from the other SSCC, a new SSCC number identifying the new pallet.

The hub's information system also allows the creation of a pallet content list that will make it easier for the recipient to process it. After shrink wrapping the pallets, the documents are inserted.

2.6. Loading and Shipping

In the last operation, many pallets are waiting to be loaded to trucks. The loading process is and the alignment of the truck to the hub doors are characterize as visual processes, however the use of barcode scanners or RFID scanners can again assist this operation.

The operators scan the barcodes of the logistics units and scan the barcode of the door through which they travel to the truck. In case there is some mistake, the system will alert the operator.

3. Literature Review

3.1. Performance Measures

Assessing the results of supply chain management is essential to understand the positive or negative state of a supply chain, but given the large number of entities present in supply chains and having different interests, it's difficult for them to assess efficiently the performance of their activities in a general supply chain context (Cooper et al., 1997).

Performance measures shouldn't be taken only by one entity but by all the entities involved in their development in order to ensure that the measures are well planned and coordinated so that they are all complied with (Gunasekaran et al., 2004).

Establishing a performance measurement system for the entire supply chain can be a solution however it will be necessary to understand the objectives of the entities and realize which system best identifies with the measurement objectives and, later, which indicators will be part of this system. In the following section some of the systems that will be mentioned may facilitate this decision.

3.2. Performance Measurement Systems (PMS)

A performance measurement system (PMS), according to Neely et al., (1995), is a set of metrics used to quantify actions taken based on their efficiencies and effectiveness. This efficiency refers to the measurement of how company's resources have been used while, effectiveness refers to the matching of consumer requests (Neely et al., 1995).

The introduction of control systems is important if these metrics are to be applied throughout the supply chain without compromising decision-making (Gunasekaran et al., 2004). These systems should present different perspectives to provide managers with sufficient information to solve problems (Kaplan & Norton, 1996).

Therefore, it is necessary to identify performance measures that have a greater impact on areas of strategic, tactical and operational planning and control so that the assessment of supply chains briefly reveals their state in relation to the objectives that have been set (Gunasekaran et al., 2004).

In terms of PMS, Balanced Scorecard, SCOR (Supply Chain Operations Reference) model and SMART (Strategic Measurement Analysis and Reporting Technique) pyramid are some of the most used. In this work SMART pyramid was used because of it's simplicity and adaptability and the fact that it contains, in it's structure, relevant operational components.

The SMART pyramid was developed by Cross & Lynch (1988) and has the objective to make the link between the strategy defined by the organization and the daily operations performed in its activities. The link is made through the introduction of objectives based on consumer priorities, and the subsequent introduction of performance measures to improve the efficiency of operations (Kurien & Qureshi, 2011). SMART pyramid is composed by four levels of performance measures: (1) corporate vision, (2) market and financial, (3) customer satisfaction, flexibility, productivity, (4) quality , delivery, cycle time and waste (Lynch & Cross, 1995). These levels approach external and internal efficiency of the organization. The advantage of this system is that it can integrate corporate objectives with operational performance indicators and manage performance measures strategically. However, doesn't provide any mechanism for identifying key performance indicators, fails to specify the form of the measures and doesn't integrate the concept of continuous improvement in it's structure (Striteska & Spickova, 2012).

3.3. Performance Indicators

The evaluation of warehouse performance differs according to the objectives, the variety of measures used to measure objectives, the type of warehouse used (distribution center, cross-dock platforms, among others), the focus activities of the warehouses (order collection, reception, shipping among others) and the tools used to measure performance (mathematical model, statistics, among others) (Staudt et al., 2015). Performance measures can be divided into two groups: soft measures and hard measures. Hard measures are based on quantitative measures related to the service provided, costs and returns on investment and assets and are calculated through simple mathematical calculations (averages, standard deviations, among others) while hard measures are based on the quality of the measures presented as manager's perception of loyalty and consumer satisfaction and are calculated through linear regressions, canonical matrices, among others (Holmberg, 2000; Fugate & Stank, 2010).

Given the large number of indicators that could be created for evaluating the performance of entities, it is necessary to organize them so that their analysis is well carried out. Frazelle (2002b) organizes performance indicators in four perspectives: financial, productivity, utilization, cycle time and quality and then intersect this perspective with the internal warehouse activities (reception, order displacement, storage, collection and shipping).

Other approach was developed by Staudt et al., (2015) similar to Frazelle (2002b) intersecting with internal warehouse activities (reception, storage, collection and delivery) but using different perspectives and classifying indicators according to their boundaries in the activities. According to Staudt et al., (2015) the perspectives used are quality, time, cost and productivity and classifies indicators in to especific, transversal, and resource related. Specific indicators are unique metrics for a particular warehouse activity, on the contrary transversal indicators are metrics that can be measure in the context of several activities like order lead time. Resource related indicadors, as the name implies, are metrics related to the resources used warehouse operations.

Staudt et al., (2015) organized the indicator analysis in two tables: one for the specific metrics, where the metrics were arranged between warehouse activities and for the transversal metrics, where they were arranged by inbound and outbound processes and the other one for the resource related metrics where they were arranged by labor or equipment and building. This two methodologies of Staudt et al., (2015) and Frazelle (2002b) will be used later on in section 4.6.

4. Methodology

4.1. Introduction

The methodology followed was focus in the performance analysis of certain 3M hubs using performance indicators. To proceed with such analysis, it was necessary to understand what rating criteria exist to assess the reliability of the indicators.

In this respect, authors such as Neely et al., (1997) and Lohman et al., (2004), addressed this issue by assigning elements that allow us to characterize the indicators according to their reliability. Lohman et al., (2004) improved on the previous work done by Neely et al., (1997) and presented a set of eleven elements: name of indicator, objective/purpose, scope, target, equation, units of measure, frequency, data source, owner, drivers and comments. In order to complete the analysis of indicators authors such as Franceschini et al., (2007) establish that a good indicator should be simple and easy to understand, be able to indicate time trends, be sensitive to external and internal changes in the organization, be accessible in the collection of information and in it's processing, and be easy and quick to perform updates.

4.2. SMART Hub

In this methodology, to assess the operational performance of hubs it was necessary to collect a high set of indicators that could be identify with this type of entities. As there is little or no performance assessment and correlation between the measurement system under study and the entity under study, an extensive collection of performance indicators within supply chains was initially carried out in order to have a good basis before going specific for these entities.

First, 55 performance metrics were collected from several authors for each of the performance measures referred to in the SMART pyramid.

Then, continuing with the focus on distribution centers, the "Market" performance measure was removed from the SMART pyramid to move the strategic side of the system towards a more operational side. Some generic indicators present in that SMART pyramid, such as total logistical productivity, were unfolded to be able to evaluate the performance of the internal activities of these entities. In addition, some indicators that were outside the scope of the distribution center were also excluded as indicators referring to production, supply, storage activities, among others. Moreover, the performance measure "Delivery" has been replaced by "Shipping" since “Delivery” is a measure that is outside the physical scope of the distribution center.

With these modifications, the SMART pyramid consisting of 8 performance measures and about 30 performance indicators was obtained.

However, the subject of this work is about the performance of 3M hubs and, although these entities are similar to the distribution center, they have their own particularities and, therefore, the SMART Hub represented in Table 1 was created. This new SMART pyramid compared to the distribution center version, stands out by eliminating some indicators such as machine flexibility, since in the hubs the only machines to operate are conveyors with very restricted actions, which isn't benefic to the application of this indicator, and indicators associated with specific activities like productivity in reception since, in these hubs, is a very complex process to obtain results to each activity due to the speed of operations. With these modifications the SMART Hub is composed with 8 performance measures and 25 performance indicators.

operations. This indicator presents weaknesses in the collection of information as it is acquired by different sources such as customers, systems, and service technicians, making it complex to maintain the reliability of this indicator.

Another indicator used by 3M is customer satisfaction, which is similar to the previous indicator however, it's focus isn't on generating customer losses. This indicator is measured by the positive or negative responses customers give to questionnaires conducted by 3M. The weakness of this indicator has to do with the scale used. In this indicator there is no differentiation between negative customer responses which makes difficult to analyze and to perform improvements.

Table 1 - SMART Hub

	Measures	Indicators	Authors
Strategic Level	Financial	• Total cost of the distribution center	(Stewart G.,1995); (Ramaa et al., 2012); (Johnson et al., 2010)
Tactical Level	Customer Satisfaction	• Order returns; • Number of complains; • Customer satisfaction rate; • Customer satisfaction;	(Rushton et al., 2014); (Williams & Naumann, 2011); (Lao et al., 2011)
	Flexibility	• Material handling flexibility; • Labor flexibility;	(Chan, 2003); (Elrod et al., 2013)
	Productivity	• Throughput; • Vehicle utilization;	(Frazelle, 2002); (Matopoulos & Bourlakis, 2011); (Van Der Vorst, 2005); (Jonsson & Lesshammar, 1999); (Hamdan & Rogers, 2008)
Operational Level	Quality	• Perfect order percentage; • Perfectly entered; • Perfectly picked; • Perfectly reliable; • Perfectly shipped; • Perfectly delivered; • Perfectly communicated; • Perfectly billed; • Perfectly documented;	(Frazelle, 2002);(Staudt et al., 2015)
	Shipping	• Orders shipped on time; • Order shipping cost; • Utilization of shipping gates (%)	(Gu et al., 2007); (Kiefer & Novack, 1999); (Frazelle E., 2002b)
	Time	• Order cycle time;	(Ramaa et al., 2012); (Bhagwat & Sharma, 2007)
	Waste	• Energy consumption; • Total materials used; • Costs associated with environmental compliance;	(Hervani et al., 2005)

4.3. 3M Indicators

To understand the performance analysis at 3M hubs and withdraw some lessons from the performance measurement procedures, the indicators currently in use in these entities were collected. It was possible to establish contact with a 3M supply chain specialist who helped identify and characterize these indicators. This contact was made only by e-mail and was the only source of accessible information from 3M, which caused limitations in the interpretation of the knowledge acquired and in the presentation of some responses.

One of the indicators collected is linked to the measure of customer satisfaction performance. The indicator "number of complaints" can be calculated in two ways through a financial approach, related to the value of the shipments claimed, in euros, or through the percentage of complaints in relation to the total number of shipments. The financial approach allows the identification of which shipments have the most impact on

In terms of productivity, 3M uses the metric labor productivity. This indicator aims to keep the internal operations of the entity as lean and efficient as possible, with a constant analysis of the resources that are employed. One way to calculate this metric is through the number of cartons that are completed by the number of man-hours, while the second way adopts a financial aspect where the costs of operations, which include for example the cost of employees, are mentioned by the number of cartons completed. In terms of weaknesses, this indicator presents a rather subjective target, stating that only a policy of no operational waste, either at the level of stopping operators or at the level of stagnation of operations however it could be interesting the adoption of a quantitative target for better control of these operations.

Regarding costs, 3M presents an indicator associated with the costs generated by product handling. This indicator called "handling costs of the hub" aims to control the limitation of the processing of goods in only necessary processing focusing on the handling activities that occur within the hubs. Its calculation is dependent on two variables: the number of units to be moved like the number of pallets, parcels, reconstructed pallets, dangerous goods, among others, and the tariffs that are applied by the logistic partners, which in this case are the carriers. These tariffs, applied to handling activities, are prices agreed between both companies and are influenced by market competitiveness. The only weakness of this indicator is that 3M doesn't have full control over these costs and is also restrictive in comparative terms. The lack of control implies greater monitoring of these same tariffs.

Regarding shipping operations, 3M uses an indicator relaying on the accuracy of the shipments. Shipment accuracy is based on the correct construction of the consignments shipped carried out in the activity of reconstruction, the assiduity of the shipment and the state of the products dispatched (existence or not of damaged products). The shipping operation is carried out inside the hub however it has no control over it. Any errors associated with consignments aren't detected by the operators that carry out the shipping but only by the carriers, who detect the errors during their operations or by the recipients, customers or hubs of destination. This control is done by the TMS (Transportation Management System) external to the hub, making this indicator dependent on the sharing information from third parties, being difficult to measure and to collect true information.

Finally, the last indicator used by 3M is regarding performance measure: time. This indicator is called "hub lead time" and represents the total duration of internal operations from the arrival of the truck at the hub until its last reconstruction task. In terms of calculations, this indicator is executed in terms of percentage by dividing the actual lead time by the expected lead time. This expectable lead time is calculated using the information available in the commodity wave planning. In a general way this indicator is well constructed and is useful for analyze the efficiency of the internal operations of the hub.

All the mentioned indicators in this section can easily be included in the SMART hub pyramid, which validates the compatibility of this system with the entities in study.

4.4. Lost logistics unit percentage in hub

With the analysis of some documents provided on the operational activity of two hubs: 3M SOA Logistics located in France and Hall located in Austria, it was possible to understand the operational dimension of each of the hubs, the total number of units handled and for each type of logistical units (reconstruction pallets, lose cartons, full pallets and reconstruction parcels) as well as to identify the number of units lost inside the hub.

To create this indicator, the number of units lost in the hub had to be reached first. By analyzing the document, it was quickly understood that the total daily number of logistical units on arrival at the hub included the logistical units lost before the arrival. Excluding these lost units, the value of the logistical units processed/finalized in the hub should be acquired, but this value doesn't correspond to the value mentioned in the document. Therefore, there are two sets of values of logistic units to be considered: the expected value and the actual value. The positive difference between these two values results is the number of units lost during the hub operations. If this difference is negative, it results in the number of logistic units found in the hub, but these values will not be considered in this analysis.

The indicator is calculated from the ratio of the difference of these two values and the total number of units handled. Table 2 shows the results of the analysis performed on the two hubs under study in 2018 and 2019, as well as the results associated with the application of the indicator. The annual number of units lost per hub, compared with the annual number of units handled, is quite small, so this indicator is presented in the context of permillage instead of percentage to present values with greater expressiveness.

The results presented by the indicator show a decrease in units lost from 2018 to 2019 in both hubs. For the Hub Hall the decrease shown is more noticeable representing a decrease of 181 lost annual units which corresponds to less ≈ 31% than in terms of the annual difference in the indicator corresponds to 0.227‰. In the 3M SOA Logistics hub, the decrease in units between 2018 and 2019 was 24 annual units lost, which corresponds to a decrease in the indicator of 0.016‰.

Table 2 - Annual data by hub

	2018		2019	
	3M SOA Logistics	Hall	3M SOA Logistics	Hall
Handled Units	1178391	651576	1156283	601723
Lost Units in Hub	263	575	239	394
Permilage of Lost Units in Hub (‰)	0,223	0,882	0,207	0,665
Monthly Average Units Lost at Hub	22	48	20	33

Although the numbers of lost logistic units are small for both hubs, the hub Hall loses two orders every day and this order value can become even more relevant if the orders are very expensive.

So, it's necessary to keep monitoring the internal operations of this entities so that operational instability can be identified.

This indicator, in terms of frequency of measurement, should be measured annually because of the reduced flow of units lost in monthly terms and should be analyzed by the operations manager who, if non-conformities are detected, should visit the site to collect concrete information. The goal of this indicator ideally is to reach zero lost units but is something complex to achieve as the operations are mostly manual.

4.5. Operational Efficiency by hub

Operational time is a crucial factor in logistics. The time factor is improved with the digitization of all informational content, led by the MixMove Match platform.

For the construction of this indicator, data from January 2020 associated with two 3M hubs called Brucargo and Kleine, located respectively in Belgium and Germany, were analyzed. The sample size of the analysis data is due to the lack of real and correct data from previous years, however with the data made available it was possible to achieve concrete conclusions with the application of the indicator. The documents analyzed had the scan times for each of the internal activities, for each of the types of logistic units, their quantity, their GINC numbers (Global Identification Number for Consignments) among other information.

The operational similarity between these two hubs outlined the path for the creation of this indicator. With this similarity, the adoption of a comparative indicator would be the best approach to measure the operational efficiency of these entities. The main purpose of this metric is to assess, in percentage terms, the operational time of construction of shipments in relation to the total number of shipments made and comparing with each hub (Figure *1* - Formula of the metric "Operational Efficiency by hub"Figure 1).

Figure 1 - Formula of the metric "Operational Efficiency by hub"

$$Operation\ Efficiency\ by\ hub\ (\%) = \frac{\frac{Total\ time\ of\ the\ n^{o}\ of\ shipments\ (B)}{Actual\ n^{o}\ of\ shipments\ (B)}}{\frac{Total\ time\ of\ the\ n^{o}\ of\ shipments\ (K)}{Actual\ n^{o}\ of\ shipments\ (K)}} \times 100$$

To calculate this indicator it was necessary, first, to know the processing time of the shipments, that were calculated by the difference between the initial processing time and the time of its conclusion. Then it's necessary to know the actual total number of shipments. The term "actual" is referred because in the documents submitted there are shipments with the same GINC number but with different arrival times at the hub. So to get the actual number of shipments, a sorting was made so that these shipments with the same GINC weren't counted as different deliveries.

The following tables represent, for each of the hubs, the number of repetitions of the GINC number which shows the actual number of shipments, for example five repetitions of one shipment means that were five GINC representing the same shipment , the processing time of the shipments and the metric operational efficiency by hub (ratio of processing time to the number of deliveries). The values of the metric (2h05 min, hub Brucargo; 3h48 min, hub Kleine) in the context

presented don't represent a reliable comparison due to the fact that both hubs have different values both in terms of processing time and number of deliveries.
For this purpose, a harmonization of the data has been held in both hubs, as represented in Table 3.
The total number of shipments established for the two hubs was 3411 units in addition, the Kleine hub repetitions of shipments were also harmonized so that both hubs had the same type of repetitions. With the total number of shipments in 3411 units and with the harmonization of the reps, the Kleine hub shows an increase of 4 minutes in the metric, from 3h48min to 3h:52min, however when comparing with the other hub, Brucargo takes approximately 58% $(\frac{2.05}{3.52})$ of the time of hub Kleine to complete the same number of shipments.
Although the total number of shipments is the same, there are shipments at both hubs which, although smaller in quantity, contribute significantly to the total shipment time. In hub Brucargo two and three shipment repetitions, contributes ≈12% of the total time. With that said, another modification was held and is also shown in Table 3. The values for the actual number of shipments, in hub Brucargo, for each of the repetition types have been replaced by the values of Table 3 regarding the hub Kleine, which means that the processing times for each repetition must be adjusted so that the metric (shipping per time), for each repetition, remains the same. When comparing the two hubs under identical conditions, the value of the indicator rises from ≈ 58% to ≈63 with a decrease in efficiency of 5%. In terms of time it can be concluded that the Brucargo hub having the same internal operations as the Kleine hub and the same number of completed shipments needs less ≈ 1h30min to process all shipments.
One of the aspects that could influence the processing time of shipments is the composition of those shipments. The shipments can be composed by full pallets, lose cartons, reconstruction pallets, reconstruction parcels and combinations of these four types. Lose cartons and full pallets are the types with the fastest processing throughout the operations, suffering little or no transformation. To understand the impact of the logistic units typology on the shipments and later on each of the hubs, first the total time quotient per type of shipment with the total number of each type of shipment was applied and then this quotient was included in the formula of the indicator "operational efficiency by hub", both in the numerator and denominator, to establish a comparison between entities. With the application of the quotient, the processing times by quantities of type of shipments were known but, as in the past, it wasn't possible to make a comparison since the quantities handled between hubs were quite different. That said, the quantities were

Table 3 - Hub Kleine & Kleine harmonized data

Kleine				
Repetitions	Actual Nº of Shipments	Σ Processing Times (min)	Time / Shipment (min)	Hours (hh.mm)
5	3	4586	1528.7	25.28
4	14	16184	1156.0	19.16
3	41	41898	1021.9	17.02
2	155	90447	583.5	9.43
1	3198	640097	200.2	3.20
Total	3411	793212	232.5	3.52
Brucargo				
Repetitions	Actual Nº of Shipments	Σ Processing Times (min)	Time / Shipment (min)	Hours (hh.mm)
5	3	24669	8223.0	137.03
4	14	29848	2132.0	35.32
3	41	17331	422.7	7.02
2	155	63331	408.6	6.49
1	3198	351993	110.1	1.50
Total	3411	487172	142.8	2.23

Table 4 - Operational Efficiency by type of shipments

Type of Shipments	Indicator
Lose Cartons	35%
Full Pallets	717%
Reconstruction Pallets	77%
Reconstruction Parcels	x
Full Pallets + Reconstruction Pallets	150%
Lose Cartons + Full Pallets	x
Lose Cartons + Reconstruction Pallets	x
Lose Cartons+ Full Pallets + Reconstruction Pallets	x

harmonized and for both hubs there were: 3867 individual parcels, 512 full pallets, 737 full pallets for reconstruction, 941 full pallets with pallets for reconstruction. Applying the quotient with harmonized quantities, the indicator presents in Table 4 the following results.

By the results obtained, it's possible to understand that values above 100% for the type full pallets and full pallets plus pallets for reconstruction indicate that the Brucargo hub takes 7 times longer to process a full pallet and 1.5 times longer to process a full pallet together with a pallet for rebuilding than the Kleine hub. However in shipments of the type lose cartons and pallets for reconstruction the Brucargo Hub takes only 35% (less 24 minutes) and 77% (less 56 minutes) of the time it takes the Kleine Hub to process an lose carton and a pallet for reconstruction respectively.

The "operational efficiency by hub" can be measure monthly or annually and it doesn't have specific goals to achieve since is based by benchmarking analysis. In terms of persons responsible for measurement, it should be someone in charge of supply chain management because it's important to contact with different entities within or outside the supply chain.

4.6. Indicator Association

In this section, all the indicators mentioned in this work are grouped using the theoretical methodologies of Staudt et al., (2015) in Table 5 and Table 6 and Frazelle, (2002b) table presented in Table 7 mentioned in section 3.1. In the tables presented, certain modifications were made to the methodologies presented to involve in some way the context of the hubs. The first modification involves changing the structure of these tables. This modification involves replacing, in Table 5 and Table 7, the activities that were represented, such as order displacement, storage and collection, by the reconstruction activity since these activities weren't present in the internal activities of 3M hubs and reconstruction is the only and the main activity that occurs between reception and shipping. In addition to this modification, in the methodology referred to by Staudt et al., (2015), the activity "Delivery" will be replaced by the activity "Shipping". Both activities aren't in the domain of the hub, however the "Shipping" activity is an internal activity to the entity and therefore was accounted for in this analysis.

In the resource table also addressed by Staudt et al., (2015) the performance measure "Flexibility" was included in the perspective's column since the metrics belonging to this measure are related to equipment and labor. In the methodology proposed by Frazelle, (2002b), besides the inclusion of the reconstruction activity, "Flexibility" was also added to the perspectives.

In terms of the position of the indicators, in the Staudt et al., (2015) methodology, for example indicators associated with customer satisfaction, although they are associated with the act of delivery and depend on the evaluation of the destination, the delivery activity is not part of the hub's operation and therefore, in order to continue to involve these indicators, they will be included in the reconstruction and shipping activities since their results depend on the performance of these activities. In Table 7 in Frazelle (2002b) modified methodology, the number of indicators is smaller because the structure doesn't allow the inclusion of transversal indicators between activities such as indicators involving customer satisfaction.

Table 5 – Indicator association [Staudt et al., (2015)]

Perspectives	Activities - Specific Indicators		
	Reception	Reconstruction	Shipping
Time	x	x	Orders shipped in time;
Quality	X	Perfectly reliable; Perfectly picked; Perfectly billed; Perfectly documented; Lost logistics unit percentage in hub;	Perfectly shipped; or Shipment accuracy;
Customer Satisfaction	x	x	x
Cost	x	x	Order shipping cost
Waste	x	Total materials used	x
Productivity	x	Operational Efficiency by hub	Vehicle utilization; Utilization of shipping gates;
Perspectives	**Processes - Transversal Indicators**		
	Inbound Processes		**Outbound Processes**
Time	Order cycle time; Hub lead time;		
Quality	Perfect order percentage; Perfectly communicated;		
Customer Satisfaction	x	Order return; Number of complains; Customer satisfaction rate; Customer satisfaction;	
Cost	Total cost of the distribution center; Handling costs of the hub;		
Waste	Energy consumption; Costs associated with environmental compliance;		
Productivity	Throughput		

Table 6 - Resource related indicators association [Staudt et al., 2015]

Perspectives	Resource related indicators
	Labor
Time	x
Quality	x
Flexibility	Material handling flexibility
Cost	x
Productivity	Labor productivity
Perspectives	**Equipment and Building**
Time	x
Quality	x
Flexibility	Labor flexibility
Cost	x
Productivity	x

Table 7 - Indicator association [Frazelle, (2002b)]

Activities	Perspectives					
	Financial	Productivity	Flexibility	Utilization	Quality	Order cycle time
Reception	X	X	X	X	X	Order cycle time
Reconstruction	x	Operational Efficiency by hub	Labor productivity; Material handling flexibility;	Total materials used	Perfectly reliable; Perfectly picked; Perfectly billed; Perfectly documented; Lost logistics unit percentage in hub;	
Shipping	Order shipping cost	x	x	Vehicle utilization; Utilization of shipping gates;	Perfectly shipped; or Shipment accuracy;	

5. Conclusion

The creation of a SMART system targeted at 3M hubs has validated the possible adaptation of the SMART pier to a more operational environment. This adaptation has made it possible to make up for the scarce information that exists between this performance measurement system and these operational entities, but this subject is far from being finalized due to the high number of indicators and the impossibility of having basic indicators that evaluate any operational entity.

With the results presented in the creation of indicators, it was possible to conclude that although many of these operations have already been optimized, it is still possible to make improvements and locate possible failures. Despite the limitation that existed in the construction of the indicators, the results presented were positive.

The association of indicators led by the modification of the methodologies of Frazelle (2002b) and Staudt et al., (2015) allows a better organization in the analysis of the performance of indicators, which can improve the performance measurement efficiency since the indicators are directly associated to the internal activities that must be evaluated.

In future steps, 3M should increase its range of performance indicators and applying the benchmarking concept to the rest of its entities in order to establish constant improvements in its operations. Moreover, they should apply the SMART system in its entirety by identifying, for each of the necessary indicators, the responsible, validating the SMART system together with the company's specialists and integrate SMART system with the information systems implemented in order to collect better information.

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