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PROPOSAL OF OEE USAGE IN SUPPLY CHAIN DEMAND MANAGEMENT:
A Case Study in the Pharmaceutical Industry

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ABSTRACT

Globalization requires enterprises greater flexibility and adaptability of its internal processes to market requirements. This flexibility results in new forms of relationships among partners, supply chains. For these supply chains differentiate themselves from their competitors, agility and flexibility become crucial. In this sense, effective management of the supply chain is needed, in addition to collaboration and cooperation among their participants, with implies in strategic and operational integration to better serve the end customer. This work proposes the application of OEE (Overall Equipment Effectiveness) to support the demand management, focusing on supply chain, considering the producer-distributor dyad, represented respectively by a drug manufacturer and its largest distributor in the pharmaceutical sector, considering the marketing of generic drugs.

Keywords: *Supply Chain, Pharmaceutical Industry, Demand Management, Supply Chain Management, OEE (Overall Equipment Effectiveness).*

1. INTRODUCTION

The social, economic and political changes occurring in the second half of the twentieth century, spurred the increasing globalization of markets. According to Hill (2011), globalization can be understood as a series of interlocking changes towards a more integrated and interdependent world, where commerce, finance, markets and production have not only a local scope.

Humphrey *et al*. (2000), Lung (2000) and Scavarda *et al.* (2001) stated, some years later, that globalization was driven by several factors. Among these factors are: the increasing deregulation of markets, falling trade barriers, the development of new modes of transport and the change of the consumer behavior, which requires higher added value services and products. Sounderpandian and Prasad (2003) indicate that, as a globalization result, industries must control the factors that influence the acquisition, processing and distribution of materials, and that these processes might be supported by appropriate information systems.

More than a decade of the first discussions, Hilletofth (2009) states that, at the beginning of globalization, companies could have economies of scale obtained by the production and worldwide distribution of large volumes, reducing costs and thus increasing sales. However, partly due to globalization, the last decade has experiencing increased competition, forcing companies to offer a greater number and variety of products, customized and with lower life cycle, fact corroborated by Christopher (2011). Thus, companies realized that to compete in more unstable and turbulent markets, they would have to cooperate, because vertical integration brings operational limitations (CHRISTOPHER and RYALS, 1999; NOVAES, 2004; CHRISTOPHER, 2011).

Bowersox (1990) already stated that logistics alliances "*reflect an existing desire between two or more participants to modify their current business practices, avoiding duplications of activities, and increasing value-added chain interfaces, as well as reducing, as possible, waste of resources in production, transport and distribution*".

Such dimensions of the businesses relationships can be different perspectives on the same structure, broader supply chains. According to Lambert and Cooper (2000), and Christopher (2011), these structures increase the competition for another level, occurring between these chains, and not between individual companies. The authors mention that agility and ability to respond adequately to the market requirements become sources of competitive advantage.

On the supply chain strategic coordination, demand management is one of the key factors to be controlled. Canever *et al.* (2008), Juttner *et al.* (2007) and Walters (2008) argue that it is essential to have effective and efficient demand management within the Supply Chain. Christopher (2011) agrees with this statement, and indicates the trend of companies operating globally, using inputs from any places of the world, off shore manufacturing and sales in many countries. In this scenario, companies continue to work with local scope to attend specific demands, such in food industry.

Juttner *et al*. (2006) and Charlebois (2008) advocate a different approach, in which the demand management chain comprises all necessary elements to identify, create and stimulate customer demand, while the processes of supply chain management, on the other hand , includes all components required to meet the customer demand processes.

Effective demand management provides a competitive advantage in supply chains operations, especially in dyads upstream, because it reduces the effects caused by the demand amplification through these chains (JUTTNER *et al*, 2007; BAILEY and FRANCIS, 2008; CROXTON *et al.*, 2008; HILLETOFTH, 2009).

This paper discusses the role of OEE (Overall Equipment Effectiveness) to support the demand management, focused on supply chain, considering the producer-distributor dyad, represented respectively by a drug manufacturer and its largest distributor in the pharmaceutical industry, considering generic drugs market.

Demand management in SC, although topic addressed by several authors, as Mentzer (2005), lacks approaches that relate it to IT processes and, especially, specific studies for the pharmaceutical industry.

For decades, the pharmaceutical industry was one of the most profitable in the market, mainly due to the non-saturated markets, and mechanisms for patents protection (HERACLEOUS and MURRAY, 2001).

However, in recent years, public health systems and private sector organizations have exerted pressure on drug prices, and allowance of generic products manufacture, partly caused by the reduction of the patent protection validation time (DANESE *et al.* 2006). Additionally, there is a sector fragmentation in this industry, besides frequent introduction of products that are, basically, refinements of existing drugs (GARAVAGLIA *et al*., 2012).
To respond to this scenario, many companies look for economies of scale in their production processes, synergy with other companies in research and development, opportunities for mergers and acquisitions in the industry, and changes in their SC (DANESE *et al*., 2006).

This paper adopts the exploratory case study as a research method, which converges with the nature of the problem to be investigated, and the current state of the knowledge, as suggested by McCutcheon and Meredith (1993), Yin (1989) and Eisenhardt (1989).

2. SUPPLY CHAINS, SUPPLY CHAIN MANAGEMENT

Lambert and Cooper (2000) consider the supply chain as a network of companies with multiple business activities and relationships, in which each link provides facilities so value is added to the product along the chain.

Mahdavi *et al.* (2009) argue that supply chains are described as inventory systems, composed of many levels.
For Quinn (1997), supply chains are made up of all activities associated with the products flow, from the stage of raw material to its final configuration, in which there is value addition.

The term "value" may have different definitions, as shown by Woodruff (1997) and Christopher (2011). These concepts, however, are not divergent and essentially consist of:

- Value for the customer is associated with a product or service usage;
- Value for the customer is perceived from the customer perspective, not from the supplier;
- Value for the customer typically involves a trade-off between what the customer gets for what he pays.

Christopher (2011) states that the SC add value whenever provide low cost (process efficiency) or differentiation (innovation). The author, however, believes that both require SCM processes revision and optimization, since activities that do not add value, contribute to aggregation costs, especially for the use of the involved resources.

Supply chain management can be defined as the chain integration of business processes upstream and downstream, producing value for the end customer (CHRISTOPHER and RYALS, 1999; LAMBERT and COOPER, 2000).

Lambert *et al.* (1998) conceptualize the process as a set of operations that produce a specific output, adding value to the customer. For the Global Supply Chain Forum (GSCF), supply chain management is the integration of key business processes, from the end customer to the original supplier, that provide products, services and value-added information to the customers and other stakeholders (CROXTON *et al*., 2008;. LAMBERT, 2004; LAMBERT and COOPER, 2000; LAMBERT *et al*., 1998).

For Lambert *et al.* (1998), the purpose of SC is "*capture the synergy of intra and inter-organizational integration, being possible to achieve excellence in business processes and competitiveness, something that changes the management of the business and the relationship with other members of the chain*".

The Council of Supply Chain Management Professionals (2013) considers that supply chain management encompasses the planning and management of activities related to the procurement and supply, as well as the processing and logistics management, including partners’ coordination and collaboration.

For Mentzer *et al*. (2001), supply chain management is the strategic and operational coordination of business functions, both intra and inter companies, which objective is optimizing long-term outcomes for chain participants.

McKone-Sweet and Lee (2009) consider internal and external integration as being the organization key competence and critical component of SCM. So, if one of the two is not reached, there is a restriction in the chain overall performance. The authors cite coordination and planning as two elements of internal organizational competence.

Croxton *et al*. (2008) state that the demand management goal is quick and correct alignment of market needs towards the suppliers, balancing demand and strategically fitting it with supply chain operational capability.

For Hilletofth *et al.* (2009), demand management is one means by which the company, having focus on their customers, adds value. However, this is also a relatively unexplored field, and it lacks academic research on their topics.

Hilletofth *et al.* (2009) add that companies are required to provide differentiated solutions to SC to meet distinct demands. This is usually achieved by combining supply, manufacturing and distribution strategies, the development of specific set of services for different markets and customers.

Croxton *et al.* (2008) consider that demand management considers two elements: synchronization and estimates, and such management is feasible arising from two perspectives: strategic and operational. Under the strategic dimension, is defined the framework for managing the processes, whereas under the operational dimension are included SCM daily activities (CROXTON *et al*., 2008).

Souza *et al.* (2005) define SCM as a logical extension of the plant management, which implies in pursuing same goals: maximizing customer and shareholders satisfaction through delivery efficiency and responsiveness to customer’s needs, minimizing stocks quantities and materials types, thus reducing operating costs.

Authors suggest the TOC (Theory of Constraints) application principles in SC demand management. Additionally, to build a production plan, authors explain that identify system performance constraints is the first task. In this sense, for TOC, productive resources is seen as interdependent links in the same chain, operating in a shared way, trying to achieve the main objective of this SC.

Simatupang *et al.* (2004) follow the same line of TOC bottleneck treatment, but applying it in three SCM specific areas: logistics, performance measurement, and logical thinking.

Specifically in logistics case, the authors suggest the use of DBR (Drum-Buffer-Rope) method for programming, inventory management, and value analysis.

For performance measuring, Simatupang *et al.* (2004) found that TOC is used as an element that enables the identification and management of the SC operations, such as throughput, inventory and operating expenses. In logical thinking, the authors address five traditional steps of TOC restrictive processes for application in the SC. Souza *et al.* (2005) present these five steps for managing constraint in TOC:

1. Identify the system limiting resource;
2. Explore the maximum use of the restrictive resource;
3. Subordinate any other resource to decision 2;
4. Raise the capacity of the constrained resource;
5. If the restriction is mitigated, return to step 1.

Croxton *et al.* (2008) show, in Figure 1, the associated activities under the demand management processes, which include the implementation designed at the strategic level. Additionally, not only means to reduce the variability of the demand, but also ways to increase the processes flexibility should be identified.

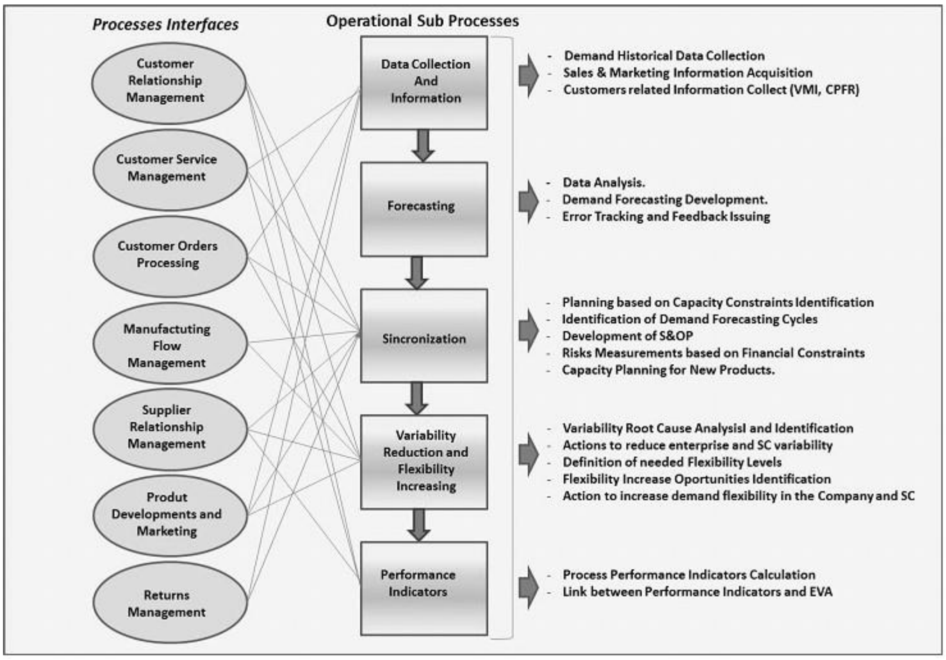

Figure 1 – Demand Management Operational Aspects (Croxton *et al.*, 2008)

Kelepouris *et al.* (2008) and Lee *et al.* (2000) cite, as reasons for poor demand management execution: imprecise demand estimates, low capacity utilization, inventory excess, and poor quality of customer service as sources for: safety stock increased levels, additional capacity needs, room space increased usage, and additional investment costs.

In this scenario, there are periods of intense use of resources, followed by periods of underutilization of these resources (CHATFIELD *et al.*, 2004).

3. OEE (Overall Equipment Effectiveness)

Measure the efficiency of a production system becomes crucial factor in markets with high volatility in demand requirements, and which became an important research field in recent decades (BRAGLIA *et al.*, 2009). The authors add that losses and inefficiencies in production processes can be quickly detected and eliminated using metrics that are able to access the degree of equipments efficiency, compared to their potential performance.

OEE (Overall Equipment Effectiveness) is a suitable metric for efficiency, initially proposed by Nakajima (1988) as a key metric for TPM (Total Productive Maintenance), but that is now widely accepted to measure the performance of an equipment (or line) in comparation to its nominal capacity, under normal operating conditions (BRAGLIA *et al.*, 2009; Anvari *et al.*, 2010.). To Nakajima (1988), losses are activities that use resources but do not add value. So, the OEE goal is to identify such losses causes. Thus, the OEE can be represented by a relationship between what was actually manufactured, and what could have been manufactured at full capacity, formalized by the equation:

- OEE = Actual Outpu / Referential Output
- OEE = (Cycle Time x Operational Added Value Time) / (Cycle Time x Load Time)
- OEE = Operational Added Value Time / Load Time

Where operational added time is defined, according Braglia *et al.* (2009) and Anvari *et al.* (2010), as "*the fraction of time in which the machine works under optimal operating conditions*", and the loading time as "*the actual time available for the operation, discounting the times of shutdowns and other stoppages*".

Hansen (2001) explains that one of the best indicators to determine the plant's effectiveness is the OEE, since its correct application allows to know machines and equipments performance, an important element to help organizations to focus on the essential parameters for competitiveness.

Tajiri and Gotoh (1992) classify losses into six main groups: equipment failures, setups and adjustments are losses to determine the actual value of machine availability.

The third and fourth groups include short breaks and machine speed losses, usually used to measure the performance rate of this machine or line.

Finally, losses in quality generally causes rework and yield decreases.

Thus, based on Gotoh and Tajiri (1992), the OEE depends on the equipment availability, its rate performance, and the resulting quality of the product from this operation, as shown in Figure 2.

Hansen (2001), on the other hand, specify performance rate as the speed rate.

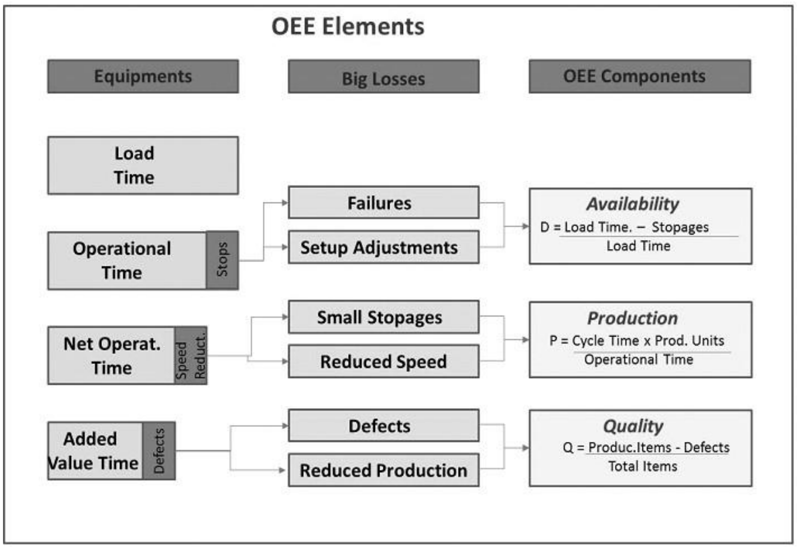

Figure 2 – OEE Elements (Braglia *et al.*, 2009)

Several existing publications of OEE concepts and its application are found. Dal *et al.* (2000) indicates OEE as an information source for everyday decisions, concerning manufacturing operations.

Hansen (2001), on the other hand, describes OEE production tool as responsible for increasing yield, while for Bamber *et al.* (2003), OEE is considered as a measure of overall performance, thus being applicable beyond the manufacturing limits.

In the same vein, Peters (2003) proposed a variation of the metric to measure labor performance, named as OCE (Overall Craft Effectiveness).

Taninecz and Brandt (2005) agree, and explain that overall efficiency also depends on other factors, besides equipment, and introduce an alternative metric, called OPE (Overall Plant Efficiency), that is obtained by multiplying the OEE by the installed capacity usage, and by the operational craft efficiency (in this case it considers staff availability, the level of accumulated knowledge, and the quality of that labor).

Anvari *et al.* (2010), on the other hand, introduced a new method called BM-OEE, used to measure the equipment effectiveness in the steel industry. This method considers internal and external changes in the markets, and it is pointed as an useful tool for performance management.

A different approach is presented by Robinson (2004), based on the fundamentals of TOC (Theory of Constraints), which considers the specific line performance as determined by the constrained operation, affecting both availability (D) and the rate of performance / productivity (P) of this line, limiting both to the restrictive machine performance (the bottleneck).

Additionally, quality defects found immediately preceding the bottleneck (US - Upstream) only affect performance if there is a material lack to fulfill this bottleneck operation, while the quality defects generated after the bottleneck (DS - Downstream), affect the line potential performance, and should be accounted for in the rate of quality OEE.

Thus, Robinson (2004) suggests that the OEE formula is changed considering both the bottleneck resource availability (D) and productivity (P), and quality rate given by the formula: (total items processed by the bottleneck operation, less total of reprocessed or defective items) divided by the total number of items processed by the bottleneck operation.

Raouf (1994) considers the allocation of weights to the different elements of OEE (availability, productivity and quality), justifying that factors that affect the OEE does not have the same importance for all cases.

Nakajima (1988) explains that ideal values for OEE components must be, respectively, over 90% for availability, over 95% of performance, and over 99% for quality, resulting in OEE of 85%, on average.

Braglia *et al.* (2009) argue that the use of OEE, however, presents some difficulties in its operationalization, and cite restrictions in the adopted losses classification, which are often not compatible with the identified instance, and which requires the addition of new losses reasons, in the existing enterprise structure.

Jeong and Phillips (2001) proposed an alternative loss classification system, based on the demonstration that the standard OEE is not totally adherent to industries that intensively use the installed capital. For these cases, the losses may be generated by preventive maintenance, shift changes, and holidays, for example.

Likewise, Ron and Rooda (2005) identified that the OEE includes losses for material lack, or restrictions caused by the production system, not specifically related to equipment (the authors suggest that the internal system losses are excluded from the OEE even their are not linked to the production equipment or line). Thus, Bamber *et al.* (2003) consider that every organization must have its specific framework for losses classification, according to its environamental conditions. Another difficulty identified by Braglia *et al.* (2009) refers to the fact that machines do not operate isolated in a factory, but within production lines, making that materials movements, queues, and stages exert a direct impact on these equipments performance, and vice versa. The authors state that, in cases where the line is unbalanced, or when the manufacturing process is made by separate machines, operating in parallel or serially, the efficiency of the system depends more on the logistics process to connect the equipment and to manage the logistics flow, than the increased equipment efficiency.

Thus, the OEE, according Braglia *et al.* (2009) and Anvari *et al.* (2010), is considered suitable tool to optimize equipment utilization, postponing financial investment needs, and decreasing operational costs of the production process.

4. OEE Supporting SCM CAPACITY MANAGEMENT

This work focus on the pharmaceutical industry production process, that is characterized as a continuous manufacturing system, in which, as described by Anvari *et al.* (2010), different machines and processes are organized in sequence of operations, for drugs manufacturing. In this scenario, a process byproduct can be used as input to the next machine, or shipped to the market. Additionally, because this is a industry with intensive capital investment, accurately measure the equipment use and effectiveness is essential (JEONG and PHILLIPS, 2001). In this environment, Anvari *et al.* (2010) emphasize that OEE losses measurements start from load time (which the authors call OEE-LB, or OEE Loading Based), excluding losses that occur before and after this load. The authors point out that other factors not considered in the calculation may restrict the level of OEE implementation, such as those from a manufacturing environment, and market restrictions, which the authors call Market Time (MT). For Anvari *et al.* (2010) MT is a significant basis for an OEE refinement, and this perspective considers all losses that really affect the equipment performance, besides reflecting internal and external market changes, and calculate the effective parameters based on best measurements to meet market demands. This approach is important, not only for the steel industry, but also for the pharmaceutical. This is because, within the scope of this paper, the OEE has dual application within the processes of demand management in the pharmaceutical industry: to serve as a basis for defining the available manufacturing capacity, which in this case is bounded by the restrictive process that occurs in lines packaging (eg.: blistering), as well as to define the average lead-time for each drug type, in order to measure the production lead time, another important component of demand management processes. Thus, for purposes of this study, the model to be adopted is that of Anvari *et al.* (2010), which includes on the OEE calculation market losses (OEE Overall Equipment Effectiveness MB-Market-Based).

Anvari *et al.* (2010) classify these losses into five major groups (before machine loading):

- Unplanned production-related time: that cause a disruption in the production program, such as current orders unloading, preparation times, and basic maintenance (such as cleaning and lubrication);
- Unplanned staff time: considering all losses due to manpower lack, resulting from, for example, plant floor daily meetings, and training;
- Unplanned times related to the Organization: all non-operating time from shift changes, without allocated program time (eg holidays night shifts, weekends);
- Unplanned times related to management: time to consider the associated management activities;
- Unplanned times related to the process inputs: all non-operational time related to lack of material, electricity and other utilities.

Beyond the loss categorized as non-scheduled times, Anvari *et al.* (2010) mention three other types of losses before loading: time for improvements, which are used in stroke research and development, plant expansion activities and other times they need machines in downtime, engineering time and planned maintenance. Anvari *et al.* (2010), prioritize these losses based on the effort degree to avoid them (the lower the priority, the easier to prevent their occurrence): 1 Unplanned time related to the Organization; 2 Unplanned programmed-related personnel time; 3 Unplanned time related to management; 4 Time in improvements; 5 Time of Engineering; 6 unplanned time related to inputs; 7 Unplanned time related to production; 8 Planned maintenance time.

Anvari *et al.* (2010) detail the concept of Market Time (MT), explaining that the product that comes out of a machine can be delivered to both the market and for the next machine. In this sense, the MT for this particular machine refers to the length of time to produce items to meet both the external market demand (ED), as domestic demand (ID). Anvari *et al.* (2010) point out that this measure consider the time spent on the machine defects (PD), losses caused by fails in this machine (PF), losses from setup and adjustments (PS), and micro stops for this machine (PP). The rate of manufacturing is measured in units per hour (UPH). Thus, the actual total units produced per hour (URPH) indicate the actual speed of the machine. As an example, it is assumed to calculate the MT of the machine 1:

- MT1 = ED1 / URPH1 + PD1 / URPH1 + ID1 / URPH1 + PF1 + PS1 + PP1

Being:

- ID1 / URPH1 = ED2 / URPH2 + PD2 / URPH2 + ID2 / URPH2 + PF2 + PS2 + PP2

Where MT to machine 1 (MT1) is defined based on its features, including the external market demand (ED2), internal market demand (ID2), defects (PD2), and actual number of units produced by hour (URPH2). Thus:

- MT1 = ED1 / URPH1 + PD1 / URPH1 + ED2 / URPH2 + PD2 / UPRH2 + ID2 / URPH2 + PF1 + PS1 + PP1 + PF2 + PS2 + PP2

Similarly, the machine 2 MT (MT2) is given by the formula below, and so forth:

- MT2 = ED2 / URPH2 + PD2 / URPH2 + ED3 / URPH3 + PD3 / UPRH3 + ID3 / URPH3 + PF2 + PS2 + PP2 + PF3 + PS3 + PP3

Because the MT represent all losses that affect the overall effectiveness of the equipment, Anvari *et al.* (2010) argue that it is necessary to specify which losses are associated with Market Time (MT). For this, it is used the OEE-MB to calculate the equipment performance during MT. Anvari *et al.* (2010) state that whenever the total demand (domestic and external) market is greater than the number of units manufactured, time losses before loading should be analyzed to identify losses related to MT. In these cases, activities performed before the loading time might be excluded, even only those considered as losses within the manufacturing time are still required to meet market needs. On the other hand, when the amount of the manufactured product is sufficient to meet the market demand, the activities performed before the loading time are not considered losses. However, in cases where part of the length of time before charging is required to meet the market requirements, all losses are classified in terms of how they can be avoided. Anvari *et al.* (2010) indicate that, among the losses, those easier to avoid (lowest rating) should be prioritized instead of the solution with the greatest difficulty, and the process should continue until all the indicated time (MT) is enough to meet market demand.

Thus, Anvari *et al.* (2010) define all losses before the loading time (TPAC) as ΣTPAC, whose losses are entered in Market Total Time as ΣTPDMT (Total Losses in the Market Time). Based on OEE-LB (traditional OEE, which measures the losses within the load time, or cycle), the OEE-BC (based on Capital) metric that considers all losses before and after the loading time (ignoring market demands); and ΣTPDMT that corresponds to losses in the MT, Anvari *et al.* (2010) propose a new comprehensive performance metric of equipment, OEE-MB, which considers the actual losses during the service time of internal customers (for processing on machines), and external customers (Figure 3).

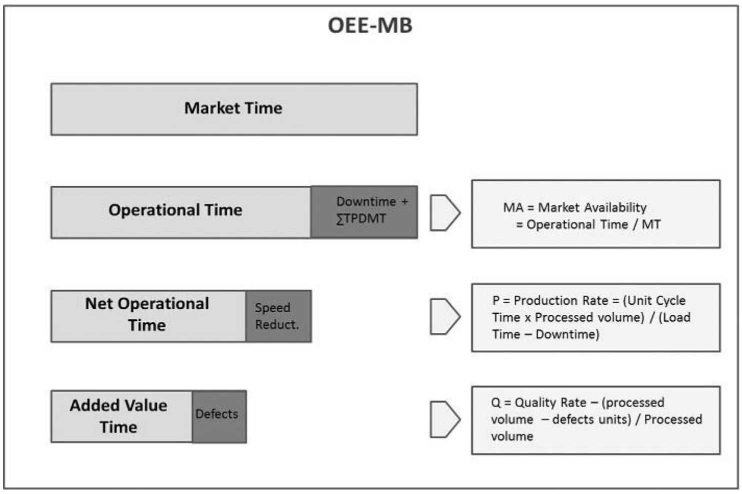

Figure 3 – OEE-MB Structure (Anvari *et al.*, 2010)

To calculate MB-OEE, it is important that the market availability (MA) be known, based on the following formula:

- MA = [MT - (Downtime + ΣTPDMT)] / MT

where

- ΣTPDMT = sum of all lost time within the MT
- P = (cycle time per unit times processed volume) / (load time - Downtime)
- Q = 1 – (Defects Units / Processed Volume)

Thus, OEE-MB can be obtained:

- OEE-MB = AM x P x Q

= [(MT – (Downtime + ∑TPDMT)) / MT] x
[(Unit cycle time x processed volume) / (load time - Downtime)] x
[1 – (Defects Units / Processed volume)]

According Anvari et al. (2010), the concept of OEE-MB can be enhanced to facilitate communication through disclosure management panels in the view, considering the use of colors for these indicators (red, yellow and green, indicating the adherence of the results to the proposed targets).

Thus, for purposes of this study, the OEE-MB is the indicator that supports the processes of demand management, both to provide elements to calculate the net production capacity, and also to establish the basis to indicate the production lead times, as for product category, as globally.

4 CONCLUSIONS

In this work, Lambert, Cooper and Pagh (1998) supply chain concept was selected, which encompasses the focal company, and comprising all the organizations that have direct and indirect relationship with it. Additionally, was considered the Croxton demand management model (CROXTON *et al*. (2008), in particular, the producer-distributor dyad in the pharmaceutical chain.

One of this study assumption was that, in a supply chain, especially in the pharmaceutical industry, the use of OEE is crucial to increase the capacity and manufacturing flexibility, which translates into better performance, reliability, agility, and lower costs, obtained by means of reduced needs for inventories, and increased reliability of deliveries. It was found that the OEE-MB, a variation of OEE, collaborate for achieving them, in this studied supply chain dyad.

Thus, this study evolved based on the literature, identifying how OEE can contribute to the processes of supply chain pharmaceutical industry demand management. Based on the results of applied questionnaires and interviews, it was identified that there is a positive correlation between the findings in the literature, and respondents' answers, indicating the viability of the OEE for manufacturing flow optimization, based on the demand management operational model from Croxton *et al*. (2008).

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