Lean manufacturing | literature review

Since the 1980s, numerous businesses in various sectors of industry have continually been introducing programs intended to improve both productivity and quality. Several authors have posited “ lean manufacturing” or “ lean production” as the best possible production system and one that can be implemented in any industry and any process (Bonavia and Marin, 2006 and Lee-Mortimer, 2006). Doolen and Hacker (2005) mentioned that different researchers have explored the portability of lean practices both within and between different manufacturing sectors. In accordance, a variety of surveys conducted in different types of industry (Soriano-Meier and Forrester, 2002, Bonavia and Marin, 2006, Doolen and Hacker, 2005, Sánchez and Pérez, 2001 and Taj, 2008) proved that lean is widely successful in a variety of industrial sectors.

However, there are two problematic issues regarding lean manufacturing have been addressed in several studies. First, Shah and Ward (2007) claimed that any discussion of lean production points to an absence of common definition of the concept. Likewise, Pettersen (2009) alleged that there is no agreed upon definition of lean that could be found in the literature. Papadopoulou and Ã-zbayrak (2005) declared that there is no consensus in different researchers’ perceptions to the concept of lean which leads to conflicting results in identifying and classifying its practices and techniques.

Second, there is conflict in using terms such as elements, principles, constructs, techniques and practices. Papadopoulou and Ã-zbayrak (2005) mentioned that some of the elements of lean are actually referring to the goals and objectives rather than techniques or tools (e. g. elimination of waste, lead time reduction) and, in addition, a number of other best manufacturing practices (such as agile manufacturing) were used in literature as lean practices. Moreover, Shah and Ward (2007) underscored that identical items are used to operationalize vastly different concepts and different items are used to operationalize the same construct. Thus, Shah and Ward (2007) argued that a great source of confusion and inconsistency associated with lean is the more substantive disagreement about what comprises lean production and how it can be measured operationally.

Statement of the problem

The above mentioned issues revealed three confusions surrounding the lean concept in literature, which are (1) the lack of a consistent definition of lean, (2) the disagreement about the elements that comprise lean manufacturing and (3) the lack of a measurement tool for assessing changes towards lean implementation.

With the aim to clarify and resolve these confusions, this chapter has three main objectives; (1) to propose a conceptual definition of the term " lean manufacturing" that captures all its main facets, (2) to provide a framework that identifies its major elements and practices, and (3) to develop an operationalized model to assess changes towards lean manufacturing implementation. To achieve these objectives, an in-depth literature review is conducted regarding the topic of lean manufacturing. At first, the concept of " Lean" and its main principles are introduced. Next, the elements of lean manufacturing and the practices for lean implementation will be investigated. Finally, different indicators that measure the progress achieved towards lean are explored.

The concept of Lean

Lean was associated with the practice of deciphering the value added activities from those that are waste in an organization and its supply chain (Comm and Mathaisel, 2005). Motwani (2003) declared that companies need to focus on each product and its value stream in order to distinguish between wasted activities and that actually create value. Moreover, Papadopoulou and Ã-zbayrak (2005) stated that leanness was introduced as an approach to manufacturing that was aiming at the elimination of waste while stressing the need for continuous improvement.

However, lean manufacturing is much more than a technique, it is, in addition, a way of thinking (Taj, 2008). The issue of lean thinking was widely discussed in different researches. Comm and Mathaisel (2005) believed that lean thinking removes the traditional way people think about roles and responsibilities through remaining focused on the customer and the core competencies that the customer values from an organization. Therefore, Bhasin and Burcher (2006) claimed that for a successful implementation, numerous cultural changes are required for embracing empowerment and disseminating the lean principles through-out the value chain. Similarly, Taj (2008) confirmed that lean as a way of thinking creates a culture in which everyone in the organization continuously improve operations. In accordance, Comm and Mathaisel (2000) introduced leanness as a philosophy that intended to significantly reduce cost and cycle time throughout the entire value chain while continuing to improve product performance.

Hence, lean should be described from two points of view; the philosophical perspective and the practical perspective (Shah and Ward, 2007). From the philosophical perspective, lean is viewed as an overall organizational philosophy that should affect the people way of thinking and behaving (Papadopoulou and Ã-zbayrak, 2005 and Bhasin and Burcher, 2006). This philosophy drives the guiding principles and the overarching goals of lean (Shah and Ward, 2007). On the other hand, the practical perspective see lean as a set of management practices, tools and techniques (Shah and Ward, 2007) that are used to apply the philosophy and to achieve the goals (Bhasin and Burcher, 2006).

This two-perspective view of lean is supported by the definition of lean as a socio-technical system. Such system combines both technical system; i. e. technology and social system; i. e. people and organizational structure (Bhasin and Burcher, 2006). In the same context, Shah and Ward (2007) asserted that to pursue lean production, firms have to effectively manage their social and technical systems simultaneously. Moreover, Cua et al. (2001) proved that joint optimization of both socially- and technically-oriented policies or practices is necessary for achieving good results.

Regarding its implementation, Panizzolo (1998) demonstrated that the wide range of lean practices are related to interventions in the manufacturing area, actions taken in other areas of the firm (design, HR, strategy, etc.) and relationships with both suppliers and customers. Likewise, Shah and Ward (2003) stated that lean should be seen as a multi-dimensional approach that encompasses a wide variety of management practices. This conceptualization of lean as multidimensional strategy is supported by a wide range of researchers (Doolen and Hacker, 2005, Karlsson and Åhlström, 1996, Shah and Ward, 2007 and Papadopoulou and Ã-zbayrak, 2005).

However, it is well accepted among researchers that lean should be implemented as an integrated system (Shah and Ward, 2007, Bhasin and Burcher, 2006, Karlsson and Åhlström, 1996 and Papadopoulou and Ã-zbayrak, 2005). Shah and Ward (2007) suggested that a well-developed lean strategy implementation will require firms to exert considerable effort along several dimensions simultaneously. Bonavia and Marin (2006) concluded that there are only few relationships between the degree of use of lean production practices individually and operational performance (in terms of productivity, quality, lead time and inventory). In the same vein, Shah and Ward (2003) provide unambiguous evidence that the synergistic effects of all lean practices are associated with better manufacturing performance.

Another feature of lean manufacturing that was emphasized in literature is its time-frame of implementation. Bhasin and Burcher (2006) and Doolen and Hacker (2005) believed that lean is a long-term multidimensional organizational strategy. Papadopoulou and Ã-zbayrak (2005) affirmed that transformation to lean requires a lot of effort, time and participation of all organization levels in addition to make changes in company culture and organizational structure. Thus, lean enterprises should continuously find ways to eliminate consumption of resources in their struggle to deliver value to their customers. In correspondence, the implementation of the lean program in the case study discussed in (Lee-Mortimer, 2006) proved that lean is not just a project, it is a long-term continuous journey which is implemented as a sequence of stages or projects.

In conclusion, lean manufacturing embraces different features that should be taken into consideration when defining this concept. Lean should be viewed as a philosophy, affecting company culture, rather than a set of tools/techniques. This, in turn, reveals the importance of managing social system as well as technical system simultaneously. Moreover, lean implementation scope is not confined to the manufacturing function of a company, rather it relates to all functions ranging from product development, procurement and manufacturing over to distribution. Since lean companies seek to deliver value to their customers, this value should be predefined and delivered, while waste, which customers are not willing to pay for, should continuously be eliminated. All the aforementioned features of lean manufacturing can be captured in the following proposed conceptual definition.

Lean manufacturing is a philosophy and a long-term strategy that is applied through a socio-technical system integrating all functions within the organization with the aim of continuous waste elimination while delivering outcomes that meet continuously predefined customer value.

Lean principles

Lean philosophy is mainly based on the principle of " eliminating waste". Waste is anything other than the minimum amount of equipment, materials, parts, and working time that are essential to add value (Taj, 2008, Bonavia and Marin, 2006 and Karlsson and Åhlström, 1996). Sánchez and Pérez (2001) cited that the main goal of lean is to eliminate all activities that do not add value to the product. Value should be specified as it is perceived by customers (Andersson et al., 2006 and Dahlgaard and Dahlgaard-Park, 2006). If the task does not add value from the customer's point of view, it should be modified or eliminated from the process (Andersson et al., 2006). It is believed that by minimizing waste and zero-value added activities, companies can reduce production costs and the overall production system will be more efficient (Comm and Mathaisel, 2005 and Karlsson and Åhlström, 1996).

Since inventory is considered one of the critical sources of waste (Sánchez and Pérez, 2001 and Karlsson and Åhlström, 1996), Dahlgaard and Dahlgaard-Park (2006) declared that the traditional way of producing in batches is inefficient as it requires goods to wait in inventories before the next production step is started up. Thus, Motwani (2003) mentioned that the value must flow to the customer without interruptions. Andersson et al. (2006) confirmed that focus should be on organizing a continuous flow through the production or supply chain rather than moving commodities in large batches.

Closely related to the continuous flow is the principle of just-in-time (JIT), since the ultimate goal that every process should be provided with only one part at a time, exactly when that part is needed (Karlsson and Åhlström, 1996). Moreover, if continuous flow is not possible (Lummus et al., 2006), the way of scheduling the flow of material should be pull instead of push (Motwani, 2003 and Dahlgaard and Dahlgaard-Park, 2006). This means that customer demand should pull finished products through the system with the aim of not carrying out any work unless the result of it is required downstream (Andersson et al., 2006).

It is obvious that to succeed in the implementation of any modern system, everyone from top management to any lower level should make sincere efforts, and set their goals jointly through active participation and understanding (Ahmed et al., 2004). According to (McKone et al., 1999), employees can contribute significantly to the organization when they are allowed to participate in decisions that impact their area of responsibility. As a result, involvement from all employees allows companies to better use of its available resources (McKone et al., 1999). This principle reflects the conceptualization of lean manufacturing as a socio-technical system, since it highlights the importance of managing social system as well as technical system.

Since lean is viewed as a long-term strategy, lean philosophy emphasizes continuous improvement. Several researchers (Karlsson and Åhlström, 1996, Comm and Mathaisel, 2005 and Sánchez and Pérez, 2001) affirmed that one of the most fundamental principles of lean is the search for continuous improvement in products and processes. Lummus et al. (2006) mentioned that processes should be managed towards perfection to continuously reduce the time needed to serve the customer. Likewise, Andersson et al. (2006) underscored that the elimination of non-value-adding elements (waste) is a process of continuous improvement. In this context, Sánchez and Pérez (2001) highlighted the importance of employees' involvement and top management support to create and train improvement teams that lead the organization to move toward zero defects.

Based on the analysis of lean previous studies, it is concluded that there are five key principles / overarching goals which can be considered the bases for the lean philosophy. These principles are; (1) waste elimination, (2) customer value identification, (3) continuous production flow, (4) employees involvement and (5) continuous improvement. Furthermore, the aforesaid lean principles confirm some issues in the proposed conceptual definition. The unambiguous believe that “ elimination of waste” is the fundamental goal is affirmed since lean is regularly defined as “ manufacturing without waste”. Likewise, identifying value as perceived by customer is asserted in the proposed definition. Moreover, seeking continuous improvement as a principle of lean philosophy reflects the long-term nature of lean implementation. Thus, the proposed definition stresses the aim of “ continuous waste elimination” and highlighted the need to “ continuously predefine customer value”. Also, the importance of employees involvement emphasizes the social phase of the lean system as a socio-technical system. Finally, holding in mind these principles / goals underscores the view of lean as a philosophy that affects the people way of thinking.

Lean implementation framework

Previous studies concerning lean manufacturing revealed a number of manufacturing practices that are commonly associated with lean implementation. The initial step towards developing a framework for lean implementation is to capture different practices and combine them into inter-related groups in accordance to the multi-dimensional nature of lean manufacturing. The term “ practices” in this context refers to the predominant methodologies that may include many techniques and tools.

Shah and Ward (2003) identified and empirically validated combining lean practices into four specific lean bundles: namely “ Total Quality

Management" (TQM), " Just In Time" (JIT), " Total Productive Maintenance" (TPM) and " Human Resources Management" (HRM). Bonavia and Marin (2006) found enough agreement in literature to identify the first three bundles; TQM, JIT and TPM, while Cua et al. (2001) are of the opinion that human and strategic-oriented practices are common practices that support all other three bundles.

Although there is general agreement within operations management literature that JIT, TPM, TQM and HRM are conceptually, theoretically, and empirically well established (Shah and Ward, 2003), there is no unanimous classification of the lean manufacturing practices that make up each of the four bundles (Bonavia and Marin, 2006). Therefore, in an attempt to provide a framework for lean implementation comprises the actual practices that represent each of the four mentioned bundles, the basic theme of these bundles are identified. Then, different lean practices are combined into each of these bundles based on reviewing different research papers regarding lean implementation practices, in addition to articles that were focused mainly on one of these bundles.

TQM bundle

Lack of quality is a major source of waste, since the defective parts and products that need to be reworked or scrapped do not add any value to the customer and should be eliminated in order to attain high productivity (Karlsson and Åhlström, 1996). Söderquist and Motwani (1999) underscored that quality should be a top management issue and continuous improvement efforts together with the zero error objective should be company-wide and extended over company limits in production chains.

Cua et al. (2001) defined total quality management (TQM) as a manufacturing program aimed at continuously improving and sustaining quality products and processes by capitalizing on the involvement of management, workforce, suppliers, and customers, in order to meet or exceed customer expectations. Söderquist and Motwani (1999) emphasized that TQM approach is the philosophy that should underpin the quality project in a lean company.

The practices combined to form the TQM bundle include; product quality control, visual management (Cua et al., 2001, McKone et al., 1999 and Söderquist and Motwani, 1999), process management (Shah and Ward, 2003, Cua et al., 2001 and McKone et al., 1999), product design and development (Cua et al., 2001 and Söderquist and Motwani, 1999), standardization (Söderquist and Motwani, 1999), suppliers quality management and customers involvement (Cua et al., 2001 and McKone et al., 1999).

JIT bundle

Just-in-time philosophy means to deliver the right part in the necessary quantity and at the right time (Canel et al., 2000, Sánchez and Pérez, 2001 and Karlsson and Åhlström, 1996). Ahmed et al. (2004) defined JIT as a philosophy and system concept of doing, maintaining and producing what is value adding or what is just needed, be it raw materials, components, parts, WIP, employees, or finished products. Cua et al. (2001) asserted that the primary goal of JIT, as a manufacturing program, is continuously reducing and ultimately eliminating all forms of waste through JIT production and involvement of the work force.

JIT basic techniques include set-up time and lot size reduction, pull production systems (Shah and Ward, 2003, Cua et al., 2001 and McKone et al., 1999), equipment layout and cellular manufacturing (Shah and Ward, 2003 and Cua et al., 2001), production leveling and scheduling and JIT delivery by suppliers (Cua et al., 2001 and McKone et al., 1999).

TPM bundle

It has been accepted beyond any doubt that maintenance, as a support function in businesses, plays an important role in backing up many emerging business and operation strategies like lean manufacturing (Ahuja and Khamba, 2008b). Without having a productive maintenance system, lean production, just-in-time (JIT) or total quality management (TQM) environment cannot be attained (Ahmed et al., 2004). TPM is a proven and successful procedure for introducing maintenance considerations into organizational activities (Eti et al., 2004). Ahuja and Khamba (2008b) stated that TPM is a methodology originating from Japan to support its lean manufacturing system, since dependable and effective equipment are essential pre-requisite for implementing lean manufacturing initiatives in the organizations.

Cua et al. (2001) and Shah and Ward (2003) defined TPM as a manufacturing program designed primarily to maximize equipment effectiveness throughout its entire life through the participation and motivation of the entire work force for performing planned predictive and preventive maintenance of the equipment and using maintenance optimization techniques.

TPM, according to McKone et al. (1999), provides a comprehensive company-wide approach to maintenance management which is usually divided into short-term and long-term elements. In the short-term, TPM basic practices include; industrial housekeeping, autonomous maintenance (Cua et al., 2001, Eti et al., 2004 and McKone et al., 1999), and planned preventive and predictive maintenance (Shah and Ward, 2003, Cua et al., 2001, Eti et al., 2004 and McKone et al., 1999). In the long-term, TPM efforts focus on new equipment and technology acquisition (Shah and Ward, 2003, Cua et al., 2001 and McKone et al., 1999).

HRM bundle

Human resources have a critical role in carrying out the continuous improvement plans which are the basis for success in lean implementation (Panizzolo, 1998). Eti et al. (2004) claimed that the degree of employees eagerness to embrace change determines the rate of progress towards that goal. Moreover, McKone et al. (1999) declared that employees are the greatest sources of information for companies to improve their performance.

Shah and Ward (2003) affirmed that the HRM bundle has significant theoretical and empirical support. The most commonly cited HRM practices are employees involvement (Shah and Ward, 2003, Cua et al., 2001 and McKone et al., 1999), multi-skilled workforce, multi-functional work teams (Shah and Ward, 2003), education and training (Shah and Ward, 2003, Cua et al., 2001 and McKone et al., 1999), performance-based compensation system (McKone et al., 1999) and information and feedback (Cua et al., 2001 and McKone et al., 1999).

Lean operationalized model

Traditionally, managers have relied heavily on accounting metrics to determine efficiency, such metrics reflect the final state achieved as the result of a long chain of decisions (Taj, 2008), while lean should be seen as a direction rather than a state to be reached after a certain time (Karlsson and Åhlström, 1996). Therefore, managing a lean factory requires key information to assess the changes taking place in the effort to introduce lean (Sánchez and Pérez, 2001 and Karlsson and Åhlström, 1996).

Consequently, in order to develop an operationalized model for lean manufacturing, the aforementioned bundles and practices will be discussed with focus on identifying the indicators that can be used in assessing changes towards lean implementation. It is important here to note that the focus lies on the changes in these indicators, not on their actual values. So, the desired direction of each indicator, if moving in a lean direction, will be also specified.

Measurement of TQM basic practices

Since the ultimate goal of TQM practices is to achieve zero defects, Motwani (2001) mentioned that the percentage of defects (TQM1) and the percentage of products needing rework (TQM2) are among the common quality outcome indicators employed by several researchers.

Product quality can be controlled through the involvement of production line workers for identification and adjustment of defective parts and their authority to stop lines when defective parts are found in order to avoid any defective parts moving to the next production stage (Karlsson and Åhlström, 1996). Thus, Sánchez and Pérez (2001) used the percentage of defective parts adjusted by production line workers (TQM3) as an indicator of transferring the responsibility for products quality from the quality control department to the line workers. In addition, Karlsson and Åhlström (1996) alleged that the number of quality control personnel (TQM4) and the size of repair area (TQM5) can be reduced as a consequence. Furthermore, Karlsson and Åhlström (1996) declared the use of autonomous defect control (poka yoke) as inexpensive means to help conducting inspection of all units with the ultimate goal of zero defects. Therefore, the percentage of inspection carried out by autonomous defect control (TQM6) is a common measure (Sánchez and Pérez, 2001 and Karlsson and Åhlström, 1996).

Visible graphs and panels are used to gather performance data, to plot different measurements and to identify specific problems and causes of delay in order to take efforts for resolution (Lee-Mortimer, 2006 and Bonavia and Marin, 2006). For this, Bonavia and Marin (2006) measured the percentage of work areas where visible graphs & panels are used (TQM7) as an indicator for visual management.

In addition to controlling products quality, process management is essential to obtain fault free parts and products from the very beginning (Karlsson and Åhlström, 1996). Cua et al. (2001) emphasized the use of Statistical Process Control (SPC) techniques in monitoring processes to ensure that each process will supply defect free units to subsequent process. Shah and Ward (2007) and Bonavia and Marin (2006) measured the percentage of equipment / processes under SPC (TQM8) as an indicator to represent the expansion of using SPC.

Panizzolo (1998) emphasized the attention that has been devoted to the relationships between product development and manufacturing activities. Söderquist and Motwani (1999) claimed that design for manufacturing through integrating product and process engineering is one of the core features of quality management within the lean production framework. Thus, the percentage of parts designed by cross-functional teams (TQM9) can be used as a measure for this practice. In addition, Sánchez and Pérez (2001) mentioned the use of common parts (TQM10) to manufacture different products as a technique used to reduce inventory and lead times as well. Moreover, participation of suppliers in the design stage (TQM11) facilitates manufacturing of components they have designed.

Standardization is an essential principle of lean manufacturing that involves establishing the sequence of tasks to be done by each worker and how those tasks are done (Olivella et al, 2008), measuring and comparing the cycle time against the required takt time (Motwani, 2003) and specifying procedures, tools and materials (Bonavia and Marin, 2006). The percentage of procedures which are written recorded (TQM12) is the measure used by Sánchez and Pérez (2001) and Bonavia and Marin (2006) to quantify the extent to which the company standardize its operations.

Several researches emphasized the significant role that suppliers can play when involved in quality improvement programs (Panizzolo, 1998, Shah and Ward, 2007, Papadopoulou and Ã-zbayrak, 2005 and Motwani, 2003). In order to enhance suppliers involvement, Sánchez and Pérez (2001) stressed the importance of information exchange with suppliers through conducting visits by engineers and technicians from both sides and interchanging documents. This will help to reduce inefficiencies and eliminate activities that are not value added (Sánchez and Pérez, 2001). This practice is measured by two indicators; the frequency of visits between company's and suppliers' technicians (TQM13) and the number of suggestions made to suppliers (TQM14) (Sánchez and Pérez, 2001).

With the focus on customers and their needs, Motwani (2001) declared that customer service programs should include quick responsiveness to complaints and maintaining a corporate goal to reduce the quantity of complaints (TQM15). Furthermore, Panizzolo (1998) affirmed that customer-driven enterprises dedicated much attention to organize customer participation in design, manufacturing and delivery activities. Thus, Bhasin and Burcher (2006) considered the percentage of projects in which the customer was involved (TQM16) as a signal of the systematically and continuously focus on the customer. In conclusion, table 3. 1 summarizes the indicators developed to assess changes towards implementing the previously discussed TQM practices.

Measurement of JIT basic practices

Several authors (Sánchez and Pérez, 2001, Karlsson and Åhlström, 1996, Lee-Mortimer, 2006 and Salaheldin, 2005) have proposed the value of WIP (JIT1) and the lead time to customer order (JIT2) as common indicators of JIT implementation. Moreover, Motwani (2003) and Bhasin (2008) affirmed that total product cycle time (total time that material spends in the production system) (JIT3) is the best measure for tracking lean progress.

Reducing set-up times simultaneously with reducing lot sizes is a technique used to reduce inventories and also it contributes to the reduction of lead times (Sánchez and Pérez, 2001) and increasing flexibility (Karlsson and Åhlström, 1996). The progress in this practice can be directly measured by two indicators; set-up times (JIT4) and production and delivery lot sizes (JIT5).

Firms use pull production systems to facilitate JIT production with the aim to produce the kind of units needed, at the time needed, and in the quantities needed (Shah and Ward, 2007). Bonavia and Marin (2006), Cua et al. (2001), McKone et al. (1999) and Shah and Ward (2007) highlighted the use of kanban squares, containers or signals as a means to pull material from an upstream station and manage product flow. Karlsson and Åhlström (1996) argued that as the work with implementing pull system proceeded, the number of manufacturing stages producing against customer orders should extend. Accordingly, they considered the percentage of stages in the material flow that uses pull (JIT6) as a determinant of the change towards this practice.

Cua et al. (2001) and McKone et al. (1999) emphasized the importance of equipment layout to facilitate low inventories (JIT1) and fast throughput (i. e. shorten lead time (JIT3)). Grouping machines together in a cell-based layout (Cellular manufacturing) is one technique that is developed to facilitate line balancing with the ultimate goal of creating single piece flow (Lee-Mortimer, 2006 and Motwani, 2003). Implementing cellular manufacturing technique helps to eliminate the frequency (JIT7) and physical distances (JIT8) of parts transportation (Karlsson and Åhlström, 1996) and to reduce the investments (JIT9) in handling systems (Sánchez and Pérez, 2001).

Panizzolo (1998) considered production leveling as a practice, in addition to small lots and pull control that is adopted to synchronize production and market demand. Thus, this practice contributes in achieving reductions in the value of WIP (JIT1) and the lead times to customer order (JIT2). Moreover, the synchronization between production output and market demand helps company to minimize finished goods inventory (JIT10).

Suppliers are required to deliver the right quantity, at the right time, and at the right quality (Shah and Ward, 2007) in order to facilitate JIT production. Many researches agreed on the importance of reducing the number of key suppliers (JIT11) for the main components and engaging with them in long term contracts (JIT12) (Sánchez and Pérez, 2001, McKone et al., 1999, Shah and Ward, 2007, Doolen and Hacker, 2005, Bhasin and Burcher, 2006 and Papadopoulou and Ã-zbayrak, 2005). Furthermore, the case study of (Comm and Mathaisel, 2005) highlighted how maintaining good relationships with suppliers helped to keep minimum raw material inventories (JIT13).

In general, McKone et al. (1999) highlighted the importance of on-time delivery (JIT14) to customers as an indicator of the JIT concept implementation. Likewise, Bhasin (2008) mentioned measuring on-time delivery as one of the customer / market indicators of lean implementation. In the same vein, Motwani (2001) recommended monitoring the amount of lateness in orders delivery as a tool in measuring the spread of delivery time. Furthermore, since the change towards JIT production and delivery is made gradually (Sánchez and Pérez, 2001), the proportion of products transferred just-in-time between production stages (JIT15) and that delivered just-in-time by suppliers (JIT16) should be measured. Table 3. 2 summarizes the indicators developed to assess changes towards implementing the previously discussed JIT practices.

Measurement of TPM basic practices

It is agreed upon in literature that overall equipment effectiveness " OEE" (