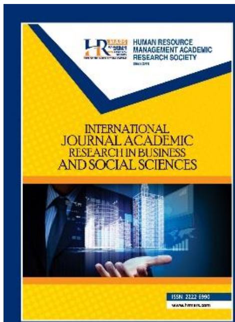

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Improving Organization Effectiveness in Manufacturing Through Lean Initiatives in Configure-To-Order (CTO) Production of Efficient Customer Delivery

[1]Khoo Teng Leong, [2]Oo Yu Hock
[1] PhD Candidate, Asia e University, Malaysia, [2] Professor, Asia e University (AeU), Malaysia

Abstract
Organizational effectiveness and operational efficiency have become significantly importance in the manufacturing industry. 'Lean' initiatives involve execution and evaluation, the former benchmarking Six Sigma is Define-Measure-Analyze-Improve-Control (DMAIC), and the latter involves three criteria of key performances indicators, viz., the lean principle assessment framework (internal), cost-related matters (external), and customer expectations. Both these processes are directed at improving manufacturing process to gain a potent momentum in mass customization: CTO production. The objective of this research is to explore how mass customization, specific to CTO production, can adopt 'lean' to improve manufacturing process-performance levels for organizational effectiveness, thereby increasing business competitiveness, and focusing on the manufacturing process of CTO work efficiency-quality product delivery at the factory floor level. The case study approach is employed to investigate how the 'lean' approach can improve the CTO manufacturing process. This research contributes to knowledge in the area of production and operations management, in particular: (a) highlighting the importance of 'organization and customer values' through 'lean' improvements to its results; and (b) mapping performance measurement relationship which extends to the sustainability, commitment and shared configured-processes results of quality end-product delivery to satisfied customers.
Keywords: Configure-to-Order Production, 'lean' Initiatives, Organization and Customer Values, Organizational Effectiveness, Operational Efficiency, Performance Measurement, Production and Operations Management, Six Sigma – DMAIC, Configure-Processes Results.

Introduction

In the competitive global market nowadays, the fast-changing environment has driven companies within many industries to be more flexible by improving their manufacturing process. To retain competitive advantage, the strategic role of manufacturing is increasingly egging companies to start enhancing their production systems to evolve a more effective way to improve speed-efficient productive capacity and sustain quality end-product on-time delivery to satisfied customers, enabling the companies to reduce production cost and increase the product quality with improved 'manufacturing' production process (Locke and Wellhausen, 2014). Moreover, production department has to focus on producing eco-friendly products by using green technologies to ensure environmental sustainability (Hossain et al., 2020). The latter is a transformation operation model, in which the input is transformed into the required output by adding value into the process mechanisms (Anil and Suresh, 2008).

The concept of 'lean', as an originating management from the Toyota Production System (TPS), was introduced by Womack, Jones, and Roos (1990). 'Lean' is aimed at improving the productivity of manufacturing process and boosting its flexibility. From the manufacturing point of view, 'lean' is mainly directed at eliminating any kind of waste within the processes because, as an integral part of the product manufacturing life cycle (from raw material until customer delivery), lean practices tend to increase the product value by reducing production inventories, costs, and time. In order to compete for the global market, the manufacturing companies are adopting product customization as a means to be more responsive to the needs and expectations of their customers and also the importance of product configuration is increasingly significant for a wide range of industrial companies. To manage such product customization, the manufacturing companies have shifted the business strategies from mass production to mass customization in order to fulfill the market demand and requirement quickly (Zhang, Zhao, and Qi, 2014). Configure-To-Order (CTO) is the strategy of products that are assembled and configured based on customer-specific requirements (Hoffman, 2009). Usually, the CTO manufacturing company has a configuration 'catalog' for the different products, which often offer the 'options' that can be chosen by the customers. The whole idea and important role of CTO production revolve around the concept of configurations. Simply, a configuration is the integration of the parts of the catalog with all the options, and they can literally be more than a number of configurations that could be selected and configured.

Overview of Lean Manufacturing

The 'lean' manufacturing approach was developed by TPS, and it is a systematic method used to eliminate wastes. Womack et al. (1990) highlighted in *"The Machine that Changed the World"* that manufacturing has changed from mass production to 'lean' manufacturing in the industry. It is a continuous improvement philosophy which is synonymous with '*kaizen'* – a worldwide recognized platform of an organization's long-term competitive strategy. The principles of 'lean' manufacturing present a practical approach to re-specify values, create value actions in the best practice, allow such activities to be coordinated without disruption, and ensure all works are executed efficiently and effectively. 'Lean' provides five basic fundamentals for all decisions within production. The principles are as follows:

a) The first principle is *"Specify Value"*. The customer is the only one who can determine the value of a product or service, followed by the stipulated requirements at a specific time and at a specified price.
b) The second principle is *"Identify the Value Stream"*. The value stream is defined as all the activities and events that take place to produce the product or service and deliver it to the customer.

c) The third principle is *"Flow"* by managing the product flowing through the value stream from the moment the customer places the order, avoiding stoppages, and delivering the finished products to the customer at just the right time.
d) The fourth principle is *"Pull".* The pull concept is that the speed and availability of downstream process would dictate the pace which products enter the stream, thereby pulling products into the system.
e) The final principle is *"Perfection"*. Perfection is a concept that the cycle of the first four principles should improve consistently to reduce waste.

Concept of Lean

The essence of 'lean' is the elimination of waste, and non-value adding activities from processes by applying a robust set of performance-change tools, emphasizing operational excellence in delivering superior value to customers. Three (3) types of actions involved are as follows:

- Non-Value Adding (NVA) – pure waste and unnecessary actions should be completely eliminated.
- Necessary but Non-Value Adding (NNVA) - may be wasteful but necessary under the operation procedures.
- Value-Adding (VA) - the processing of raw materials through the use of labor. This involves activities including assembly parts and forging raw materials.

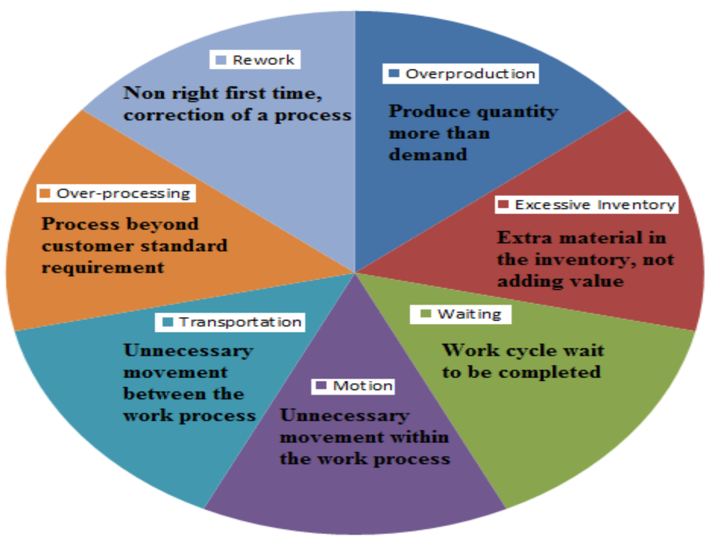


Figure 1: **The Seven Wastes**
Source: Modified from Gao and Low (2014)

Figure 1 shows the seven wastes to be eliminated in the manufacturing process. The 'lean' manufacturing methods and tools assist in the identification and steady elimination of waste in the production. As waste is eliminated, quality is improved while production time and cost are reduced. The following tools are the proven methods to achieve a state of 'lean' within the business, and they need to be adapted appropriately, and refined to suit specific-demand situations as and when necessary.

a) Value Stream Mapping (VSM)

VSM is a manufacturing tool in 'lean' that originated from the TPS known as *"material and information flow mapping"*. The mapping tool primarily uses the manufacturing method of 'lean' to analyze and evaluate certain work processes in a manufacturing operation. This tool is used to identify, analyze, and reduce waste, as well as to create flow in the manufacturing process that requires producing a product or service for customers (King and King, 2015).

b) Kanban

Kanban is used "*to regulate the flow of materials information between process and employees by linking sequential value-added works"* in the manufacturing. The Kanban system is able to define the accuracy of product quantity needed to support the customer demand. This system is beneficial to build the products only when the customer places the order, hence eliminating the tendency of over-production waste (Voehl, Harrington, Mignosa, and Charron, 2013).

c) Just-in-Time (JIT)

JIT refers to the idea that a process activity in the production must be calculated and designed with a high precision of material control to minimize the inventories. The objective of JIT is an inventory control system used to increase efficiency and decrease unwanted waste by receiving goods when they are required in the production process, thereby reducing the inventory costs (Wilson, 2009).

d) Kaizen

Kaizen is the concept of improving a process by a series of small continuous steps. Kai means *"change"*, while Zen means *"for the better".* Kaizen consists of three principles: process orientation, people orientation, and maintaining standards (Medinilla, 2015).

e) Process Mapping

Process mapping represents a system structure and its relationships by using flowcharts. The process flowchart presents a graphical representation of the process steps (Voehl et al., 2013).

Implementation of Lean Initiatives

'Lean' initiatives are driven by two facets of improvement: "*results outcome"* and *"value"*. The three-step approach (**Initiation, Execution, and Evaluation**) is applied to implement 'lean' (Anderson, Eriksson, and Torstensson, 2006). There are four elements of project **Initiation**. The first element is "*top management support through engagement"* for project initiation. The second element is *"highly competitive market pressure"* that could drive an organization to improve its manufacturing process problem and product quality. The third element is derived from the customer requirements as "*high demand and customer expectations"*. The fourth element is *"team-based improvement"* which involves the team members participating in initiating the improvement and taking up the ownership.

For the implementation of **Execution**, it benchmarks Six Sigma - DMAIC method (Grima, Marco-Almagro, Santiago, and Tort-Martorell, 2014). The DMAIC activities are described briefly as follows:

The **Evaluation** of 'lean' initiatives targets at providing a company to support its production works to solve the specific problems in improving the operational manufacturing process, employee relations, and organizational effectiveness. The impact of improvement initiatives generally occurs in three major criteria of key performance indicators (internal), cost related matters (external), and customer expectation, based on three main considerations:

The first criterion considers the results of operational processes and employee perspectives from key performance indicators are measured. The operational processes such as productivity increment, production efficiency, improvement cycle time, reduction in material inventory and WIP, and removal of NVA activities are directly measured.

Table 1: **DMAIC Steps**

DMAIC	***Objectives***
Define	Define the objectives of Critical-To-Quality (CTQ) and focus on the viewpoints of business stakeholders.
Measure	By considering CTQ to identify the process measures
Analyze	Understanding of the process problem, collect and analyze the variation data, then determine the root cause
Improve	Come out with a proper improvement action to solve the problem
Control	Structures and systems are established to sustain the improvements

Source: Adapted from Grima et al. (2014)

The employee perspectives are commonly assessed through Voice of Employee (VOE), in terms of skills development, attitudes, communication, knowledge, leadership, and working environment. In production, it is useful to know the relationships of 'lean' initiatives and organizational effectiveness, through the key-performance improvement indicators which can provide and gain the best results on customer expectations. The latter is the second criterion for measuring improvement results in terms of technical specifications (i.e., speed, flexibility, dependability) and functional requirements (i.e., reliability, responsiveness services, assurance). The last criterion is the cost- related matters in terms of hard (short-term) and soft (long-term) savings which can be quantifiable in the terms of monetary. The cost savings aspect is the most important criterion for measuring the outcome of improvement initiatives which are actively engage by the top management of organizations.

Mass Customization as A Supply Chain Production Strategy

The mass customization strategy is focused on producing personalized goods at near mass-produced costs, through modularized designs, flexibility and a company-costumer interaction at some point in the production cycle (Fogliatto, Da Silveira, and Borenstein, 2012).

Holweg (2005) had quoted that *"responsiveness is the ability to react purposefully and within an appropriate time-scale to the customer demand or changes in the marketplace, to bring about or* *maintain competitive advantage"*. Companies rely on strategic alliances based on core competencies and information technologies to achieve flexibility and responsiveness. In history, the manufacturing line-style of production for standard products was primarily defined by the manufacturer. Today, customers are demanding more customizable products. In other words, the business decision has now changed from supplier to customer.

This environment drives organizations to be more agile and flexible in terms of performance and capability for meeting customer requirements. In the literature, the related development concept such as mass customization has increased public attention during the last decade These new concepts of industrial value creation share a common objective, that is, to provide ways of enabling companies to increase cost efficiency while simultaneously increasing the ability to react to changing customer needs (Zhang et al., 2014). The four main design structures of supply chain production strategy are presented in Figure 2 below.

a) Build-to-Stock (BTS)

In BTS situation, the products are produced prior to receiving a customer order. Customer orders are filled up with the existing stock, and those stocks are then replenished through production orders.

b) Build-to-Order (BTO)

For BTO, the manufacturing is only started after receiving customer orders, which means to start a pull-type supply chain operation when demand has been confirmed.

c) Engineer-to-Order (ETO)

ETO is one of the basic design structures of the supply chain which a company designs and manufactures the product based on specific customer requirements. Customer engages throughout the entire ETO design and manufacturing phases to ensure its product specifications are met despite issues of complexity.

d) Configure-to-Order (CTO)

CTO is a hybrid of Build-To-Stock (BTS) and Build-To-Order (BTO) operations. CTO model represents the ability to define the component make-up (configuration) of a product at the very moment of ordering that product, and the manufacturer then builds that configuration upon receipt of the order.

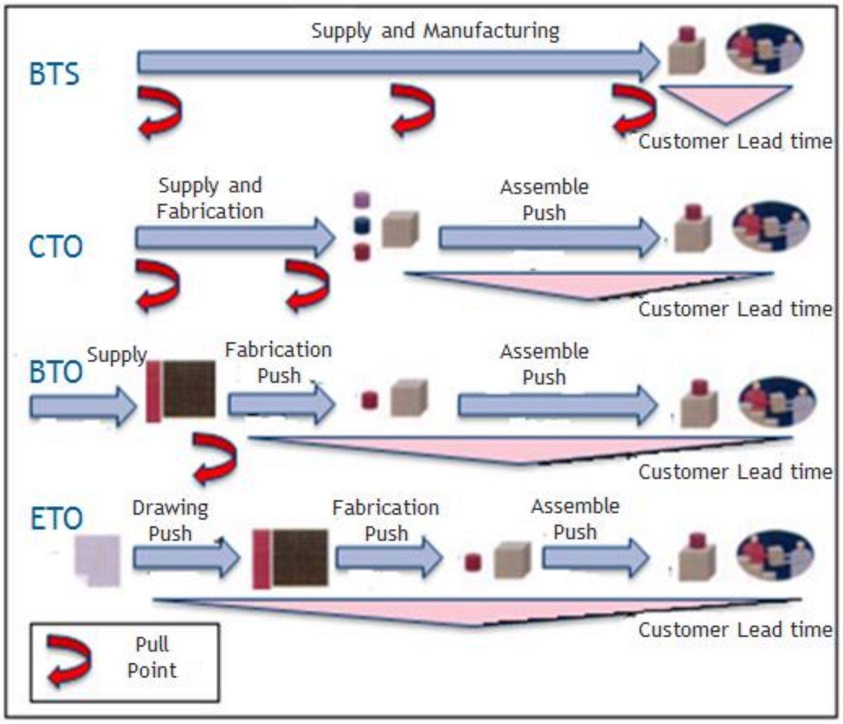


Figure 2: **Four Main Design Structures of Supply Chain**
Source: Adapted from Reeve and Srinivasan (2005)

Table 2: **Summary of Four Main Design Structures of Supply Chain**

Production Strategy	***Definition***
BTS	The standard product builds to a forecast requirement prior to any committed orders coming in
BTO	The standard product is not held in the inventory and it is only build after a committed order comes in
CTO	The standard product has variations, as many as not to justify the creation of a part number for every variation but not as many as to make the underlying structure handle high complexity
ETO	The customer-specified projects and complex structures are never built before and they are impossible to be handled with standard variations

Source: Summarized from Reeve and Srinivasan (2005)

Performance Measurement of Lean Implementation

Performance measurement describes the process of quantifying action, where the measurement process of quantification and action correlates with performance that helps to improve organizational performance. The performance measurement is also defined as the efficiency and effectiveness of action, which leads to the next definitions (Lieder, 2014):

- Performance measurement is defined as the process of quantifying the efficiency and effectiveness of action.
- A performance measure is defined as a metric employed to measure the efficiency and/or effectiveness of an action.
- Performance Measurement System is defined as the set of metrics used to quantify the efficiency and effectiveness of action.

a) Effectiveness and Efficiency

To quantify the *"efficiency"* and *"effectiveness"* of actions, performance measurement these values are defined as follows:

Effectiveness refers to the extent to which customer requirements are met, while efficiency is a measure of the economic use of resources when providing a given level of customer satisfaction. This is an important point because it not only identifies two fundamental dimensions of performance but also highlights the fact that there can be internal, as well as external, reasons for pursuing a specific course of action" (Neely, Gregory, and Platts, 1995).

Effectiveness is usually described as *"doing the right things"*, while efficiency means *"doing things right"*. Both high efficiency and high effectiveness are important and necessary to achieve high productivity. The following shows a generalized attempt to differentiate measures in production, where different types of measures are listed by their unit of measure.

- Ratios are defined as the relation between two elements of the same unit of measure.
- Utilization is defined as the relation between two elements, both having time as a unit of measure.
- A rate is defined as the relation between two elements of different units of measure.

b) Categorization of Performance Measurement

A frequently used classification is to group the performance measures in terms of the five performance objectives. The five areas of performance measures consist of quality, speed (delivery), dependability, flexibility, and cost can be identified. In Figure 3 below, these result-oriented measures can be broken down as follows, with each of these performance objectives contributing to ensuring high quality, dependability, speed, flexibility, and low cost (Slack, Brandon-Jones, and Johnston, 2013).

- *"Quality"* of a product is to maintain customer expectations and requirements, with errors to be prevented at shop-floor level only. In production systems quality ratios are often used by describing the relationship between different parts that fulfill quality requirements.

- *"Speed"* reduces the level of in-process inventory between operations. Products can also be delivered to the customer earlier. As a result, the speed of delivering the right products at the right time turns out to be a crucial competitive factor.
- *"Dependability"* in production systems indicates how stable production processes operate and how well resources are utilized. The dependability is usually calculated as a ratio, i.e., the

relationship of deliveries which have been on time and the total amount of deliveries in a defined time period.

- *"Flexibility"* adapts to changing circumstances quickly and without disrupting the operation. This change ought to be realized with as little effort as possible.
- *"Cost"* can indicate how well a goal has been achieved. For example, profit margin or return on assets can be considered as cost measures. Low-cost operations allow the company to sell their products at a competitive price and increase profitability.

Performance objective	*Some typical measures*
Quality	Number of defects per unit Level of customer complaints Scrap level Warranty claims Mean time between failures Customer satisfaction score
Speed	Customer query time Order lead time Frequency of delivery Actual *versus* theoretical throughput time Cycle time
Dependability	Percentage of orders delivered late Average lateness of orders Proportion of products in stock Mean deviation from promised arrival Schedule adherence
Flexibility	Time needed to develop new products/services Range of products/services Machine changeover time Average batch size Time to increase activity rate Average capacity/maximum capacity Time to change schedules
Cost	Minimum delivery time/average delivery time Variance against budget Utilization of resources Labor productivity Added value Efficiency Cost per operation hour

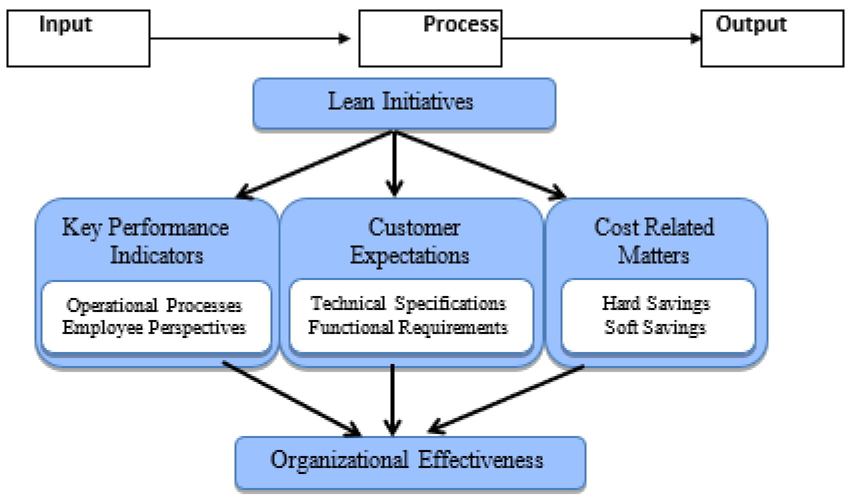
Figure3: **Categorization of Performance Measures**
Source: Adapted from Slack et al. (2013)

Development of Theoretical Framework

Figure 4 below presents the development of a theoretical framework for 'lean' improvement in manufacturing processes. It depicts the contributing factors/elements to CTO production that are essential to the 'lean' methods and its results, which are used as a type of evaluation measure. On the one hand, as revealed in the review of CTO literature, there is a lack of empirical evidences for 'lean' improvement; hence, Figure 4 highlights the 'lean' initiatives that can be considered in CTO production to understand its adoption starting from initiation, execution, until evaluation. On the other hand, 'lean' outcome is equally important to improve the organizational effectiveness by considering the key performance indicators and customer expectations into account.

Customer expectations and values would be considered as an output of this manufacturing process improvement. From the review of the literature, the key performance indicators include operational processes and employee perspectives associated with the project delivery. Also, this is related to the customer expectations in terms of technical specifications and functional requirements, which are directly linked to cost-related matters (hard savings and soft savings). All these elements are included and highlighted as the essential factors of CTO production improvements in this theoretical framework, developed to explore the analysis of, and confirm the essential aspects of 'lean' improvement in the manufacturing production.

Figure 4: **Development of Theoretical Framework**



Source: Original conceptualization of researcher

Research findings and Analysis

a) Implementation of 'Lean' Initiatives into CTO Production

The objective of this research is to explore how mass customization specific to CTO production can adopt 'lean' to improve manufacturing process performance levels for organizational effectiveness, thereby increasing business competitiveness, and focusing on the manufacturing process of CTO work-product delivery at the factory floor level. The case study approach is employed to investigate how the 'lean' approach can improve the CTO manufacturing process. The case study's unique strength is in its ability to deal with a full variety of evidence - documents, surveys, interviews, and observations while investigating contemporary issues within a real-life context (Yin, 2014). As given strengths mentioned above, multiple cases from different sites were deemed to be used and taken from a single case of manufacturing company for this study. It is convinced that this could help to determine the differences and similarities of 'lean' methods in the CTO organization to emerge the theory.

b) Research Methods

Building theory from case studies is embedded in rich empirical evidence that can consist of qualitative and/or quantitative data (Eisenhardt and Graebner, 2007). The qualitative method is deemed as the main methods used for the aims of this study. This method allows to gain in-depth understanding and explanations of the phenomenon being studied. The interview is the most efficient way to gather rich empirical data; thus, it has been chosen as the primary data collection method for the case study.

The interview data is an essential source of information. It provides in-depth evidence gathered from key participants of executive positions in order to understand the phenomenon of 'lean' adoption. By using a semi-structured interview with an open-ended questionnaire format, interviewees can gain the experiences by developing opinions openly and pertaining to each question.

Furthermore, documentation and archives are employed as secondary empirical data in view to support the interview information which can be used as data triangulation to strengthen the reliability of empirical evidence. In essence, the analysis of within-case and cross-case are used for data analysis in multiple sites of the case study company. To determine the insights on the case study company has employed, the 'lean' approach of various cases was thus collected and compared 'lean' for this research study.

A document was written to support the 'lean' adoption as basic description and the database was stored the empirical evidence which is required for cross-case analysis. For the qualitative approach, the methodological triangulation was applied (combining different methods to add the confidence level in the obtained results). Throughout the data collection and data analysis, the validity and reliability are employed and each element can be observed that support by either in the analysis activities or data collection from a number of research phases. Therefore, the appropriate steps are considered to be involved for both internal and external of validity and reliability and assure research quality in terms of the case study.

c) Assessment Framework and Performance Measurement: Application of 'Lean' Principles

In the research findings, the 'lean' principles (LPX, X = Number) were applied in the company's case study as follows: 1) Specify value, 2) Identify the value stream, 3) Pull, 4) Flow, and 5) Perfection. The application of these principles provided an understanding of how 'lean' initiatives have been adopted into the CTO production, highlighting the implementation of 'lean' approaches and identifying the dependencies.

The research findings and analysis obtained from the three-step approach (Initiation, Execution, and Evaluation) of this research study were employed to revise the developed theoretical framework and presented in Figure 5 as an assessment framework. The relationship between the 'lean' initiatives with its outcomes (organization and customer values) are presented the basis to evaluate the results. Both internal and external dimensions supported the improvement of the manufacturing process for organizational effectiveness in the CTO production.

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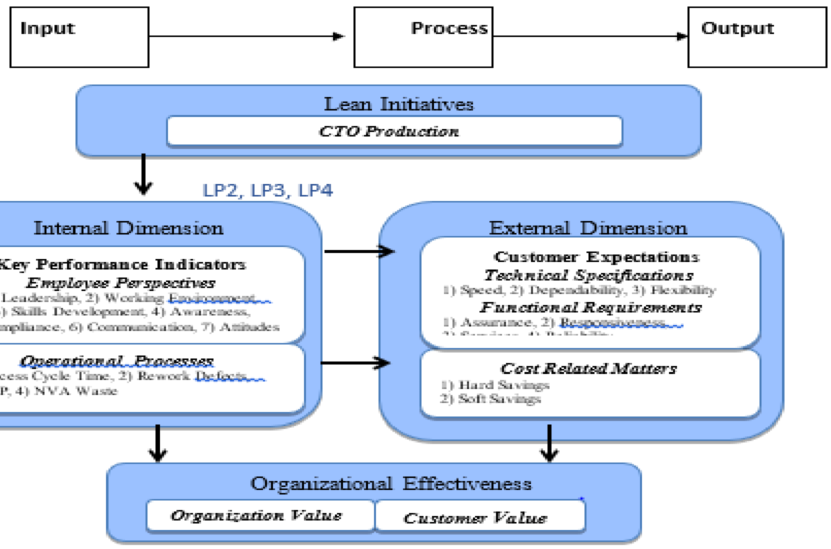
Figure 5: **Lean Principles Assessment Framework**



LP1, LP3, LP4

LP5 LP1

LPX = Lean Principles, X = Number (1 to 5)

Source: Research findings of researcher

Therefore, the 'lean principles assessment' framework is developed on the process-improvement to show the efforts of 'lean' initiatives and its results.

At the organizational level, the detail perspectives of the operational process, employee and customer expectations relevant to the organization and customer values are provided in the 'lean principles assessment' framework. The systematic structure, provided in the 'lean principles assessment' framework, consists of theory elements and their linkages. The elements of the theory conceptualized and evaluated use the empirical evidence and data obtained from the case-study company. The assessment framework considers internal and external dimensions, cost, organizational capacity and customer values; and it is aligned with the findings of the CTO manufacturing process whose performance measurements of technical specifications and functional requirements meet customer expectations. In the assessment framework, the relationships between the theoretical elements show their direct and indirect relationships conceived as both customer expectations and employee perspectives to measure the outcomes of improvement initiatives.

Recommendations

The research study is based on the qualitative research and quantitative secondary data from a single case manufacturing company in the same geographical location within the time-proven Free Trade Zone complex of Penang. It is recommended that, to understand the key elements in the external circumstance and situation such as politics, economics, and environment conditions locally and regionally could impact the operational processes, the significant mutual influence of employee and customer relationships and performances can be further established by collecting more data to generalize and commercialize the assessment framework.

Conclusion

The research study has provided and established the understanding of 'lean' initiatives in the manufacturing processes and its practices. In considering the adoption of 'lean' protocols in manufacturing, a challenge for both researchers and practitioners is to explore further the potentials of 'lean' initiatives pertinent to the methods and tools adopted in the CTO production of mass customization. This is because there is relatively limited empirical research on the subject in manufacturing and manufacturing redesign, particularly on process improvement using 'lean' approach in the CTO production.

This would be a significant contribution to the paucity of literature on the efficient and effective 'lean' applications in productive manufacturing processes. Even though the 'lean' approach outcomes typically stressed on operational process performance, there is an absence of measurement of 'lean' approach outcomes on performance measures.

The developed theoretical framework in this study is therefore conceived and directed to support the manufacturing industry to evaluate the 'lean' initiatives for improving the CTO manufacturing process. It encompasses a viable framework for a generic evaluation at the organizational level.

The 'lean principles assessment' framework shows the relationship between the 'lean' initiatives with its outcomes (organization and customer values) and present a basic foundation to evaluate the results. Both internal and external dimensions support the improvement of the manufacturing process for organizational effectiveness in the CTO production. In essence, the detail perspectives of the operational processes, employee and customer expectations pertinent and relevant to the organization and customer values respectively are incorporated into the framework.

In conclusion, the systematic structure in the 'lean principles assessment' framework consists of theoretical elements and their linkages which are conceptualized and evaluated using the empirical evidences and data obtained from an electronic device manufacturing company where multiple practical cases (as part of the main author's experiential managerial job commitment) studied periodically over time have been recorded and verified systematically. And this is different from databases or case studies results abstracted from the literature. The assessment framework has considered the internal and external dimensions, cost, organization and customer values, thus expanding the understanding of issues prior to initiating the manufacturing process improvement. Finally, the structure of 'lean principles assessment' framework is refined and separated into internal and external dimensions related to the manufacturing organizational effectiveness. This is then aligned with the findings of the CTO manufacturing process where the technical specifications and functional requirements meet the customer expectations. Thus, in the assessment framework, the relationships between the theoretical elements do show their direct and indirect relationships.

Corresponding Author
Oo Yu Hock
Professor, Asia e University (AeU), Malaysia

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