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# Configure-to-Order (CTO) Production through Lean Initiatives: Manufacturing Delivery in COVID-19 Pandemic Milieu

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***Abstract: Manufacturing is a critical demand-supply chain of production to meet consumption needs in fulfilment of contractual obligation under planned delivery schedule or on-demand as needed. This is particularly the case with certain manufacturing concerns that continue to advocate a normative practice of market-response or business-purchase reactions as and when it arises. The maintenance of capital-intensive production and high-cost related products are examples of a typical and common business process in operations management that is reactive rather than proactive. However, as a Business Process Improvement (BPI) strategy that works beyond the practice of normative manufacturing is this proposed model of configure-to-order (CTO) production through lean initiatives. It is a proactive change-driven flexible-adaptive manufacturing enabler that produces ever-shorter delivery times, with economies of scale, operational efficiency, systemic-aligned management and overall productive organizational effectiveness. A case in point is the agility of medical equipment and related products manufacturing business during an unexpected surge of not only critical demand but urgent-fast delivery for its products to combat the death-threatening crisis of Covid-19 pandemic onslaught. In essence, the adoption of 'lean' initiatives that incorporates a combined approach of 'lean' and 'agile' elements - capsulated in the acronym of 'leagility' – is a hybrid strategy that facilitates CTO production to deliver the output on time, the result-expected secured and outcome-anticipated fulfilled.***

***Key words: critical demand-supply chain, market-response or business-purchase reactions, BPI, CTO, business proactive change-driven flexible-adaptive manufacturing enabler, lean, agile, leagility, operations management (OM)***

## 1. OVERVIEW

The Covid-19 pandemic milieu today continues to bear the widespread economic brunt of declining domestic, regional and international wealth-creating industries and value-adding businesses, reinforcing a negative resignation to '*que sera sera'* (*whatever will be will*) outlook. The vulnerability of coronavirus life-threatening infections still hovers over the better discretion of decisive decisions to restart interrupted business operations during designed pandemic lockdown or partial movement control restrictions. Compounding such government-policy and pandemic-compliance decisions are two fire-fuelling catalyst - the drastic oil-price decline and the ominous uncertainty in the stock market, both of which mirror the spiralling fluctuations of values in many industries with prolonged stressful impact. For example, in the semiconductors and enabling technologies manufacturing industry, "a

3%-6% decline in annual revenues for semiconductor companies this year (2020) is the most likely scenario," according to Mario Morales of International Data Corporation (IDC) – the San Mateo, California-based company – "with a 54% probability, while the second likeliest scenario, at 24% probability, would have annual revenue decline 12% or more." However, a hopeful expectation is that "technologies like 5G, IoT and high performance computing could help redress the vulnerability to the supply chain disruptions and (help) the industry recover in the long run," given "the global ventilator market is expected to grow from US$2.4 billion in 2019 to about US$12.1 billion in 2020 … (based on a ) massive surge in demand due to COVID-19 treatment of millions of patients, … (and) expected to stabilize and reach US$4.2 billion at a compounded annual growth rate of 14.7% through 2023. [Research and Markets Report (STARBIZ 2020).

## 2. INDUSTRY BACKGROUND

Manufacturing, usually a large-scale production process with internal and external economies of scale in converting raw materials, parts and components into finished goods or merchandise using tools, equipment or machinery and human labour including technology inputs such as robots and computers, is more than an economic-wealth generating activity. It is also a quintessential business that enables its core tangible and intangible assets of advanced technologies-based assembly-line work station-to-work station processes to further add and create values, that is, the tangible assets include machinery, production facilities, distribution and storage outlets, associates or affiliates and subsidiaries of a parent company, and the intangible assets include trademarks, patents, or intellectual property (Hossain et al., 2020). In short, manufacturing today is the nexus of a complex supply-demand chain of lucrative revenue-streams and profit-avenues through its efficient prime-conversion costs production and delivery of finished goods sold directly to consumers, to other manufacturers for the production of more complex products, or to wholesalers who distribute the goods to retailers (Amgad et al., 2019).

The three main types of manufacturing production are Build-To-Stock (BTS), Build-To-Order (BTO), and Build-To-Assemble (BTA). The first type is a traditional manufacturing strategy that relies on past sales data to forecast consumer demand and plan the production activity in advance. The second type allows customers to order products that are customized and manufactured to their specifications, with the manufacturing process starting only after the order is received. And the third type, a hybrid of BTS and BTO approaches, is a strategy that relies on demand forecasts to stock the basic components of a product, but begins assembling them after the order is received. All three types of manufacturing businesses have certain risks involved. Producing too many goods leads to financial losses as money is tied up in unwanted stock; producing too little means not meeting the demand, which can cause the customer to turn to competition and induce a drop in sales for the manufacturer. Thus, to reduce the risks, any type of manufacturing business should focus on keeping production costs low, maintaining good quality control and investing in excellent sales management. Even then, the fortune of manufacturing business is very much dependent on the interplay of market forces. And markets can change very quickly, not only in the global economy but under abnormal circumstances or situations such as the coronavirus or Covid-19 pandemic worldwide. This is why irrespective of any situational circumstances that affect the market volatility the goals of lean and agile manufacturing combined has kept a company ahead of the competition.

## 3. CONCEPTUAL DIFFERENTIATION AND INTEGRATION

The three basic conceptual foundation, and to comprehend the application, of Configure-To-Order (CTO) production advocacy and practice are lean, agile and leagile. ***Lean***, as defined by Womack and Jones (1996), is "a way to do more and more with less and less - less human effort, less equipment, less time, and less space - while coming closer and closer to providing customers exactly what they want" based on five key principles that "precisely specify value by specific product, identify the value stream for each product, make value flow without interruptions, let customer pull value from the producer, and pursue perfection". Simply stated by Rizzardo and Brooks (2008), "Lean production is about doing things that add value from customer's perspective". But Davis and Heineke (2005), assuming that "nothing will be produced until it is needed," have asserted that lean production is "a whole new way of thinking and includes the integration of vision, culture, and strategy to serve the customer with high quality, low cost and short delivery time".

***Agile***, according to Goldman, Nagel and Preiss (1995), is "the capability to **survive and prosper** in conditions of **unpredictable change** by **reacting quickly and effectively** to changing markets," enabling on-demand differing variations in performance and product delivery as needed to meet changing customer demand. Although Fountain (2017) stresses that "Agile Manufacturing is a combination of speed and flexibility," yet he cautions that this is "difficult to achieve because it requires radical changes to traditional thinking". Related to lean manufacturing, agile manufacturing, according to Leunendonk (2016), is about what and how a company has created the processes, tools, and training to enable it to respond quickly to customer needs and market changes while still controlling overall costs and high standards of quality in the production of a particular product. The goal is to retain its competitive advantage, even grow its competitive edge, to continue innovating and introducing new products to remain financially stable with a sustaining customer support base.

***Leagile***, a conceptual combination of lean and agile, enables a company and its network to shape an appropriate profile to confront the volatility of markets due to changing customer demands or environmental disruptions and also to exploit markets in terms of cost, quality, response-time and service level where the customer seeks quicker service to meet its need. In this way, according to Boschi, Borin and Batocchio (2010), the company not only gains competitive advantage but increases its competitive edge, particularly through the leagile production which establishes a total supply chain strategy by positioning the decoupling point best suited to the need for responding to a volatile demand downstream and providing level scheduling upstream from the marketplace.

Thus, while lean is about reducing costs through continuous improvement, measurement of performance and eradication of waste in the chain, agile is more focused on the response time to react to customer needs quickly through flexible production design. One can be neither, one or both. The paradigm involving lean and agile creates a virtually brand new management framework - in manufacturing theory, it is often referred to as leagile. According to Martin Christopher, "when companies have to decide what to be, they have to look at the customer order cycle (COC) - the time the customers are willing to wait, and the lead-time for getting supplies. If the supplier has a short lead time, lean production is possible. If the COC is short, agile production is beneficial". Both, however, impact the way companies produce products and operate, relying on data-backed observations, a customercentric supply chain, IT systems and open communication at all levels – the contention of the Configure-to-Order (CTO) paradigm in this paper, under normal and new normal circumstances of pre-COVID and post- coronavirus pandemic influences respectively.

## 4. CTO PRODUCTION AND STRATEGY

Luh and Lin (2005) had asserted that the fundamental characteristics of a CTO model are to reduce the time to market by offering product choices with highest customer value. This concept is from the mass customization phenomenon which suggests that the product features or components are mostly pre-designed from choice-select specifications of the customers (Papadakis, 2003; Shamsuzzoha, Kankaanpaa, Helo, and Iqbal, 2011). Shamsuzzoha *et al.* (2011) had earlier stated that the CTO is a true mass customization which can be defined as the product individualization process in which the customer can participate from the start of the desired product-design process to the subsequent developmental processes of the product itself., with a CTO strategy that can manage differentiation or increase the level of the product. This approach enables all the functional requirements of diverse customer requirements to be fulfilled according to various design parameters of the customized products (Chen, Lu, Yu, Tzent, and Chang, 2003; Reeve and Srinivasan, 2005).

*a) Characteristics of CTO*

CTO has been identified as an efficient way to deal with the trends of mass customization (Tyan, Wang, and Du, 2003). It is a process whereby products or services would not be built or configured until the customer has placed the order (Papadakis, 2003). According to Tyan *et al*. (2003), "this process allows the retailers and manufacturers to shorten the planning cycles, compress the manufacturing lead times, and expedite the distribution," thus enabling CTO manufacturing to become market-strategy drivers that lead to mass customization from the very beginning (Luh and Lin, 2005). The reinforcing dynamics lead to fuel the continuation of mass customization whose criteria are as follows:

- Different customers have different requirements resulting in demand fragmentation
- Heterogeneous markets form to supply the changing needs of the customer base
- Market competition lowers cost and raises quality in custom products
- Greater flexibility in manufacturing is achieved as process technology advances, with improved ability to customize new products.
- Product life-cycles shorten as product technology changes at a faster pace, abetted by mass customization
- Product development facilitates faster process of mass customization production
- Customization conditions customers to expect a greater diversity of products

*b) Requirements for CTO*

As highlighted, the advantages of CTO are shorter planning cycles (dependability), compressed lead times, and expedited distribution (Dallasega, Rally, Rauch, and Matt, 2016) which support the important underlying capabilities of successful CTO implementation to achieve its *"*no work is processed by the end of the day, zero finished product inventory and building products to order only*"* (Wagner, Guralnik, and Phelps, 2003). However, these manifestations of a working CTO system, according to Dallasega *et al*. (2016), is a dynamic approach to ensure that all the appropriate parts to reduce or eliminate Work In Progress (WIP) and inventory are duly observed efficiently.

CTO implies some level of completed sub-assembly components and stocks such as BTS, ready to differentiate based on the demand, with parts ready for configuration rather than made to specification. Given that the BTS and BTO systems rely on a push-pull interface at the point of product differentiation, that is, the boundary between a buffered supply and the location where the pull materials flow begins, CTO suggests that having a high demand uncertainty and low economies of scale are most appropriate for a pull-type strategy (Simchi-Levi, Kaminsky, and Simchi, 2008; Khan, Christopher, and Creazza, 2012).

In the CTO case, the work would not process an order unit; and this leads to those processes to become more at the mercy of the market and therefore higher demand of uncertainty (Khan et al., 2012). In the economies case of scale, one of the CTO enablers is flexible manufacturing which drives down the products setup-costs, thereby reducing the effect economies of scale. As the push-pull interface moves closer to the customer, the more responsive the system would be to the customer needs for such as lead time. To balance this, the further downstream the interface is, the more the company would likely have to pay for inventory-holding costs (Simchi-Levi et al., 2008). Thus, a company must make specific choices to the product it makes in order to accommodate the requirement for fast product development cycles and multiple product offerings. Firstly, by reducing the complexity of product design and manufacturing, the company can use those saved resources for deploying other products. Secondly, the use of modular product design allows the company to leverage resources across products and pool risk associated with demand variation. Through simplifying and leveraging common designs, it can enhance the effectiveness of CTO by driving the cost down with variation.

The CTO production system in the supply chain is strongly dependant on the integration of the upstream supplier or incoming material parts, the midstream manufacturer, the assembler components, and the downstream distributor to the finished product. This integration necessitates a timely and efficient channel of communication (Chen et al., 2003). Overall, there are associated behaviours in each part of an organization that makes CTO successful in the company. Traditional models of supply chain and CTO supply chain are different in terms of flexibility and responsiveness to changing and meeting market requirements. In Table 1, the comparison of traditional supply chain and CTO supply chain demonstrates many of these concepts in the different characteristics of the organization (Gunasekaran and Ngai, 2004). It is clear for a company to change to CTO operations; where there is a tremendous shift must occur in almost every aspect and angle of its operations.

Table 1: Differences between Traditional and CTO Supply Chain

| ***References*** | ***Traditional Supply Chain*** | ***CTO Supply Chain*** |
|---|---|---|
| **Marketing** | Push - sell from stock | Pull - configure to customer order |
| **Production** | Focus on the level and stable schedules; fixed order line up | Customer demand focused on supply chain flexibility and agile |
| **Logistics** | Mass approach: non differentiated | Fast, reliable, customized |
| **Customer Relationship** | Dealer-owned | Shared across the extended enterprise |
| **Managing uncertainty** | Finished goods inventory buffers | Strategic part buffers and information management |
| **Finished goods Inventory** | High stock control | Fewer stock control, instant delivery |

| | | |
|---|---|---|
| **Suppliers** | Long lead times | Collaborative/responsive |

Source: Adapted from Gunasekaran and Ngai (2004)

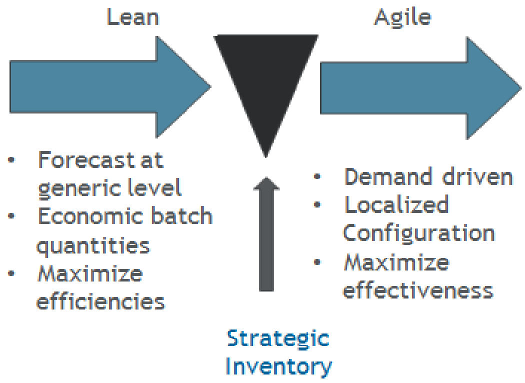
## 5. CONCEPT OF FLEXIBILITY

In the review of the literature, Christopher (2000) commented that the manufacturing companies must become more responsive in order to meet the demands of customers for ever-shorter delivery times and to be highly flexible. Flexibility is the key characteristic of CTO production. The companies could also enable rapid changeovers (reduced set-up times) and thus permit a greater responsiveness to changes in product mix or volume through manufacturing flexibility (Zhang and Huo, 2013). In other words, this has led to the emergence of the 'agile' paradigm. In the manufacturing systems, flexibility is the origin of agility in a business concept that links partially (Christopher and Towill, 2001; Zhang and Huo, 2013). Christopher and Towill (2001) stated that the internal processes and external relationships are not captured and manage by the 'lean' concept all the time. When the predictable and high volume demand is presented in the business, the 'lean' manufacturing performs the best (Diaz, 2019). Cox and Chicksand (2005) commented that the supplier capabilities would be more challenges when the customer requirements are unpredictable, and it is difficult to control when the demand is volatile and volume is low. Also, the 'lean' methods such as Just-In-Time (JIT) and Kanban are difficult to sustain unless the production leveling is performed (Cooney, 2002; Diaz, 2019). When handling with the product variety and volatilities in volume, the 'lean' concept shows less robust in the manufacturing (More and Babu, 2009).

To standardize, simplify, and optimize the manufacturing process, it is required to reduce the demand variation. The 'agile' is capable to cope with the volatilities in the market with flexibility and adaptability (More and Babu, 2009). Regardless a pure 'lean' or 'agile' approach across the whole supply chain, both 'lean' and 'agile' approaches can be combined as a hybrid strategy and turn into an improvement by strategic use of a decoupling point (Cozzolino, Rossi, and Conforti, 2012; Aktan and Akyuz, 2017). Cozzolino et al. (2012) stated using the hybrid combination of both 'lean' and 'agile' approaches as the term of 'leagility' (as shown in Figure 2.11). Naylor, Naim, and Berry (1999), Christopher and Towill (2001), and Cozzolino et al. (2012) empathized this combination of a hybrid strategy.

Naylor et al. (1999) stated that regardless 'lean' or 'agile' approach, all depend upon the requirements of the customer. Various common factors between 'lean' and 'agile' are combined together to provide benefits and cost for the clients (Christopher and Towill, 2001; Aktan and Akyuz, 2017). Afterward, the authors conceived three approaches to establish the *"combine"* between 'lean' and 'agile'. The Figure 1 is referring to both approaches of integration base on the decoupling point creation and integrated with a form of postponement (Christopher and Towill, 2001). The postponement means that the companies start to assembly or even design when only the customer order has been received. Harrison and Van Hoek (2005) quoted that it is possible for manufacturing companies to increase their ability to configure the products to specific customer requirements increase responsiveness without sacrificing efficiency, therefore a combination of both 'lean' and 'agile' are then achieved.

Figure 1: Combination of Lean and Agile




Source: Adapted from Christopher and Towill (2001)

From the decoupling point, the product variety can be reduced when the supply chain demand in upstream has become more stable when postponement is utilized (Christopher, 2000; Christopher and Towill, 2001; Aktan and Akyuz, 2017). The idea is to apply the 'lean' concept to the upstream parts of the supply chain to produce generic and semi-finished products in a typical BTS setting, whereas the 'agile' concept can be applied to the final customizations at the downstream in a BTO setting, represented by a higher degree of product variety and a more volatile demand. By using the concept of 'leagility', the manufacturing companies can utilize 'lean' methods up to the decoupling point and 'agile' methods beyond it (Christopher and Towill, 2001; Aktan and Akyuz, 2017). Christopher (2000) declared that the advantages of postponement are various as follows:

- Inventory can be held at a generic level and there would be fewer stock-keeping variants and this results in less total inventory.
- Since the inventory is generic, it has better flexibility. In order words, the same components, modules or platforms can be used in a variety of finished products.
- Forecasting is easier at the generic level rather than at the finished products level.

## 6. RESEARCH FINDINGS AND ANALYSIS

*a) Manufacturing Process Improvement*

The case study was selected a US-based of electronic devices manufacturing company with multiple sites due to they were relatively mature for the adoption of 'lean' initiatives and obtained the access permission to CTO manufacturing process. The sites focus on manufacturing process and customer expectations to initiate the 'lean' improvement in the company. The manufacturing works were based on task-oriented projects. Sometimes the workers encountered difficulty when there are issues occurred, i.e., machine downtime, product build schedule changes, process quality problem, etc. The workers were limited by manufacturing process skills and knowledge, causing under-utilized, as well as lack of quality awareness. The issues had been brought up and concern raised by top management that the workers need to improve their skills in terms of quality mindsets, and manufacturing process capability to meet customer expectations. Some observations have been highlighted that the business improvement methodologies had been applied to improve the manufacturing process in CTO production. The completed projects included improvements and changes of inventory turnaround, process capabilities, and manufacturing cycle time, as well as an introduction of reduction costs, the increment of business throughput and improvement in productivity which focus on improving CTO production, customer expectations and satisfaction. Simply, applying Gemba walk and data collection, identifying the skills and implementing changes to a new target, the three primary objectives were addressed to achieve the flexible manufacturing as follows:

- Delay time (the time delayed on some manufacturing activities)
- Process cycle time (period required for manufacturing process multiple activities to complete the product build)
- Resources utilization (number of manufacturing process skill by a worker)

In Table 2, various manufacturing projects were carried out through root cause analysis, Kaizen and process capability study to identify the area of improvements, improve process cycle time, and minimize the delay time by enhancing the people skills in CTO production.

Table 2: Manufacturing Process Improvement

| ***Measurement*** | ***At Start*** | ***Target % Changes*** | ***At End*** | ***Actual % Changes*** |
|---|---|---|---|---|
| Process Cycle Time | 120mins | 50% | 70mins | 52% |
| Delay Time | 40mins | 50% | 15mins | 72% |
| Resources Utilization | 1skill | 100% | 2skills | 100% |

Furthermore, it has been observed that both business changes (i.e., work practices, accountability) and technical changes (i.e., delivery speed, process architecture, and manufacturing infrastructure) are duly important in improving organizational effectiveness. It has been notified that the current organizational structure is not conducive to work in a robust and flexible way.

As such, it is clear that the changes are required to meet the business and technical perceptions. Through the value stream mapping, the improvement project was implemented to redesign the manufacturing process flow and line re-layout in order to achieve a quicker and shorter process flow by eliminating the non-value adding works; whilst maintaining the overall operations performance and quality. The new process flow had shown that there are collaboration opportunities after eliminating the wastes such as overproduction of Work In Progress (WIP), excessive handovers, and transportation time reduction.

The process trial run and fine-tuned for three months and it has been executed by integrating the processes and delivered the followings:

- 12.5% of space savings
- 33.3% of production lead time improvement
- 62.5% of WIP reduction
- 43.75% of resources reduction

*b) Material Inventory Control*

The material inventory control has raised the concern due to many parts occupying the shop floor space. Also, the dependability of production loading was required to prevent material shortage or delinquent. Therefore, the material parts raised the concern by the quality team on how to ensure the correct parts are used during the manufacturing process. The following key problems were highlighted from the JIT material control due to lack of control, not agile to manage, and rely on the production loading to pull the material. Thus, the inventory management knowledge on JIT material control has to pick up by improving the

JIT inventory control and determining material issuance, production process and flow in supporting flexible manufacturing.

The outcome has provided the material control after the JIT concept of ‘lean’ implementation. The documentation has highlighted the improvements significantly in controlling system flow and inventory handling process. The improvement reports also presented that the knowledge training was provided, which led the material staffs to continue contributing to the inventory control commitment. Employees who worked on this initiative were formed as a team, where allocate the work easier. Furthermore, the material inventory turnaround has improved by leveraging the process capability to determine the components issuance process flow and consumption, as well as production loading and meeting customer expectations.

## 7. RECOMMENDATIONS AND CONCLUSIONS

The implementation of ‘lean’ initiatives is recommended to require continuing to address and improve the validity if there is a new empirical data available. For instance, the existing data obtained from the statistical results and used as a supporting evidence but it could be the changes when there is a new process implementation. The ‘lean’ improvement is limited at the manufacturing project level in the operation and thus, it has limitation on the finance report which should including into the performance measures in terms of cost savings, profit and loss.

As a result, the adoption of ‘lean’ initiatives has been proven as a BPI methodology in the ‘lean’ has led to ‘excellence’ in the CTO manufacturing process performance compared to those processes do not implement such practices. In other words, ‘lean’ has become a common nomenclature of OM over the last decades. It has been practiced widely in many industries including the manufacturing, industrial, and service sectors in order to satisfy customers better by combining both ‘lean’ and agility as a hybrid strategy.

## 8. CONCLUSION

Currently, under the restrictive constraints of life-threatening coronavirus pandemic, and the abnormal (unusual) high demand for critical medical equipment and related paraphernalia, the manufacturing linkage is also disrupted by the internalities and externalities of the overall market turbulence and logistics uncertainty of product or merchandise movements, by land, sea and air. And leagile manufacturing under disruptive circumstances and new normal standard operating procedures such as the COVID-19 pandemic era is a case in point, particularly when medical equipment and related-healthcare materials manufacturers have to respond to abnormally high demand in record delivery time at different destinations.

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