A novel framework for a pull oriented product development and planning based on Quality Function Deployment

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Abstract— *Nowadays, manufacturing organizations face with increasing pressures from the frequent changes in product type, continuous demand fluctuations and unexpected changes in customer requirements. In order to survive in this turbulent environment, manufacturing organizations must become flexible and responsive to these dynamic changes in the business environment. In this research, this papers has reviewed the current literature in the area of pull-oriented product systems and has suggested a novel framework for a pull-oriented product development system compatible with today's manufacturing environments. In the proposed framework, using the Quality Function Deployment (QFD) 4-stage matrix, a framework for product development has been proposed. The paper has used four general processes for products assembly. The framework provides capabilities for customer order analyze by a decision support system for order acceptance/rejection decision. Moreover, the accepted orders are prioritized into high and low priority orders, considering profitability of orders and a proposed assemble-to-order (ATO) production system for pull-oriented environments will handle the orders' fulfilment. The validity of proposed framework has been investigated by process analysis and simulating a scenario.*

Keywords— Product development system, Pull-oriented system, Quality Function Deployment (QFD), Assemble-to-order production (ATO).

I. INTRODUCTION

In a highly competitive environment, manufacturing organizations need a suitable production policy for the control of the production line so that the resources including machines as well as the buffer can be better utilized in conducting the manufacturing activities [1]. Manufacturing companies use different production policies to satisfy customers' demands. The most applicable production policies are Make-To-Stock (MTS), Make-To-Order (MTO), Assemble-To-Order (ATO) and Engineer-To-Order (ETO). Each policy has some specific advantages and disadvantages. Among them, MTS and MTO systems have been widely used in the production companies. In MTS companies, the customers' demands are satisfied with stocked inventories of finished products. The dominant features of such systems are short delivery time, heavy storage cost and low flexibility in responding to customized needs of customers. A substantial proportion of the research prior to 1990 in the production planning area had been aimed at the needs of MTS companies [2, 3]. On the other hand, MTO companies produce their products based on the customers' orders. Long delivery time, low storage cost and higher flexibility in responding to customers' demands are the main features of MTO systems [3, 4].

The success of an MTO system is heavily dependent on the selectivity of an order acceptance policy that seeks to maximize the average revenue per unit cost of requested capacity when demand exceeds capacity. It is noteworthy that the rejection of an order may have strategic repercussions for future customer relations, and may drastically change order arrival rates and patterns. The decision an MTO system has to make for an incoming order is whether to accept, negotiate or reject it depending on the available capacity, the profit contribution margin of the order and expected arrival times for future orders. A negotiation process of an order is only worth pursuing if accepting it may contribute significantly to generate more revenues per installed capacity and market niche development. Resorting to an order acceptance policy is thus a key decision-making problem at the interface between marketing/sales functions and production planning [5].

Unlike the make-to-stock manufacturing mode which holds finished products in stock as a buffer against demand variability, MTO production systems must hold production capacity and workin- process inventories to accept only orders of the most profitable type. The main issue is thus how to selectively accept/reject/negotiate in order to maximize cumulative profit gains. In the absence of a more elaborated policy, orders are accepted on a 'first-come-first-serve' basis. If the available capacity is not enough to process an arriving order on time, the order is rejected [6].

The build-to-order supply chain (BTO-SC) or make-to-order (MTO) system has received a great deal of attention in recent years because of the success of high-tech companies such as Dell, BMW, Compaq, and Gateway. In recent years, BTO-SCM has become prevalent among high-tech companies, including traditional manufacturing companies such as automobile companies. BTO-SC can be defined as ''the system that produces goods and services based on individual customer requirements in a timely and cost competitive manner by leveraging global outsourcing, the application of information technology and through the standardization of components and delayed product differentiation strategies" [7].

Recent years have proven a number of changes in companies' production policies and they are gradually moving more to hybrid MTS/MTO production mode. In a MTS/MTO production mode, a portion of the production system operates in a MTS mode and the remaining portion operates in a MTO mode. A proper combination of MTO and MTS can exploit the advantages of both lower inventory and short delivery time [3].

Assemble-to-order (ATO) production is a popular strategy used by firms that seek to be responsive and cost-efficient at the same time. ATO is particularly attractive when component supply lead-times are long or the supply processes are capacitated compared to final assembly. Furthermore, by pooling components stocks, an ATO strategy can reduce the cost of offering high product variety. Hence, by using this strategy a firm can shorten its response time to its customers and offer a high variety of the end product. An example of such practice is used by computer manufacturers and mail order retailers [8].

The assemble-to-order (ATO) strategy emerges in manufacturing environments where many finished products are assembled from a relatively small set of standard components and subassemblies. In a typical ATO manufacturing environment, components and subassemblies are acquired according to a forecast, while finished products are assembled only after actual customers' orders have been received. In other words, component and subassemblies are replenished in a make-to-stock (MTS) fashion, but finished products are assembled in a make-to-order (MTO) manner. Such a hybrid planning approach is particularly advantageous in situations where the assembly time of a product is considerably shorter than the procurement and/or manufacturing time of its components and subassemblies; thus, making a tradeoff between inventory holding cost, product variety, and delivery time achievable [9].

Successful and innovative product (or service) development is highly correlated with the company's success and reason for existence. It is imperative that a company's main purpose for existing is to provide goods and/or services to meet and even exceed the expectations of their customers [10]. To survive, companies need to transform themselves from production-focused to value-adding design-focused businesses [11]. Requirement understanding plays an important role in product design. Conventionally, customer needs come from questionnaires which are mainly collected by customer investigations [12]. Nowadays, QFD has been applied in a wide variety of quality control, decision-making, product design and improvement, etc. It is a customer-driven approach that can create a high level of buy-in and reach a better control of the problem [13].

Mass customization is a manufacturing approach to produce customized products based on customer requirements while maintaining the high quality and efficiency of mass production. Compared with the traditional mass production approach, mass customization can offer large variations of products to the market while leveraging the economies of scale and scope within the manufacturing capabilities of enterprises. One-of-a-kind production (OKP) is a special type of mass customization where each product is created based on requirement of an individual customer [14].

The purpose of this paper is to propose a framework for a pull-oriented product development system. In the first process, the paper has used quality house for translating customer demands into technical specifications. Customer order aanalyzed by decision support system for order acceptance/rejection decision. In sales and support product process orders are prioritized into high and low priority orders, considering profit of order. In other two processes the Production planning and manufacturing operations have been considered.

II. LITERATURE REVIEW

The literature review on pull-oriented product development issue indicates that lot attention has been paid to this issue in the production environments. Moreover, the existing research regarding this issue has been mostly focused on MTO production environments. Hendry and Kingsman [2] first emphasized on the importance of order entry stage in production environments, especially in MTO environments where the delivery date management becomes more crucial.

M.Kalantari et al [3], M. Ebadian et al [15], K.L.Choy et al [16] and S. Hemmati et al [17] presented a decision-making structure for the order entry stage in make-to-order environments. The aim of the proposed structures is to manage the arriving orders so that the MTO system just proceeds to produce those arriving orders which are feasible and profitable for the system. S. Hemmati et al [17] proposed structure composed of three phases. At the first phase, arriving orders are prioritized into high and low priority orders, considering characteristics of order and customer and utilizing technique for order performance by similarity to ideal solution (TOPSIS). At the second phase, rough-cut capacity was calculated for each order regarding priority level and so, acceptance or rejection decision is taken based on it. Finally, at the third phase, the previous phase accepted orders are evaluated based on their due dates and material arrival times and final decisions for orders are made. M. Ebadian et al [15] proposed decision support system is comprised of five steps. At the first step, the customers are prioritized based on a fuzzy TOPSIS method. Rough-cut capacity and rough-cut inventory are calculated in the second step and in case of unavailability in capacity and materials, some undesirable orders are rejected. Also, proper decisions are made about non-rejected orders. At the next step, prices and delivery dates of the non-rejected orders are determined by running a mixed-integer mathematical programming model. At the fourth step, a set of guidelines are proposed to help the organization negotiate over price and due date with the customers. In the next step, if the customer accepts the offered price and delivery date, the order is accepted and later considered in the production schedule of the shop floor, otherwise the order is rejected.

van der Laan et al [18] extend the PUSH and PULL control strategies to evaluate numerically the effects of lead-time duration and lead-time variability on total expected costs in production/inventory systems with remanufacturing. Although both strategies are non-optimal, they are relatively easy to analyze numerically and, more importantly, they are actually used in practice. The most important outcomes of the study are, that for both control strategies: (i) manufacturing lead-times have a larger influence on system costs than remanufacturing lead-times; (ii) a larger remanufacturing lead-time may sometimes result in a cost decrease; and (iii) a larger variability in the manufacturing lead-time may sometimes result in a cost decrease.

Sharma and Agrawal [1] presented a multistage serial production system. A generalized model has been developed with the use of probabilistic demand situations for the end product. The demand situations considered are binomial, exponential, lognormal and Poisson. These demand patterns are used as input parameter for various production control policies. The output values for performance parameters are obtained by simulation.

The literature available on BTO-SCM has been classified based on the nature of the decision-making areas and then sub-classified to focus on solving problems with modeling and analysis. Gunasekaran and Ngai [7] have focused mostly on the modeling aspect of the BTO-SC, but have not extended our efforts to empirical research. They have developed a unified framework for modeling and analyzing BTO-SCM and suggest some future research directions.

The objective of Ozbayrak et al [19] paper is to estimate the manufacturing and product costs by using activity-based costing (ABC) method in an advanced manufacturing system that is run under either material requirements planning (MRP) or just in time (JIT) system. ABC is a method that can overcome many of the limitations of traditional costing systems. This paper reports and discusses the implementation of the ABC alongside a mathematical and simulation model to estimate the manufacturing and product cost in an automated manufacturing system. The potential effects of manufacturing planning and control strategies implemented on financial structure of the manufacturing system are initially analyzed. ABC has been used to model the manufacturing and product costs.

Ioannou and Dimitriou [20] consider the problem of dynamically updating the manufacturing lead times estimates that are used in MRP systems. Once a new order with specific and known processing requirements enters a make-to-order manufacturing system, an exact completion time estimate is assigned to it that is based on the system's current status. The approach that is suggested addresses multi-machine, multi-product manufacturing environments with no special configuration of their resources: To this objective, simple, iterative algorithms are used to substitute the fixed lead time estimates of typical MRP systems. The results that are presented underline the significant improvement of the proposed approach over static, constant MRP lead time estimates that are as yet exclusively resorted to.

Olhager and Prajogo [21] analyze these improvement initiatives and their impact on business performance. In particular, they explore potential differences between make-to-order (MTO) and make-to-stock (MTS) firms. They use data from 216 Australian manufacturing firms. They find a clear difference of improvement focus between MTO and MTS firms. MTO firms exhibit a significant impact of supplier integration on business performance, but not for lean practices and supplier rationalization. The situation is completely reversed for MTS firms, since they have significant effects for internal lean practices and supplier rationalization, but not for logistics integration with supplier.

ElHafsi [22] study a pure assemble-to-order system subject to multiple demand classes where customer orders arrive according to a compound Poisson process. The finished product is assembled from m different components that are produced on m distinct production facilities in a make-to-stock fashion. He shows that the optimal production policy of each component is a state-dependent base-stock policy and the optimal inventory allocation policy is a multi-level state-dependent rationing policy. Using numerical experimentation, he first studies the system behavior as a function of order size variability and order size. He shows that the optimal average cost rate is more sensitive to order size variability than to order size. He also compares the optimal policy to the first-come first-serve policy and show that there is great benefit to inventory rationing. He also propose two simple heuristics and show that these can effectively mimic the optimal policy which is generally much more difficult to determine and, especially, to implement.

III. FRAMEWORK DESCRIPTION

Through the aforementioned section, the paper has achieved the requirements for framework by literature review in pull-oriented product development. So, the paper has focused on fulfilling those requirements in the proposed framework. Because of, have developed a framework in level-0 that includes four general processes (fig. 1). In review pre-order and customer process, the paper has used quality house for translating customer demands into technical specifications, and provides capabilities for customer order analyze by a decision support system for order acceptance/rejection decision. The second process (product sales and support) orders are prioritized into high and low priority orders, considering profit of order. Our third process in level-0 IDEF0 model included two QFD matrixes, this matrix are product design and process design. Furthermore, this process includes production planning, overall planning, master production scheduling (MPS) and inventory control (fig. 2). Fig. 2 is a level-1 IDEF0 model process of production planning (operation & overall plan). First stage of these processes is production planning (A21) that contains QFD second matrix. In this process, product concepts are created during this phase and part specifications are documented with product design matrix by product designers. The second process in fig. 2 is master production scheduling (MPS).

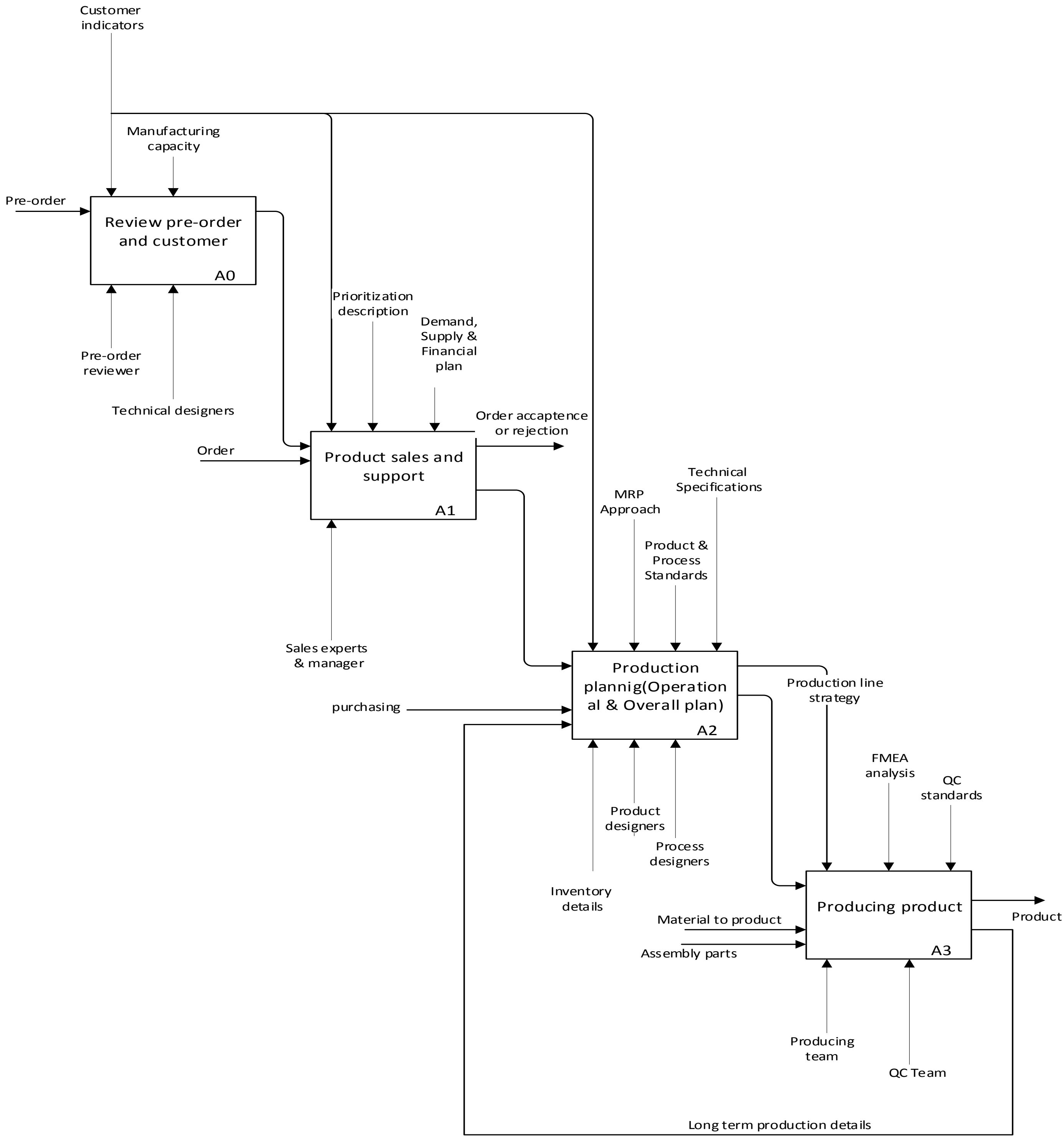

FIG. 1: FOUR GENERAL PROCESSES LEVEL-0 IDEF0 MODEL

This process include QFD third matrix. During process planning, manufacturing processes are flowcharted and process parameters (or target values) are documented. In other words, production processes will be planned according to product concepts and Production scheduling is performed. Third process of fig.2 belongs to the inventory control. In this process be done purchasing, material and assembly parts sent. Moreover, the paper has also shown the level-2 of inventory control stage in fig.3. In this level, our processes composed from raw material (A231) and assembly part (A232). The assembly part process's task is reception operation process chart (OPC) and needed parts sent.

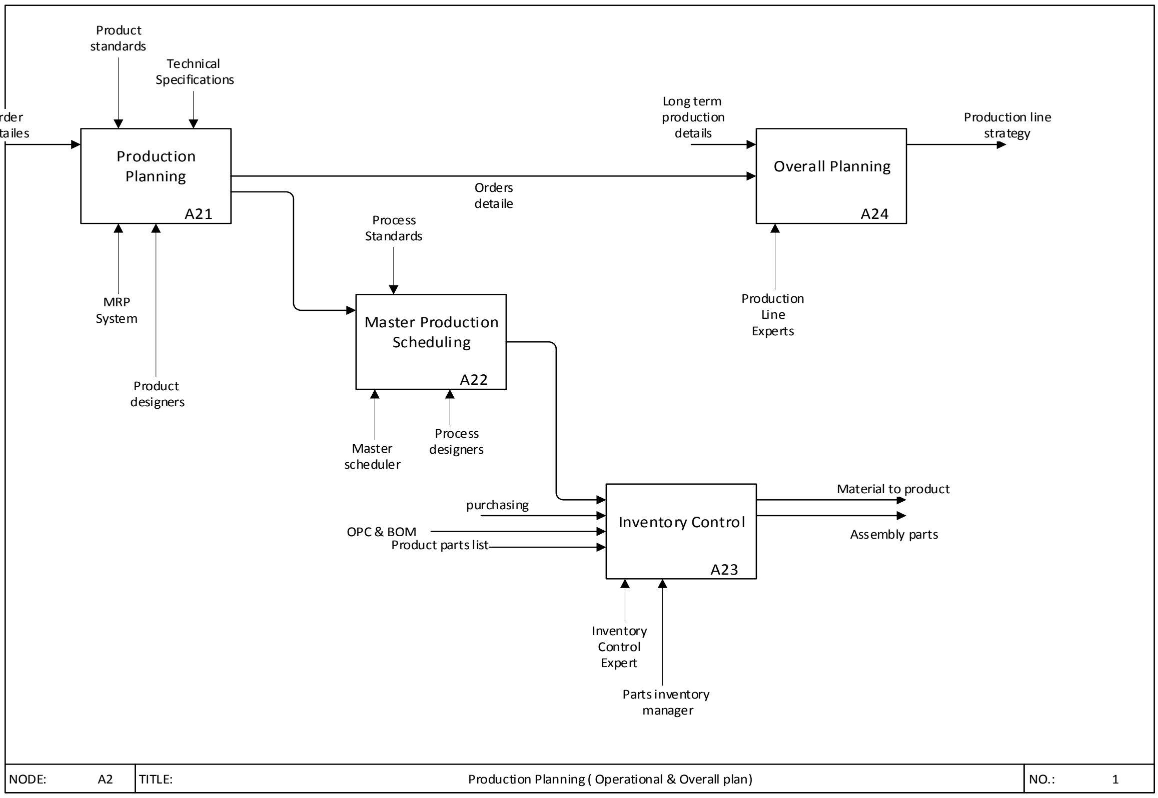

FIG. 2: PRODUCTION PLANNING LEVEL-1 IDEF0 MODEL

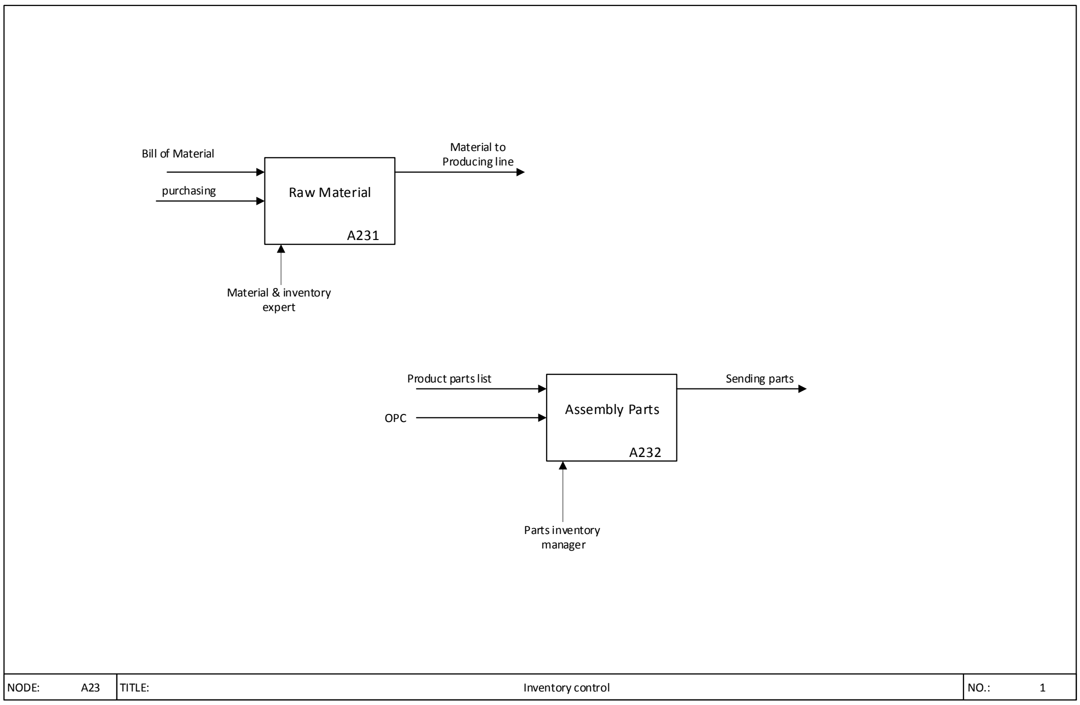

FIG. 3: INVENTORY CONTROL LEVEL-2 IDEF0 MODEL

And the raw material process's task is purchasing material and sent it to producing line. Our last level-0 processes is producing product (A3). This process contained phase 4 of QFD matrix. Finally, in this stage product assembly will be done, performance indicators are created to monitor the production process. The quality assurance department will analysis with FMEA as to which process poses the most risk and controls are put in place to prevent failures.

IV. THE USE OF QFD

In this research, the customer demands and requirements in product have been considered by using of Quality function deployment 4-stage matrix. Each of the four phases in a QFD process uses a matrix to translate customer requirements from initial planning stages through production control. Each phase, or matrix, represents a more specific aspect of the product's requirements. Relationships between elements are evaluated for each phase. Only the most important aspects from each phase are deployed into the next matrix [23].

Phase 1, Product Planning: Building the House of Quality. Led by the marketing department, Phase1, or product planning, is also called The House of Quality. Many organizations only get through this phase of a QFD process. Phase1 documents customer requirements, warranty data, competitive opportunities, product measurements, competing product measures, and the technical ability of the organization to meet each customer requirement. Getting good data from the customer in Phase1 is critical to the success of the entire QFD process.

Phase 2, Product Design: This phase2 is led by the engineering department. Product design requires creativity and innovative team ideas. Product concepts are created during this phase and part specifications are documented. Parts that are determined to be most important to meeting customer needs are then deployed into process planning, or Phase3.

Phase 3, Process Planning: Process planning comes next and is led by manufacturing engineering. During process planning, manufacturing processes are flowcharted and process parameters (or target values) are documented.

Phase 4, Process Control: And finally, in production planning, performance indicators are created to monitor the production process, maintenance schedules, and skills training for operators. Also, in this phase decisions are made as to which process poses the most risk and controls are put in place to prevent failures. The quality assurance department in concert with manufacturing leads Phase4.

In framework that presented in this research, each of the four phases in a QFD process used in the different stages of framework and the fulfillment of customer needs in the configuration and assembly of products. In this model, the paper used the first phase of QFD in the review pre-order and customer process A0 (fig.1). In this process after reaching the customer with special demands, this demands translated to technical specifications of parts with technical designers. In this process it becomes clear what the configuration of the product can be offered to customers. The paper has considered the second phase of QFD matrix in the production planning process A21 (fig.2). In this process, product designers choose the best configuration of components and parts according to technical specifications. Master production scheduling A22 (fig.2) included third phase of QFD matrix. In this phase, after identifying the product components and configuration in earlier phases, product assembly processes are considered. Required materials and parts allocated for product configuration and production scheduling. Last phase of QFD matrix considered in producing product process A3 (fig.1). In this process, manufacturing process control and product quality assurance have been considered.

V. BENEFITS OF OUR FRAMEWORK

In this section, the paper will review proposed framework and will be considered the advantage of this. The motivation of this research is meet customer requirements, a decision support system for order accept or reject, a ATO system to reduce costs of design and product manufacturing. These factors have been considered and solutions for fulfilling these requirements are proposed. For this purpose, the processes and tools that are responsive to our needs in framework are used. Despite our efforts the proposed framework will not be perfect but will have advantages to other models. So the paper pointed out the advantages of our framework to show that our proposed processes have a great effect on to achieve the objectives of product development frameworks. Of the most important one, the following items can be described:

- Benefits of Using QFD: Customer driven: The focus is on customer wants, not what the company thinks the customer wants. The "Voice of the Customer" drives the development process. Reduced development time: The likelihood of design changes is reduced as the QFD process focusses on improvements to be made to satisfy key customer requirements. Careful attention to customer requirements reduces the risk that changes will be required late in the project life cycle. Time is not spent developing insignificant functions and features. Reduced development costs: The identification of required changes occurs early in the project life cycle. Minimizing changes following production reduces warranty costs and product support costs.

- Benefits of DSS: Helps in saving time: Research has demonstrated that decision support systems help to reduce decision cycle time for an organization. DSS provides timely information, which is then used for decision making and results in enhanced employee productivity. Improves efficiency: Another advantage of DSS is efficient decision making, resulting in better decisions. This is because use of DSS results in quick transfer of information, better data analyses, thus resulting in efficient decisions. Enhanced organizational control: Due to the use of DSS business transaction data is easily available for monitoring the performance of employees and ad hoc querying. It thus leads to enhanced understanding of business operations for the management.
- Benefits of ATO: Businesses that want the ability to make a large number of different products from common parts benefit the most from assemble to order method. They can stock the common parts and sell varied customized products to meet customer needs. Another key benefit of assemble to order method is that businesses can reduce errors in the delivery of products. For example, a business that sells computers to customers can reduce the amount of errors when choosing this method rather than the options method.
- Benefits of the FMEA: The FMEA procedure is a highly effective way to evaluate processes, services or products. It is as valuable for revealing areas needing improvement as it is for guiding the development of new processes. It is a logical, structured way to identify areas of concern while reducing development time and cost. It’s also valuable when the intent is to apply a particular (typically successful) process of one product or service to another. It has proven to be an effective way to identify how to improve areas where performance might be lagging, such as sales or customer satisfaction ratings or high expense to income ratios, for example.

Furthermore, the framework has enabled the prioritization of orders into high and low priority orders, considering profit of orders that reduce the risk of lost sales lucrative orders. Also, the proposed framework has overall planning that takes long-term data from the production line. This process, provide data and offers a long-term strategy that cause increase efficiency and reduce the idle time.

VI. CONCLUSIONS

Although the bulk of research on production planning and control has taken into account the ATO systems, most of the companies have to work in a ATO environment in practice to decrease their production costs and also improve their customers service level and demands. The paper has used Quality function deployment (QFD) 4-stage matrix to meet the customer requirements. With the appearance of ATO systems, many issues have been coming up regarding the planning and scheduling of such systems. One of these issues, which have a direct impact on the customer satisfaction, is the matter of acceptance/rejection of new arriving orders to the system with respect to the resource limitations and customer importance. Other of these is an accurate translation customer demands to product features. This research has proposed a novel framework for pull-oriented product development system (ATO system) by using the QFD.

The main future research which can be considered for our study is (i) the implementation of this framework in a real production environment (ii) Prepare a case study for this framework

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