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Benefits and Barriers to Successful Concurrent Engineering Implementation

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***Abstract*—Also known as Simultaneous Engineering, Concurrent Engineering is a manufacturing approach of product design and development whereby all the production stages run simultaneously instead of sequentially, thereby leading to remarkable increase in quality of New Product, as well as decrease in production cost and lead time. This paper gave a detailed definition of Concurrent Engineering, and noted that its early stage of implementation involves a company's entire workforce, the production processes, the technology, intensive trainings as well as the need for it. It explained that shorter lead time, improved communication and product quality, reduced design changes, ensures better management, reduced development costs, and increased profit as some of the numerous benefits of implementing the manufacturing strategy. Organizational and technical barriers which include lack of management and staff commitment, inadequate improvement of production processes, lack of expertise and properly coordinated team, inadequate management support etc, were identified as the impediments that confront the successful implementation of Concurrent Engineering. The paper concluded that despite the numerous barriers to its successful implementation, that Concurrent Engineering is a long time manufacturing initiative with a long term benefits to manufacturing, as it creates an enabling environment for designing and timely manufacturing of high quality products which offers a competitive advantage.**

***Keywords*—simultaneous, product development, product design, teamwork, concurrent engineering, customer requirement, product lifecycle, lead time**

1. Introduction

In the past according to Debackere (2016), commercial success was practically guaranteed if manufacturing companies could design, develop, and manufacture high quality products that satisfied the customer's needs at competitive prices. However, he observed that "beginning from the early 1990s this traditional routine radically changed as time-to-market became a vital component of commercial success." He explained that research has shown that being late to market is worse than having a fifty percent cost overrun when these overruns are related to financial performance over the lifestyle of a new product or service, as time has become a major driver of competitive advantage, from design and development to the actual launch of a new product or service.

The traditional approach to product development is no longer feasible in today's world class manufacturing, due to its shortcomings and inadequacies which lead to increased lead time, delays, stoppages, and defects. Today, different tools and techniques have been developed to assist manufacturers to decrease the cycle time of the product design and also enhance the product design effectiveness. One of such techniques is Concurrent Engineering (CE) which is one of the most important approaches to the development of new products or redesign of existing products and processes.

According to Winner (1998), "concurrent engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support." He explained that the manufacturing approach is "intended to cause the developers, from the outset, to consider all elements of the product lifecycle from concept through disposal, including quality, cost, schedule, and user requirements". In manufacturing, Concurrent Engineering shortens time to market and also reducesproduct development timeby exploiting the extent of design processes through integrated product development and the application of procedures, work culture, as well as tools, and techniques.

In their study, Jain and Aggarwal (2009), explained that Concurrent Engineering also referred to as Simultaneous Engineering is a new technique embraced to improve the productivity of product design and reduce the lead time of product design, as it represents one of the most substantial contemporary approach in the development of new products. As a long term business strategy with numerous benefits,it is a method of simultaneously developing the different stages of products unlike the traditional approach where new products are developed sequentially.

Concurrent Engineering encourages collaboration and teamwork among various departments, as well as the application of diverse knowledge and skills to deliver many competitive successes in manufacturing.

Stjepandic, Verhagen, and Wognum (2015), noted that being justified by higher competitiveness, that it is an encompassing concept that emphasizes collaboration between relevant stakeholders throughout any innovation process, whether product, process or organization innovation, as its aim is to reduce time-to-market, improve quality and reduce costs by an ever more efficient product creation process.

As a methodical procedure to the simultaneous design and development of products by multi-disciplinary teams, as figure 1 depicts, Concurrent Engineering considers the total usefulness of a product from conception, design, assembly, manufacture, usage and disposal; thereby reducingtime to market by decreasing considerably the product life cycle.

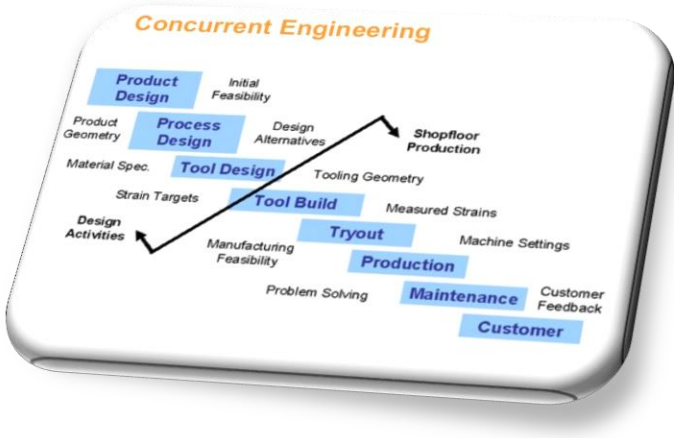

Figure 1: Simultaneous activities of Concurrent Engineering

Also, in today's manufacturing where a firm's profitability and increased control of market share is mainly dependent on early introduction of high quality products and services, CE is very vital as it leads to design and development of products in parallel instead of in sequence.

As shown in figure 2, Concurrent Engineering gives the employees that work in teams the advantage to add values on the product right from inception to the entire process, by paying attention on the entire job, unlike the traditional or sequential engineering where the staff had to wait for those in the earlier stages of work to complete theirs before they can come in. Instead of allowing the different functions like analysis, implementation and deployment to be separated, the manufacturing process in CE moves in succession from stage to stage.

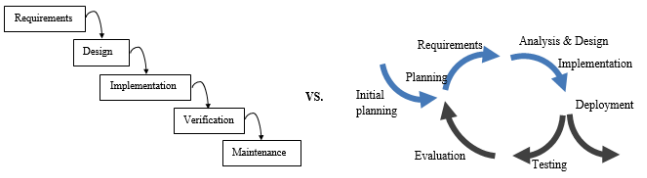

Figure 2: Sequential Engineering vs Concurrent Design and Manufacturing

According to Jain and Aggarwal (2009), the rigorous teamwork between production planning, manufacturing and product development is very vital for proper functioning of Concurrent Engineering. They observed that the teamwork also brings further advantages which include: the cooperation between different specialists and systematic application of special methods like Quality function deployment,Design for Manufacture and Assembly (DFMA), and Failure Mode and Effect Analysis (FMEA), which ensure faster optimization of design and early detection of possible faults in product and production planning, thereby enhancing the quality of the products and also leading to considerable reduction in lead time.

2. The Implementation of Concurrent Engineering

Stark (1998), observed that the major objective Concurrent Engineering aims to achieve is improved product development performance, as it is a long-term strategy that should be considered only by organizations willing to make up-front investments and then wait for long-term benefits. He pointed out that the implementation of CE involves major organizational and cultural change, with multidisciplinary groups acting together early in the workflow and also taking informed and agreed decisions relating to product, process, cost and quality issues, as they can make trade-offs between design features, part manufacturability, assembly requirements, material needs, reliability issues, serviceability requirements, and cost and time constraints.

The early stage of Concurrent Engineering implementation involves a company's entire workforce, the production processes, the technology,intensive trainings that are geared towards sensitizing the entire workforce on what CE entails, as well as the need for it.Start (1989), noted that CE "involves major organizational changes because it requires the integration of people, business methods, and technology and is dependent on cross-functional working and teamwork rather than the traditional hierarchical organization."He pointed out that one of the primary issues is the formation of teams, as collaboration rather than individual effort is standard, and shared information is the key to success. Also, team members must commit to working cross-functionally, be collaborative, and constantly think and learn, where the role of the leader is to supply the basic foundation and support for change, rather than to tell the other team members what to do, as training addressed at getting people to work together in teams plays an important role in its successful implementation.

As depicted in figure 3, even with the formation of a cross functional team, the customer and external supplier also makes input in the design and manufacturing of a product through the salesmen and production planning managers respectively, thus leading to customer satisfaction.

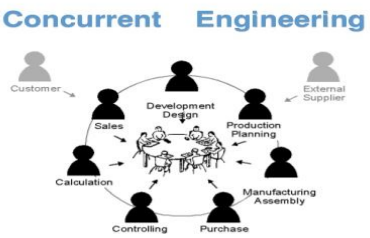

Figure 3: Concurrent Engineering Implementation

Sofuoglu (2013), explained that although results of CE can be impressive, the adoption rate and the completeness of the implementation differ markedly between different companies and different countries, as CE is an integrated approach which consists of different tools, techniques,policies, etc. therefore the measures of such implementation are not straightforward. He listed the following as the seven elements in team cooperation philosophy:

- flexible, unplanned and continuous collaboration,
- commitment to meet the goals,
- communication (exchange of information),
- ability to make compromises,
- consensus in spite of disagreement,
- coordination (managing interdependencies between activities),and
- continuous improvements in order to increase productivity and reduce process times.

The CE implementation model depicted in Figure 4 shows the importance of multi-functional teams that are equipped by the management to achieve optimum results. Also, the successful introduction of the product development cycle requires both technological and organizational enablers for efficient integration of processes. The cooperation and collaboration among multidisciplinary teams in Concurrent Engineering is of great importance as team members interact and brainstorm to achieve a productive design that will reduce lead time, inefficiency and other wastes that are inherent in manufacturing processes. The teams include staff from research and development, design, marketing, manufacturing, logistics, inventory, as well as suppliers and customers.

According to Hartley (1992), successful Concurrent Engineering implementation relies heavily on functional integration, informationsharing and collaborative problem solving among all participants, as effectivecommunication is one of the most important ingredients to support the manufacturing strategy. He explained that accurate up todate information must be readily available to enable team members to make correctdesign decisions.

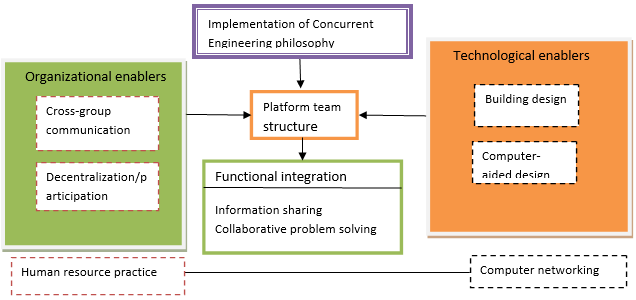

Figure 4: CE Implementation Model. Source: Hadad (1996)

The implementation of CE in a manufacturing company is usually introduced through gradual processesthat require modifications and long period for organizational culture change. Also, the acceptance and encouragement of management and leadership of a firm is very crucial to a successful CE implementation. Other factors are the participation of the entire workforce, continuous improvement, as well as communication and collaboration of multifunctional team.

The integrated development process that is involved in concurrent design is shown infigure 5.

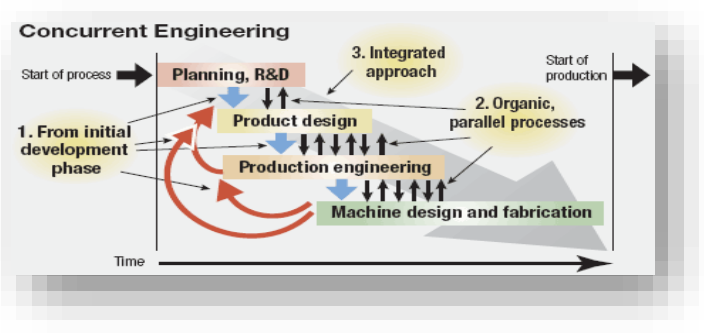

Figure 5: Concurrent Engineering Process

The first step involved in the implementation of Concurrent Engineering is the acceptance of management and leadership of a company to accept the manufacturing approach, this will be followed by intensive staff training to enable the workers to understand and appreciate it. Other steps are setting up of multi-functional teams that will drive innovations, as well as investment in information technology development.

3. Benefits of Concurrent Engineering

As a flexible and more recent approach of product development which enables a manufacturing company to gather the required information from customers and suppliers to simultaneously design, produce and sell, concurrent engineering has many benefits. The production approach enables a firm to be responsive to the demands of the customer to ensure their satisfaction.

As shown in figure 6Abdalla (1999), listed shorter time to market, improved communication, improved

product quality, reduced design changes, better management, reduced development costs, and increased profit as some of the numerous benefits of implementing Concurrent Engineering.

Figure 6: Benefits of CE Implementation. Source: Abdalla (1999)

Other numerous benefits of Concurrent Engineering implementation include:

- **Lead time reduction**

Unlike the traditional manufacturing where product development runs sequentially, as the workers in the design phase must complete their work before work can commence on prototyping stage etc, concurrently engineering as shown in figure 7 enables workers on different stages to work concurrently, thereby leading to reduction in lead time and time to market. By integrating tasks and overlapping activities which leads to lead time reduction, Concurrent Engineering enables firms to not only maximize their profits and market shares, but to also outwit the competitors. Sandip et al. (2013) put it very succinctly that the goal of current engineering is to shorten product lead time and increase efficiency at a reduced cost.

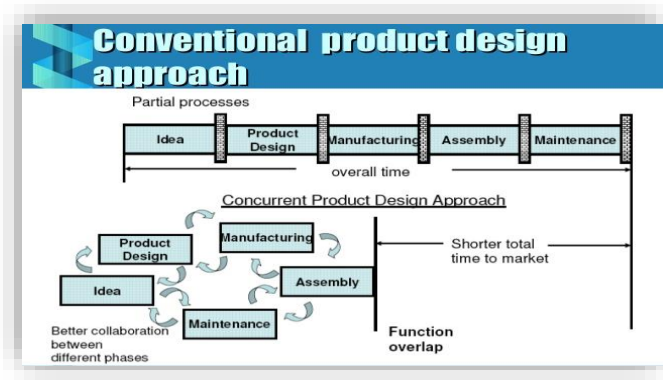

Figure 7: Concurrent product design versus traditional product design

- **IncreasedProduct Quality**

Apart from lead time reduction, the major competitive advantage of Concurrent Engineering is in manufacturing of high quality products. It is a general knowledge that quality must be designed into the product, not inspected into it. Quality can be viewed as exceeding customers' needs and providing superior value.The outstanding efforts that are made at the design stage of production which includes numerous tests and known data utilization, ensures the manufacturability of designed products and elimination of unrealistic prototypes, thereby leading to the production of high quality products at a reduced lead time. This is because production problems are identified and resolved at early stages, thereby eliminating unrealistic designs anddefects.

According to Autotec (2017), by paying attention to downstream activities like construction, operation, maintenance, and decommissioning while performing upstream activities such as conception, specification, and design, "Concurrent engineering can bring cost effectiveness and produce nothing less than top quality for the ultimate buyer and consumer of constructed facilities, i.e., owners and end users, respectively."

- **Enhancement of Multidisciplinary Teams**

Teams of skilled and proficient experts from diverse departments are motivated to brainstorm and collaborate from the design stage of production to ensure the manufacturing of high quality products. The collaboration among the various disciplines that plan, design, schedule, optimize, manufacture, and sustain the product for its entire life cycle apart from promoting effective communication also leads to reduction in lead time, errors, and other forms of wastes that are inherent in manufacturing processes.

According to Abdalla (1999), through team working and the support of integrated information technology tools, designers as well as manufacturing planners will be able to cope with late changes, share data with other parties involved in the product development process.The main features of an effective team include combined group effort of all members, clear goal, mutual trust and support, open communication, democratic processes and group members focused on learning.

- **Competitive Advantage**

Concurrent Engineering provides manufacturing companies with effective communication, collaboration, and management procedures that are required for cost effective, timely design and production of quality products, as efforts are shifted from meeting the customer's requirements to exceeding his expectations, thereby leading to competitive advantage. Here, even when some manufacturing processes cannot be accomplished simultaneously, the production team is advised by managements to accomplish tasks integration among activities that are in sequence, in order to outwit the competitors in New Product Introduction (NPI).

- **Customer Satisfaction and Production Cost Reduction**

One of the most important benefits of Concurrent Engineering Implementation is its ability to achieve customer satisfaction,through the efficient manufacturing of high quality products at a reduced cost. These enables manufacturing companies to thrive as a result increased profitability, repeat purchase and

increase in market share.CE achieves product quality through quality function deployment.Quality function deployment aimed at satisfying the consumer needs by translating the consumers demand into design targets and major quality assurance points to be used throughout the production stage (Akao, 1990).

Quoting Garza et al, Nabozniak (2017), noted that Concurrent Engineering brings together, from project inception, multiple individuals to address all angles of a project and enables the accumulation of knowledge and information so as to reduce downstream risks and anticipate constructability, operability, and maintainability expectations, thereby reduce considerably the cost of manufacturing. He concluded that "Cost-effective and top-quality facilities can be conceived, designed, built, and operated if these activities are not performed in a vacuum, but rather, performed in a life cycle context."

4. Barriers to Successful Implementation of Concurrent Engineering

Benneth and Lamb (1996), explained that as with any plan to implement change that it is important to know where the barriers to the intended change are, in order to ensure that they are reduced or possibly eliminated. They pointed out that despite the numerous benefits of Concurrent Engineering it has encountered numerous complex barriers which tend to overshadow its numerous benefits.

Organizational and technical barriers have been identified as the two impediments that confront the successful implementation of Concurrent Engineering. Although the two barriers are interconnected, the implication of unavailability of the required technology for effective communication and data sharing for successful Concurrent Engineering implementation is regarded as a technical barrier, while organizational culture as well as management style, values and norms are organizational barriers.

Some of these barriers and challenges include the following:

- The erroneous belief that Concurrent Engineering can be applied haphazardly without adequate trainings in teamwork.
- Lack of management and staff commitment;
- Lack of adequate expertise and knowledge on Concurrent Engineering application;
- Inadequate improvement of production processes;
- Inadequate management support;
- Lack of properly coordinated team;
- Suppliers' failures;
- Employee's resistance to accept and adhere to production changes which consolidates Concurrent Engineering;
- Unfavorable reward Systems and performance appraisal;
- Unrealistic schedules;
- Lack of information technology tools;

To overcome the barriers, manufacturing companies must establish effective and workable plans to address the challenges one after the other. This is because to achieve success in the implementation of Concurrent Engineering, the multidisciplinary team must synergize, as all the required information about all the stages of production must be provided at the right time.

5. Conclusion

World class manufacturing is becoming the panacea for survival in ever dynamic competitive global markets, as focus has shifted from meeting the customer's demands to exceeding his expectations, in order to ensure maximum satisfaction and continuous brand loyalty. Therefore, enhanced cost effective qualityproductsthat are manufactured at a reduced lead time is the target of all result oriented manufacturing companies, hence the need for Concurrent Engineering.

The successful implementation of Concurrent Engineering requires the endorsement and support of the leadership and management of a company, as their motivation is very crucial to the attainment of the numerous benefits of the manufacturing initiative. The management's involvement is also required for the identification, reduction and possible elimination of all the technical and organizational barriers that mitigate the huge impact of the successful implementation.

Getting manufacturing right at the first time which entails making sound decisions at the early and design stage of product development is the major hallmark of Concurrent Engineering. As a long time manufacturing initiative with a long term benefits to manufacturing, it creates an enabling environment for designing and timely manufacturing of high quality products which offers a competitive advantage, despite the numerous barriers to its successful implementation.

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