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Concurrent sustainable engineering mainly to reduce TQM costs

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Abstarct

The industrial companies have become in front of a new reality that necessitates them to strive towards modern costly and administrative techniques and methods instead of continuing to rely on the traditional cost-effective methods that have become insufficient to provide the appropriate information and do not keep pace with the new requirements. And manufacturing, production and marketing simultaneously, which provides savings in total quality management (TQM) costs and gives flexibility in developing and improving products, which in turn helps companies to provide products at reasonable prices to meet the desires of customers, maintain their market share and achieve the greatest amount of profits.

To achieve the goal of the research, this research has been divided into four parts. In the first topic, the research methodology was discussed, and the second topic dealt with synchronous sustainable engineering, and in the third topic, the costs of total quality management (TQM) were addressed, leading to the fourth topic showing the importance of simultaneous sustainable engineering in Reducing the costs of total quality management (TQM), and finally, the most important conclusions reached by the researchers and the most important recommendations made in light of them were reviewed.

Introduction

Synchronous engineering is based on synchronization in the performance of various activities and events through carrying out the processes of designing, developing, manufacturing and assembling products simultaneously depending on a multifunctional team that seeks to reduce the design, manufacturing and assembly time of products in addition to achieving cost savings and maintaining an acceptable quality level. In addition to solving all the problems facing the economic unit simultaneously in order to reach good industrial performance, this process requires four stages: The preparation and preparation stage, the design stage, the review and evaluation stage, and the transition to production stage. Commitment to these stages and carrying out the design and development processes simultaneously can create an appropriate base for carrying out the manufacturing and assembly operations simultaneously, which helps to achieve additional savings in both cost and time.

Study problem:

In light of the modern and developed manufacturing environment and the intensification of competition between companies and their quest to provide products in a shorter time and at a lower cost to their customers and to ensure that their products remain as long as possible in competition, traditional techniques are unable to achieve this, which requires adopting modern methods and techniques that keep pace with developments in that environment. Concurrent sustainable engineering technology is one of the most prominent of those techniques that achieve what companies and their customers alike alike, and therefore the research problem can be formulated in the following question:

What is the effect of concurrent engineering technology in reducing total quality management (TQM) costs?

The importance of the study:

The importance of this research stems from the scientific level as it deals with one of the modern concepts in the literature of production and operations management, which is the entrance to simultaneous sustainable engineering.And then this research comes as an attempt by the researcher to shed light on the different dimensions of this approach, as the philosophy of this technology is based on synchronization in the design and manufacturing processes and thus achieving a reduction in costs as well as a reduction in the time required to complete those operations.

Objective of the study:

- This research seeks to identify the sustainable simultaneous engineering technology and to clarify the importance of that technology in reducing costs and total quality management (TQM) at an early stage of product design and manufacturing, and thus achieving the company's goals in providing products at reasonable prices in response to the customer's desire.
- 2- The applied objective of the research is to provide data and information on the expected benefits and difficulties of applying sustainable simultaneous engineering in product design and development, reducing development time, improving quality, reducing cost, and achieving customer satisfaction.

Study assignments:

Based on the problem that the research seeks to answer its question, the researcher formulated the following hypothesis:

((The application of sustainable concurrent engineering technology contributes to reducing total quality management (TQM)) costs.

The concept of simultaneous engineering:

The concept of concurrent engineering consists of two terms, engineering and concurrent, and the dictionary defines engineering as "management or directing". As for synchronicity, it is “the event that proceeds at one time or is convergence at one point” (Barahona, 2003, 22).

This concept is based on the general assumption that experts from all areas necessary for the entire product development (marketing, design, process planning, manufacturing and assembly) participate in such operations. Participants collaborate to reach defined goals and share data continuously and directly at all stages of the product life cycle. (Rihar, et.al., 2020 :2)

From the point of view of product design (Deshpande, 2019:7) he defines concurrent engineering as a systematic approach to the integrated and simultaneous design of products and related processes, including manufacturing and support. This approach aims to get developers to take into consideration from the beginning all the elements of the product life cycle from the initiation of the product idea to its disposal including quality, cost schedule and user requirements.

As (Panayotova, 2018:1) sees it as a systematic approach to the integrated and joint design of products and related processes. That is, the use of modern highly efficient methods, tools and procedures based on the latest developments in the field of computer technology and software, as well as specific techniques of teamwork that ensure the production of competitive products.

By applying simultaneous engineering, the greatest economy of time is achieved, because the effect of time shortening and reconciling of times allowed for the different phases of the engineering project and the entire project cycle is used simultaneously. The effectiveness of using simultaneous engineering in different directions can be summarized as follows: (Panayotova, 2018:1).

- Reducing the time from the birth of the idea of designing a new product to its launch in the market.
- Presenting the product as required by the quality characteristics of the market.
- Optimizing the process in terms of design costs incurred.
- To obtain products in the form required by the user's quality characteristics for the shortest possible period of time and occupy the maximum place in the market.

Dimensions of Simultaneous Geometry:

(Ebrahimi, 2011) presented a set of main dimensions of synchronous engineering, which include best practices that are more appropriate to the operations and circumstances of each company, as these dimensions are linked to the organizational culture of the company in order to run a synchronous engineering program within the economic unit, and the following is a presentation of the most important dimensions addressed (Ebrahimi, 2011: 51):

1. Organizing: This dimension affects functions such as design, manufacturing, marketing, sales and finance. In addition, the consequences of impact depend on the forces of change which are the ability of an economic unit to bring about changes in technology, tools, tasks, talent, and time.

2. Communication: Communication infrastructure facilitates the collection, analysis and organization of information, so that knowledge and understanding of product and process development can be shared between different functions. The more complex the product, the more complex infrastructure is required. The information technology designed for the concurrent engineering program supports the core requirements of the programme. Failure to support engineering software concurrently with appropriate IT facilities may result in loss of control over the collaboration process, loss of product functionality, testability problem, manufacturing delays, and eventual loss of the customer.

3. Requirements: The requirements dimension focuses on identifying and approving customer requirements. The requirements dimensions should define the key decision-making areas and define the conditions that must be reviewed before a decision is made.

4. Product Development: The product development dimension includes all the activities through which the design process can be linked to manufacturing processes and the transformation of requirements into an expected reality.

5. Quality Function Deployment (QFD): Quality Function Deployment (QFD) has three steps to interpreting customer voices: First, identifying customer requirements. Second, the QFD must evaluate how to translate customer requirements into production standards specifications. Finally, you must determine how responsive the product development process is to the customer's voice.

6. Reverse engineering: prioritizes process planning and manufacturing procedures rather than product design.

7. Virtual Reality: It includes computer graphics technology that enables the creation of computer images in real time as if it were a virtual model as good as a solid model. Head-mounted audio-visual devices, a 6D position sensor, and haptic interface devices are some examples of VR equipment. CAD/CAM tools are also mentioned as important tools that are more flexible and faster than solid modeling.

Principles of Concurrent Engineering:

The principles of simultaneous engineering have become an alternative to traditional manufacturing methods to deliver benefits in terms of cost, quality and time, making full use of the best available equipment and technology, while effectively controlling the organizational structure to produce high-quality, well-designed products at low prices and in less time. (Doshi, et al., 2016:257).

In general, a number of researchers see, for example (Karningsih, et.al., 2015, :202; John Stark Associates, 1998, Hambali et al., 2009:10), that the principles of simultaneous engineering can be divided into three main factors that contribute In reducing time, reducing cost, improving product quality and meeting customer needs:

First: People: In the concurrent engineering approach, using the right human resources at the right time is critical and accelerates development by minimizing defects. To achieve success in the application of simultaneous engineering with respect to people requires some factors as follows:

1- Teamwork: Teamwork is the basic principle of simultaneous engineering. It emphasizes interpersonal relationships, cooperation, negotiation, and collaborative decision-making. That is, teamwork is an integral part of simultaneous engineering, as it represents the means of organizational integration. (Kusar et al., 2004:6).

2- Multidisciplinary work teams: Concurrent engineering relies on a multidisciplinary product development team. Multidisciplinary teams, are teams that include experts from all stages of the product development process such as design, operations, production, marketing, manufacturing, etc., which are very important to a successful CE implementation. Multidisciplinary teams can break down barriers between departments and provide effective means of communication (Kusar et al., 2004:6).

3- Communication: Communication is the cornerstone of success in concurrent engineering. Concurrent engineering must be implemented in an environment where communication and collaboration between departments is facilitated. This requires sharing of data within the work environment and an open exchange of information. Effective communication can be achieved through data sharing and through the quality and structure of communications between and within the group, Additionally, simultaneous engineering projects benefit from high-frequency, face-to-face, and two-way communication between team members. Thus, the distribution of key functions and team meetings are important in this aspect. (Bhuiyan et al., 2006: 6).

4- Administrative Support: Leadership and support from senior management are critical to the successful implementation of concurrent engineering. The role of senior management should not only depend on supporting concurrent engineering, but should also be involved in the activities of formulating and implementing its objectives. (Hambali et al., 2009:10).

5- Customer and Supplier Involvement: In product design and manufacturing, integration between customers, suppliers, and manufacturing economic units is essential in determining product success. Concurrent engineering can reduce a significant portion of design error and rework due to misunderstanding or miscommunication between the economic unit and customers and suppliers in the early stage of the product development process.

6- Second: Processing: The key to implementing a concurrent engineering approach is to have one well-defined process with clear objectives. Thus, the process and schedule of the activities concerned should be based on some basic principles, as follows:

1- Work Structure: In general, all activities in the product development process must be carried out in a parallel and simultaneous manner. In order to build a clear framework or structure, factors such as defining and formalizing the concurrent engineering process, defining the overlapping activities, defining process ownership and clearly defining goals must be worked out.

2- Early problem detection: Problems that are discovered at the early stage of the product development process (especially during the first 20% of the life-cycle time of the product) are easier to solve than those discovered later.

3- Early decision making: The opportunity to influence the design is much greater during the early design stage than at a later stage, when some decisions are frozen and the design matures.

Third: - Tools and Technology: An appropriate set of tools and technology must be selected to help achieve the maximum benefits that enable the enterprise to develop the integrated product. In order to effectively implement concurrent engineering, there is a great need to use tools and technology.However, there are two aspects to consider when implementing tools and technology; First, the tools and technology that make the effective implementation of concurrent engineering possible must be identified, and second, the people who will use these tools and techniques must be trained (Hambali et al., 2009:10).

Phases of Concurrent Engineering Application:

Each institution follows steps and a timetable in implementing synchronous engineering independently and differently from the rest of the economic units, as each institution has different organizational circumstances and cultures, so (ogawa, 2008: 20) identified the sub-processes for the application of synchronous engineering, which are as follows:

1- Initialization and preparation stage: This process plays an important role in the application of concurrent engineering, but before the actual activity is designed by the work team, this team must do many things that must be planned, prepared and meet their requirements in order to cover the design and the estimated time of Before the cross-functional team, the most important of these requirements are:

- Special requirements or needs of customers.

- A list of the required system functions, and the relevant precise terms of reference.

- Scope of design activity.

- Capabilities and limitations of tools and specialists.

- List of stakeholders and their initial input.

2- Design sessions: By design sessions we don't mean meetings. Team members come together in the same room to communicate, but only when they need to. Engineers perform their individual work as if they were in their home base. This process is similar to the "open office" concept used especially in Japanese economic units.This process is similar to the "open office" concept used especially in Japanese economic units. Under the "open office" concept, employees do not have individual booths. Instead, the team places their desks in the same room allowing all group members to see what others are doing and making it easy to start personalized discussions when they want to.

3- Documenting the results: Much work needs to be done in the design sessions and their periods. This means that short-term results must be documented. While a set of design information is generated in these sessions, it would be of great help to the team if they used an automated documentation system and design process; The outputs of the design sessions and memos are converted into an automatic report and the team does not need to write the report from scratch.

4- The stage of transition to production: after approving the final design and submitting a recommendation for its implementation, the transition to production, through which the manufacturing and assembly processes are carried out simultaneously, taking into account adherence to the proposed design for each of the product, process and supply chain in order to reach the desired goals of this technology With regard to cost, quality, time and flexibility, taking into account the commitment to continuous improvement processes, and constantly striving to develop production processes. (Al-Zamili, 2017: 84).

Concurrent sustainable engineering:

The basic premise of sustainable concurrent engineering revolves around two concepts: one is the idea that all elements of the product life cycle, from functionality, productivity, assembly, testability, maintenance issues, environmental impact, disposal, and ultimately recycling, must be carefully considered in Early design stages. The second concept assumes that the above design activities must all occur at the same timeconcurrently.The idea is that the simultaneous, sustainable nature of these processes greatly increases productivity and product quality. This way, errors and redesigns can be caught early in the design process when the project is still flexible by identifying and fixing these issues early, enabling the design team to avoid often costly errors as the project moves to more complex computational models And finally to the actual manufacture of the products. (Mani, et al., 2015: 128)

(Stevenson, 2015: 160) considers concurrent engineering as bringing design and manufacturing engineers together at an early stage of design to develop sustainable product and product creation processes simultaneously, and more recently, this concept has expanded to include manufacturing personnel (such as materials specialists) and marketing and purchasing personnel in Integrated and multifunctional In addition, feedback from suppliers and customers is often sought for the purpose of achieving sustainable product design that reflects customers' desires as well as manufacturing capabilities.

while knowing. William, Stevenson that: Concurrent engineering in the narrow sense means bringing the design and manufacturing engineering personnel together early in the design stage for the simultaneous development of products and processes needed to produce a sustainable product, and then this concept has recently expanded to include sustainable manufacturing personnel, marketing and purchasing personnel in absolute integration and cross-functional teams in addition to To consider the perspectives of suppliers and customers in order to arrive at sustainable product designs that reflect the needs of the customer. (William, Stevenson, 2019: 163)

BS Baker & DE Carter defined it as: an organized approach that integrates technology, tools, tasks, talents and time into well-managed resources for the product development process towards sustainability (BS Baker & DE Carter,2018:288) .

The researcher believes that sustainable simultaneous engineering is making sustainable production decisions and sustainable processes in parallel as much as possible, and the union of production considerations in the early stages of designing a sustainable product within the system and after making sure that it is appropriate to convert it to other jobs.

Total Quality Management (TQM) costs:

Concept of Total Quality Costs (TQM):

Total quality costs (TQM) are defined as the total expenses incurred by the organization in achieving and maintaining good quality as well as in managing poor quality in all stages of its operations in order to achieve the highest level of customer satisfaction (Donauer, et.al, 2015:2).

It is also defined by (Neyestani, 2017:32) as the price of “conformance” and “non-conformity, where the price of conformity is the price required to ensure that things are going right, and the price of “nonconformity” is the expense incurred in doing the wrong things, and is manifested This concept is more in the manufacturing sector because of the need to comply with the specifications and standards set by the company or customers.Martínez&Selles, 2014: 2) define quality costs as “the total costs incurred by investing in the prevention of non-conformance with requirements, and the evaluation of a product or service for conformity with requirements and failure to meet requirements”. This means: they are costs that will disappear if there is no possibility of making mistakes.

Schiffauerova, 2006:1 & Thomas (2006) also agree that quality costs “are the costs incurred to ensure error-free operations, and are divided into a group of conformity costs and non-conformance costs. Whereas, conformity costs: are the costs incurred to prevent The occurrence of poor quality, and the costs of non-conformance: These are the costs of poor quality as a result of the failure of products or services to conform to specifications.

Types of Total Quality Costs (TQM) and their classification

Several studies have stated that quality costs consist of two main types:

1- **Apparent quality costs:** They are also called tangible quality costs, and this type of costs is restricted to the accounting records of the economic unit, and is available to users, whether they are internal or external, especially in industrial establishments, where they can be measured and monitored through the data installed in the books and records of the unit. The economic, and expressed financially, and this group includes all the elements of quality costs of materials, wages, and expenses are apparent.

2- Hidden (non-obvious) quality costs: There is another term synonymous with it, which is intangible quality costs, and it means the costs incurred as a result of lost profit due to the effect of lost sales and the effects of low prices, and many researchers point out that it is difficult to measure these costs, which is Which led to the inability to be recorded in the books of the economic unit, where the hidden quality costs extend to the reputation of the facility, and the loss of many of its current and prospective customers, and therefore the hidden quality costs are a strong motive for the establishments to adopt one of the improvement approaches.

Based on the foregoing, we see that total quality costs (TQM) mainly consist of two main components:

A- Conformnance Costs: It includes all the elements of costs associated with the activities necessary to produce products according to the planned and pre-determined quality, and these costs aim to achieve compatibility with specific specifications for quality by avoiding the occurrence of any deviation from these specifications, and these costs are often optional because they depend on the discretion of management, and therefore can be controlled In which. (Shehab El-Din, 2010:29).

B- Non-Conformance Costs: This type of quality costs is called failure or non-conformity costs, which are costs that result from the existence of production that does not conform to quality specifications. Hence it is called failure costs because it arises from the failure of prevention and evaluation activities to achieve the quality standards used. (Abu Khasbah, 2003: 111).

The apparent costs of quality consist of two main types: control costs, which include prevention or prevention costs, and evaluation costs. The second type is failure costs, which include internal failure costs and external failure costs (Sower, et al, 2007: 124).

First: Prevention Costs: The quality pioneer (Juran) considers prevention costs as the costs incurred to keep the costs of evaluation and failure as minimal as possible. Thus, the most effective way to reduce total quality costs and maintain high quality is to avoid the occurrence of quality problems since The beginning, and this is the goal of prevention costs, as these costs pertain to activities that reduce or exclude the production of defective goods or the provision of service less than the standard level,the economic units have found that the cost of prevention is less than the cost of repairing defects after their occurrence (Garrison, et.al, 2015: 67), and therefore they are the costs that occur to prevent the production of products that do not conform to specifications (Drury, 2008: 176), or they are the costs associated with preventing the production of A defect that does not meet the needs and expectations of customers (Krajewski, et.al, 2010: 176).

Second: Appraisal Costs: For the purpose of discovering products that do not conform to specifications, evaluation costs must be spent, which represent the costs of maintaining the level of quality through the means of official evaluations of product quality, or they are the costs of examination and testing in order to ensure that the process or product Acceptable in terms of conforming to the specified quality standards (Chase, et.al, 2001:269).

Third: Internal Failure Costs: Internal failure costs occur when the product does not conform to its design specifications, and Juran believes that these costs disappear if there are no defects in the product before it is shipped to the customer.Therefore, these costs are related to errors or defects that occur within the economic unit, so they are the costs that occur to discover the defective product before it is shipped to the customer (Horngren, et.al, 2009:662).

Fourth: External Failure Costs: External failure costs occur in the event that the customer receives a product that does not conform to the specifications so that it cannot meet his needs and expectations, as (Juran) emphasized that these costs disappear when there is no external defect, Since these costs arise after the customer receives the product, they are related to his service, and thus the costs that arise when the defective product has been delivered to the customer (Krajewski, 2005: 196).This can be illustrated by the following figure:

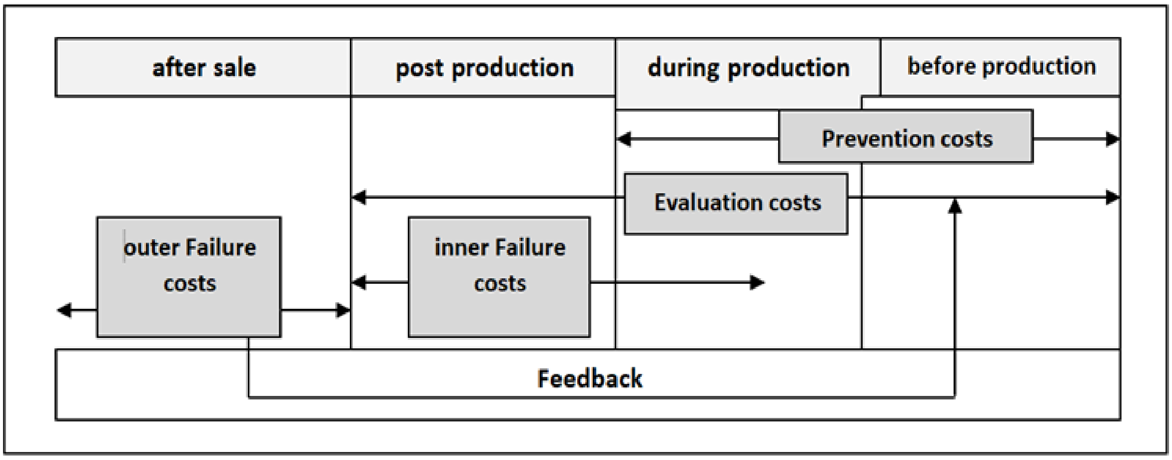

Figure (1): The stages of the emergence of total quality costs

The importance of sustainable concurrent engineering in reducing total quality management costs:

Concurrent sustainable engineering is a final word for total quality costs (TQM) as it arises after it, and the following figure shows the relationship between sustainable concurrent engineering and total quality costs (TQM).

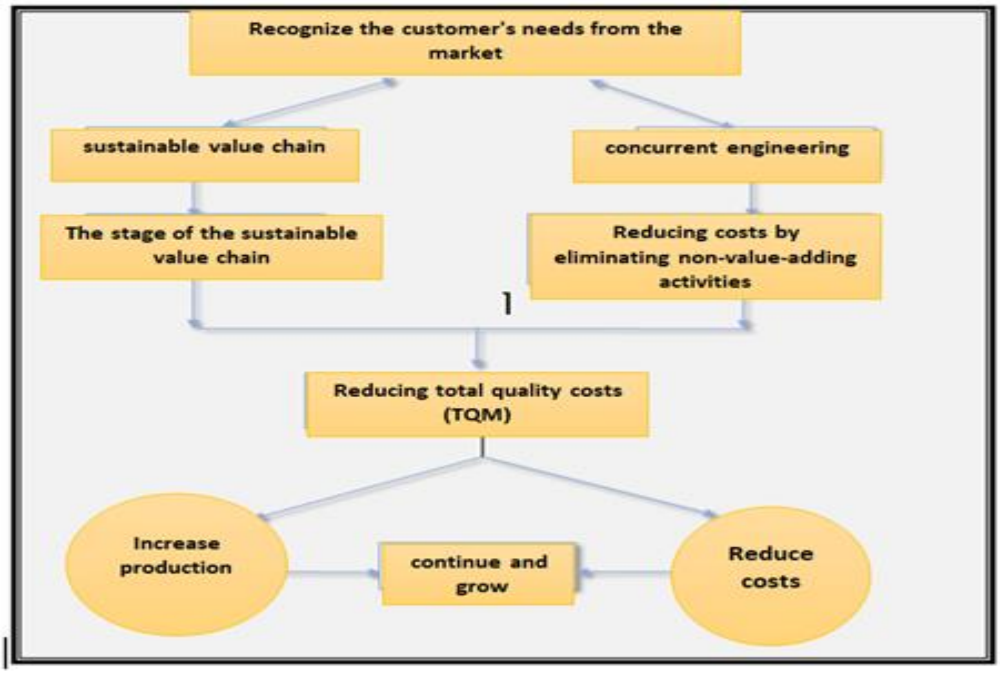

Figure (2): The relationship between sustainable concurrent engineering and total quality costs (TQM)

The adoption of TQM technology requires the company's management to review the steps and procedures of its business performance on a permanent basis, and one of the pillars of improvement upon which TQM is based is to rely on the best way to improve the product – a good or service – that depends on continuous continuous improvement of operations, (Besterfield, 2019: 84)

As judging quality in the framework of TQM is not only made through the results of the product or service and their conformity with the expectations of the internal and external customer, but extends to include the quality and design of operations to give results without errors, on the basis that continuous improvement achieves access to quality results and customer satisfaction. Juran that Kaizen's philosophy depends mainly on continuous improvement in performance in all operations within the company, as each individual has to perform two tasks: performing and improving his work, and from this perspective, not a single day should pass by the company without improvement in work.(Juran, 2009: 6).

A sustainable concurrent engineering environment provides an opportunity to significantly reduce the overall project cost. This is because integrated concurrent engineering work teams with members from different skilled disciplines, enables simultaneous contribution to early product development and identification. Therefore, within an integrated product development cycle, multidisciplinary teams working together increase the potential for lower life cycle cost by avoiding costly modifications later in the design process. With this view in mind,concurrent engineering is a great step forward when compared to a traditional system, where each department operates in 'isolation'. However, the concurrent engineering environment presents several new challenges to cost estimators who are arguably more commonly used for forecasting the cost of a 'cross-the-wall' environment. The implications of adopting a concurrent engineering philosophy are significant and often require major changes in long-term business practices. The whole culture must begin to change. Existing cost methods and systems quickly become obsolete and require modernization to reflect the new environment,thus, estimators find it very difficult to predict cost in this new environment using their existing tools. This is not entirely bad because it provides an opportunity to introduce new approaches to old and possibly outdated work practices. This may cause difficulty for some, as technological and technical progress has grown rapidly over the past decade and this period of change can be a frightening opportunity unless practitioners have the opportunity to follow recent trends and developments,and quality costs do not pertain to the production process only, but extend beyond that to all activities in the company, starting from the birth of the idea, research and development, until serving the customer. al, 2015 :67)

The following is an explanation of each of the four elements of quality costs and their connection to value chain activities:

1-**Prevention costs:** Prevention costs include quality engineering and quality planning, and this is related to design activities according to sustainable simultaneous engineering. It also includes the costs of quality training, supplier evaluation, and preparing quality reports, which is related to research and development activity. It is worth noting that the costs of prevention extend to all simultaneous sustainable engineering as it can provide great returns for the company by reducing quality costs related to (configuration and preparation, design, documentation and results, production).

2-**Evaluation costs:** The evaluation costs include the necessary inspection and testing operations for raw materials, production under operation, and finished production in light of the dimensions of sustainability, as well as the costs of evaluating inventory and equipment used in the examination (Horngren, et.al, 2021: 779).The researcher believes that these costs are related to the production activity only, and after documentation and results are done under simultaneous engineering, it may be in conformity with the specifications or not, and thus the costs of repairing it will fall within the costs of internal failure.

3-**Internal failure costs**: These costs occur due to the poor quality of the product, which entails reworking the damaged units and dismantling the defective product, in order to repair it and make it conform to the specifications, and this is before it is sent to the customer: 66) 2015 (Garrison, et.al) and it is linked to an activity Production within sustainable concurrent engineering stages.

4-**The costs of external failure**: (Al-Sharifi, 2005: 64) emphasized that the costs of external failure are the result of several reasons, including:

- The inability of market research to translate the needs and desires of customers to product designers.
- The absence of preventive measures resulting from defects or deficiencies in the products. The costs of external failure are the warranty, customer complaints, and the repair of the defective product after shipment to the customer, and this is related to the activities of distribution and customer service,external failure is also associated with design activity within the simultaneous sustainable engineering stages. , as the improper design of the products may lead to the inappropriateness of the products for use and thus not satisfy the customer, as it is linked to production due to the inefficiency of inspections and stock assessment. (Horngren, et.al, 2021: 779).

Conclusions and Recommendations:

Conclusions:

1. The importance of measuring total quality costs and reporting on them comes through what they constitute an important percentage of sales revenue. Studies have indicated that companies that are interested in managing total quality costs and accounting for them achieve a competitive advantage over other companies, especially since the lack of adequate disclosure about quality costs. Or not categorizing it correctly leads to misleading information and then not achieving the desired benefit of measuring and reporting it.
2. Total quality costs are related to the simultaneous sustainable engineering stages, as the prevention costs are related to research, development and design activities, while the evaluation costs and the internal failure costs are related to the production activity, and the external failure costs are related to the design, production, distribution and customer service activities.
3. By adopting simultaneous engineering, manufacturers can balance the elements of total quality management costs by eliminating unnecessary requirements while focusing on the important and necessary parts.

4. The adoption of simultaneous engineering should be in line with the huge and rapid developments in our time, especially with regard to cost forecasting and the method of estimating it by the committees, taking into consideration the changing and growing quality requirements with technological progress.

5. Concurrent engineering requires a socio-technical approach that takes the environment into consideration as the product and process are developed, as there is a great interaction between this social environment and the concurrent engineering technology and thus orientation towards sustainability.

Recommendations:

1. The necessity of applying the concept of simultaneous sustainable engineering in its scientific name, by clarifying the tools and policies contained in this concept that achieve benefits at various levels for the company, as well as benefiting from the advantages achieved by this method.

2. The management of a company that wants to apply simultaneous engineering technology should devote special attention to this technology and there should be greater communication and flexibility if this technology wants to work effectively.

3. It is necessary to take advantage of the dimensions of simultaneous engineering as a whole, given what these dimensions will achieve in the success of the production operations of the organization in a way that makes them integrated and characterized by parallelism and standardization in order to reach the reduction of total quality management (TQM) costs.

4. The necessity of simulating some successful experiences of applying sustainable simultaneous engineering and total quality management (TQM) and trying to transfer them to the company to take advantage of the benefits that have been reached.

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