# The Impact Of Multidimensional Concurrent Engineering On The Possibility Of Establishing A Hybrid Manufacturing System: An Analytical Diagnostic Study Of The Opinions Of A Sample Of Workers In The Northern Cement Assistant / Badoush Cement Factory

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**ABSTRACT**

By relying on smart manufacturing systems, organizations seek to reduce the damage and loss in their products to the lowest levels, trying to achieve distinctive levels of quality through which they can outperform their competitors. Therefore, this research attempt came to address two important topics in management thought, namely concurrent engineering and the hybrid manufacturing system, in an attempt by the researcher to analyze the relationships correlation and Impact between the dimensions of concurrent engineering represented by (product design, process design, supply chain design) and the hybrid manufacturing system represented by (continuous improvement, waste management, information systems, deferral point) in order to identify the most important dimensions that can contribute significantly to establishing the hybrid manufacturing system. The research was conducted in (Northern Cement Cooperative / Badoush Cement Expansion Plant) on a sample of department managers, division officials and engineers in the company, numbering (213) individuals. The research relied on a questionnaire form for the purpose of collecting data, and used in the research a set of computerized statistical methods using the ((Spss/Amos) system to process and analyze data. The research reached a set of conclusions, the most prominent of which were: The company under study is interested in applying concurrent engineering technology, which enhances the improvement of the hybrid manufacturing system, and its need to achieve distinctive levels of flexibility in manufacturing its products, with the aim of increasing its ability to meet customer demands. The research reached a number of recommendations, the most prominent of which is that the company's management must focus its attention on updating and developing machines and equipment with the aim of adapting them to produce the required products and making continuous improvements to them to achieve distinctive levels of flexibility in manufacturing.

**Keyword :** *Concurrent Engineering; Hybrid Manufacturing System.*

## 1. First Axis: Literature Review

### 1.1 First: Previous Studies on Concurrent Engineering

1.1.1. **Study (Kincade, ETAL-2007) : Concurrent Engineering for Product Development in Mass Customization for the Apparel Industry :** This study pointed to the possibility of the ability of concurrent engineering to rearrange the process of developing production lines for the production of clothing of various kinds from the traditional method to the use of advanced concurrent engineering methods as a method focused on the implementation of the modern processing chain, it also cares about the timing of entry into the market and its needs, where the study aimed to search

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for ways and processes through which the broad recommendation is implemented by addressing a sample of three companies working in the field of clothing industry for three categories (men, women, children), the process of collecting information was carried out through conducting a field survey of these companies and personal interviews, the most important finding of the study is that product development processes using a concurrent engineering strategy are more efficient and effective in real-time order execution, reduced market entry time by using traditional and sequential activities of linear operations.

1.1.2. **Study (OGAWA-2008) Concurrent Engineering for Mission Design in Different Culture :** This study came to show the basic reasons why organizations fail to implement concurrent engineering and design activities effectively, is the cultural factor the decisive factor in determining failure or success through a case study with other successful organizations? This study found that one of the most important reasons for the failure of organizations to implement concurrent engineering is due to some narrow limitations such as reliability, product metrics requirements, lack of clarity of strategic objectives, weak standard design tools, poor support from senior management, as well as lack of design time, these are specific factors that contributed to the failure of organizations in the implementation of concurrent engineering, therefore, these organizations must work on applying a scientific and modern method in the preparation of some business tasks designed to accomplish what is required of them and perfectly, concurrent engineering as a new method helps to reduce cycle time, reducing resources used through collaboration for a computer-based team and improving product quality, CE technology helps to increase the organization's design capability.

### 1.2 Second: Previous Studies on The Hybrid Manufacturing System

1.2.1 **Study (Al-Jubouri, 2020) The Possibility of Applying a Hybrid Manufacturing System and Agile Hexagonal Diffraction to Improve the Process :** This study showed that the hybrid manufacturing system is one of the most important modern manufacturing systems, which solves many of the problems inherent in the inability to apply the agile manufacturing system and agile hexagonal diffraction in order to improve the process, the hybrid manufacturing system is one of the modern manufacturing systems, which represents a new field of study of the problems of companies that seek to achieve responsiveness and flexibility in dealing with changes at high speed using modern technologies such as (agile hexagonal diffraction) and DMAIC methodology, Krongi Company for the production of soft drinks, juices and healthy water was adopted as a field of application of the study, as the study sample included (48) workers in the production line of category (A) for the product (Cola - Kazuz), a conclusion was reached that the company suffers from the problem of its lack of awareness of modern technologies such as the hexagonal diffraction technology, as well as the high cost of using modern technology and applying it in its production lines.

1.2.2 **Study: (Yoshi, 2021) Impact of Leagile Manufacturing System on Industrial Up gradation of Apparel Industry of Bangladesh :** This study sought to explore the impact of the introduction of hybrid manufacturing on the garment industry in Bangladesh, with the aim of improving product quality, reducing costs, raising labor efficiency, and keeping pace with the requirements of the global market, this study also reached solutions to the problem of the extent to which the application of the hybrid manufacturing system contributes to modern industries in order to encourage the owners of the company to increase production lines capable of creating new varieties of modern clothing through the development of the company's technologically targeted machines and using customization and flexible production system, the study found that the hybrid manufacturing system is progressively succeeding in Bangladesh's industries to upgrade their industrial systems, the study also showed that there is a positive relationship between hybrid manufacturing variables, which are not only concerned with continuous improvement and reduction of waste only, but also related to product modernization.

## 2. Second Axis: Study Methodology

### 2.1 First: Research Problem:

Requires keeping pace with the rapid changes and developments in the industrial environment and the existence of a new direction of work responds to those changes, today's existing companies must adopt modern technologies in the field of production that enable them to adapt, survive and grow in the industrial environment and overcome their competitors from the companies working with them in the same field, whereas the intensification of competition and changes in the market environment necessitate these companies to adopt contemporary methods and techniques that enable them to eliminate or reduce the gap between them and their customers, concurrent engineering is one of these techniques that focuses primarily on adopting teams consisting of individuals with distinctive experience and skill that enable them to adopt this approach successfully, as well as suppliers and customers who are also involved in the work in order to design and develop the product and process in order to improve the company's manufacturing performance..., therefore, through the researchers' access to the departments and laboratories of the company, it was found that there is no interest by the company's management in concurrent engineering and its dimensions, although it is available in a form that is not clear due to the lack of knowledge of the company's management of the explicit meaning of this concept, which contributes to enhancing the application of the hybrid manufacturing system, in a way that contributes to increasing its efficiency and effectiveness, which prompted the researchers to address this topic in some detail... Therefore, the researchers deliberately identified the research problem within its specific and functional paths by raising a number of questions that lie in:

i. Do the managers in (Northern Cement Associate / Badoush Expansion Cement Plant) have a clear vision of concurrent engineering?
ii. Is there a correlation between the dimensions of concurrent engineering and the hybrid manufacturing system in the field studied?
iii. Is there an impact of concurrent engineering in the hybrid manufacturing system?

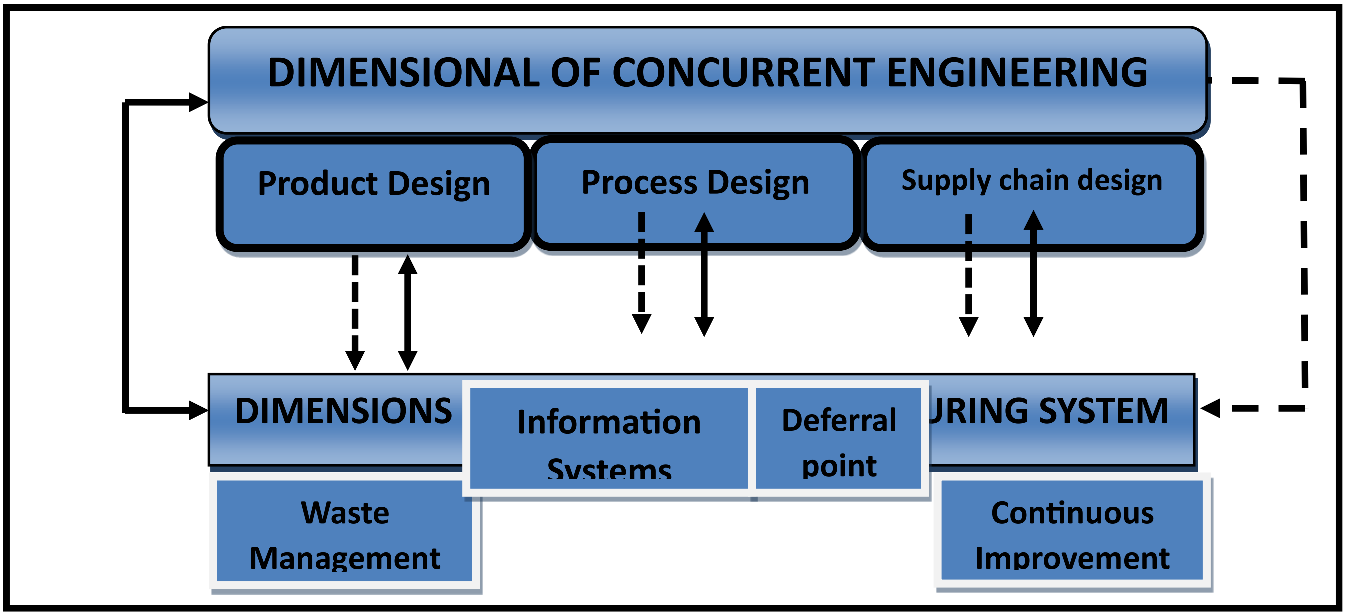
### 2.2 Second: Research Objectives: The research aims at a number of things represented in

i. Identify and diagnose the availability of concurrent engineering dimensions and hybrid manufacturing system in the field researched.
ii. Test the correlation and influence relationship between the dimensions of concurrent engineering and the hybrid manufacturing system statistically in the research principles
iii. Coming up with a set of recommendations for the field of research in the field of application of the dimensions of concurrent engineering according to a strategic plan and scientific methodology take into account the attention of the basic success factors to apply them in order to improve performance in an optimal manner.

### 2.3 Third: Research Importance: The importance of research can be clarified through the following:

i. The importance of the research stems from the importance of the variables that the research seeks to address (concurrent engineering, hybrid manufacturing) being contemporary approaches consistent with the goals that most companies seek to achieve in the field of product design, process and supply chain, as well as trying to enhance the ability of the research field to keep pace with the continuous changes in the use and application of technologies that contribute to the applicability of the hybrid manufacturing system.
ii. Provide a theoretical and field framework linking concurrent engineering and hybrid manufacturing system, this link represents a modest scientific addition provided by the researchers that can be a new contribution to the Arabic library.

### 2.4 Fourth: Hypothetical Research Scheme: The hypothetical scheme of the research was built in the light of the contents of the research problem, its objectives, which clarifies or determines the main variables and the influential relationships between them, as shown in Figure (1).




**2.5 Fifth: Research Hypotheses: The current research depends on testing the validity of the following two main hypotheses:**

**First**: There is a significant correlation between the dimensions of concurrent engineering (combined) and the hybrid manufacturing system,

The following sub-hypothesis emerges from the first main hypothesis:

**A.** There is a significant correlation between the dimensions of concurrent engineering (**Singular**) and the hybrid manufacturing system.

**Second**: There is a significant effect of the dimensions of concurrent engineering (**Combined**) in the hybrid manufacturing system, and the following sub-hypothesis emerges from the second main hypothesis:

**B.** There is a significant effect of concurrent engineering dimensions (**Single**) in a hybrid manufacturing system.

**2.6 Sixth: Research Methodology**

The researchers relied on the descriptive analytical approach in their research, which included office and electronic surveys in order to benefit from references and sources to build the theoretical framework for research, the questionnaire form was also used to collect data from the field and was analyzed statistically to test the research hypotheses.

**2.7 Seventh: Research Limits**

A. **Time limits**: The period in which the research was prepared extends from 21/12/2024 to 27/3/2025 for both theoretical and field research aspects.

B. **Spatial limits**: The Northern Cement Assistant / Badoush Expansion Cement Plant was chosen as a field of research because it is one of the organizations that have passed through different leadership styles during the performance of its work.

C. **Human limits**: The research sample was represented by a number of individuals working in the sections of the field researched .

**2.8 Eighth: Means of data collection and processing tools**

The researchers adopted the questionnaire form that was prepared based on the theoretical side of the research, in addition to taking the opinions of a number of professors specialized in the field of current research, the interview was also relied upon to collect data from working individuals, the sample included a random group of individuals, so the number of forms that were distributed was (222) forms, of which (213) forms were retrieved, so the response rate was (96%). The form included three main axes, the first axis included the personal data of the individuals surveyed, and included (age, gender, academic achievement), the second axis included phrases related to concurrent engineering, while the third axis included phrases related to agile manufacturing, where the Likert five-point scale was used to measure a variable and dimensions of the research.

## 3. Third Axis: Theoretical framework of research

### 3.1 First: Concurrent Engineering

#### 3.1.1 Historical development of concurrent engineering

The literature suggests that the concept of concurrent engineering is not a newborn, in an article on the historical roots of concurrent engineering Smith concluded) that concurrent engineering is the synthesis of the best applications developed since the beginning of manufacturing to solve the various problems encountered during the development of product manufacturing (Makinen,2011:20), this concept emerged in the early sixties of the last century in the US state of Lockheed, presented by the Advanced Project Group (Barzanji, 2007: 23). The term actual concurrent engineering began to emerge in the 1980s due to threats that emerged as a result of the growth of Japanese industries that forced many American and Western industrial companies to carefully research their practices and activities to develop their products and production processes, since then it has been adopted in many literature in the field of engineering and management, it has become a key element of product development and process in many electronics and communication companies (Makinen, 2011, 20), At the end of the 1980s, American, Japanese and German companies used concurrent engineering in the manufacture of automobiles, aircraft, machinery, computers, electronics, etc. Concurrent engineering was seen as an active element in improving quality and reducing cost (Hongjun & Tiancheng, 2010:1). In the mid-nineties, the concept was used as a comprehensive philosophy that takes into account the concurrent design of the product and all its processes related to the product life cycle in a parallel manner, at the beginning of 1991, Carver & Bloom presented a concurrent architecture structure in which they explained that it refers to the integration of people, systems, and processes through an efficient and responsive system (Sami, 2013:29).

#### 3.1.2 The Concept and Definition Of CE

Concurrent engineering has received its synonymous concept as a philosophy of production management that receives great attention in the field of manufacturing in order to achieve the desired goals to save time, it means overlapping processes rather than sequencing them in product design and process (Bogus, *et.al*., 2005:1).

Concurrent engineering takes into account all areas that affect design concurrently and concurrently (Makinen, 2011:4), The idea of concurrent engineering has been developed to allow designers to evaluate their designs as much as possible, in traditional methods, the development and evaluation of different products was a repetitive work that involved wasting a lot of time, which necessitated the need to evaluate different products and eliminate routine methods (Prieur, 2006:31). The idea of concurrent engineering is based on the implementation of many steps of the project process in real time whenever possible rather than in a sequential manner, this calls for a cross-functional team that includes a wide variety of individuals from different departments (Shouke, *et.al*., 2010:709).

There are many concepts and names synonymous with concurrent engineering that refer in their content to concurrent engineering but differ from it in terms of nomenclature, however, the most common designations are Concurrent Engineering, Parallel, or Concurrent as a collaborative approach to product development, all related functions, including design, manufacturing, marketing, and finance, are involved in the product development team to secure design requirements and ensure production, marketability, and financing, this ensures early treatment of problems at a lower cost, higher quality and less waiting time (Al-Faihan, 2011: 42). According to the above, the researchers have worked hard to define a specific definition of concurrent engineering, it has been defined as "a structured approach to the concurrent design of processes associated with product design considering all elements of the product life cycle from a concept or idea." Until the product was put on the market including quality, cost, schedule and user requirements (Khalfan, *et.al*, 2001:223), Referred to it as "the idea or concept that brings production and process engineers, marketers, buyers, information specialists, quality specialists and suppliers together to design the product and processes necessary to meet the needs of the customer. (Krajewski, *et.al*, 2010:380).

(Alkaraz, *et.al*., 2014) Noted that it is a combination of multiple tools to help eliminate activities that do not add value to the product or process by increasing the value of each activity, and aims to eliminate or reduce waste and improve processes, it is an approach to achieving excellence in manufacturing based on the continuous elimination of waste, and uses technologies that improve the efficiency of value-added activities. While both added (Botti, *et al*.,2017) stated that it is a manufacturing strategy that aims to increase profit while reducing resource consumption, on-time production, lean reduction, continuous improvement strategies, flawless production and work standardization are key characteristics of lean manufacturing. He also added (Davim, 2018, 70) as an organizational philosophy aimed at systematically eliminating waste in the manufacturing process and adding value to customers.

**3.1.3 Advantages and importance of concurrent engineering**: Kamara and colleagues have shown that the advantages of concurrent engineering are as follows: (Kamara, *et al*., 2007:2)

- Integrate product information, process information, and business information across the project lifecycle, and integrate lifecycle issues into product design definition.
- Integrate the supply chain involved in the delivery of the project through effective cooperation, communication and coordination.
- Integrate techniques and tools used in the project development process (e.g., through cross-work).

Dhillon pointed out that the importance of concurrent engineering is summarized as follows: (Dhillon, 2002: 173)

- Focus on the customer and include them in the process.
- Early and continuous intervention of processors in the process of designing multi-functionality, self-orientation, team empowerment.
- Increased participation in the use of information.
- Focus on the life cycle.
- Organizational and integrated approach.
- Concurrent design teams.
- Use of modern tools (CAE/CAM/CAD) and analysis of specific elements.
- Continuous improvement of all processes.

**3.1.4 Basic Principles of Concurrent Engineering**: Concurrency and simultaneity are the main forces of concurrency engineering, synchronization and timing can be achieved by enabling or activating seven principles (Anumba, *et al*., 2000, 201-203).

1. Parallel work group: Parallel work groups are one of the basic elements of concurrent engineering, concurrent engineering revolves around multi-functional teams that bring the necessary specialized knowledge to the project.
2. Parallel Product Decomposition: Product Decomposition is an essential input to address complexity in design, this decomposition allows activities to be scheduled to start in parallel. Many aggregates can be resolved seamlessly although not all events of the product lifecycle are independent.
3. Concurrent Resources Scheduling: It means scheduling distributed events so that they can be performed in parallel, there are many cases in which the events are fixed but need to be scheduled in parallel with other events, and the simple case is overlap, there is no need to wait until the other task is finished, although each activity depends on the other, if a new activity is initiated and generates the information required for a subsequent activity, the subsequent task must begin as soon as the required information is available, there is no need to wait to complete the previous task. If the two activities are independent, they can be scheduled in any order necessary.
4. Concurrent Processing: The time management process is the fulcrum of concurrent engineering, and concurrent processing means the direction and optimal arrangement of events in the distribution of work groups and building information, concurrent treatment is not easy, especially in industrial environments that are culturally oriented and resistant to change, events in concurrent engineering are organized in a series of overlapping dates (performed spontaneously or overlapping) and are not executed sequentially, keeping up with these complex functions that vary over time is a critical task in concurrent processing and appropriate synchronization efforts must be made between different concurrent engineering teams.
5. Minimize Interfaces: It entails minimizing all types of interactions required for product processes, these include the interaction between cost management, design, manufacture, assembly, procurement, processing... Etc. Such interactions are very long and tend to depend on the size of the industry and the complexity of the process, the main focus is on diagnosing the different sources of interactions and determining whether they are actually needed or not.
6. Transparent Communication: This provides virtual communication between individual divided (analyzed) events and team members, transparent communication involves diagnosing and identifying critical message data, all team members need to have the same common understanding of frequently used terms and their meanings, the elements that contribute to transparent communications are: global reach, global product representation, electronic data interchange, and technical memory.
7. Quick Processing: It means performing individual activities as quickly as possible using production tools or design aids and accelerating the preparation time in building information content before and after the implementation of the activity, this confirms the mandate to shorten the pre- and post-processing time and the time it takes to complete the dissolved events themselves.

**3.1.5 Dimensions of Concurrent Engineering :** The dimensions of concurrent engineering can be determined by addressing two basic inputs:

**First Entrance: 2D - CE interface:**
This approach assumes that product design and production processes should be real-time involving a multifunctional team, which in turn includes both suppliers and customers (Albizzati, 2012:8). The concurrent design of the product and process results in a design that includes more precise processes in terms of expertise and technology, as a result, costs are generally reduced as well as outstanding levels of quality are achieved (Finch, 2006, 119), and Foster pointed to two main stages in engineering: product design and process design, product engineering includes all activities associated with product development, starting from concept development to final design and implementation of this design, and product design and process are one of the basic fields of engineering, concurrent engineering is a product of the concurrent performance of these activities and has allowed managers and engineers from different fields to work together and concurrently in the development of both product design and process (Foster, 2001:9). Marchetta and colleagues stated that for the integration of product design and process, concurrent engineering must be used, whereas, the design of parts, production planning, as well as manufacturing facilities, must be taken into immediate consideration for this purpose, the design and manufacturing cycle can be reduced with attention to manufacturing constraints and early whenever possible, because markets are characterized by development and change, therefore, it requires advantages for different options and the decrease in batch size has increased the need to design and manufacture the product together while avoiding delays in delivery (Marchetta, et al., 2011, 18). In this approach, the product design is implemented at the same time as the process is designed through the continuous interaction between the two.

**Second Entrance: 3D - CE concurrent engineering entrance**
Fine is the first to submit a proposal to add the third dimension of the processing chain to the other two dimensions by recognizing the strategic nature of the equipment chain design according to his view, the concurrent design of the three dimensions is called 3D concurrent engineering (3D - CE) (Fine, 1998:272), most researchers agree that the dimensions of concurrent engineering are three basic dimensions that are implemented concurrently: product, process and supply chain (Albizzati, 2012: 22). These dimensions will be adopted as basic variables in the research due to their compatibility with the field researched… The dimensions of 3D-CE engineering are illustrated below:

**The First Dimension : Product Design**: Product design is strategically important for manufacturing processes, because every business needs a long-term vision or plan, so the company's product manufacturing strategy must support product designs, it is keen on the participation of customers in product design decisions to suit the preferences and needs of the customer group targeted by the company's business strategy on the one hand, and to maintain its customer base and position in the market on the other hand.

(Al-Bakri, 2001:175) defines product design as "putting the specifications and forms of a particular product, a good or service, in a template that enables the organization to meet the needs of consumers in the market, according to (Slack, *et al*.,1998:108), product design is "a conceptual treatment by which a number of functional requirements of customers are satisfied individually or collectively through the use of products, concurrent engineering is used to ensure that product designs match the capabilities of production companies efficiently, it emphasizes the involvement of process management specialists along with design specialists in product design at every stage of product design and manufacture (Martinich, 1997: 215, 216). (Slack, *et al*., 1998: 166) suggest that concurrent engineering refers to how products will be designed and made, companies try to reduce the time and costs required to deliver products to customers and improve their quality, this can only be done through the participation of the various specializations available to companies from operations, marketing, finance, sales and others specialists with each other.

**The Second Dimension: Process Design**: (Slack, *et al*., 2004) shows that process design is "the process by which certain functional requirements of individuals are satisfied by establishing a framework or form for the resources and activities that constitute the good or service, or the transformation process it provides." The design of the process includes identifying all the individual activities required to achieve its objectives and determining the sequence through which the daily activities of each individual participating in the process and who will perform it will be performed, when designing the process, there are some limitations in carrying out some activities before others, as well as the fact that some activities can be performed by specific individuals or machines (Slack, et al., 2004:102). Process design objectives must be well understood and the sequence that leads to their achievement must be determined in order to reach an effective process design that contributes to supporting other activities in a way that leads to a more effective response to internal and external customers, hence, the effective contribution to supporting the competitiveness of the operations function represented by competitive priorities through the significant impact of process design on the activities of operations on the one hand, and on determining the role of each individual in performing the tasks of the process on the other hand (Al-Jashami, 2013: 71). Therefore, it is necessary when designing the process to determine whether the process will be used to make a product or to prepare a service, determining this is important because it will in turn be reflected in the identification of human resources, materials and equipment used (Krajewski & Ritzman, 1999:88).

**Third Dimension: Supply Chain Design**: Supply chain design means the ability to coordinate and cooperate between suppliers, manufacturers, distribution channels and customers, it is an integral part of the strategic planning process of any organization, because the supply chain includes all the functions and operations of the organization, providing high-quality products and services should be at the lowest cost (Ali, 2005:46). (Corbett & Karmarkar, 2001:966) show that the main determinant of supply chain design is the cost structure associated with major manufacturing processes, supply chains often consist of several layers, with different numbers of organizations competing in each layer. (Lambert & Cooper, 2000:17) added that the process of supply chain integration and re-engineering should be designed to increase the efficiency, effectiveness and equal delivery of benefits throughout the supply chain, thus, the supply chain adds value not only to the organization, but to the whole supply chain network to include even the end customer, supply chain management does not achieve its objectives efficiently if it performs its work independently and individually, while it is more efficient when it operates as an integrated network of rings, the objectives of the chain have become more expansive because the delivery of the product in time, space and cost requires coordination between the links of the chain (Dilworth, 2000: 374). (Ali, 2005:46) pointed out that the aim of designing the supply chain is to minimize inventory and achieve better cooperation and coordination between suppliers, manufacturers and customers.

**3.1.6 Phases of Implementation of Concurrent Engineering**: The stages of implementation of concurrent engineering are classified into three stages, which are as follows: (Ogawa, 2008: 18):

**First Phase: the preparation phase**: Before starting the actual activities of the design, there are many things that must be prepared to prepare because the design sessions are an opportunity for intensive team work and in a short period of time, as the design process will stop when there is a lack of information, resources or capabilities of the company or work team, hence the most important requirements in the stage of preparation and preparation are:

- Define the customer's requirements or special needs.
- Inclusion of required system functions and specialists in each discipline.
- Determine the scope of the design process.
- Capabilities, tools and specialists.
- Inclusion of beneficiaries' inputs.

The inclusion of the customer's requirements or needs gives the design team a preliminary perception of how difficult the technical challenges are and in what area, it also determines the nature of the tools to be used and the tools that must be developed or adapted to cover and analyze the proposed design, this stage requires tight communication between the team manager, the project manager, customers and engineers to determine the overall workload, and this process plays an important role in the implementation of concurrent engineering, as despite the presence of specialized skills and expertise and high social skills, but not good preparation results in critical times, which may extend from one to eight weeks depending on the size and type of experience required.

**Second Phase: Design Phase**: This sub-process is the one that creates the most added value from concurrent engineering, where the process of actual integration between work teams, specialized expertise, work environment, communication systems and physical integration of information systems with other physical components is witnessed, at this stage the idea of an open office (Open Office) is adopted, as is the case in Japanese companies, so that team members see what others are doing, this enables direct and open discussions and dialogues between team members as well as the creation of an integrated information environment to answer emerging questions.

Post Design Phase: Includes automated documentation of design activities and design session outcomes which is translated into a final report that includes design information, logical processes for implementation, alternation between technical and customer requirements and other information.

## 3.2 Second: Hybrid Manufacturing System

**3.2.1 The Concept of Hybrid Manufacturing System** : The hybrid manufacturing system is one of the modern systems in the field of manufacturing, as it works to achieve integration between multiple technologies to achieve the highest levels of efficiency and accuracy, this system aims to take advantage of the advantages of each of the advanced manufacturing techniques and reduce the weaknesses in each of them, therefore, the hybrid manufacturing system has become an ideal choice in advanced industries that require in their production processes precise and complex methods, the concept of hybrid manufacturing system is relatively recent, as this concept appeared in (1999), in fact, the concepts of agile, efficient and hybrid manufacturing stem from the supply chain management literature, where hybrid manufacturing is a newly emerging technology that focuses on the comprehensive view in management and on raising the level of service, it also works to achieve a balance between the level of performance and the level of cost by making good use of the advantages provided by this comprehensive view, the philosophy of hybrid manufacturing has attracted the attention of researchers and industrialists all over the world, especially after the fierce market competition in the business environment, the short life cycles of products at present, and the high prices of resources, the increasing number and diversity of customers is therefore a competitive advantage of great benefit compared to the rest of the manufacturing systems, as it seeks to significantly improve the performance of production processes (Muhammad, 2019, 144).

From the above, it is clear that there are still different views among researchers regarding the concept of a hybrid manufacturing system, based on this difference and divergence in their intellectual premises, we will review some of the researchers' contributions to the most important contemporary concepts of the hybrid manufacturing system and according to their chronology, (Nagaba, 2016,15) emphasized that a hybrid manufacturing system is a combination of agile and efficient models that stem from the overall supply chain strategy and by identifying the point of non-convergence (postponement) that is not commensurate with market fluctuations and customer demands. As explained (Virmani, 2017, 94) that the hybrid manufacturing system uses modern technical systems and virtual companies to explore profitable opportunities, especially in volatile markets, and develops the process of value flow and eliminate losses, while (Naveen,2018,386) pointed out that it is a strategy based on measuring the effectiveness and efficiency of the activities and operations of organizations by improving their work to reduce the cost of producing the product and to be a basic pillar that meets the needs and desires of customers, (Dao, 2019, 46) showed that if it is achieved, we can produce with the least amount of waste due to the elimination of unnecessary activities and inefficient processes that do not add value to the product, while the system must be effective and flexible to suit the ever-changing requirements of customers, (Fatime, 2019, 2) also emphasized that a hybrid manufacturing system is a system designed to achieve maximum benefit by combining performance standards that include cost, flexibility, quality and reliability, which gives indicators of great diversity in products as well as addressing activities related to technologies, equipment and machinery through continuous improvement and inventory reduction, (Dulanji, 2020, 1136) noted that the system is a methodology that promotes synergy through effective and agile systems, by achieving high flexibility through the optimal use of inventory and the strategy followed to deliver products, specifically in the field of manufacturing.

(Al-Bakri, 2021, 50) indicated that the hybrid manufacturing system is nothing but the philosophy of integrating the two systems of agile and efficient manufacturing through production with minimal damaged or lost production and optimal use of the organization's resources, using agile processes, focus on achieving market and customer requirements while achieving high product diversity across efficient processes, based on the above, the researchers have developed a concept of hybrid manufacturing that it is an advanced method of manufacturing that combines more than one production technology in one process or system, such as the combination of manufacturing such as 3D printing and subtract manufacturing (such as turning or milling). This integration aims to take advantage of the advantages of each technology to provide outstanding accuracy, speed in production, and flexibility in the design of complex parts, while reducing waste in materials and time.

**3.2.2 The Importance of The Hybrid Manufacturing System**: In light of the rapid development of manufacturing technologies and the increasing need for more complex and accurate products, hybrid manufacturing has emerged as one of the effective solutions to meet the requirements of modern industries, the importance of this type of manufacturing lies in its ability to integrate more than one production technology, allowing to take advantage of the advantages of each of them and overcome their disadvantages, stressed (Kawa, 2019,235) that hybrid manufacturing enables organizations to use methods and systems that would work to produce goods and provide services that take into account the level of cost and quality while reducing the lead times between the customer's request and meeting it, as this type of manufacturing works to add value to the final product, in the same context, (Khote, 2024, 612) pointed out that the hybrid manufacturing system has a number of advantages that are important in the following advantages:

1. Reduce material waste and energy consumption: by performing tasks accurately and reducing unnecessary operations, hybrid manufacturing contributes to reducing material losses and energy consumption, which reflects positively on cost and the environment.

2. Production of complex components with multiple functions: hybrid manufacturing can produce parts with fine details and complex internal structures, this opens the door to new designs that were previously difficult to verify.
3. Flexibility in design and modification: Hybrid manufacturing allows designs to be easily modified during the manufacturing process, this provides high flexibility in meeting changing customer requirements.
4. Integration with intelligent manufacturing systems: Modern hybrid manufacturing systems integrate with technologies such as digital twin and live monitoring, which enhances the quality of production and reduces errors.
5. Repair and remanufacturing of parts: Hybrid manufacturing can be used to repair or remanufacture damaged parts, this extends the life of the equipment and reduces costs.

**3.2.3 Dimensions of Hybrid Manufacturing**: The hybrid manufacturing system is one of the modern and advanced systems that mix more than one production technology within the same manufacturing environment, with the aim of making the most of the advantages of each dimension and achieving superior efficiency and outstanding quality in products, hybrid manufacturing is based on a set of basic dimensions that determine the effectiveness and efficiency of the system, the dimensions of the hybrid manufacturing system include several main elements that the researchers agree are important, and the dimensions of the hybrid manufacturing system were determined with what (Fatime,2019,58) and (Yaacob,2020,680) went to in four dimensions: (continuous improvement, waste management, postponement point, information systems) being the most useful in serving the research field under its components that contribute directly to improving the quality of products as follows:

1. **Continuous Improvement**: The roots of the concept of continuous improvement or (Kaizen) according to the language of the Japanese go back to Japan, after World War II Japan began what was called reconstruction operations, many Japanese companies such as Toyota, Toshiba have implemented and adopted continuous improvement programs (Kiki, 2012, 122). The philosophy of continuous improvement consists of a set of elements, namely customer focus, teamwork, on-time production, comprehensive productive maintenance, quality rings, automation, management and personnel cooperation, it aims to work on the development of processes and activities related to individuals, machinery, materials and production methods continuously and to reach full mastery of the continuity of improvements in the company's production processes, continuous improvement with Kaizen is a pioneering idea to eliminate waste in processes, where the Kaizen principle is based on the fact that all employees in the organization have the right to continuous development and change, through small steps, which have a great impact in the future, every work carried out can be improved, every process must contain some waste, whether material, moral, or intellectual, and reduce this waste even by small percentages (Hamid, 2016,4).

Mentioned (Juma, 2016,3) as a system that aims to eliminate waste across all processes and activities in the organization by involving everyone in the organization to make improvements without the need to make huge investments. Defined it (Al Baik & Miller, 2016, 389) as a comprehensive thinking philosophy that includes many techniques and methods that empower employees and encourage them to constantly rethink the way they perform their work in a more efficient and effective way, regarding the goal of continuous improvement, (Mora, 2014) indicated that it aims to improve information, material flows and products in order to control the quality and costs of production. (Smith, 2016, 21) stated that it enables the organization to increase the efficiency of its work and improve its performance, enhance the spirit of cooperation and teamwork, and reduce the complexity of the manufacturing process, reduce production cycle time, reduce inventory, increase serviceability, and increase employee and customer satisfaction alike (Baomer,2017,29)

2. **Waste Management** : Waste management is one of the most prominent environmental and economic challenges facing modern societies, especially in light of the rapid population growth and increasing industrial development, defined by Beer (Beer, 2013, 8) as the purposeful and systematic control of the generation, storage, collection, transport, treatment, recycling, recovery and disposal of productive waste in a hygienic, aesthetically and economically acceptable manner, while (Frostel, 2014, 800) sees waste management as the control of the processes of generation, storage, collection, transportation, treatment, recycling, and final disposal of waste in its various forms in a manner and manner consistent with public health standards and environmental considerations, (Baird,2016, 88) pointed out that waste management is a social, environmental and institutional culture that effectively affects the continuity of its sustainability (waste management based on long-term strategies). Explained (DJAJA, 2017,1) that the management of industrial waste in its various forms has become a science and art and in continuous development, where many international organizations seek to innovate methods, methods and techniques to reduce and treat this waste, and to design an appropriate administrative system to achieve several goals, most notably:

1. Community health protection.
2. Achieving superior quality to protect the environment.
3. Save energy and reduce the depletion of natural resources and conserve them to achieve sustainability.
4. Reduce environmental degradation .

Added (Ilakovac, 2017:241) that the goal of any scientific system of standards for industrial waste management is to reduce and discharge pollutants to maintain the quality of life, these criteria may be direct so as to stipulate the maximum concentration of pollutants through the development of production, and through this the types and requirements of production as well as the quality of products are determined, based on several aspects directly related to the waste management system, these aspects support each other, and interact with each other, and Figure (2) shows the most prominent of these aspects.

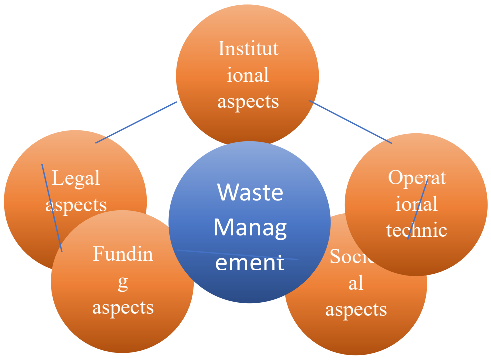



**Fig (2): Aspects of the waste management system**

**Source**: Mukhit,2018, The Importance of Integration Waste Management Aspects as a System in Good and Sustainable Waste Management. Journal of collaborative global commons vol. 73.N 70. P2

Based on the above, researchers define waste management as a set of processes that aim to collect, transport, treat and dispose of waste in a safe and efficient manner, while minimizing its negative impact on the environment and public health, modern waste management systems seek to achieve sustainability by applying the principles of reduce, reuse, and recycling, as well as adopting advanced technologies to convert waste into energy or new resources, waste management is important not only on environmental aspects, but also on economic and social dimensions by reducing costs, enhancing employment opportunities and preserving natural resources.

3. **Information Systems**: Information systems play a pivotal role in supporting and developing hybrid manufacturing systems, as they are used to collect data from various stages of production, analyze them, and monitor processes in real time, by integrating information systems with hybrid manufacturing technologies, organizations are able to improve product quality, reduce costs, and increase operational efficiency, these systems also contribute to the coordination of manufacturing processes, enhancing its accuracy and speed of response to market needs, the term information systems appeared in the mid-fifties and sixties of the last century at the beginning of the era of information explosion to indicate the rapid increase in the field of scientific information production, followed by the emergence of the information revolution in the mid-seventies, this resulted in recent developments in the field of production and manufacturing, and the view of this technology differed according to the fields applied in it, defined (Karim, 2011, 459) as a set of sequential production techniques made in a modern way with the development of methods and performance of production processes in a broad sense, i.e. includes administrative, organizational, social and service activities to achieve the goals of the organization, (Beikzad,2013, 374) sees a strategic weapon that can help build and strengthen the organization's productive capabilities by providing the latest advanced digital programs through which the organization's relationship with suppliers, customers and other organizations can be strengthened. Stressed (Al-Bakri, 2021, 63) that it is the basic base in which administrative organizations build their competitive advantage, systems of all types of scientific and applied knowledge that can contribute to the provision of equipment, machinery, mechanical and electronic devices with high efficiency and better performance, which reduces human effort and saves time and achieves the organization's qualitative and quantitative goals with distinctive efficiency and effectiveness.

Pointed out (Jesson, 2018, 78) that many studies that deliberated on the subject of information systems monitored many factors that had an important role in the use of these, among the most prominent of which is the impact of economic globalization and the accompanying breaking of traditional barriers between markets, the intensive use of information in production processes, the great development in the business environment in the current era and its impact on changing the structure and structure of activities and methods used, the rapid technical change and its impact on the decline in transport and communication costs in the world, fierce competition that forced many industries to search for new and advanced production methods to increase their efficiency.

4 **Postponement point**: It is a management concept used in supply and production chains, it refers to the stage at which the allocation of the final product is postponed or the allocation of some process (such as packaging or customization to the customer) until an actual order is obtained from the customer, where (Can, 2008:6) touched on the concept of the deferral point as a technology that gives industrial companies the ability to manufacture different shapes and types of goods and services according to the customer's request, at relatively low prices, with high quality and specifications, and relying heavily on total quality management in order to achieve competitive advantage in business organizations. (Juan, 2010, 249) stressed that the postponement point is a comprehensive manufacturing method through which organizations ensure the production of complete goods on time to eliminate waste in the design, manufacturing and production process, and (Wang, 2010, 21) indicates that the point of postponement is a successful strategy that focuses on the principle of flexibility in production processes to provide adaptable goods and services to satisfy special needs according to customer requests and respond to their desires as soon as possible and less expensive. (Seyedi, 2012:648) has defined the point of postponement from two theoretically different aspects, several strategies based on preparing customers with anything they want and in any way they prefer, while the practical side is based, (Howells, 2024, 8) indicates that it is a stage in which the implementation of some activities such as final assembly, packaging or customization is postponed until an actual order is received from the customer or the parameters of market demand become clear, the goal is to reduce unnecessary inventory, offer customized products, and achieve greater flexibility in meeting changing market needs, and (Shahin, 2016, 1) indicates that the postponement point works to reduce production costs by improving and coordinating production networks by adopting three main factors that have an important role in determining the postponement point (product, production factors, market).

## 4. Fourth Axis: Practical Side

**4.1 First: Description of the research sample**: An intentional sample was selected represented by the individuals surveyed who have experience and know-how and are aware of the activity of the laboratory and its tasks to ensure that the benefit is achieved from the accurate and useful information provided by them, as well as the possibility of obtaining ideas and proposals that enhance the importance of research, in line with that, the researchers began to distribute (222) forms that included both the general manager, heads of departments, directors of branches, units and divisions, as well as supervisors of production lines, (213) valid forms were obtained for analysis, that the response rate reached (96%).

**4.2 Second: Factorial Confirmatory Analysis**: Factor Factorial Analysis provides a set of indicators, which are called good conformity indicators, which must fall the indicators of the hypothetical scheme within its range in order for the model to be acceptable and valid for the analysis of research hypotheses, we also relied in the current research to apply the confirmatory factor analysis on the method of (Scale Free Least Square) instead of the method of Maximum Likelihood, which requires the availability of a set of conditions, including that the data be distributed normally and that there are no abnormal values, the sample size should be five or ten times more than the number of variables observed (Hsien, 2016, 375) (Sabaoui, 2019, 20). This condition was not met in the data for the current research, as shown in Figure 3 and Table 1.

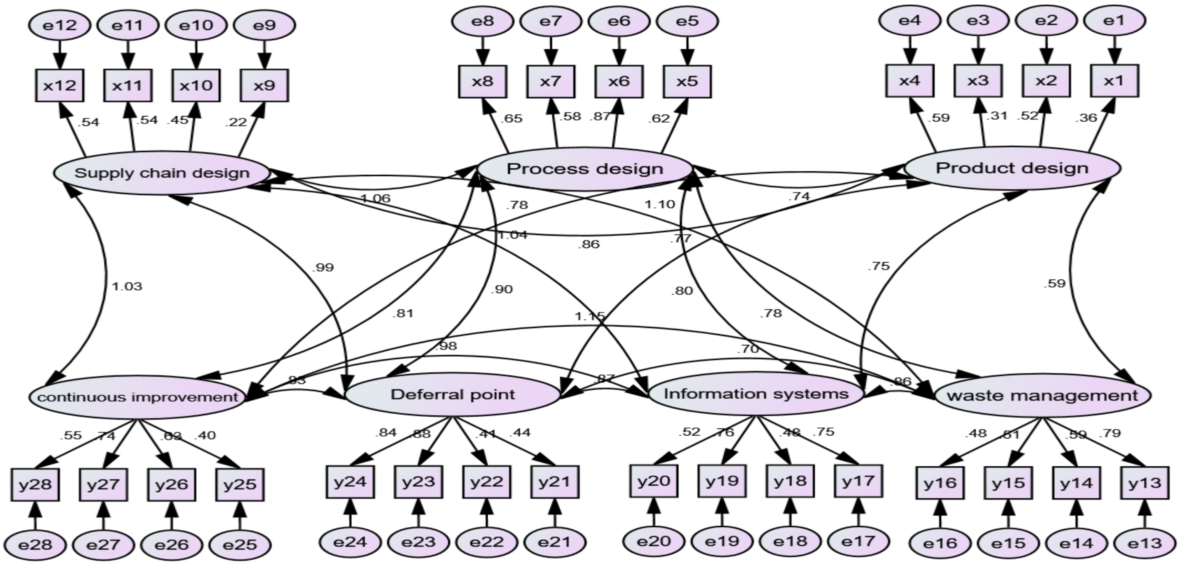



**Figure (3) Prototype**

**Table (1) Quality indicators of the prototype of research**

| Standard indicators | Admission Limits | Model indicators | Matching result |
|---|---|---|---|
| GFI | GFI > 0.90 Model Quality | 0.965 | Matching |
| AGFI | AGFI > 0.90 Best Match | 0.957 | Matching |
| RAMMER | RMR value between 0.08 and zero | 0.069 | Matching |
| NFI | NFI > 0.90 Best Match | 0.953 | Matching |
| RFI | RFI >0.90 Data match with model | 0.946 | Matching |

**Source**: Table prepared by the researcher

We note from Table (1) that the indicators of the hypothetical scheme are good and fall within the limits of the model quality indicators, thus, the model is accepted without modification and becomes eligible for the stage of testing research hypotheses.

4.3 **Third: Hypothesis Testing**: After carrying out the confirmatory factor analysis and ensuring that our research model conforms to the field data and reaching the model to the required conformity quality standards, we will move on to testing the research hypotheses as follows:

4.3.1. **The first main hypothesis**: there is a significant correlation between the dimensions of concurrent engineering (**combined**)

**Hybrid manufacturing system**: This axis undertakes the task of verifying the validity of the first main hypothesis, which states that there is a significant correlation between the dimensions of concurrent engineering (combined) and the hybrid manufacturing system, whereas the data of Table (2) indicate that there is a positive correlation between the dimensions of concurrent engineering (combined) and the hybrid manufacturing system, the correlation value was (0.963*) at a significant level of (0.05), thus accepting the first main hypothesis

**Table (2) Relationship between the Dimensions of concurrent Engineering (combined) and the hybrid manufacturing system**

| **Independent variable** / **Dependent variable** | **Dimensions of Concurrent Engineering** |
|---|---|
| Hybrid Manufacturing System | 0.963* |

**Source** : Table Prepared by researcher

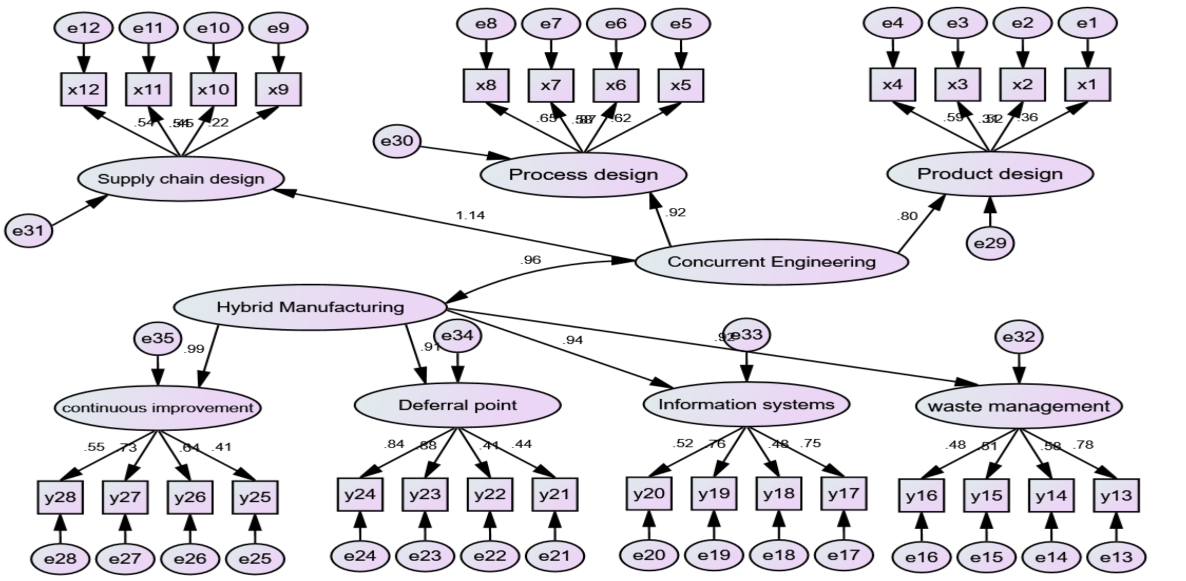



**Figure (4) Correlation model between concurrent engineering (combined) and hybrid manufacturing system**

**The following sub-hypothesis emerges from the first main hypothesis:**

A. There is a significant correlation between the dimensions of concurrent engineering (singular) and the hybrid manufacturing system .... As described in:

1. The relationship between dimension (product design) and hybrid manufacturing system: This axis undertakes the task of verifying the validity of sub-hypothesis (a) of the first main hypothesis, which states that there is a significant correlation between the dimension (product design) and the hybrid manufacturing system, the data of Table (3) indicate that there is a significant correlation between the dimension (product design) and the hybrid manufacturing system, as the value of the correlation coefficient was (0.778*) at a significant level (0.05).
2. The relationship between dimension (process design) and hybrid manufacturing system: This axis undertakes the task of verifying the validity of sub-hypothesis (a) of the first main hypothesis, which states that there is a significant correlation between the dimension (process design) and the hybrid manufacturing system, the data of Table (3) indicate that there is a significant correlation between the dimension (process design) and the hybrid manufacturing system, as the value of the correlation coefficient was (0.884*) at a significant level (0.05).
3. The relationship between the dimension (processing chain design) and the hybrid manufacturing system: This axis undertakes the task of validating sub-hypothesis (a) of the first main hypothesis, which states a significant correlation between the dimension (processing chain design) and the hybrid manufacturing system, the data of Table (3) indicate that there is a significant correlation between the dimension (supply chain design) and the hybrid manufacturing system, as the correlation value was (0.999*) at a significant level (0.05).

**Table 3: Correlation between concurrent engineering dimensions (single) and hybrid manufacturing system**

| Dimensions of concurrent engineering | Product Design | Process Design | Supply chain design |
|---|---|---|---|
| Hybrid Manufacturing System | 0.778* | 0.884* | 0.999* |

**N = 213** **P ≤ 0.05**

**Source** : Table prepared by researcher

In light of this, sub-hypothesis (a) of the first main hypothesis of a positive significant correlation between the dimensions of concurrent engineering (singular) and the hybrid manufacturing system is accepted.

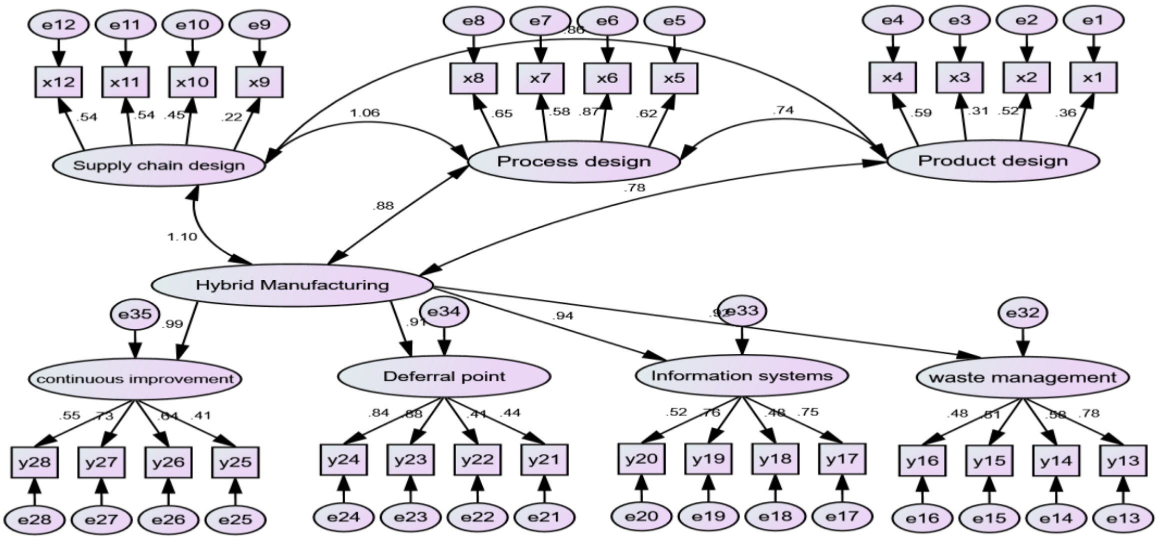



**Figure** (5) A model of correlation relationships between the dimensions of concurrent engineering (singular) and the hybrid manufacturing system

**4.3.2. Second hypothesis :** There is a significant effect of the concurrent engineering dimensions in the hybrid manufacturing system holistically at the level of the surveyed organization, in order to test this hypothesis, a structural equation model was built, as shown in Figure (6) and the statement of the values of the tests of this model, which leads us to accept our hypothesis or not, shown in Table (4) as follows:

**Table (4) Values of the analysis of the second hypothesis**

| Influential variable | Direction of influence | Variable affecting it | Estimate | SRW | Upper | Lower | P |
|---|---|---|---|---|---|---|---|
| Dimensions of Concurrent Engineering | ⟶ | Hybrid Manufacturing System | 0.654 | 0.963 | 1.034 | 0.895 | 0.01 |

**N = 213** **P ≤ 0.05**

**Source** : Table prepared by researcher

**Table 4** data indicate a direct and significant impact of concurrent engineering dimensions in the hybrid manufacturing system through the standard regression coefficient (SRW) value of (0.963) as well as the non-standard regression coefficient (Estimate) of (0.654), this effect is significant in terms of the P-value of (0.01), which is less than (0.05), and the same result confirms the confidence limits (95% confidence interval) for the value of the non-standard regression coefficient which is at its lower and upper limits (1.034 – 0.895), the interval does not include the value (**Zero**) between its limits, which is evidence of the importance of the effect of the interpreted variable on the dependent variable, so the second main hypothesis is accepted.

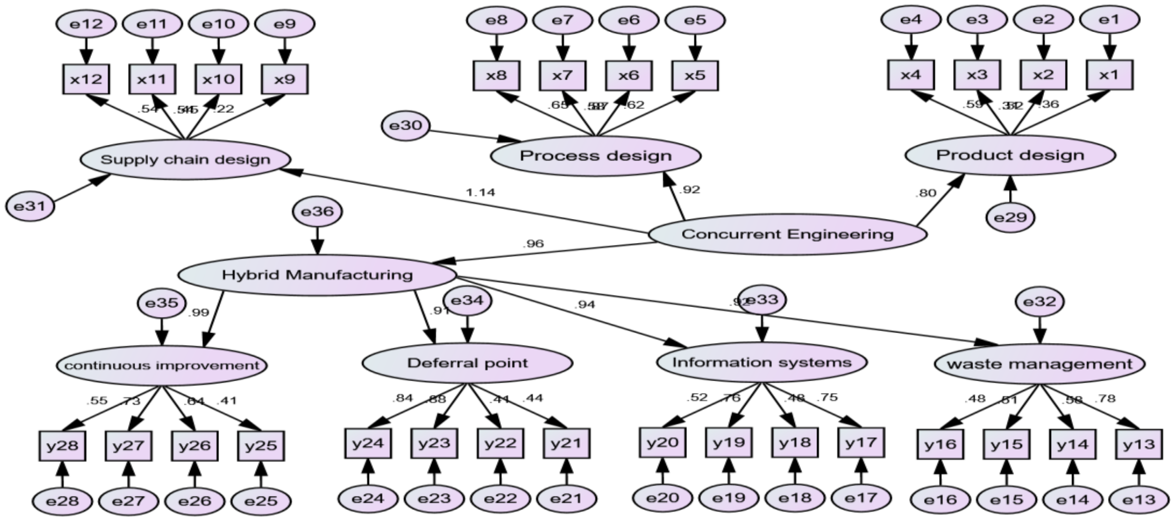



**Figure (6) Model of influence relationships between concurrent engineering dimensions (combined) in a hybrid manufacturing system**

**The second main hypothesis emanates from the following sub-hypothesis:**

**A.** There is a significant effect of concurrent engineering dimensions (individually) in the hybrid manufacturing system at the level of the surveyed organization, in order to test this hypothesis, the structural equation model was built as shown in Figure (7) and the values of the tests of this model, which lead us to accept our hypothesis or not, were shown in Table (5) as follows:

**Table (5) Values of the analysis of the second hypothesis**

| Influential variable | Direction of influence | Variable affecting it | Estimate | SRW | Upper | Lower | P |
|---|---|---|---|---|---|---|---|
| Product Design | → | Hybrid Manufacturing System | 0.273 | 0.423 | --- | 0.057- | 0.04 |
| Process Design | → | Hybrid Manufacturing System | 0.884 | 1.606 | --- | 0.933 | 0.01 |
| Supply chain design | → | Hybrid Manufacturing System | 0.753 | 0.972 | 0.355- | --- | 0.01 |

**Source** : Table prepared by researcher

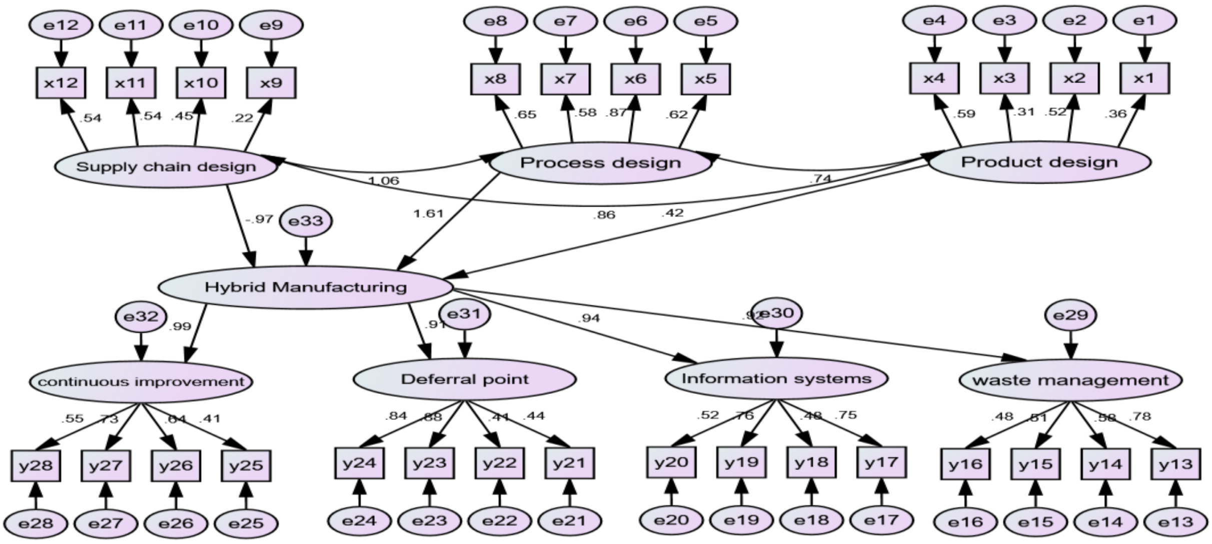



**Figure (7) Model of influence relationships between the dimensions of concurrent engineering (singular) in a hybrid manufacturing system**

The results of the statistical analysis of the modeling of the structural equation showed the significance of the model designed to test sub-hypothesis (a) of the second main hypothesis, this is in terms of the positive indicators obtained and shown in Table (5) as well as the values of high saturations that exceeded (45%) and as shown in Figure (7) and through the follow-up of the standard error values, it turns out that the highest effect was in the dimension of (process design) in the dimensions of the combined hybrid manufacturing system, while the lowest effect was in the dimension of (product design) in the combined hybrid manufacturing system, while the critical ratio C.R. (4.88), which is higher than the standard value of (1.96) at the level of significance (0.005) and its value of (2.91) at the level of significance (0.01), which is equivalent to the value of (T) in the normal regression test, thus, the second sub-hypothesis is accepted to prove the existence of a significant effect of the dimensions of the concurrent engineering individually in the dimensions of the hybrid manufacturing system.

## 5. Fifth Axis: Conclusions and Proposals

**5.1 First: Conclusions :** The study concluded a set of conclusions related to the variables of the study as follows:

1. Concurrent engineering is one of the most important principles of modern industrial management applied today, it is an essential input to efficiently improve industrial and operational processes.
2. The individuals surveyed in the laboratory under study have an appropriate level of experience, also, most of them have good scientific qualifications, and this gave them sufficient understanding of their work, which contributed to their understanding of the paragraphs of the questionnaire accurately and reaching realistic results.
3. A significant effect of the combined concurrent engineering dimensions was achieved in the hybrid manufacturing system of the laboratory under study, which suggests an impact of hybrid manufacturing in some way: it contributes to the successful application of concurrent engineering in the laboratory under study in the future.
4. The study showed that the integration of concurrent engineering technology, which relies on early collaboration between design and manufacturing departments, with hybrid manufacturing systems leads to reducing the overall time of product development and improving the quality of finished products.
5. Reduce costs and increase efficiency by combining integrated design (in concurrent engineering technology) and smart technologies (in hybrid manufacturing system), which contributed to reducing waste in materials and time, which contributes to reducing cost and achieving better productivity.

**5.2 Second: Proposals :** The study concluded with a set of proposals related to the variables of the study as follows:

1. Increasing the interest of the laboratory management under study in the components of administrative thought in modern fields, especially the concurrent engineering and hybrid manufacturing system, and deepening its role among the managers and employees of the laboratory under study, this contributes to the ability to survive and grow in the business world.

2. Increase the attention of the laboratory management under study to the dimensions of concurrent engineering such as product design, process design and supply chain design, in an attempt to produce products that meet the needs of its customers in terms of quality and appropriate cost, as well as the economic benefits that the company derives from the application of concurrent engineering in its three dimensions.
3. Officials and managers in senior management should work to raise the morale of individuals and workers and enhance their belonging to the factory in which they work by giving them more powers to make decisions, as well as working to provide sufficient information about the application of modern systems in the laboratory so that individuals can deal with them and make decisions about them.
4. Continuously Measure Performance: It is advisable to create clear performance indicators that measure the impact of integrating concurrent engineering technology and hybrid manufacturing system on productivity, quality, and time, to identify and emphasize points of improvement and development.
5. Increasing the awareness of the laboratory under study of the need to adopt the dimensions of the hybrid manufacturing system as well as seeking to adopt the dimensions of concurrent engineering by increasing interest in discovering untapped opportunities, as well as the pursuit of advanced technologies in manufacturing and the actual interest in the digital control of the laboratory and clarify the important role they play in improving the performance of the laboratory.

## 6. Conflict of Interest

The authors declare that they have no conflict of interest.

## 7. Funding Declaration

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## 8. References

Al-Baik, O., & Miller, J. (2016). *Kaizen cookbook: The success recipe for continuous learning and improvements*. IEEE Journal.

Al-Bakri, S. M. (2001). *Production and operations management - systems introduction*. University House.

Al-Barzanji, H. S. N. (2007). *The effect of concurrent engineering on product development* [Master's thesis]. University of Baghdad.

Al-Faihan, E. A. H. (2011). *Production and operations management* (1st ed.). University of Baghdad.

Al-Jashami, K. A. J. (2013). *The role of manufacturing flexibility and process design in the dimensions of the content of operations strategy* [Doctoral dissertation]. Al-Mustansiriya University.

Al-Kiki, G. M. A. (2012). The possibility of applying the elements of lean production: A field study in the children's clothing factory in Mosul. *Tikrit Journal of Administrative and Economic Sciences, 8*(26).

Al-Rubaie, B. A. H. (2019). *Designing a lean manufacturing system using the value stream map and its impact on improving productivity*. Al-Mustansiriya University.

Al-Taweel, A. A., Al-Ghadrofi, M. H., & Al-Talbi, A. A. (2019). Lean manufacturing techniques and their impact on the dimensions of sustainable development: An exploratory study in a number of small industrial organizations in Nineveh Governorate. *The Third Scientific Conference of the Faculty of Administration and Economics - Anbar University*.

Alzidani, M. (2021). *Optimization of the scheduling strategy using meta-heuristics approach in the context of cellular manufacturing with multiples products* [Doctoral dissertation]. École de Technologie Supérieure.

Baird, J. (2016). The concept of waste and waste management. *Journal of Management and Sustainability, 6*(4).

Beer, C. (2013). *Sustainable waste management: A decision support framework* [Master's thesis]. Stellenbosch University.

Beikzad, J. (2013). Management information system, challenges and solutions. *European Online Journal of Natural and Social Sciences, 2*(3).

Botti, L., Mora, C., & Regattieri, A. (2017). Integrating ergonomics and lean manufacturing principles in a hybrid assembly line. *Computers & Industrial Engineering*. https://doi.org/10.1016/j.cie.2017.05.011

Can, I. (2008). Case study S.C. Redplast S.R.L., operation management. *International Journal of Bulletin, Transylvania University of Braşov, 9*(58)(1).

Djaja, K. (2017). The importance of waste management knowledge to encourage household waste-sorting behavior in Indonesia. *International Journal of Waste Resources, 7*(4).

Dulanji, P. (2020). Moving from lean to leagile: A framework to improve supply chain performance of fashion garment manufacturing. *International Journal Conference on Industrial Engineering and Operations Management Dubai, 2*.

Evans, J. (2007). Impacts of information management on business performance. *Benchmarking: An International Journal, 11*(4).

Fatime, A. (2019). *Leagile manufacturing practices and supply chain performance, of food and beverage manufacturing companies in Kenya* [Master's thesis]. University of Nairobi.

Finch, B. J. (2006). *Operations now: Profitability, processes, performance* (2nd ed.). Prentice-Hall.

Fosters, S. T. (2001). *Managing quality: An integration approach* (1st ed.). Prentice-Hill.

Frostel, K. (2014). Progress and challenges to the global waste management system. *Journal of Permissions, 32*(9).

Haizer, J., Render, B., & Mlinson, C. (2017). *Operations management: Sustainability and supply chain management* (12th ed.). Pearson.

Hossain, M. M., Hossain, D., Hossain, M. A., Ahmad, F., Hoque, M. M., & Rahman, M. (2016). Lead time reduction and process cycle improvement of an ice-cream manufacturing factory in Bangladesh by using value stream map and Kanban board: A case study. *Australian Journal of Basic and Applied Sciences, 15*(10).

Ilakovac, B. (2017). Concept of sustainable waste management in the city of Zagreb: Towards the implementation of circular economy approach. *Journal of the Air & Waste Management Association, 67*(2).

Jawahar, N., & Subhaa, R. (2017). An adjustable grouping genetic algorithm for the design of cellular manufacturing system integrating structural and operational parameters. *Journal of Manufacturing System, 44*.

Jesson, J. (2018). The unacceptable face of the global knowledge economy. *New Zealand Journal of Teachers, University of Auckland, 19*, 78.

Juan, M. (2010). The integration of Six Sigma and lean management. *International Journal of Lean Six Sigma, 1*(3).

Kamara, J., Avaraba, C. J., & Deceller, A. F. C. (2007). *Concurrent engineering in construction projects*. Taylor & Francis.

Kawa, A. (2019). Lean and agile supply chains of e-commerce: Empirical research. *Journal of Information and Telecommunication, 3*(2).

Karim, A. (2011). The significance of management information systems for enhancing strategic and tactical planning. *Journal of Information Systems and Technology Management, 8*(2).

Kraiewski, L. J., Ritzman, L. P., & Malhotra, M. K. (2010). *Operations management*. Pearson Education.

Makinen, J. T. (2011). *Concurrent engineering approach plastic optics design* [Doctoral dissertation]. University of Oulu.

Khote, M. D. (2024). Hybrid manufacturing processes: Integrating additive subtractive techniques for enhanced manufacturing efficiency. *International Journal of Novel Research and Development, 9*(10).

Marchetta, M. G., Mayer, F., & Forradellas, R. Q. (2011). A reference framework following a proactive approach for product lifecycle management. *Computers in Industry, 62*(7).

Marr, B., & Rowe, C. P. I. (2008). *Managing and delivering performance* (2nd ed.). Chippenham and Eastbourne.

Mikva, M., Prajova, V., Yakimovich, B., Korshunov, A., & Tyurin, I. (2016). Standardization - One of the tools of continuous improvement. *Elsevier Journal, 149*.

Muhammad, A. (2019). Lean and agile paradigms in humanitarian organizations' logistics and supply chain management. *Scientific Journal of Logistics, 15*(1).

Nagaaba, N. (2016). *Lean, agile and leagile manufacturing as antecedents to plant performance of manufacturing firms in developing countries: Empirical evidence from Uganda* [PhD proposal]. Mbarara University of Science and Technology.

Naveen, R., Saha, R., & Sahai, R. (2018). Leagile manufacturing: A review paper. *International Journal of Productivity and Quality Management, 23*(3).

Ogawa, A. (2008). *Concurrent engineering for mission design in different cultures* [Master's thesis]. Massachusetts Institute of Technology.

Owuor, O. B. (2016). *Impact of lean manufacturing practices and operational performance of beer brewing process: A case study of Kenya Breweries Limited* [Master's thesis]. University of Nairobi.

Roth, B. K. (2014). *Enablers for lean process sustainability within South African manufacturing industries* [Master's thesis]. Nelson Mandela Metropolitan University.

Sami, A. M. (2013). *Contributions of concurrent engineering to enhancing marketing excellence* [Master's thesis]. University of Mosul.

Scoggin, J. C. (2017). *The interdependence of lean implementation and organization development* [PhD thesis]. The Chicago School of Professional Psychology.

Seyedi, M. (2012). Supply chain management, lean manufacturing, agile production, and their combination. *Interdisciplinary Journal of Contemporary Research in Business, 4*(8).

Shahin, A., Gunasekaran, A., Khalili, A., & Hadi, S. (2016). A new approach for estimating leagile decoupling point using data envelopment analysis. *Assembly Automation, 36*(3).

Shouke, C., Zhuobio, W., & Jie, L. (2010). Comprehensive evaluation for construction performance in concurrent engineering environment. *International Journal of Project Management, 28*(7).

Slack, N., Chambers, S., & Johnston, R. (2004). *Operations management* (4th ed.). Prentice-Hall.

(IJTBM) 2025, Vol. No. 15, Issue No. III, Jul-Sep **e-ISSN: 2231-6868 p-ISSN: 2454-468X**

Smith, P. G. (2016). *Development of a four stage continuous improvement framework to support business performance in manufacturing SMEs* [Master's thesis]. University of Wolverhampton.

Sun, S. (2011). The strategic role of lean production in SOE's development. *International Journal of Business and Management, 6*(2).

Virmani, N., Saha, R., & Sahai, R. (2017). Quantifying key factors affecting leagile manufacturing system. *International Journal of Industrial and Manufacturing Engineering, 11*(4).

Wang, L. (2010). *The effect of visibility in the integration of lean and agile for supply chains* [PhD thesis]. University of Warwick, Warwick Manufacturing Group.

Wilson, L. (2010). *How to implement lean manufacturing* (2nd ed.). McGraw-Hill.

Yaacob, N. (2020). Measuring leagile supply chain, information sharing, and supply chain performance: Pre-test and pilot test. *International Economic Journal, 11*(4).