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# The Role of Integration of Methods and Techniques Adopted in Product Design and Development – An Analytical Study in Diala State Company

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Today in the global competitive market, companies strive to maintain their competitive advantage by offering good products with high value, low cost and not harmful to the environment, as well as ease of design, engineering, manufacturing and assembly of products. From this perspective, the research problem focuses on the fact that manufacturing companies should apply the best methods and techniques in the design and development of their products. Therefore, the research aims to clarify the role of integration of methods and techniques adopted in the process of product design and development. This research has presented 14 methods and techniques that have a very big role in the process of product design and development. The integration of these methods and techniques provides a new direction for designers and manufacturers in line with the rapid developments and the ongoing changes in the global industrial environment. To achieve the research objective, a questionnaire was prepared as a main tool to collect the necessary data on the research sample. The questionnaire included 42 items. Diala State Company for Electrical Industries was selected as the site for the research. A number of statistical techniques were applied including arithmetic mean, standard deviation as well as factor analysis that includes Kaiser-Meyer-Olkin measure, Bartlett test and Principal Components method. The Statistical Package for Social Science (SPSS) was used to extract the results. The research found that the deployment of the quality function came first while the concurrent engineering team came in the lowest rank in terms of the relative importance in the design and development of products and the existence of significant correlations between methods and techniques adopted in the design and development of

products. The cumulative percentage of the explanatory variation of the combined factors recorded a value amounted to (79.075) which indicates that the methods and techniques adopted affect the design and development of both the distribution and power transformers products. The research also found that the company pays attention to the methods and techniques of product development, such as computer-aided design, computer-aided engineering, environmental design, information technology and standard design. This demonstrates the importance of these factors for both the distribution and power transformers products.

**Key words:** *Product, product design, product development, product design and development methods and techniques.*

## Introduction

The key factor that distinguishes successful international manufacturing companies from their competitors is the way in which the design and development processes of products are managed, so that these companies can provide products of high quality, speed, low cost and meet the expectations of customers.. The design and development of products must fit with material selection, planning, quality standards, manufacturing processes, product design software (Computer-Aided Design (CAD) and Computer-Aided Engineering (CAE). Worker skills, machine selection, assembly processes, environmental considerations and other issues related to product design and development compatible with continuous developments and changes in the global market.

Many writers and researchers have proposed methods and techniques for the design and development of products, but they have provided some and overlooked others, for example, (Kumar and Suresh, 2009). (Bamford and Forrester, 2010). (Russell and Taylor, 2011). (Reid and Sanders, 2013). (Das, 2016). (Heizer et. al., 2017). (Schroeder and Goldstein, 2018). (Jacobs and Chase, 2018). (Slack and Johes, 2018) and (Stevenson,2018). While, some researchers focused on one or two methods and techniques for the design and development of products, for example, (Belay, 2009). (Naaranoja et. al., 2012). (Siva, 2013). (Ameknassi et. al., 2016). (Asadi,2017). (Kolbasin and Husu,2018) and (Essienubong, 2018).

## Research Methodology

### *Research Problem*

Product design and development is considered critical to the survival of manufacturing companies, so companies should seek to apply methods and techniques in the design and development of their products to make the design of products compatible with the

engineering, manufacturing, assembly, and environmental processes and meet the needs of customers.

The research problem can be formulated by the following question
"Does the management of Diala State Company for Electrical Industries apply the methods and techniques adopted in the design and development of both the distribution and power transformers products so that these two products have high value and meet the needs of customers?"

***Research Objective***

The research aims to
1. Determine the methods and techniques adopted in the design and development of products so as to create an integrated situation between all the processes of design, engineering, manufacturing, assembly, environment, and meet the needs of customers.
2. Identify the relative importance of methods and techniques adopted in the design and development of distribution and power transformers products in the Diala State Company.
3. Prove the existence of significant correlations between methods and techniques adopted in the design and development of products.
4. The methods and techniques adopted in the research affect the design and development of distribution and power transformers products.

***Research Methods***

Methods of the research include the following:-

***Research Tool***

For the purpose of collecting information on the research sample (Factory of Distribution Transformers Product and Factory of Power Transformers Product). A questionnaire was prepared for the 14 methods and techniques for product design and development. The questionnaire included 42 items. The five-point Likert scale was used.

***Field Visits and Interviews***

The researcher conducted a number of field visits to get acquainted with the reality of work in Diala State Company and in the Factories of Distribution and Power Transformers products. The researcher also conducted a number of interviews with engineers who work in Department of Design and Department of Technology and the manager and engineers working in the Factories of Distribution and Power Transformers, the manager of Quality

Department and the manager of Environment Management Department. Forty-three questionnaires were distributed to them for the purpose of collecting information.

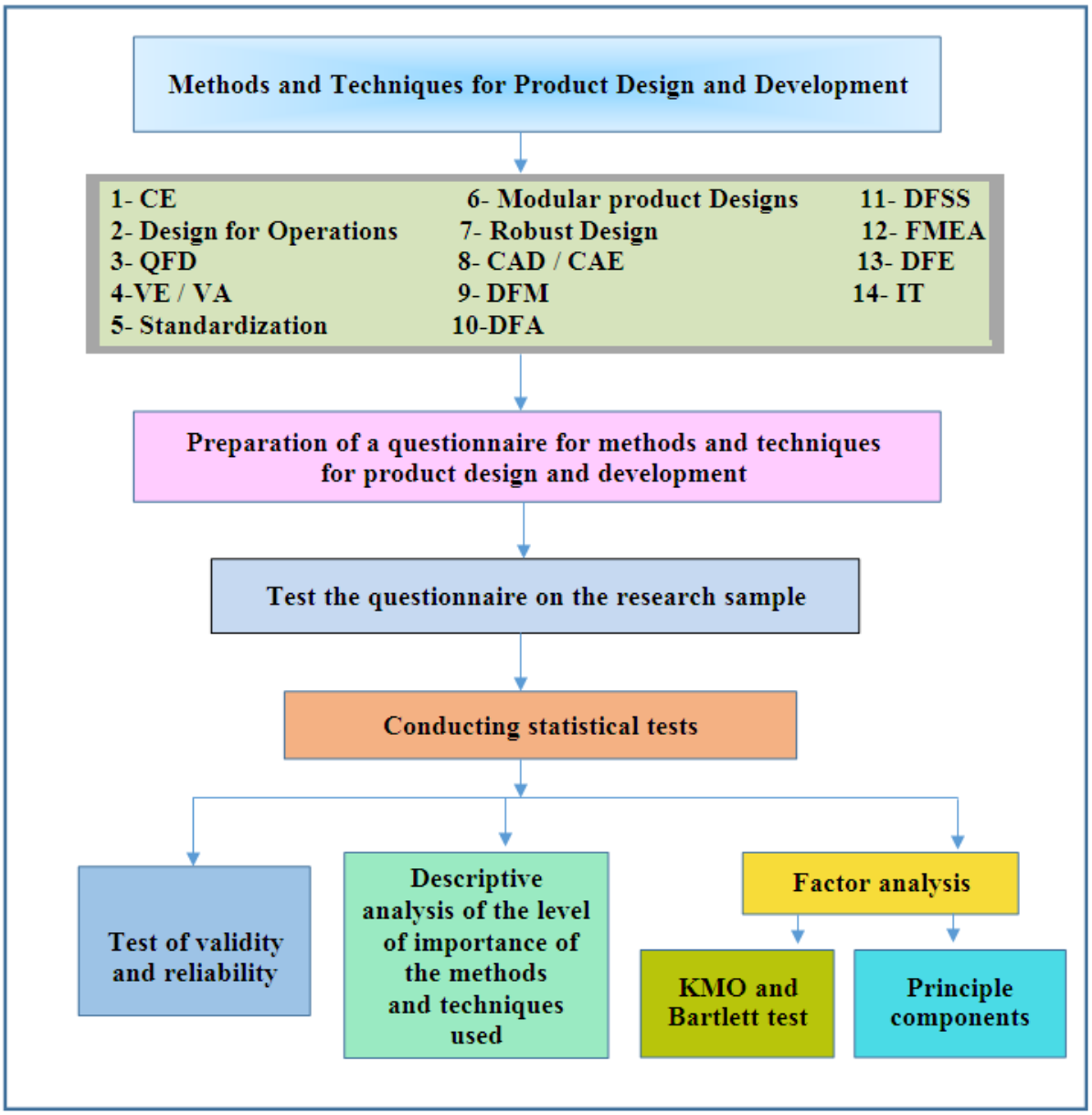
***Statistical Methods***

Cronbach's Alpha statistical methods were applied to test the content validity and reliability of the research tool. Other statistical methods were also applied such as arithmetic mean and standard deviation to determine the relative importance of the methods and techniques adopted in the design and development of product, as well as the application of factor analysis which included the Kaiser-Meyer-Olkin Measure – KMOM and Bartlett test to identify the correlations between the methods and techniques adopted in the design and development of product. Moreover, the principal components method was used to measure the effect of methods and techniques in the design and development of product. To extract the results, the SPSS was used.

***The Procedural Diagram of the Research***

Figure (1) shows the procedural diagram of the research.

**Figure 1.** The procedural diagram of the research




## Theoretical Framework

### *Concept of Product Design and Development*

A product is anything - a good or service - offered to individuals who may need or want it (Kamauff, 2010) and (Loukakou, 2012). The concept of design and development means a set of processes that transform requirements into specific characteristics or specifications of a product, process, or system (ISO 14006, 2011). The product design and development cycle begins with market needs and ends with the introduction of the actual product to the market

and once again the market demand and expectations begin, so the cycle begins again for a new or improved product (Dwivedi and Dwivedi, 2013). Slack et. al., (2010) argues that designing products should include three aspects

1. Concept: It helps to understand the nature, use and value of a product.
2. Product Components: They provide the benefits defined in the concept.
3. Process Definition: It is the way in which the components of the product are produced and delivered.

(Stevenson, 2015) believes that companies should ask designers to follow guidelines when designing products such as:-

1. Product designs which are consistent with the objectives of the company.
2. Give customers value that meats their expectations.
3. Maintain the health and safety of workers who manufacture the products, workers who transport the products, as well as customers who use the products.

***The Strategic Importance of Products Development***

At present, the development of products and services has increasingly gained strategic importance for the company for the following reasons (Slack et .al ,2015).

1. Increased international competition: The presence of a number of competitors in the market makes the small advantages in product specifications have a significant effect on competitiveness.
2. Increasing market fragmentation: Markets are becoming more fragmented, so companies have to follow relatively small specialized markets, in order to face the development of products that can be adapted in different ways to different markets.
3. Short life cycles of products: As a result of short life cycles of products companies should provide updated products.
4. The existence of a range of pressures affects the resources of operations that have to develop and provide new products, as well as the pressures of changes and developments of rapid technology that affected most of the work of industries.

***Approaches of Product Development***

The product development process occurs at one of the following approaches (Schroeder and Goldstein, 2018):

1. Technology push: In this approach, technology is the main determinant of products to be manufactured with little interest in the current market. The company must pursue a technology-based advantage through the development of superior technology and products, then products are pushed to the market and the marketing function has to create demand for

those superior products. As long as the products are made with superior technology, they will have an advantage in the market and will attract customers to buy them.
2. Market pull: In this approach, the market is the main factor to determine the products that the company manufactures with little attention to current technology. Therefore, the company must produce what it can sell. The customers' needs are determined, and then the company regulates the technology, resources and processes needed to provide customers. Finally, the market will pull the manufactured products.

Thus, competition and differences in multifunctional teams must be overcome to achieve a degree of cooperation required for successful product development.

***Methods and Techniques for Product Design and Development***

**1. Concurrent Engineering (CE)**

As a result of the increasing development of product technology and process, increasing competition, increasing customer demand for products of high quality, reliability and good value for the product, as well as the appropriate time for the market or the speed of the market has become a model for global manufacturing. To respond to all these dynamic and growing developments, the manufacturing companies resorted to the implementation of concurrent engineering in order to reduce the design cycle time and to create value for the product (Pullan et. al., 2010).

Concurrent engineering is a technique combining multifunctional teams that includes procurement, design, engineering, manufacturing, packaging and logistics in the early stages of product design to achieve a smooth transition from the design stage to actual production in a short time from the development time with the determination of cost and quality standards (Dos, 2016) so as to improve the competitive advantages of a company (Kowing and Rasli, 2011). Concurrent engineering is also one of the integrated approaches to the development of products by focusing on responding to market expectations through producing better, simpler, shorter time and less costly products (Aslani et. al., 2012).

The application of concurrent engineering in medium and large-sized manufacturing companies enables companies to (Basu et. al., 2013):

1. Manage the design and development of complex products
2. Control the cost and provide the product at the lowest possible cost
3. Manage the introduction of a new product
4. Execute the process of customization faster
5. Provide a program to reuse the product

## 2. Design for Operations

Product design greatly affects operations by determining products to be manufactured. Existing operations and products are restricted by the technology available in the company and thus product design and development are also restricted. Therefore, new products and products to be developed should be identified to take into account the production operation that will be used to make the product (Schroeder and Goldstein, 2018). The need to change design at the production stage is due to unexpected mismatches in operations, equipment, workers' skills, materials, packaging, storage, and transportation which may cause very high costs (Dos, 2016).

## 3. Quality Function Deployment (QFD)

The Quality Function Deployment (QFD) was first introduced at the end of the 1960s by Yoji Akao in Japan. In 1972 it was implemented at Mitsubishi Heavy Industries, it was adopted to design an oil tanker at the Kobe shipyard. At the end of the 1970s this concept became known as QFD (Eversheim, 2009). It was then applied at Toyota Automobile Production Company as a tool that guides the customer with its design and manufacturing process, and has been widely applied in the development of new products. One of QFD's means is the House of Quality, which uses a planning matrix to associate the customer's “wants” with appropriate technical requirements of the product “Hows” (Rosati et. al., 2012). For the purpose of building House of Quality, the following steps should be taken (Reid and Sanders, 2013):

1. Determination of customer requirements: What the customer wants and what he expects of the product should appropriately be determined.
2. Competitive Evaluation: The Company product should be compared with the product of competitors to determine the strengths of their product and use them in the development of the company product.
3. Identification of Product Characteristics: The product technical characteristics (requirements) necessary to meet the customers’ requirements should be identified.
4. The Relationship Matrix: The matrix shows the relationship between each requirement of the customer and technical requirements of the product.
5. The Trade-Off Matrix: The trade-off matrix determines how the technical requirements affect each other positively or negatively. The main purpose of the matrix is to find negative correlations between technical requirements.
6. Setting Targets Products: The degree of relative importance in the light of the relationship of customers’ requirements with the products technical characteristics (requirements) should be determined. Benefit and cost indicators associated with technical requirements are also defined for the purpose of fulfilling the customer's requirements.

## 4. Value Engineering and Value Analysis

Value Engineering (VE) and Value Analysis (VA) are considered ways to improve the benefits and costs of a product through detailed examination of product functions (Swink et. al., 2014). Customers look at product design by analysing the "value" they see in the final product. Since, it is very important that the value in products is designed.

Value engineering is implemented before the production stage to avoid costs. While value analysis deals with products under production and is used to analyse product specifications and requirements as described in the production documents and purchase orders. In practice there is a correlation between the two for a particular product, because new materials, processes and others require the application of VA technologies to products that have previously been subjected to VE. Value Engineering and Value Analysis approaches include the application of brainstorming technique (Jacobs and Chase, 2018).

## 5. Components Standardisation

Standardisation of Components is the combined use of components, products or processes to meet heterogeneous needs (Agard and Kusiak, 2004). Standardisation is considered an attempt to overcome the high costs of diversification through the standardisation of components; so many companies have minimised diversity precisely, which has significantly improved their profitability by evaluating the real profit or contribution of each product (Slack et. al., 2018). Standardisation of Components helps reduce development and production costs and increases product quality.

## 6. Modular Product Designs

Modular design is a design in which parts or components of a product are divided into models that can be easily exchanged or replaced (Heizer et. al., 2017). Of these models by different ways can create unique products.

Modular design is commonly used in the electronics and automotive industries. (Russell and Taylor, 2011). Modular design makes it possible to obtain a relatively diverse range of products and a small variety of components. The basic idea is to develop a series of basic product components, or modular products, which can be grouped into a large number of different products.

## 7. Robust Design

Genichi Taguchi method in quality engineering is referred to as Taguchi or Robust Design (RD) for quality improvement. Taguchi method has been successfully applied in the Electrical Communications Laboratories of the Nippon Telephone and Telegraph Co (Park et. al., 2006). Taguchi method focused on "build-in quality" through designing specifications, to reduce unwanted variation in product performance by looking at the sources of variation in the early stages. Some products operate as designed within a narrow range of circumstances, while other products operate as designed on a much broader scale than the conditions in which they were developed, thus having a robust design, and then are less likely to fail due to the changing environment in which they are implemented (Stevenson, 2018).

## 8. Computer-Aided Design (CAD) and Computer-Aided Engineering (CAE)

The computer is coupled with all the logical steps of product design and development, and it can help in two ways (Dwivedi and Dwivedi, 2013, 175):

1. The computer is used with relevant programs at different stages (design, analysis, processing, planning and manufacturing, etc.).
2. The database can be dealt with and managed efficiently.

Computer-Aided Design (CAD) means the use of computers to design products interactively and prepare engineering documents. Computer-Aided Design uses 3- D to save time and money by shortening development cycles for almost all products. The ease and speed with which sophisticated designs can be processed, analysed and modified using CAD help to review many possible design options (Heizer et. al., 2017). Computer-Aided Design systems offer many advantages (Najy, 2013, 299). These are:

1. Improvement of quality of the design and the products manufactured therein.
2. Computer-Aided Design systems enhance communication and stimulate creativity in multifunctional design teams by providing interactive visual focus on discussion.
3. Computer-Aided Design systems reduce time and cost by improving product design stages.
4. Computer-Aided Design systems contribute to the communication between the designer and the supplier through electronic communication.
5. Computer-Aided Design systems provide a database to store and retrieve design data at any time quickly.
6. Computer-Aided Design systems contribute to achieving all competitive priorities (cost, quality, speed and flexibility)

For CAE, it tests products generated by CAD more quickly through the engineering analysis, which is performed using CAD. Computer-Aided Engineering retrieves the description and engineering of part of CAD database and subjects it to test and analysis on the computer screen without creating a physical prototype. Thereby, developments in virtual reality and motion capture technology allow designers and users to experience design without creating a physical prototype (Russell and Taylor, 2011).

**9. Design for Manufacturing (DFM)**

The design origins of manufacturing date back to the industrial revolution by standardising parts, features and components through permittivity with a focus on standardising the parts and their changeability for the possibility of producing volumes of production (Moultrie and Maier, 2014). Design for manufacturing means designing a product so that its manufacturing processes are easier, faster, and cheaper and without compromising quality (Kumar and Suresh, 2010). There are a number of design guidelines for manufacturing (Reid and Sanders, 2011):

1. Minimising parts
2. Designing parts for different products
3. Using the modular design
4. Avoiding tools
5. Simplifying processes.

The design for manufacturing also leads to (Belay, 2009):
1. Improving all manufacturing functions, lubrication, assembly test, measures, shipping, services, and repairs
2. Assuring cost, quality, reliability, safety, time to market, and satisfaction of customers
3.Ensuring that no manufacturing capability does not harm design, introduction of new products, introduction of products, improvement programs, strategic initiatives, and unexpected increases in product demand

**10. Design for Assembly (DFA)**

Design for assembly focuses on reducing the number of parts in the product and facilitating assembly by determining the assembly techniques and the sequence to be followed in the assembly process. Good design should take into account how the product will be created and how the product will be assembled (Stevenson, 2018).

Design for assembly methodologies can be classified into four basic types according to their method of analysis (Stone et. al., 2004):

1. Design for assembly systems that are based on design principles and rules 2. Design for assembly systems that are based on quantitative evaluation procedures
3. Design for assembly techniques that use knowledge-based approaches
4. Design for assembly techniques that are computer-aided design for assembly techniques affect product development time, product development cost, product quality and also produce more reliable products.

Design for assembly analyses product designs to improve easiness of assembly and reduce assembly time by identifying assembly problems during the product design process. Further, design for assembly helps avoid assembly problems in the final stages of product development. Design for assembly has been widely used by durable goods manufacturers to design cost-effective products leading to simplification of products, standardisation of materials, manufacturing processes, and design of products (Asadi, 2017).

***Design for Six Sigma Design (DFSS)***

Design For Six Sigma is considered a relatively new approach for product development that focuses on introducing the appropriate product at the right time and the right cost. Design For Six Sigma provides a systematic way to build important customer requirements in all aspects of product development that can be measured, verified and improved (Lee and Chang, 2010). Design for six sigma approach uses training and measurement tools to design products that meet customer expectations according to quality levels. It is also an approach that uses data to analyse and identify the root causes of business problems and then work to resolve those problems (Patil et al., 2013). Design for six sigma approach consists of five stages as follows (Gryna et. al., 2007):

1. Define: Definition of product design as a whole, defining the objectives, laws, and infrastructure of the product design project. During this stage, activities are also divided between the management team and the product design team, and the management holds the final responsibility to identify the design problem.
2. Measure: Identification of key customers, this includes identifying main customers, determining their critical needs and diagnosing critical quality requirements as well as conducting a market evaluation.
3. Analysis: Identification the optimal design that is characterised by high quality from numerous alternatives of design, establishing the detailed requirements of the design in light of the optimal design details in the subsequent design stage.
4. Design: Determination of optimal design: This includes determining the optimal design criteria, defining the optimal tolerances and design settings, determining details of functional design and verifying the validity of design details.

5. Verify: Verification of the new design: This assures that the new product design can be manufactured and meets the requirements of quality, reliability, and cost standards.

***Failure Modes and Effects Analysis (FMEA)***

Failure Modes and Effect Analysis (FMEA) widely uses engineering technology to identify, define and eliminate failures, problems, and known and / or potential errors in the system, design and process before reaching the customer. Failure mode means that the component, subsystem, system, process, etc., have failed to meet the design. Failure mode in one component can be the cause of another component's failure mode (Wang et. al., 2009). Failure modes and effect analysis is defined as a systematic approach to identifying priorities, assessing potential failure risks in each stage of product or process design (Jacobs and Chase, 2018). Failure modes and effect analysis help reducing development costs, shortening time, and providing insights for product testing and maintenance (Swink et. al., 2014). The purpose of FMEA is to anticipate and prevent cases of failure to occur (Russell and Taylor, 2011). Failure modes and effect analysis consists of five main steps to accurately identify the problem (Swink et. al., 2014):-

1. Determination of the parts of the product to be analysed
2. Identification of possible types of failure
3. Diagnosis of failure situation priorities
4. Formulation of plans to deal with each critical failure situation
5. Implementation of plans and measurement of their effect and repeat the analysis as needed.

***Design for Environment***

In line with sustainable development initiatives, environmental considerations have been incorporated into the process of product design and development throughout the life cycle of products including raw materials, production, distribution, and final disposal of waste to improve the environmental performance of products (Jacobs and Chase, 2018) and (ISO 14006, 2011). There are three main ideas in the design for environment. First, sustainability considerations should be developed at an early stage in product design. Second, the sustainability considerations should be integrated into the tools adopted in product design. Third, it is necessary to adopt a product-life-based systems approach (Siva, 2013). With regard to the implementation of design for environment, there are three key interrelated issues to consider (Ameknassi et. al., 2016):

1. Environmental aspects integrated into product development process require specific capabilities and expertise to manage the complexities of product design.

2. Provision of support to designers on how to identify appropriate design for environment-related techniques and tools and how to implement them effectively to generate innovative environmental products.
3. Implementation of design for environment requires communication skills

***Information Technology (IT)***

At present, Information Technology (IT) plays a large and significant role to help manufacturing companies manage design and manufacturing processes to increase overall efficiency and meet customer requirements (Dwivedi and Dwivedi, 2013). Information Technology helps store and retrieve information and vital data of companies. It contributes to the process of product development. Because the product development cycle extends across different fields of knowledge and disciplines, IT helps facilitate all activities related to the product development cycle, which requires the existence of computers and networks among the departments of the company and outside it for the success of product development (Essienubong, 2018).

**Practical Aspect of the Research**

***Description of the Research Population and Sample***

Diala State Company was chosen as one of the leading companies in the Iraqi Ministry of Industry and Minerals specialised in electrical industries. It is considered one of the old and distinguished companies in their products and type of production and its accuracy. It consists of a number of factories each one specialises in producing an independent product. The sample company includes Distribution and Power Transformers Factories. Each factory produces two types of transformers with different capacities.

***Statistical Tests of the Research***

**1-Validity And Reliability Tests of the Measuring Tool (The Questionnaire)**

Table (1) shows that items of the questionnaire successfully passed the validity test, where the criterion validity amounted to (0.896), confirming that items of the questionnaire represent good integration of the methods and techniques of product design and development.

Table (1) also shows that the value of the reliability test (Cronbach's Alpha) for all items of the questionnaire is equal to (0.802), which is more than (0.500) confirming that items of the questionnaire successfully passed the reliability test. This indicates the existence of high

reliability in the all items of the questionnaire, especially that the value of Cronbach's Alpha) was more than (0.700).

**Table 1:** Validity and Reliability tests of the questionnaire

| Tests | Methods | The value of the measurement | Analysis |
|---|---|---|---|
| Validity | Criterion Validity | 0.896 | The questionnaire passes the validity test successfully |
| Reliability | Cronbach's Alpha | 0.802 | The existence of high reliability in the questionnaire paragraphs |

**2- Descriptive analysis of the level of importance of methods and techniques adopted in the design and development of products**

The researcher used the hypothetical mean (3), which represents the boundary between "available with high or very high degree" and between "lack of availability or low availability". In order to highlight the level of response of the respondent to the items of the questionnaire, the researcher relied on the matrix of the response power, which represents the estimated balance according to the five-point Likert scale, as shown in Table (2).

**Table 2:** Response power matrix of the respondent on questionnaire items

| Value of weighted arithmetic mean in the period | Power of response on the questionnaire paragraphs | Response level by the respondent |
|---|---|---|
| from 1 to less than 1.8 | Not available | Low |
| from 1.8 to less than 2.6 | Available in low degree | |
| from 2.6 to less than 3.4 | Available in medium degree | Medium |
| from 3.4 to less than 4.2 | Available in high degree | High |
| from 4.2 to 5 | Available in very high degree | |

Table (3) shows the results of the arithmetic means, the standard deviation and the relative importance of the methods and techniques of the design and development of products.

**Table 3:** Level of importance of the methods and techniques used in the design and development of products

| Items | Content | Weighted Mean | Std. Deviation | The relative importance% |
|---|---|---|---|---|
| 1 | The company's management is changing its traditional sequential work environment in accomplishing the work to an environment based on the completion of activities in a parallel form | 3.1163 | 0.58592 | 62.33 |
| 2 | The company management delegates the concurrent engineering team sufficient authorities to make decisions for the purpose of accomplishing tasks | 3.1860 | 0.85233 | 63.72 |
| 3 | The concurrent engineering team designs and develops all the processes and information needed to produce, sell, and distribute a product | 3.3256 | 0.99333 | 66.51 |
| X1 | Concurrent Engineering | 3.2093 | 0.81053 | 64.19 |
| 4 | When designing a product, the type of machinery and processes available, handling equipment and type of personnel skills are taken into consideration. | 4.0000 | 0.69007 | 80 |
| 5 | Designers study the current product mix | 3.6512 | 0.75226 | 73.02 |
| 6 | When designing a product, present suppliers, raw materials, level of use of machines and quality standards are taken into consideration | 3.7907 | 0.74188 | 75.81 |
| X2 | Design for Operations | 3.8140 | 0.72807 | 76.28 |
| 7 | The company's management is concerned with applying the deployment of quality function to update the designs of its products and reduce the design time | 3.9767 | 0.73964 | 79.53 |
| 8 | All customer requirements are specified | 4.0233 | 0.63577 | 80.47 |

| | | | | |
|---|---|---|---|---|
| 9 | Standards for product design and manufacturing are specified | 3.8140 | 0.54580 | 76.28 |
| **X3** | **Quality Function Deployment** | **3.9380** | **0.64040** | **78.76** |
| 10 | Designers simplify, standardize, and improve design specifications and performance characteristics | 3.6512 | 0.75226 | 73.02 |
| 11 | All kinds of changes that increase the value of the product and reduce its costs are identified and implemented | 3.7907 | 0.70906 | 75.81 |
| 12 | The company's management is keen to review and improve the successful products during the production process | 3.7907 | 0.77331 | 75.81 |
| X4 | Value Engineering and Value Analysis | 3.7442 | 0.74488 | 74.88 |
| 13 | Parts and components used in various product designs are standardized | 3.3721 | 0.87351 | 67.44 |
| 14 | Components can be standardized to reduce designing and developing production costs and increase product quality. | 3.4186 | 0.79380 | 68.37 |
| 15 | Designers want to standardize components to make the supply chain less complex | 3.4884 | 0.73589 | 69.77 |
| X5 | Components Standardization | 3.4264 | 0.80106 | 68.53 |
| 16 | Products are designed as groups of parts for the purpose of adding or exclude any part of the group | 3.3953 | 0.87667 | 67.91 |
| 17 | The modular design has contributed to providing a variety of products with different levels of functionality and cost | 3.2558 | 0.92821 | 65.12 |
| 18 | The modular design helps meeting customer needs | 3.4419 | 0.88108 | 68.84 |
| X6 | Modular Product Design | 3.3643 | 0.89532 | 67.29 |
| 19 | When designing and developing products, it is considered to be less likely to fail due to environmental change | 3.7674 | 0.89532 | 75.35 |

| | | | | |
|---|---|---|---|---|
| 20 | Designers work to minimize natural variations in product characteristics during production process | 3.6744 | 0.68443 | 73.49 |
| 21 | Designers work to make product performance less sensitive to the variations that ocurr | 3.6279 | 0.77830 | 72.56 |
| X7 | Robust Design | 3.6899 | 0.75666 | 73.8 |
| 22 | The company's management employs CAD and CAE technologies in the stage of product design and development | 3.3953 | 0.76031 | 67.91 |
| 23 | Quality function deployment outputs are being included in technologies | 3.3023 | 0.93948 | 66.05 |
| 24 | CAD and CAE technologies study and analyse products, as well as analyse the design for the assembly to identify areas of potential interference between parts | 3.0465 | 0.99889 | 60.93 |
| X8 | Computer-Aided Design and Computer –Aided Engineering | 3.2481 | 0.89956 | 64.96 |
| 25 | The factory's management is concerned with designing for manufacturing to reduce the total number of unique parts in the product | 3.2326 | 0.92162 | 64.65 |
| 26 | Design for manufacturing has contributed to reduce manufacturing time, manufacturing costs and improve product quality | 3.4884 | 0.85557 | 69.77 |
| 27 | Design for manufacturing increases usability and maintenance | 3.7674 | 0.71837 | 75.35 |
| X9 | Design For Manufacturing | 3.4961 | 0.83186 | 69.92 |
| 28 | Designing all assembly tasks to be one-way and eliminating the need for adjustments | 3.1395 | 0.96563 | 62.79 |
| 29 | The design of the assembly reduces the use of tools required in the assembly process | 3.3023 | 0.88734 | 66.05 |
| 30 | There is interest in designing easy and less complex parts for better assembly | 3.5814 | 0.76322 | 71.63 |

| | | | | |
|---|---|---|---|---|
| X10 | Design For Assembly | 3.3411 | 0.87206 | 66.82 |
| 31 | The company's management is concerned with the application of DFSS approach | 3.4419 | 0.73363 | 68.84 |
| 32 | Designers determine the optimal design criteria (including the relationship of design specifications to critical quality characteristics) and are constantly reviewed | 3.4186 | 0.79380 | 68.37 |
| 33 | There is sufficient flexibility to respond quickly to changes in product designs | 3.6047 | 0.87667 | 72.09 |
| X11 | Design For Six Sigma | 3.4884 | 0.80137 | 69.77 |
| 34 | Potential quality problems are early identified during the design process to determine failures | 3.4884 | 0.82728 | 69.77 |
| 35 | Corrective action plans are developed to address failures | 3.7442 | 0.84777 | 74.88 |
| 36 | Corrective action plans to address failures and measure their impact are implemented | 3.6047 | 0.79101 | 72.09 |
| X12 | Failure Modes and Effects Analysis | 3.6124 | 0.82202 | 72.25 |
| 37 | Parts and components that are reusable, disassemble and recyclable can possibly be manufactured or used, | 3.2093 | 1.01320 | 64.19 |
| 38 | Lighter and less harmful parts and components are used in manufacturing a product | 3.4884 | 0.90953 | 69.77 |
| 39 | Parts and components requiring less energy are used in manufacturing a product | 3.4651 | 1.00827 | 69.3 |
| X13 | Design For Environment | 3.3876 | 0.97700 | 67.75 |
| 40 | The company's management has communication means associated with all beneficiaries for the purpose of participating in the process of design and development of products | 3.5581 | 0.85363 | 71.16 |

| | | | | |
|---|---|---|---|---|
| 41 | There are computerized databases to increase efficiency and speed in completing all design, manufacturing, assembly, packaging, and packaging processes | 3.3488 | 0.86969 | 66.98 |
| 42 | Information technology has contributed to make the design and development of products good and green | 3.1395 | 0.80420 | 62.79 |
| X14 | Information Technology | 3.3488 | 0.84251 | 66.98 |

Table (4) shows the order of methods and techniques adopted in the design and development of products in the research sample according to the results of relative importance. The table clearly indicates that deployment of the quality function came first, the design for operations in the second and then engineering and value analysis in third place in terms of the relative importance in the design and development of products. While the concurrent engineering came in the lowest order in terms of the relative importance in the design and development of products.

**Table 4:** The relative importance of methods and techniques adopted in designing and developing product distribution and power transformers

| **Items** | **Methods and Techniques for Product Development** | **The relative importance%** |
|---|---|---|
| 1 | Quality Function Deployment | 78.76 |
| 2 | Design for Operations | 76.28 |
| 3 | Value Engineering and Value Analysis | 74.88 |
| 4 | Robust Design | 73.8 |
| 5 | Failure Modes and Effects Analysis | 72.25 |
| 6 | Design for Manufacturing | 69.92 |
| 7 | Design for Six Sigma | 69.77 |
| 8 | Components Standardization | 68.53 |
| 9 | Design for Environment | 67.75 |
| 10 | Modular Product Designs | 67.29 |
| 11 | Information Technology | 66.98 |
| 12 | Design for Assembly | 66.82 |
| 13 | Computer – Aided Design and Computer –Aided Engineering | 64.96 |
| 14 | Concurrent Engineering | 64.19 |

***Factor Analysis***

Factor analysis is one of the advanced statistical techniques and has several uses, including making the items in the factors according to their importance. Factor analysis indicates that the items to be included in the first factor are more important than the items to be included in the second factor and the items to be included in the second factor are more important than the next factor and so on until the last factor. The following statistical techniques are adopted in this research: Kaiser-Meyer-Olkin Measure (KMOM), Bartlett test and the second Principal Components method.

**1. KMO Measure and Bartlett Test**

Table (5) shows that the value of KMOM was (0.662) which was significant as it was more than (0.500) confirming that the sample size adequacy requirement for data was available. The sample size was thus suitable for the application of factor analysis. Table (5) also shows Bartlett test. The value of Chi-Square measure was (874.21). which indicated a significant correlation between the methods and techniques adopted in the design and development of products.

**Table 5:** Results of KMO measure and Bartlett test

| **Tests** | | |
|---|---|---|
| **Bartlett Test** | | **Value of KMO Measure** |
| Significance Probability Value | Calculated Chi-Square Value | |
| 0.662 | 874.21 | 0.000 |

**2. Principal Components Method**

Principal Components Method is considered one of the most common techniques of factor analysis. Table (6) shows the following results:

1. The cumulative percentage of the explanatory variance of the combined factors recorded a value of (79.075%). which was more than (60%). This result showed a greater indication that the methods and techniques adopted affect the design and development of product distribution and power transformers.
2. Eigen values for all factors formed values more than the correct one.
3. Value of the coefficient of correlation of items within the factor was more than (0.50). which proves the existence of a strong correlation between each items and the factor that includes it.

4. The first factor included all three items of methods and techniques for the development of products, namely, computer-aided design and computer-aided engineering, design for environment, information technology, as well as the inclusion of two items of design for assembly, and one items of concurrent engineering.
5. The second factor included all items of both standardisation and modular design.
6. The third factor included all items of the design for processes. It also included two items for both robust design and quality function deployment and one items from the design for assembly.
7. The fourth factor included all items of failure patterns and impact analysis, as well as the inclusion of two items of value engineering and value analysis.
8. The fifth to eighth factors included all items of the design for manufacturing and the design for six sigma. These factors also included two paragraphs of concurrent engineering and one items for value engineering, value analysis, quality function deployment and robust design.

**Table 6:** Result the principal components method

| The factors | The factor 1 | | The factor 2 | | The factor 3 | | The factor 4 | | The factor 5 | | The factor 6 | | The factor7 | | The factor 8 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | L | I | L | I | L | I | L | I | L | I | L | I | L | I | L |
| The factors are ranked from the most important to the least ,in addition to the items within each factor are ranked from the most | 29 | 0.898 | 18 | 0.800 | 6 | 0.796 | 39 | 0.727 | 32 | 0.784 | 25 | 0.847 | 7 | 0.844 | 1 | 0.667 |
| | 28 | 0.865 | 13 | 0.777 | 9 | 0.719 | 12 | 0.655 | 33 | 0.734 | 26 | 0.827 | | | 3 | 0.542 |
| | 41 | 0.843 | 17 | 0.741 | 4 | 0.646 | 11 | 0.589 | 31 | 0.680 | 10 | 0.652 | | | | |
| | 42 | 0.811 | 14 | 0.694 | 21 | 0.633 | 38 | 0.564 | | | | | | | | |
| | 34 | 0.784 | 16 | 0.687 | 20 | 0.619 | 37 | 0.509 | | | | | | | | |
| | 23 | 0.762 | 15 | 0.604 | 8 | 0.607 | | | | | | | | | | |
| | 22 | 0.761 | 38 | 0.537 | 5 | 0.606 | | | | | | | | | | |
| | 40 | 0.625 | | | 30 | 0.522 | | | | | | | | | | |
| | 24 | 0.585 | | | 12 | 0.505 | | | | | | | | | | |
| | 35 | 0.585 | | | | | | | | | | | | | | |
| | 2 | 0.549 | | | | | | | | | | | | | | |
| | 36 | 0.523 | | | | | | | | | | | | | | |
| initial root | 7.781 | | 5.688 | | 5.664 | | 3.439 | | 3.311 | | 3.248 | | 2.049 | | 2.031 | |
| The percentage of explanation variance % | 18.527 % | | 13.543 % | | 13.486 % | | 8.188 % | | 7.884 % | | 7.734 % | | 4.878 % | | 4.835 % | |
| Cumulative percentage of variance % | 79.075% | | | | | | | | | | | | | | | |
| Loading : the strength of the items relevance to the dimension it contains | | | | | | | | | | | | | | | | |

I: Items L: Loading

## Conclusion

Achievement of the success in manufacturing companies requires the implementation of how to improve the development of products. Therefore, this research dealt with most of the methods and techniques adopted in the design and development of products. This research presented (14) techniques and tools that were tested in the Diala State Company, which makes distribution and power transformers.

Diala State Company operates in a competitive environment, so the success of the transformer product is considered a critical factor in the success of the company. Diala State Company seeks to develop the product of distribution and power transformers to increase its efficiency and effectiveness and to meet the needs of its customers.

Therefore, the company applies methods and techniques to design and develop the products of distribution and power transformers to provide outstanding transformers for its survival, growth, increase of profits and retaining customers.

The results of the research show that there is interest by management of the company in the methods and techniques adopted in the design and development of distribution and power transformers products. All the 14 methods and techniques tested were applied but in varying proportions. The results also show:-

1. Deployment of the quality function came first, the design for operations in second place, then engineering and value analysis in the third place. While the concurrent engineering came in the lowest rank in terms of relative importance in the design and development of products. Therefore, management of the company should pay great attention to those methods and techniques, especially that the rate of their application ranges between the average and good.
2. There are significant correlations between the methods and techniques adopted in the design and development of products
3. The cumulative percentage of the explanatory variance of the combined factors recorded a value of 79.075%, which shows that the methods and techniques adopted affect the design and development of distribution and power transformers products.
4. Diala State Company pays attention to all methods and techniques of product development, namely computer-aided design, computer-aided engineering, design for environment, information technology, standardisation and standardised design, which indicates the importance of these factors for the distribution and power transformers products.

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