Proposal of a new cyclic product development (CPD) model

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مقترح لنموذج جديد لعملية تطويرالمنتج

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الملخص:

في الآونة الأخيرة، حولت بعض الشركات العالمية انتباهها إلى أسواق البلدان الأقل نمواً البلدان النامية من أجل الاستفادة من الأسواق الواسعة المتنامية في هذه البلدان. هذه المنافسة وضعت الشركات المحلية في حالة حرجة جدا نظرا للفروق الواضحة في الموارد، والاستثمارات الرأسمالية وتوافر التكنولوجيا بين قدرات الشركات العالمية والمحلية. وبذلك، أصبح على الشركات أن تحسن أدائها من خلال إعادة التفكير في عملية تطوير المنتجات وتجاوز التخوف من أن عمليه تطوير المنتج هي عمليه معقده، تحتاج لوقت، مكلفه وبها درجه مخاطره عاليه. ففي النهاية على هذه الشركات أن تدرك إن عمليه تطوير المنتج هي النهج الوحيد لتقديم منتج قادر على المنافسة حيث إنها عملية أساسية في رفع جودة المنتجات ومساهم رئيسي في تميز منظمات التصنيع.

تهدف هذه الدراسة لتقديم نموذج متكامل لعملية بناء و تطوير منتج قادر على زيادة ربحيه والحصة السوقية والاعتمادية للمؤسسة الصناعية. حيث إن هذا النموذج يراعى الأهداف العالمية لعمليه بناء وتطوير المنتج وهى: رفع جوده المنتج وتقليل تكلفه ووقت الإنتاج كما انه يشمل متطلبات الأيزو ٩٠٠١:٢٠٠٨ وكذلك يشمل جميع المراحل والخطوات. كما أن النموذج يوضح التفاصيل الهامة والتقنيات المطلوبة في كل مرحلة من المراحل لتنفيذ العملية بنجاح و فاعلية بحيث يكون دليلا مفصلا لعملية بناء وتطوير المنتج ويقدم كل المعلومات الضرورية لهذه العملية ليساعد كل من يريد بناء أو تطوير منتج للوصول بالمنتجات المحلية للمنافسة العالمية.

Summary

Recently, some of the global companies have turned their attention to the markets of the less developed countries in order to tap into the vast growing markets in these countries. This competitiveness put the local companies in a very critical situation due to the obvious difference between the capabilities of the global and local companies' in recourses, capital investments and technology availability. Therefore, a possible solution for those local companies is to improve their performance by rethinking in Product Development Process (PDP) and abandon their fears about its complexity, time consuming, expensive and risk. Those companies have to recognize that PDP is the only approach to introduce product that is able to compete. Thus Product development process (PDP) is an essential process in enhancing the products quality. It is a major contributor in the business excellence of any manufacturing organization.

The aim of this paper is to present the Cyclic Product Development (CPD) model that aids the increase of the profit, market share, product reliability and customer satisfaction as well as reduces time to market, cost, assembly parts and time. The model not only illustrates the main PDP phase but also it illustrates the process involved in each phase in a separate flowchart. In addition the model presents the different approaches and techniques that can be applied in each phase. This guides the organizations in less developed countries that deal with real problems in understanding and implementing the PDP.

The CPD model is concerned to both the technical and managerial prospective. This model covers most of the essential activities, tools and techniques required to attain an efficient PDP and organize them in a cyclic path. In addition this model combines between the general philosophy for the PDP and ISO 9001:2008 adaptations .

Keywords

Product development, process modeling, cyclic product development

Introduction

The PDP produced from the cumulative experience of the manufacturing companies. Thus, the manufacturing process passed several changes from hand craft to over-the-wall manufacturing process. As a result to this cumulative experience, general philosophy for the PDP had been build. This philosophy involves basic elements; they are market research, concept generation and selection, design process, prototyping, production and post production activities. Each element is a phase and each phase contains many steps. The set of phases becomes a discipline that describes the process of converting the idea into a salable product. This discipline must tend to develop a high performance product in the minimum development time and cost. To achieve this aim, many PDP models were developed.

Most of the previous developed PDP models weren't mainly concerned by illustrating PDP phases from the technical prospective instead most of these models concerned on represent the PDP from the managerial prospective such as the models developed by Ulrich [1], Cooper [2], Broughton [3], Andreason [4] and Peters [5]. Also, there are many previous developed PDP models were developed just to represent certain idea such as the model developed by Toyota [6] to represent the idea of the set-based approach and the model developed by Paul et al [7], to represent the idea of applying the IPD approach on small-to-medium companies and the model developed by Rahim [8] to represent the use of DFA (Design For Assembly) and DFM (Design For Manufacturability) in PDP. As well as the model developed by Wei et al [9] represent the use of electronic technologies in developing a product.

Previous Cyclic Product Development Models

In the earliest days, Products were simple that one person could design and manufacture an entire product [10]. The products had been made by skilled craftsmen who custom fitted parts using simple and flexible tools. This type of production were called craft production, it was costly and slow [11]. Then by the middle of the twentieth century, products had become so complex that the manufacturing process had been broken into more understandable individual functional units such as marketing, designing, manufacturing, and management where different group of people was responsible on each function unit. Later on this approach called "over-the-wall" design approach [1].

Thus each function walled off from other functions and the information is thrown over the wall. This is a one-way communication which usually result on manufacturing products differ than what customers expect [1]. Since 1980 breaking down the walls between functional units had begun. This is called simultaneous development of the product and the manufacturing process. This approach achieved by assigning manufacturing representatives to be members of design teams to

interact with the design engineers during the design process. This approach was broadened later and has been called Product Development Process (PDP).

The PDP is a process which consists of sequence of steps, phases or activities that an enterprise employs to conceive design and commercialize a product [1]. In the PDP, the design team includes representatives from all people who have a concern for the product. Also the PDP have great concern on all information required in design process and share this information with the right people at the right time. The information in PDP not only excludes on design drawings but, also includes requirements, concepts, and process plans and any other information cannot be represented as formal drawings.

There are many researchers' efforts for integrating different tools and techniques in PDP to enhance its performance such as SWOT (strength, weakness, opportunities, threats) analysis, Quality Function Deployment (QFD) and Design for Manufacturability (DFM) and Design for Assembly (DFA). Many other researchers were interesting to develop models to support PDP. PDP models was simplified to represent a certain idea such as the model developed by Toyota[6] to represent the idea of the set-based approach and the model developed by Paul et al [7] to represent the idea of applying the IPD approach on small-to-medium companies and the model developed by Rahim[8] to represent the use of DFA and DFM in PDP. As well as the model developed by Wei et al represent the use of electronic technologies in developing a product. The model developed by Fang [12] represents the methodology of implementing the PDP but it was sophisticated. Moreover, it ignored the tools and techniques that must be used in implementation.

In the following sections, a proposed CPD model will be discussed to cover the previous drawbacks and combines between the PDP philosophy and ISO 9001:2008 adaptations. This proposed model provides more details to previous phases and adds other new phases than previous models.

The proposed Cyclic Product Development (CPD) model

The CPD model consists of two parts: General framework and phases charts.

Figure 1 illustrates the general framework part. It shows that the PDP phases putted in a cyclic way. The CPD model not ends neither by developing the product nor by service after sale, but it must extends during the various stages of the product life cycle (introduction, growth, maturity, saturation and decline). The first task for the PDP is to develop a new product and introduce it to market; this will be the introduction stage. When the product becomes familiar to the buyers of the product, that PDP task is to improve the developed product to be more reliable and less costly that will increase the market demands; this will be the growth stage. After passage of time, the product reaches the maturity stage eventually, market becomes saturated, this will be the beginning of the decline stage that PDP task will be either to improve the product to extend its life, or developing a new product. The general framework includes three essential activities to support and control the PDP phases therefore

optimizing the effectiveness of the PDP; they are review, Verification and validation check and Documentation requirements. Those activities were putted in a separate blocks connected with the PDP phases with double face arrow because they must be taken in consideration before the transition from phase to another. ISO 9001:2008 was putted as a large title that cover all the PDP phases and activities to indicate that the implementer must adopts ISO 9001:2008 during implementation.

The researcher used the flowchart technique to illustrate the main stages that are included in each phase in the general framework "shown in figure 1". This will help in understanding the PDP phases, and facilitating the implementation of the PDP projects.

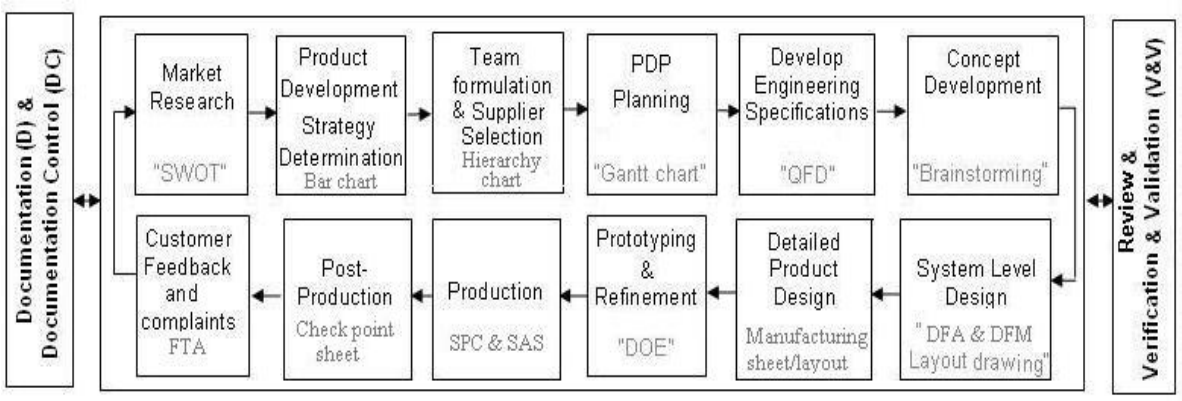

Figure 1 the General framework

Figure 2 shows two phases; market research and product development strategy. The aim of market research phase is to discover the unmet areas in the market and identify the opportunities and threats faces the organization as well as its strength and weakness points. This can be done by gathering and analyzing data about the customers and market demands.

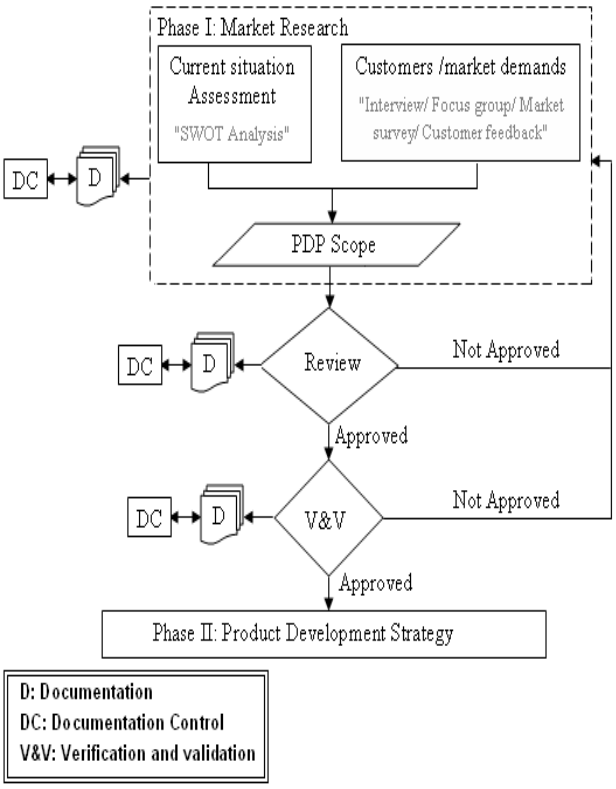

Figure 2 Flowchart # 1 "Market research phase"

According to ISO 9001:2008, the PDP cannot pass any phase without an approval. In market research phase, approval comes through verification and validation (V&V) check which shall ensure that:

- The product requirements are well defined
- The requirements of the customer cover the post-production activities such as delivery and maintenance.
- Contract or order requirement are different from those previously expressed and resolved
- The organization valid to meet the defined requirements

The PDP strategy phase aims to specify the PDP strategy by defining business strategic objectives and prioritize them. This phase can be illustrated as in the flowchart shown in figure 3.

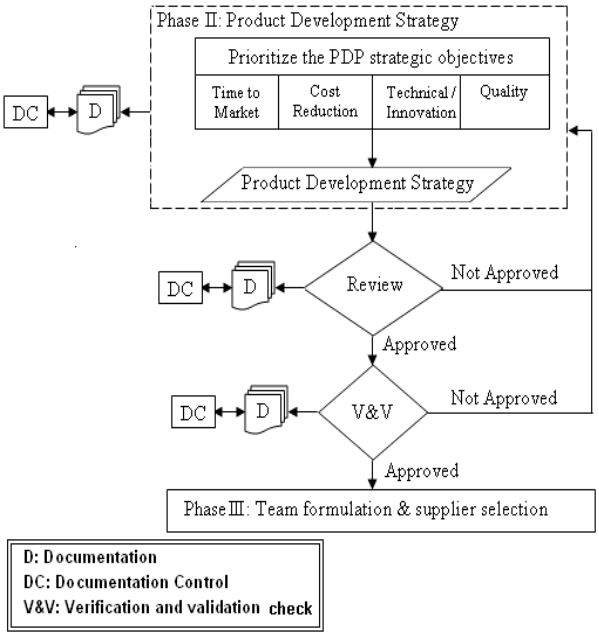

Figure 3 Flowchart #2 "PDP Strategy Analysis Phase"

As shown in figure 3, determination of the product development strategy depends on one main stage which is, prioritize the PDP strategic objectives.

Prioritizing the strategic objectives is the responsibility of the marketers, engineers and scientist. Engineers and scientists are interested in technology while marketers are interested in business issues [1].

According to ISO9001:2008, the procedures taken at this phase should be reviewed. The top management or his/her representative should verify that the PDP strategy meets the outputs of the market research phase also the top management or his/her representative shall ensure that the intended PDP strategy is capable of meeting the market demands.

The third phase; PDP team formulation and supplier selection phase", wasn't presented by most of the previous models. The researcher considers this phase as one of the most essential phases. That aims to put together the necessary skills and resources to facilitate informal communication and share the information during the product development project which in turn results in complete understanding of the requirements "customer's requirements and organization requirements, such as productivity and cost ensures a successful development of competitive products. The successful PDP team leads to fewer efforts in correcting the initial design deficiencies through reviews and engineering changes. Flowchart shown in figure 4 gives more illustration to this phase.

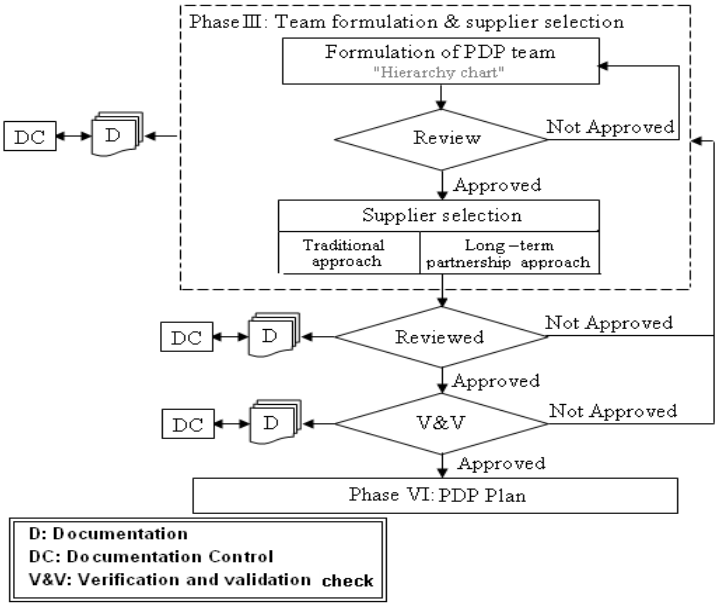

Figure 4 Flowchart #3 " Team formulation and supplier selection phase"

The PDP team consists of a leader and members. The PDP leader is responsible for reporting to the manager and organizing the relation between PDP team members. Also, it may have the authority to take some decisions. The team may include an engineering assistant to help in solve problems that face manufacturing processes. Also, it may include representative for suppliers and customer. All the contributors in PDP team must meet in a regular meeting and problem solving sessions. According to ISO9001:2008, this phase shall be reviewed before passing to the next stage, also the top management or his/her representative should verify that formulated PDP team has the skills and qualifications required to achieve PDP strategy , ensure that the appropriate communication processes are established within the PDP team and the suitable work environment is placed.

The CPD model provides two approaches to deal with the supplier, they are, Long-term partnership approach and traditional approach. Table 1 illustrates the difference between the two approaches.

Table 1 comparison between the traditional approach and long-term partnership

Criteria	Traditional Approach	Long Term Partnership
Philosophy	"keep suppliers on their toes"	"mutual dependence"
Supply base	Large supply base	Few suppliers - "single sourcing"
Contract length	Often short term contracts	Often long term contracts
Awarding contracts	Low cost bid	Negotiated

Supplier costs	Either company or supplier wins	Share cost savings (win-win)
Cooperation	Cooperation as needed; company protects knowledge	Frequent joint problem solving

The PDP team must carefully select a small group of highly competent, knowledgeable and trusted suppliers, then the organization management approves on the suppliers which expect from them the quickly response, responsibility and reliability.

This stage shall be reviewed before passing to the next phase, also the top management or his/her representative shall verify that the selected supplier(s) will provide the PDP team with required collaboration and have the ability to supply product in accordance with PDP project requirements.

The next phase is to prepare the PDP plan, figure 5. None of the previous reviewed PDP models mentioned the "PDP preparation stage" because they were not concern about the details of the phases.

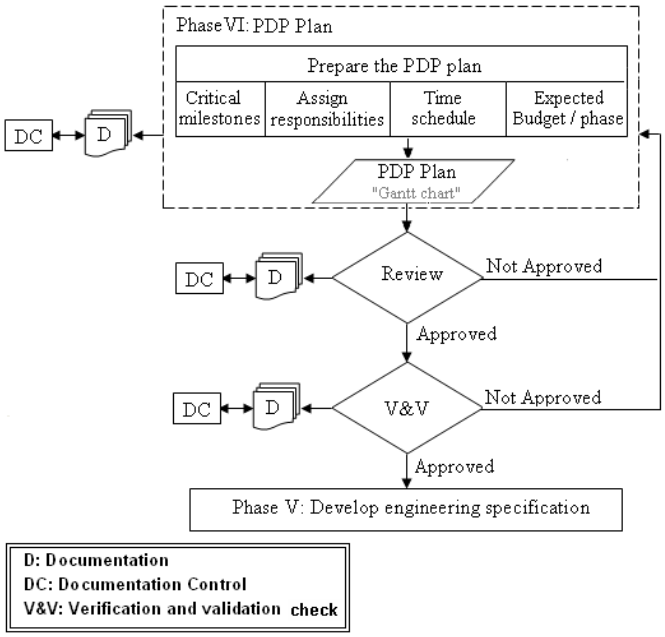

Figure 5 Flowchart # 4 "PDP planning phase"

As shown in Figure 5, there are four aspects must be taken into consideration to cover ISO requirements, they called "PDP preparation".

According to ISO 9001:2008, the PDP plan must then be reviewed carefully before presented to the manager or her/his representative. The PDP team leader must discuss the plan with the manager or her/his representative before execution. The manager should verify that the PDP plan is carried out in order to achieve the product development strategy also the manager must check the validity of the plan based on the organization capability.

Figure 6 shows the engineering specification phase. It aims to translate the customer's needs to engineering specifications.

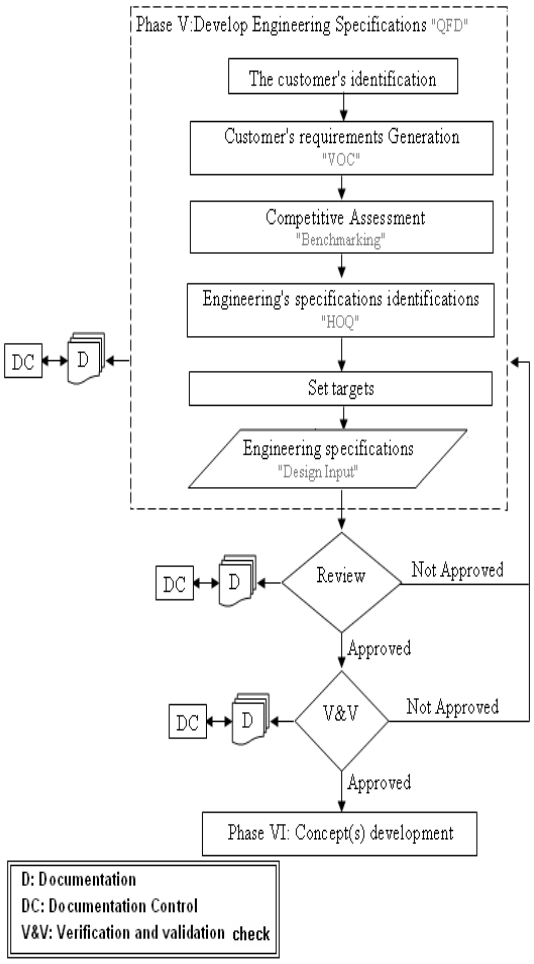

Figure 6 Flowchart #5 "Develop Engineering Specification Phase"

The Quality Function Deployment (QFD) technique is a most common technique used to translate the VOC (input) into measurable design requirements (output) with regard to application of engineering and technical knowledge. Figure 6 shows the major steps of QFD techniques.

According to ISO 9001:2008, this phase must be reviewed. The PDP team shall verify that driven engineering specification met the technical statements. Also the PDP team must ensure the ability of the engineering specification to meet the customer requirements, organization capabilities, regulation and standards.

The concept development phase, figure 7, was considered in most of the reviewed PDP models such as the models develop Ulrich [1], Broughton [3] , Rahim [8] , Paul [7], Fang [44] and Peters [5].

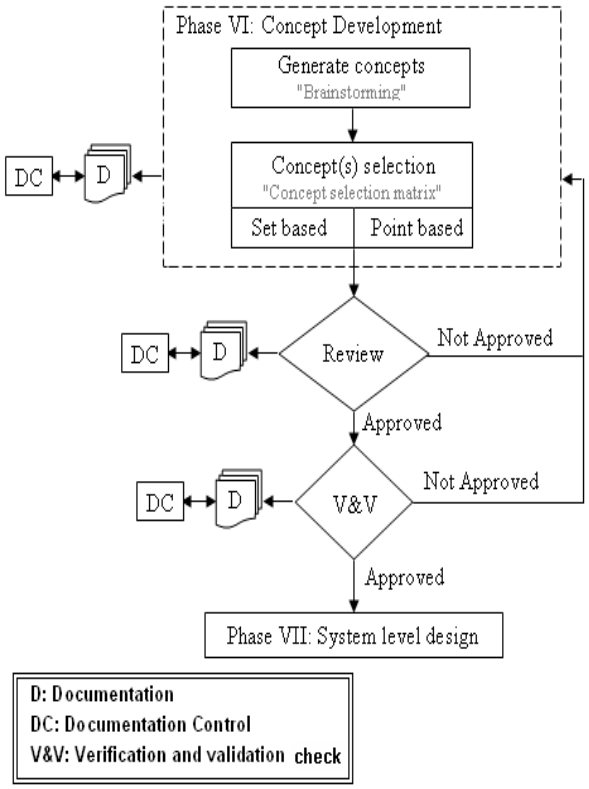

Figure 7 Flowchart #6 "Concept(s) Development Phase"

Through the concept(s) development phase, ideas are generated to satisfy customer requirements and specify a full description to the form, features and functions of a product [1]. It is important at this phase to encourage the innovative thinking to achieve the desired properties and performance.

Most of the reviewed models didn't neither present the concept selection criteria nor use the concept selection matrix technique.

The concept selection matrix will help the PDP team to judge between concept(s) in different criteria. This technique can be applied in "point-based" approach to determine the best concept. However, in case of "set-based" approach, this technique will help to specify a manageable number of concepts as well as organizing them.

The system level design phase, represented by the flowchart in figure 8, consists of one major step which is decomposing into sub-system. The aim of this stage is to decompose the product into subsystems. Each subsystem may be analyzed to sub-subsystem if required.

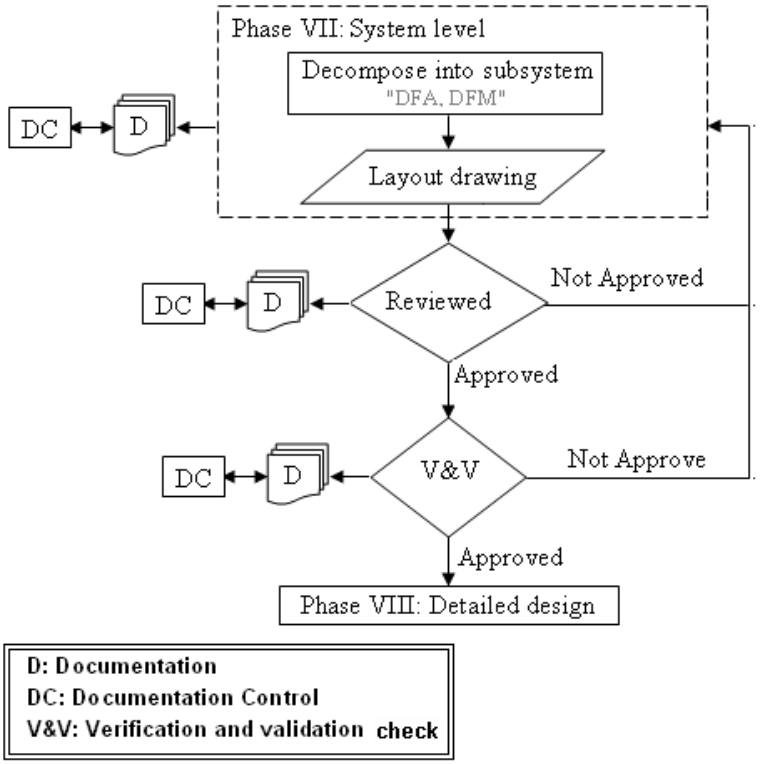

Figure 8 Flowchart #7 "System-level Design Phase"

The Design for Assembly (DFA) is a useful technique at this stage where it simplifies the product structures due to reduce the number of parts or simplify the assembly methods or sequence. The result is a product layout drawing without dimension which will be input for the next phase “detailed design phase”

According to ISO 9001:2008 requirements, this phase must be reviewed and the PDP team must verify that the output of this phase "layout drawings" meeting the selected concept(s). Furthermore, the PDP team must ensure the ability of the layout drawing to represent the product that will meet the customer's needs.

The detailed design phase, figure 9, can be considered as the core of PDP model. Its aim is to find all the information related to the product design.

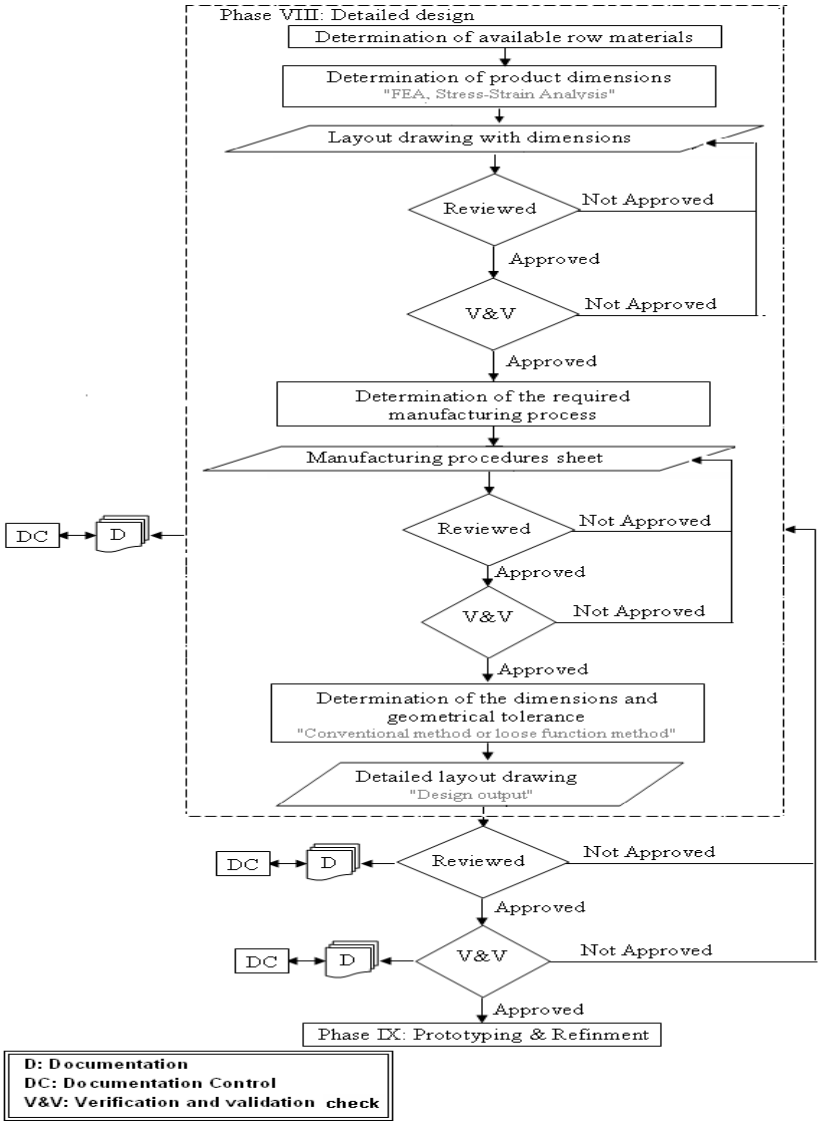

Figure 9 Flowchart #8 "Detailed Design Phase"

This phase consists of many steps some of them related to the product design and the other phases related to the manufacturing process design.

The PDP team must review those stages before passing to the next stage and verify that the developed layout meets the selected concept(s) and that the specification of the row materials includes the acceptance criteria.

Also, the designed manufacturing procedures must be approved from the manager or her/his representative and from any other interested agents to be valid.

The prototyping and refinement phase, figure 10, aims to provide a better look for the PDP team at final product and the problem(s) that could face them in production. The researcher adds some details to illustrate this phase.

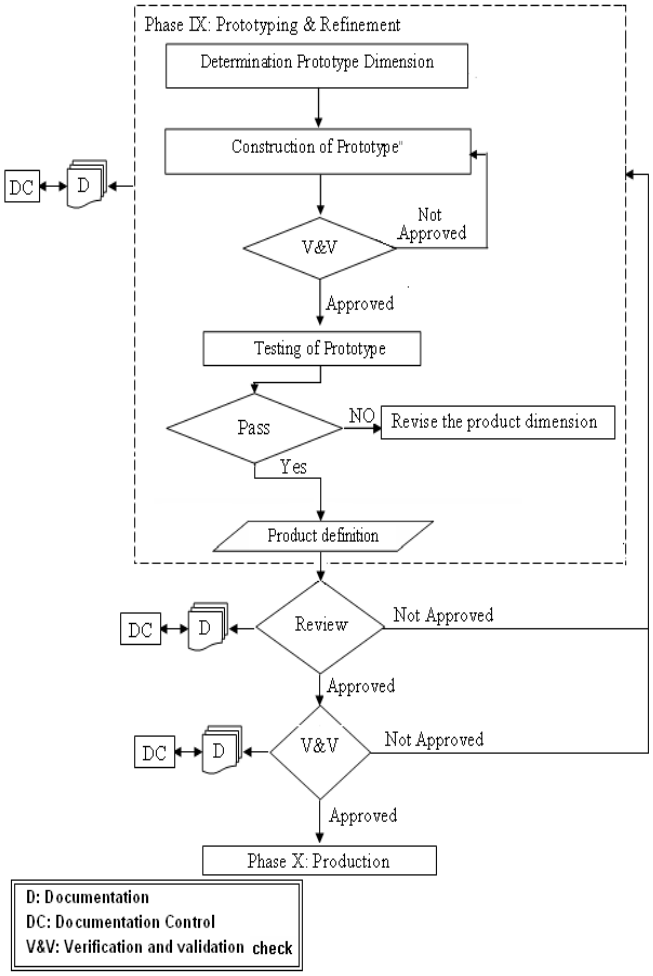

Figure 10 Flowchart #9 "Prototyping and Refinement Phase"

According to ISO 9001:2008 requirements, each stage must be reviewed before passing it. The PDP team must verify that prototype tests records "phase out" are driven from correct and accurate process.

At this point, the PDP team finished the development tasks and starts the supervision tasks. Thus the PDP project shall be approved by the manger or her/his representative and take the manufacturing decision.

The production phase, figure 11, aims to manufacture the required product. The production process requires ensuring that the manufacturing preparation (man, machine, method, material & environment) is done.

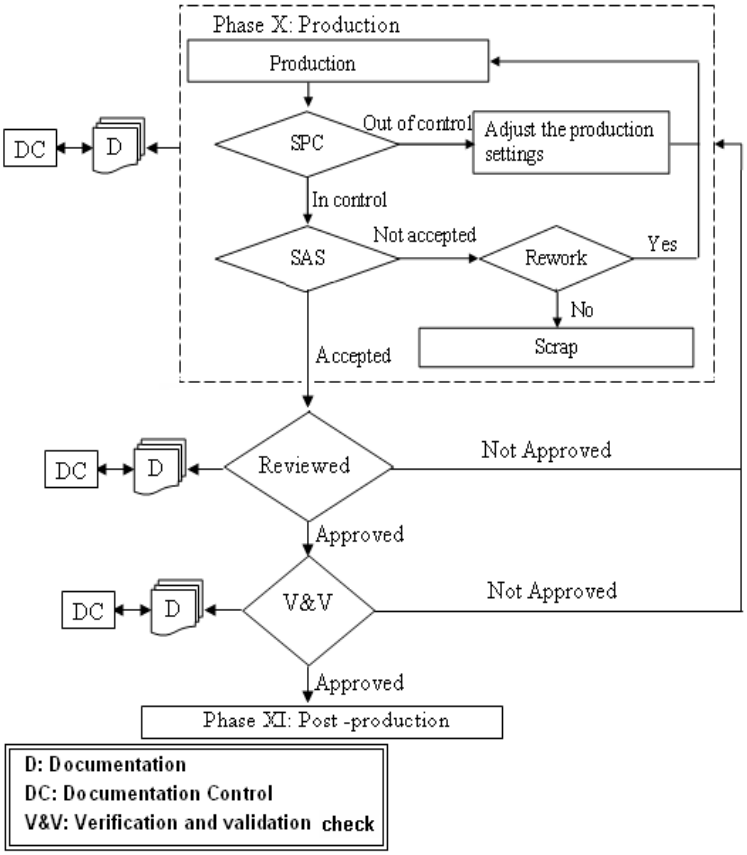

Figure 11 Flowchart #10 "Production phase"

The major key of a successful production is to have valid and suitable methods to control and monitor the quality of the developed product using Statistical Process Control (SPC) and Statistical Acceptance Sampling (SAS).

According to ISO9001:2008, the PDP team must verify that the production phase leads to product meet the defined engineering specification. Also the PDP team must ensure that the produced product satisfy the customers' requirements.

The aim of the post production phase, figure 12, is to clarify the major post production process. Thus it's ensure that the end user receive the product with the intended quality.

Each one of the shown activities must be reviewed, also the PDP team must verify that those activities are done on the right manner also the PDP team must ensure the quality of the final product will be kept at the same level till received to the customers. In addition, the PDP team must ensure that the product after sale will do its desired function through its expected life time.

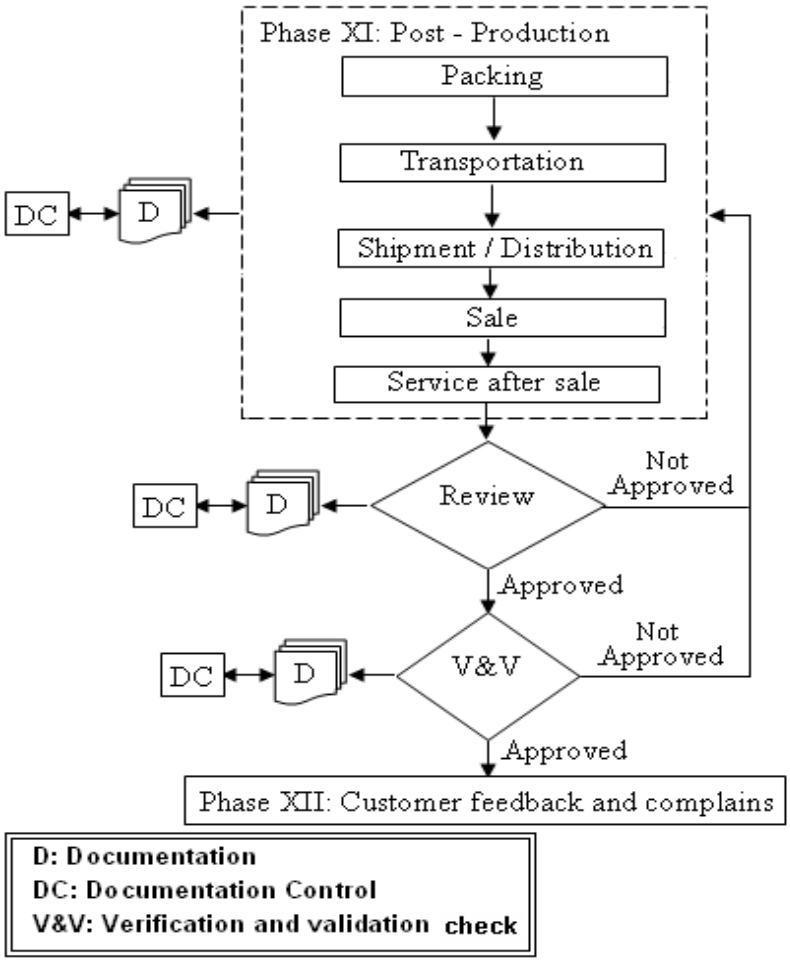

Figure 12 Flowchart #11 "Post-production phase"

The final phase is the customer Feedback and Complaints Phase, figure 13. Although most of the previous reviewed PDP models didn't consider the customers feedback one of the essential PDP phases, the proposed model "CPD model" considered the customer feedback and complains an essential.

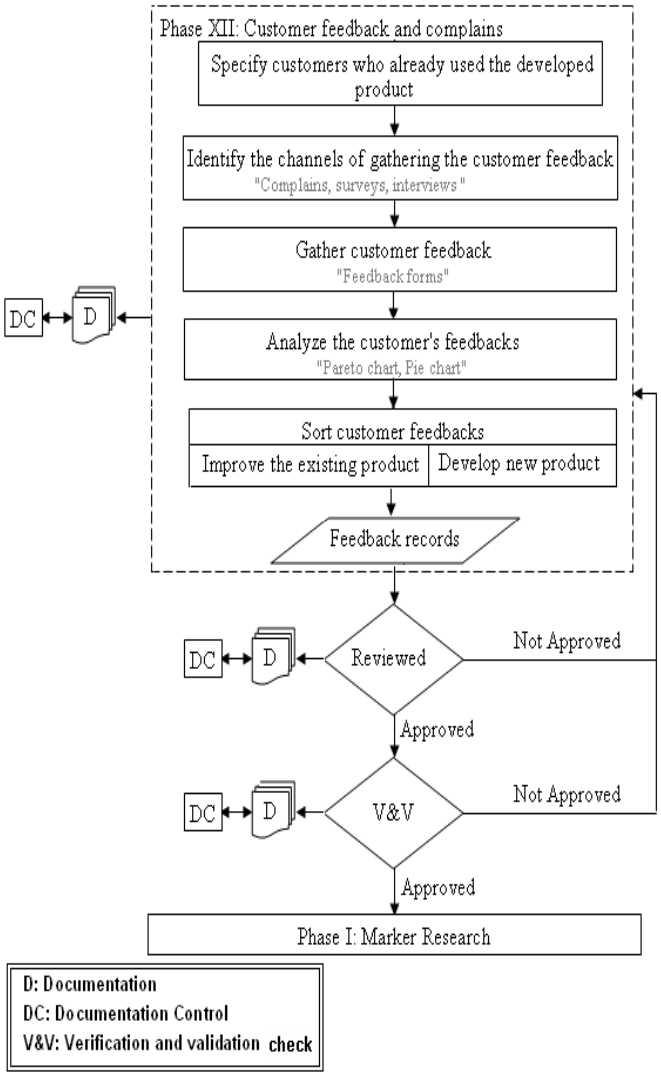

Figure 13 Flowchart # 12 "Customer Feedback and Complaints Phase"

It is an important phase to determine the results of the executed efforts and will help to specify opportunities for further product improvement. Also, it may result in the development of new product.

The findings of the feedbacks is used as input to the market research phase "phase I" to improve the existing product or to develop new product.

The PDP team must ensure that the feedback records the feedback records are reflect the data collected from the customers' feedback and complains.

According to ISO9001:2008, all the procedures involved in PDP and the occurred changes should be documented. The documentation of changes should include the reason of changes and its effect of the PDP project. The documentation can be in any type or form and filled adequately to facilitate the use of those documents when required. The PDP documents should be controlled to prevent unintended changes.

Conclusion

The researcher proposed a PDP model to be guide for the Product Development Process (PDP) implementation. The CPD model consist of twelve phase, they are market research, Product development strategy determination, team formulation & supplier selection, PDP Planning, develop engineering specifications, concept development , system level design, detailed product design, prototyping & refinement, production, post-production and customer feedback and complains. The phases are attached with the some tools and techniques such as, SWOT analysis, Gantt chart, QFD and DOE.

The model title is Cyclic Product Development (CPD) because the twelve phases are organized in a circular path. This circulation approach is adopted to make the PDP going on with Product Life Cycle (PLC). Thus, the PDP have tasks to do during PLC stages (introduction, growth, maturity and decline). The last phase in the CPD model "customers feedback and complains" will be the fuel that moving the product development cycle.

The phases are controlled and monitored by three activities; they are review, Verification and Validation (V&V) check and documentation (D) and Documentation Control (DC). In addition, the researcher putted all the phase and activities under the frame of ISO9001:2008 to indicate that the implementation must be within the scope of ISO 9001:2008.

The phases are illustrated by the flowchart technique to aid in understanding the phases and facilitates the PDP implementation, thus the researcher developed flowchart for each phase. The flowcharts consists of many details that are not mentioned in the previous PDP models.

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