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CONCURRENT PRODUCT DEVELOPMENT IN SOFTWARE ENGINEERING: A LITERATURE REVIEW

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***Abstract*— Concurrent development model which is also referred to as concurrent engineering, is an approach to design and develop products where different stages are executed simultaneously. The product development time and the time to market are decreased, leading to improved productivity and reduced costs. In this paper, we will discuss about the process involved in the development, the model of organization of the development process, and further we will focus on various attributes and elements of concurrent process development and we will also discover how it finds its application in today's world.**

Keywords— **Concurrent Development Model, Improved Productivity, Reduced Costs**

I. INTRODUCTION

As we progress into the future, the demands of the customer are getting higher with respect to the fast economic development, result being high expectations for the personalization, re- liability, price and speed delivery. This process of development has a huge influence on the competition among the enterprises that develop the product, who face various difficulties and challenges in flexibility with the new technology or the lack of technology required for the particular project. The point that is of utmost importance for immediate consideration is to look at the traditional method of product development that ignores the environmental factors and the crisis involved in the development process. The process of development of architecture and the requirements of the system for engineering needs to be carried out parallelly in the real world. Since the sequential model of the product development has a lot of shortcomings and it often results in delay and challenges in the process. A set of major technical operations, tasks, and their related states can be represented schematically in the con- current process model. For each of the software engineering operations, the concurrent process model describes a sequence of events that will cause transitions from one state to the next. An inconsistency in the research model, for example, is discovered during the early stages of design. This helps us to rectify the problem which in turn leads to the correction of model. The concurrent process model is commonly used to develop the client/server applications. A client/server framework is made up of a number of different components. The concurrent process model distinguishes operations in two dimensions when applied to client/server: a device dimension and a part dimension. Three exercises are used to solve system-level issues: design, assembly, and usage. Design and realization are the two tasks that discuss the part dimension. Concurrency is accomplished in two ways:

1. Device and component operations happen at the same time and can be modelled using the state-oriented approach; 2. A standard client/server program is made up of several components, each of which can be built and realized at the same time. This model is relevant for all forms of software development and it also provides an exact update on the current state of the project. It describes a network of activities rather than confining software engineering activities to a series of events. Each operation on the network occurs at the same time as other activities. Transitions between the states of an activity are triggered by events that occur within a given activity or elsewhere in the activity network.

II. APPROACH TO CONCURRENT ENGINEERING

Concurrent engineering process model is adapted and used by very few organization and instances. The main reason of organizations not opting for it is due to the fact that very few organizations are able to set the right approach, let alone implementing those approach. Therefore, concurrent engineering has developed three parts to it so that organizations can have a NAD (New Application Development) using concurrent engineering.

A. Elements of Concurrent Engineering –

Concurrent Engineering has defined five elements to take care of while engineering a product, keeping them in check

will help to make sure we benefit from all the advantages of concurrent engineering. The five elements are: -

1) Co-location of members in the team: All the team members should be in close proximity of each other during implementation. Although this practice is not necessary it is encouraged. The intent of having close quarters is to have enhanced communication and frequent team meetings.

2) Coordinating with other members in the team: The main idea here is everyone in the team co-ordinates with each other through out the lifecycle of product development in a market driver manner. This can be done by:

- Designate a concurrent engineering team leader.
- Clearly defining the roles of different people.
- Planning and creating a work schedule
- Make other members familiarize with practices, processes used.
- Making teamwork an integral part of employee performance evaluation.
- Showing token of appreciation by rewarding members of the team when goals are met.

3) Sharing necessary information.: This is needed so that right people have the right information at the right time. So whenever a team wants to work on a process like testing a part of code or deploying a part of code, the necessary information should be available. The most apt solution developed for this is to implement a form of data/information management that will understand the team needs and disseminate pertinent information to team members in a timely manner. This needs to done carefully so that data integrity is preserved and making sure multiple versions are recorded.

4) Capturing past company resources.: This is a part of long term efficient concurrent engineering process. This includes the documentation of lessons learned from past experiences and reflecting on those such that mistakes are not repeated and thus makes room for improvement.

- Collect important metric data
- Make sure lessors are learned from previous developments and best practices are incorporated.
- Set up training programs so that experienced staff can share necessary information to the younger staff.
- Document the lessons learned during and upon completion of current development.

5) Integrating appropriate services and tools: This is the part that defines the method of communication with other members using automated technologies for information sharing such as phones, E-mails, LANs, Online meet and other tools. Organization can even maintain simplicity by just maintaining a search functionality in the database that will come up with relevant information when required, however this might possess security issues if it is found on the hands of wrong people.

- Define a tool that is feasible for all the team members of the project.
- Implement the set of tools that finalized by the development team.
- Provide education on the usage of these tools.
- Set ground rules and standards for tool usage

B. Product Concurrent Development Process –

Initially the process of the concurrent product development resembled to a relay racing competition, where the task passed from one group to another like a baton in the relay. The process started with the market research departments bringing forth an

innovative idea, which is handed over to the designers, who further transform the idea into an actual design with the help of the existing scientific and technological advances, then draw the designs and pass these drawings to the production sector to assert the production of the final requirements with the help of existing equipment. The same process is continued many times in a cycle. Once the design is prepared, it is the duty of the supply sector to order the necessary equipment and materials, this part takes a long time. The result of the above chain is that process of the product development had to be held from proceeding further, to analyse if there exist any mistakes or faults in the existing design. The modification of design includes large number of amendments that are ancillary. The process traditionally is start of downstream after the finishing of upstream. The limitation or the disadvantage of the of this traditional method is that it is a really long and time consuming in the production development phase due to the high number of changes in the design; since the realization of the product is considered from a technical view by the designers, so it becomes difficult to reflect all the requirement stated by the customer.
Concurrent engineering (shown in the Figure 1) involves the designing of the product concurrently. It is the requirement of this method for the product developers to consider all the factors that are a part of the whole life cycle that starts from Concept to the product abandonment (which includes quality, schedule, cost etc.. . .). The methodology of Concurrent engineering does not mean holding speed with the method, but rather it means performing work that is arranged orderly and concurrent in development. The Concurrent Development method comprises the use of process decomposition, information releasing and sharing information among the integrated product as they key in development. This method as described helps in overcoming the barriers involved in the traditional methods and aims at achieving higher efficiency.

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The entire process of concurrent design can be done using the computer which have the capability to define a digital product without drawing [2,3].
CAPP: Computer-aided process planning CAFD: Computer-Aided Fixture Design.

Organization Model that Product Concurrent Development follows*:* The essence of this type of development process is that the product development team, develop the product concurrently. Various parameters for design, process and manufacture, and various factors such as product design, process, manufacture etc. . . are taken into consideration by the product development team, to meet the requirements of the customers as the primary goal. The integrated product development team consists of a number of people from different departments and professions. A matrix structure is required by the organization team, which enables them to focus on the enterpriser resources to find solutions to complex problems and gain control over the challenging technology. In the paper a "crisis" concept is used to simulate sense of suffering, consciousness and creative spirit. The crisis concept is based on ensuring horizontal and vertical communication in the integrated product development. Different stages of development of the product have different crises from external environment, which keep changing. Crisis management team in the organization structure follow a set of principles:

- Prior Forecast Principle: analyzing all areas where there is any possibility of crises, and anticipate the risks. An insightful plan must be formulated to solve the situation of crises. The principles also incorporate that the decision makers present in the organizations should have the ability to determine the pattern of crisis and the degree to which the control is affected, in order to prevent further harm.

- Quick Reaction Principle: There is an ethereal opportunity, that is seized by the fast response to the market ratings. The method often encounters competitors who use advanced technology and design features. With the respect to this situation the organizations must rapidly respond and make effective adjustments in their product development plans.

- Flexible Principles: to flexibly deal with the crisis, the changing situations can be combined by the team managing the crises. This process is not only successful in overcoming the crisis, but also might provide the path of changing the crisis into opportunity.

Organizations often encounter delay in putting the product on the market and are often found extending their product development cycles because of some reasons. In accordance with one's own advantages, the crisis managers can offset their loss by methods of making the function better and making use of newer tools to market the product. An efficient system of crisis warning has been set up by the team managing the crisis. The warning gadget analyses variable from organizations external environment, product improvement and generating commercial enterprise process. Pre warning indicator is installation with the aid of using disaster pre warning gadget. The indicator is set up on some place, where it can capture the crisis prompted warning. Warnings are sent at any time and hence enterprises must be taking action and narrowing the scope of the loss and outbreak scale. Figure 3 shows the four components of the crisis pre warning measurement and the functions of the general enterprises.

C. Leadership –

Strong leadership and managerial skills are required to implement and foster an environment that is able to have concurrent engineering. Leaders needs to imbibe a philosophy among its employees to have a long term vision for the company. Each employee should be competitive enough and should have alpha quality to them, such that they possess excellent problem solving skills. Employees shouldn't envy and is essential to have a friendly positive environment. The culture of "I did this" and "It was their fault", should be removed. Managers needs to encourage other employees to have ownership, responsible, innovative and creative. Horizontal integration of work place should be encouraged by having different departments working alongside. Individual priorities should be entertained and team priorities should stand first. For a firm to make changes and have a concurrent engineering environment, managers and team leaders need to thrive for excellence and should encourage employees to have that attitude where employees are always looking for improvement. The firm shouldn't focus of plans that are imminent instead should focus on long term goals that will be achieve if firm is able to have such a concurrent engineering environment. For these cultural changes top quality management is required, and these cultures need to be companywide. Team skills and leadership can be taught to employees through education and must be encouraged. Improving the communication with management, business staff and development team will help support continual

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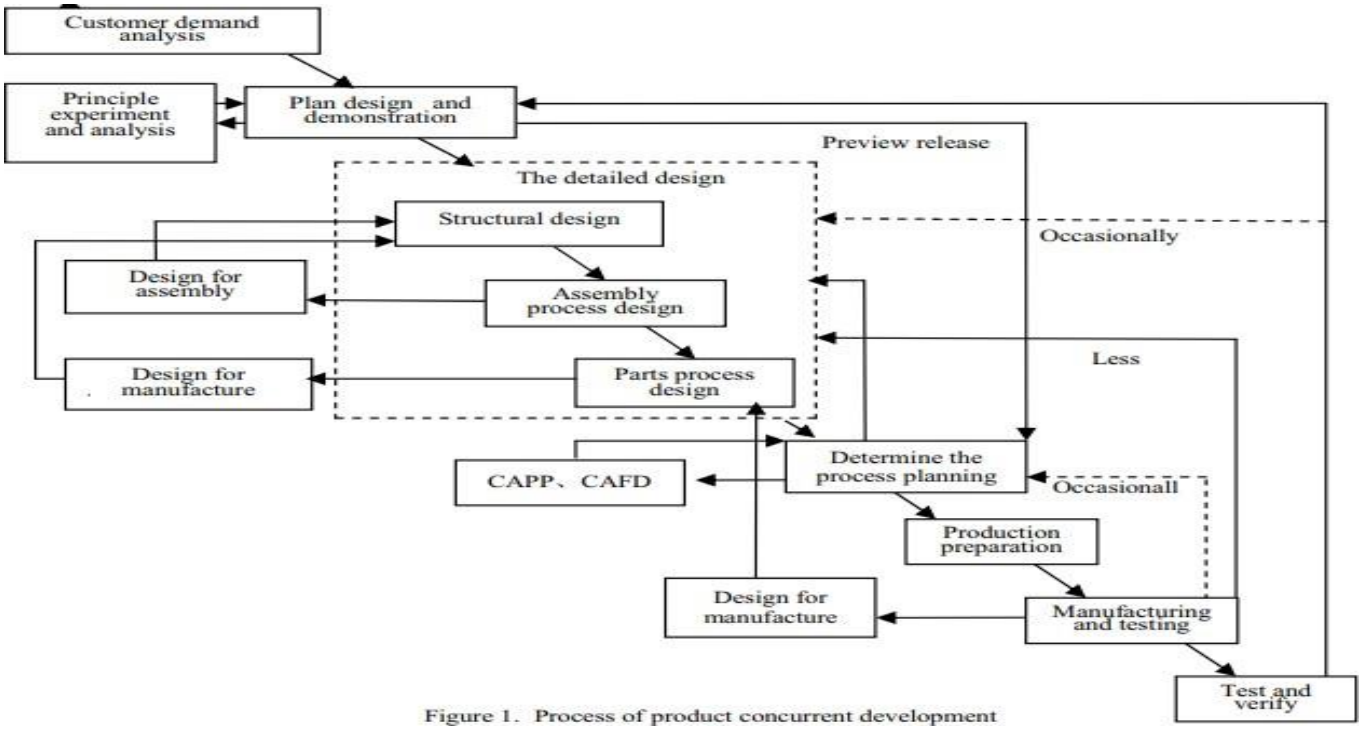

Figure 1. Process of product concurrent development

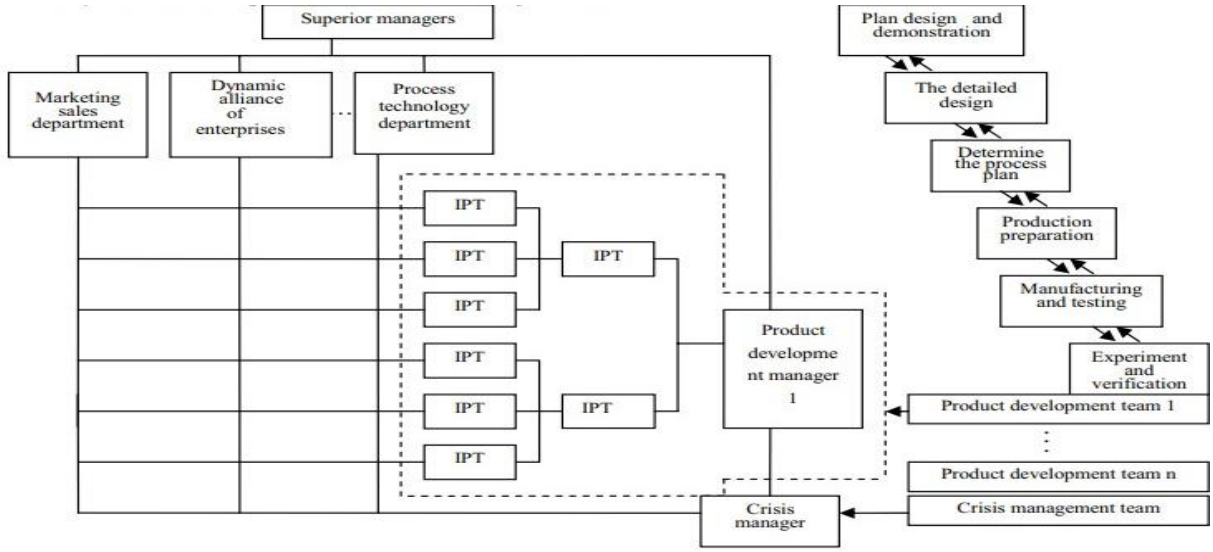

Figure 2. Model of organization in product concurrent development

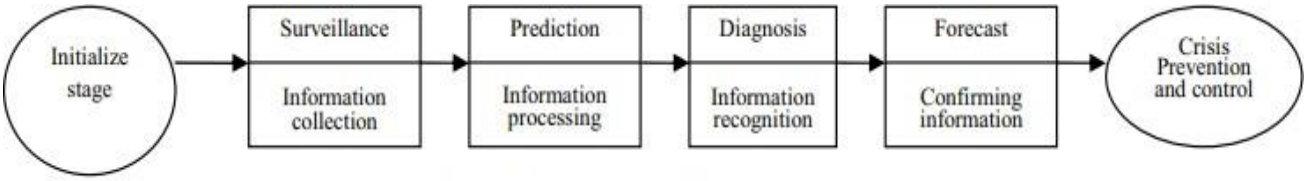

Figure 3. Frame diagram of the enterprise pre—warning

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process improvement and refinement. Pro- cesses should be broken into parts by managers and each part should be addressed with best possible solution, keeping in mind the finest of details. The parts then should be built up by combining everything. Managers should also omit the old office culture of timing and should enforce less bureaucracy amongst its employees and have work standards that are both flexible and adaptable.

III. NEED FOR CONCURRENT ENGINEERING

Nowadays, companies try to find ways to improve the end result of their goods, services in order to compete in the market against rival companies and to make their product development process more effective. A growing number of businesses are adopting this strategy after having discovered that the traditional approaches to product life cannot achieve these objectives. Earlier, certain engineers known as proposal engineers used to write proposals and then hand them over to systems engineers to work on during the program development phase. After that, these engineers generally used to create specifications related to software for another set of engineers commonly known as software engineers, who would then begin with their work that is coding. The engineers who used to work on all the aspects related to the hardware received the product design and construction specifications. Verification and validation programmers would test the specifications of the software and the engineers who deal with checking and testing would eventually check the end result. This process followed a sequentially working system and alteration in the design of the product often led to delays, rework, need of higher man power and an increased cost. Furthermore, there was always a disconnect between the expectations of the customer and the final delivered product. Concurrent

development translates the customer's expectations towards the finished good by engaging a team in this complete process. Concurrent engineering implies construction of a product and the processes that support it at the same time. Methodology and quality of product are of utmost importance along with everything else. Concurrent development deals with all the stages of the process right from defining the requirements to manufacturing. It also deals with all the concerns related to the entire life cycle of production and development. A common understanding between the team members makes it easy to achieve effective solutions for design issues and concerns. With rapid development in this field, customer satisfaction has become a major priority for everyone involved in the project. Concurrent development techniques and user-friendly environments are extremely important to enhance the coordination and relationship between team members. This further helps them to focus on one common goal of improving and succeeding. Therefore, concurrent development has proved to be quite fruitful and advantageous.

IV. FEATURES

The features of concurrent engineering vary widely across numerous fields and industries.

A. Multidisciplinary teams:

1. People from various areas of interest come together and form groups to develop products. These groups referred to as teams consist of product-specific members. Many such teams are formed depending on the need and necessity.

2. These teams generally include people from various disciplines such as engineering design, manufacturing, finance, research and development, logistics, quality control and marketing. The organization and orientation of the team depends upon the group members.

3. A team might consist of various other small groups within itself with each group comprising of people specializing in their own respective fields. This hierarchy is created for better functioning and ease of development of various parts of the final product. The division of work amongst various groups makes the overall process easier thereby making the production of a complex product quite simple.

4. Even though every team has a team leader, it is the responsibility of each and every member to ensure complete participation and contribution towards the development of the product.

5. Issues related to the working and the development stage can be resolved by actively networking with all the sub- groups.

B. Tools:

1. There are many electronic tools available for portraying the work done by the engineers in designing and development of the product. Rather than the conventional paper drawings, the output or the final product work can be presented in the form of computer-generated images. CAD tools are used for this purpose.

2. The computer software and its tools are quite efficient in conveying the final designs to the members. All details related to the product can also be kept in electronic form. This has indeed led to

innovation and development of concurrent engineering.

3. These computer tools are usually easy for everyone to learn and execute. They not only make the work easier but also help in creating interesting and informative graphics which are understandable to people from all disciplines.

4. Communication between people becomes simpler and data storage becomes even more efficient. There is no need to stock data sheets for records as it had to be done previously.

C. Design and Communications:

1. Rules and certain schemes have been designed and developed to help mitigate problems and reduce costs for design engineers.

2. Design For Manufacture (DFM) is one of the rules that warns the designer when cost for machine tools exceeds the limit. It helps the designer to avoid certain configurations that are not practical and sensible. It also saves time as designers do not have to wait for the estimates of total time and cost that might be needed for completion of the design.

3. Design For Assembly (DFA) is a rule that helps the designers to avoid problems related to assembly while Design For Inspection (DFI) warns the designer of problems in the respective area. Design For X (DFX) rules are incorporated by the system to see to it that the users are strictly following all the rules while designing.

4. Computer-Aided Process Planning (CAPP) is a tool that is quite helpful in manufacturing process. It helps to determine the machine and equipment required for the task. It also highlights how and when they have to be used during the implementation.

5. The systems, CAD and CAPP allow the designer and the manufacturer to make adjustments and necessary changes to the product.

D. Facilities:

1. A dynamic environment is created for the employees, managers and team members to communicate and share ideas for the development of the product.

2. The workspace provided makes it comfortable for teams to gather and conduct discussions and meetings.

3. The equipment, computer software and other advancements have led to rapid development and progress.

E. Organization structures, culture and change:

1. The organization structure that comes along with con- current development is different and might be new for many people. Teamwork, participation and simultaneous execution of tasks might be a change of culture.

2. Vision, accountability and discipline, such values are shared among team members so that they can make complete use of technology and all resources that are available.

3. Concurrent engineering helps the designers to gain authority in decision making and helps them focus more on designing and other mechanics.

4. Due to the implementation of a properly planned structure, repetitive and continuous changes during the development stages of the product can be avoided.

F. Accounting and Metrics:

1. Accounting helps the team to evaluate the impact of its decision on the total cost. This is one of the most important features of concurrent development.

2. All the departments go through the reports of cost management and analyze them according to their own point of view.

3. Accounting not only helps in determining the present expenditure but also helps in formulating future expected costs which is an integral aspect of planning.

G. Quality Methods

1. The maintainability of product and quality assurance are important objectives of concurrent development process.

2. The methods related to quality improvement are implemented in the beginning itself before actually starting with designing.

3. Inspection of task after its completion always resulted into rework and wastage of resources and money. Making use of quality methods in the beginning itself ensures optimum usage.

4. The quality of final product after having used the effective methods is much better than the quality that was achieved earlier.

V. ADVANTAGES

Concurrent Development has numerous advantages.

- The main benefit of concurrent development is improved customer satisfaction. The goal of every employee is to work towards the happiness of customers and fulfilling their needs and wants.
- Quality of product has improved drastically since the evolution of this concept. It has a much better finish than the earlier products.
- The cost for development of a product has reduced considerably as there is little to no room for error in the designing stage or the finishing stage.
- The total time required for developing a product has also decreased.
- Time required to market has reduced which in turn helps the companies to design strategies and work on increasing market share.
- Another advantage is reconciliation of conflicting requirements in product development.
- Concurrent development has a positive effect on throughput and efficiency of various industries such as agriculture, aerospace, automotive, chemical, computer, electronics, heavy machinery, medical devices and telecommunication.
- Scrap and rework, engineering changes and lead time has decreased by leaps and bounds
- Execution of design in parallel has led to improvements in a number of areas such as communication, cash flows, production processes and profitability.
- Due to well defined and documented processes, full volume production is achievable.

VI. LIMITATIONS

There are a few limitations concerning concurrent development.

- As concurrent development involves the usage of various software tools and techniques, it is a little complex to manage.
- Lack of expertise and knowledge on concurrent development and its application can create a lot of confusion thereby affecting the overall development of the product.
- The success of the complete process relies on communication and understanding between the team members.
- Cooperation and coordination between the groups is critical, without which it is impossible to execute and implement the plans efficiently.
- A small mistake can have a negative impact on all departments and disciplines. Therefore, the room for committing mistakes is close to zero.
- Every step has to be performed in proper sequence without using any shortcuts. If the teams fail to do so, it will be difficult for them to achieve the desired output.
- As concurrent development process involves a large number of people and groups, it might give rise to differences in opinion during decision making.
- Unrealistic work schedules can act as a barrier.
- Inadequate support from the management can pass on a negative vibe to the employees resulting into lack of motivation and interest in performing their job and duty.

VII. CONCLUSION

All in all, concurrent engineering process model is a very robust process model and when implemented correctly the benefits are endless. The concurrent process model philosophy can be concluded as a process where emphasis is not only given to the practices and tools to be used but also people, including the employees and the managers. The process model works on targeting and deploying the problem statement as a whole team without any facing an ambiguity in communication. The unsaid part of concurrent engineering is wanting the betterment of the organization and clients rather than self. With the right approach in concurrent engineering, we can save time as well as money. In the article the

integration of a group that manages the crisis is done, since it emphasizes to promote the enterprise groups to participate in managing the crisis in the concurrent product development.

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