Improvement in Subsisted Product Delivery Process of Manufacturing Organization using Concurrent Engineering

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Abstract: There is a strong market demand to develop product quickly, according to customer requirements at lower cost. To fulfill this demand, it is essential to develop product in such a way which is quicker and improved than traditional sequential way of product development. This can be achieved by replacing existing practices of product development with a collaborative approach of Concurrent Engineering (CE), which explores the opportunities of removal of design errors at initial stage. In this paper an attempt has been made towards exploration of implementation of CE. An existing Product Delivery Process (PDP) of local manufacturing organization has been closely observed and analyzed on the basis of Concurrent Engineering principles. Possible areas of improvements have been identified and prioritized for improvements. A comparison is made between the traditional and concurrent approaches and based on analysis; comparison has been made for bringing the current Product Delivery Process (PDP) of a manufacturing organization closer to the Concurrent Engineering (CE) concept. The recommendations advocate user companies to implement CE as a tool in manufacturing organization which is justified after comparison that the approach is valid and implemented in similar organization.
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Key Words: Concurrent Engineering; Discrete parts Manufacturing Industry; Product Delivery Process; Supply Chain; Program Approach

1. Introduction and Literature Review

The objective of a manufacturing company is to make use of resources efficiently to maximum profit. In the new era, the paradigm is shifting from mass production to mass customization. There is a demand by the companies to launch the product with minimum possible product development time with existing recourses. The new product is launched to the market early to earn profits. The existing industrial environment is a form of sequential process. These activities include design process, planning, manufacturing, QC, packing etc. Theses activities may increase in number in different industrial sectors depending upon the complexity of the products and processes. The engineering changes and production impediments is quite high in existing setup. This is considered a slow approach and time to launch new product is high which added cost of the product. In order to cope with this situation, concurrent as a tool is a likely approach which is a collaborative approach. This paper is an application of the Concurrent Engineering (CE) tools used to improve the existing product delivery process of a manufacturing Company.

The Integration of team, empowerment of team, training & education will be more thoroughly discussed in the topic of cross functional teams [1, 2]. The product development process is from concept design stage to the delivery of the product and is important for product development [3]. The product design is checked with respect to manufacture, assembly, QC, packing or cost [4, 5], following design strategies may be used in the process design, Design for Manufacturing (DFM); Design for Assembly (DFA); Design for Quality (DFQ); Design for Cost (DFC). One of the important areas in this regard is to use the latest CAD/CAM Techniques and to share the data between design, manufacturing and other departments [6, 7, and 8]. All these requirements demand a strong communication infrastructure which is required for the effective implementation of concurrent engineering. The main component of Concurrent Engineering studied by [9] is also beneficial in this regard. The papers related to the new directions of CE from cross functional teams, multi agent distributed systems is significant [10, 11 and 12]. The work of reworking in CE has been reviewed in order to include it within the company [13]. Some suggested using simulation based tool for performance optimization and embedded the concepts of CE for the organizations, the related work of [14, 15] is important too. The expanded form of managing CE has been adopted in this case study and work of [16] approach is followed for implementation. The following section describes a case study of a local surgical company. The company exports surgical instruments and facing with problem of late delivery and high cost of the products. To cope with the above problems application of Concurrent Engineering principles are explored, investigated and compared in the selected case company. To Achieve the above purpose, various persons in the company were interviewed, existed design process was thoroughly checked, design phases were analyzed, manufacturing system was studied, design and manufacturing department communication was studied, quality checks and various data was collected (thus as a whole the Product Delivery Process was studied). This all was done by observing the whole process followed in design and development of a product which is in early design phase. CE has following four major advantages. a) Reduction of product launches time; b) Reduction in product cost, c) High quality of the product; d) Team work Environment. Four area of the Concurrent Engineering consists of following components are organization, product development, communications and requirements.

2. Existing Product Delivery Process: A Case Study

The organizational structure employed in case company is somewhat similar to functional structure and is shown in figure 1

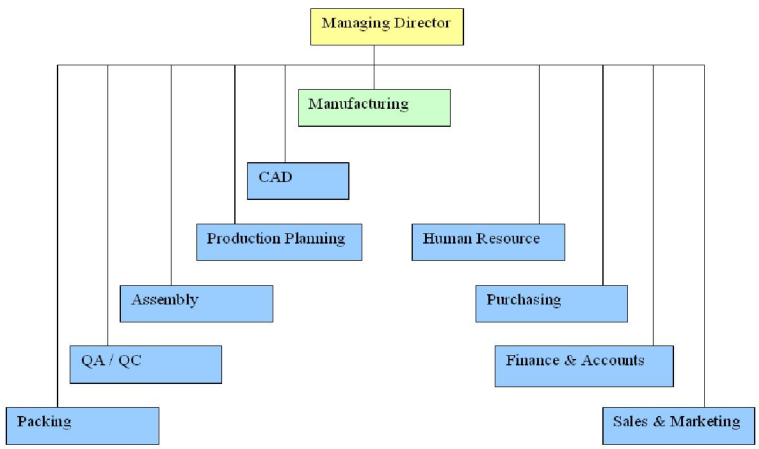

Figure 1 Organizational Structure (Existing case)

Mainly 11 departments are working in this organizational and sole proprietorship organization is Managing Director of the company. Marketing Department accesses the Market demands by taking part in different exhibitions held in different occasions of Europe. The design function will take the idea and specification gathered by marketing department and then translates them into drawings and detailed manufacturing specifications. After detailing the drawings are thrown over the wall into the production planning department and after scheduling, planning take place and subsequent to which manufacturing department become responsible to manufacture the required part. If needed some parts are subcontracted and then checked by the QC departments. The rejected parts are either scrapped or sent for further reworking. Engineering changes were usually not raised because the manufacturing department thinks it's the point of "EGO" for them to raise engineering change .They took it as challenge and cost of manufacturing goes on increasing. There were certainly barriers amongst the department. The team approach and the communication infrastructure is not well organized .The existing product delivery process is shown in figure 2.

The customer Requirements; Overall Length = 202mm; Over all width =22 mm; Over all depth = 62mm. It consists of handle which is used to pull that device along with jack assembly and also consists of mechanism by which it can be attached de-attached from the Jack Assembly easily. It can withstand the load of hand jerk made during pulling process of the tissues along with the jack and product should not have sharp edges as it can cause injuries during operation. The tool used is Auto-CAD and final Assembly consists of four components: T-Bar; Post; Clamp Block and Screws. In existing case, total time required for manufacturing is 2.5 hours and this is shown in figure 3 as lead time of existing product delivery process.

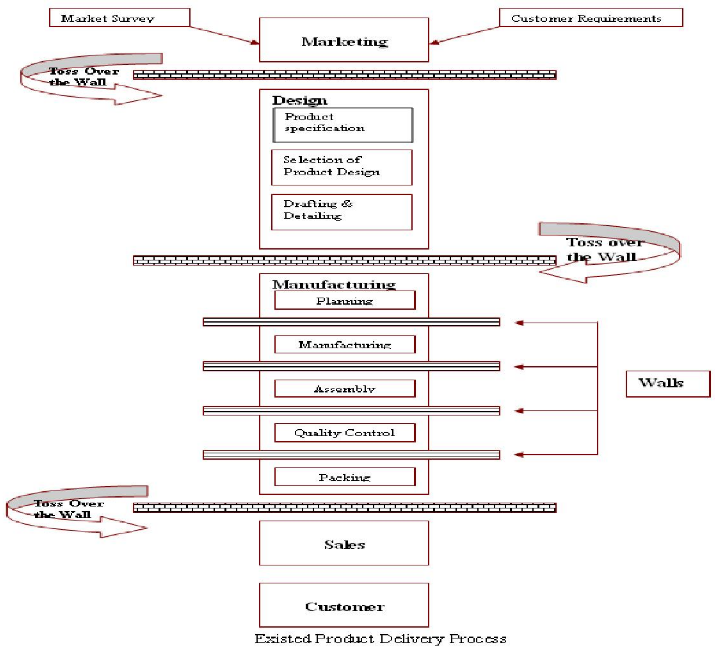

Figure 2 Existing Product Delivery Process

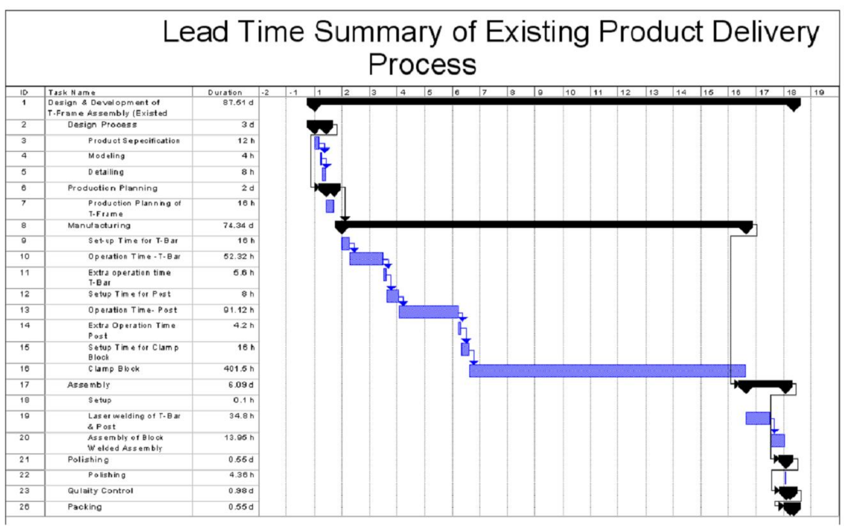

Figure 3 Lead Time Summary of Existing Product Delivery Process

3. Concurrent Engineering Assessment in the Case Company

If few individuals take part in the development of product which is relatively simple then the approach will be *'task approach'*. This is the lowest level of concurrent Engineering. If personals from same engineering department are involved in the development of fewer numbers of parts then this type of approach is called *'project approach'* (which also includes task approach). If cross functional team or teams from different departments are required for the development of the product the approach is called *'program approach'* (this includes task and project efforts). If along with the mixed discipline or cross functional team third part or vendors are also involved in the development of the product then the approach used is called *'enterprise approach'* (which includes task, project, and program efforts). The assessment includes the Assessment Questionnaire as given in figure 4. This assessment questionnaire will be used to identify the current status of company in which it is operating. All the questions are presented here in the form of four groups as four Areas of CE. The answers of the questionnaire will be given in *"Yes" (Y) and 'NO" (N) form*. From matrix chart it is identified that the required approach of concurrent engineering is *'program approach'*.

The next step is concurrent area map, which consists of four steps: **Step 1:** Area map has four quadrants for four major areas of concurrent engineering, which are further subdivided into components of each area. There are four rings representing the task, project, program and enterprise approach. According to the CE approach and area of concurrent engineering, the question numbers are plotted on the map, **Step 2:** The dots under *"Yes"* answers of assessment questionnaire are filled red and then the outer most-red dots are connected with the red line, **Step 3:** CE approach necessary to develop the product is refined from matrix of method. This will appear as thick line on the circle corresponding to program approach on the CE Area Map. Now some points *(Yes answers)* are at the thick line and some points are below the thick line.

Organization

Components	Task Approach	Project Approach	Program Approach	Enterprise Approach
Integration of team	There is very small interaction amongst individuals & disciplines Individuals have specific task and data is controlled by Individuals.	Project perspectives is used by the individuals of a single-discipline team. Data is not easily accessible by other disciplines.	Program perspective is used by a mixed-discipline team (Cross functional team). Data is easily accessible by other disciplines.	Mixed discipline team have members from the entire enterprise, including management, Suppliers, manufacturing, purchasing, customers, Service.
Empowerment of team	Individuals have responsibility while management plays a leading role. Rewards are given to individuals.	One of the member of single discipline team is selected as team leader by the management Decisions are a team Responsibility. Rewards are given to the single-discipline Team.	There is a leader of Mixed discipline or Cross functional team. The team has the authority to make Decisions. Rewards are given to the mixed-Discipline team.	Mixed –discipline teams involving customer and third party select a leader. The teams have authority to make decisions and to carry them out . Rewards are given to mixed-discipline Teams.
Training and Education	Individuals receive Specialties.	Single discipline team receive training on Procedures, tools, and standards.	Training on tools, procedures and standards used in mixed discipline environment is given to mixed-discipline team (Cross functional team)	An enterprise team(Cross functional team + Supplier or third party) receive training on procedures, tools and standards.

Communication

Components	Task Approach	Project Approach	Program Approach	Enterprise Approach
Product Management	Appropriate reviews are done at pre defined review stages.	Disciplined and consistent project approach is used for product management.	Clear communication paths are used for all aspects of product management and system requirements.	Mangers, Cross functional team, customer and third party are informed about the problems occurred.
Product Data	Individuals are responsible for controlling and storing the product development data	Individuals of single discipline team can access and control the data.	Mixed-discipline data in the product development database is accessible by the mixed discipline teams (Cross functional team).	Mixed discipline team has access to product development data as well as third party and customer supplied data.
Feed Back		Feedback from the customer is handled by the individuals of marketing and design department.	Feed back is handled by the members of single discipline team (Design Department).	The feedback from the customer is discussed by the cross functional team as well as the third party.

Requirements

Key Factors	Task Approach	Project Approach	Program Approach	Enterprise Approach
Requirements formulation	Customer expectations are converted into customer requirements by individuals.	Customer requirements are partitioned into functional requirements and specification by the single dicipline team.	Functional specifications are traced back to the customer by the cross functional team.	Costumer requirements are traced back to the customer by the cross functional team and the third party.
Planning	Short term planning is done before straing a task	Long term planning is done before starting a project.	Long term planning is required for a product family.	Company measures best-value product designs for cost, functionality, fitness for use, reliability, performance, and supportability.
Standards	Some basic standards are used by the company.	Reliability is checked on some developed standard	Design standards are used to ensure product testability, manufacture-ability supportability, and usability.	Design standards are regularly reviewed and continuously improved.

Development of Product

Key Factors	Task Approach	Project Approach	Program Approach	Enterprise Approach
Component Engineering	Individuals are responsible for development, control, and maintenance of their own component libraries. These libraries are discipline-specific.	Single discipline team is responsible for maintaining component data.	Component data of all disciplines is stored on single library system	Component data from multidiscipline, customer and third party is stored on single library system.
Design Process	Standard documented design process involving few individuals of design department is used.	There is documented procedure of reviewing the product design at defined design stages by the designers (Single Discipline team)	Cross function teams, involving representatives of down stream processes (manufacturing, assembly Quality), to review the product design early in concept design stage.	There is early supplier involvement in the design process along with cross functional team.
Computer Integration	Latest Computer Techniques are being used by the individuals.	Integrated CAD system is used by the designers at design center.	Integrated CAD/CAM system is used by the members of multi discipline team (Cross functional team) members.	Integrated computer system is used by the multi discipline team as well as the venders (Third party)

Figure 4 Assessment of Questionnaire (CE approach)

Step 4: In this step the area between the selected level of the concurrent engineering approach and the line joining the outer most circles of the *"Yes answers"*, is filled with gray color.

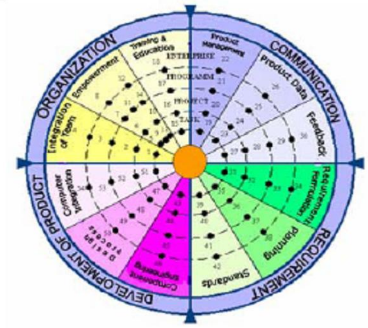

Figure 5; CE Area Map Step 1

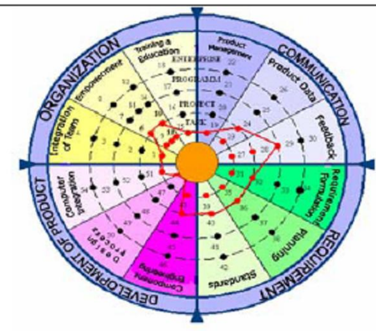

Figure 6; CE Area Map Step2

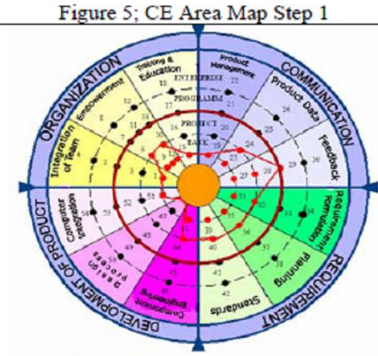

Figure 7; CE Area Map Step3

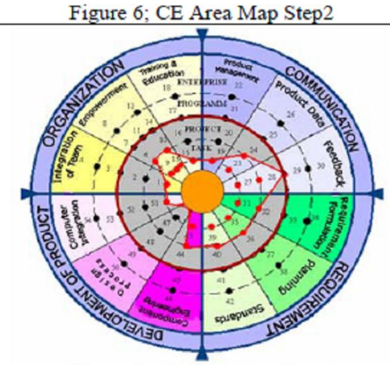

Figure 8; CE Area Map Step4

Figure 5~8 CE Radar Mapping (four steps)

3.1 Improvement Areas Priority Setting

This part is used to set the priorities of the lacking areas to be improved to balance the four major areas of concurrent engineering. In this part firstly priority is set to improve the four major areas of CE and then component within each area is prioritized. This is shown in figure 9 as priorities in the product development.

Development of Product

component	Action Item	Priority
Component Engineering	1- Establishment of multidiscipline data library system.	03
Design Process	1- Establishment of Standard Design Process	01
	2- Definition of appropriate design review stages.	01
	3- Early involvement of representatives of manufacturing, assembly, planning and people (Cross Discipline or Cross functional team) in design process right from concept design stage.	01
	4- Use of design for manufacture/Assembly & QC concepts	02
Computer Integration	1- Provision of centrally used CAD /CAM System.	01

Organization

component	Action Item	Priority
Integration of Team	1-Understanding of product development process.	01
	2-Presensence of decision making mechanism.	02
Empowerment of Team	1-Creation of mixed discipline team (Cross functional)	01
	2- Decision making by mixed discipline team	02
Training & Education	1- Provision of cross functional training for procedure, tools and standards.	01

Requirements

component	Action Item	Priority
Requirements Formulation	1- Traceability of requirements back to the customer	01
Standards	1- Use of Standards for manufacturability, testability, assembly (Design for manufacture , assembly & QC)	02

Communication

Component	Action Item	Priority
Product Management	1-Diciplined & Consistent Product Management.	03
	2-Definning the clear communication path.	03
Product Data	1- Making access of cross function team members to each others data.	03

Figure 9 Actions and Priorities (scale 1 to 3)

3.2Oorganisation and Product Delivery Process

On the basis of the CE based assessment new CE based product delivery process is suggested. Time and cost of the T-frame is recalculated using suggested product delivery process. The proposed organizational structure is shown in figure 10 and 11 as organizational structure and product delivery process of case company respectively.

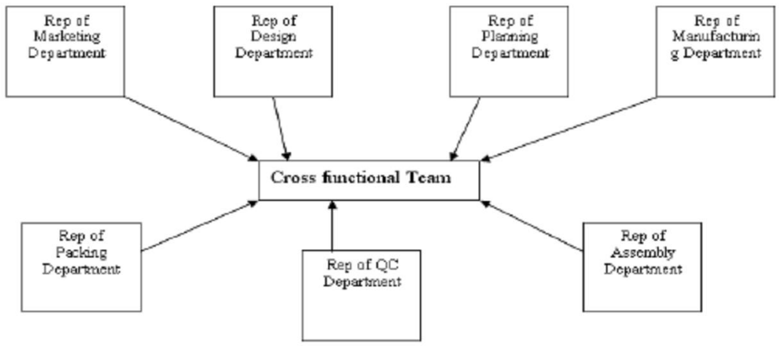

Figure 10 Proposed Organizational structure (cross functional team approach)

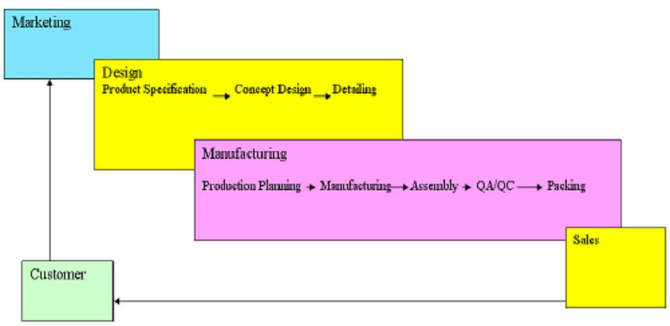

Figure 11 Product Delivery Process (CE Based)

3.3Design and Development of T-Frame

Since different review stages are defined and it is suggested to have two to three models at concept design stage. Out of three, one has been selected by the cross functional team. The suggested software tool used for modeling is Del CAM Power Shape. This has better modeling capability and can be used with Del Cam Power Mill for generation of G & M-Codes. The CE based documented design process is shown in figure 12. The detailing are a) the tolerance are now given using ISO 2768-1 medium grade Standard which is one step in using standards, b) instead of threads on the clamp block side of the post, laser welding will be used to join it, c) using the system of fits wherever there is hole and shaft fitting requirement.

The lead time or product launch time is calculated using the standard operational information and consists of 62.692 days. The lead time summary of CE based product delivery process is shown in figure 13.

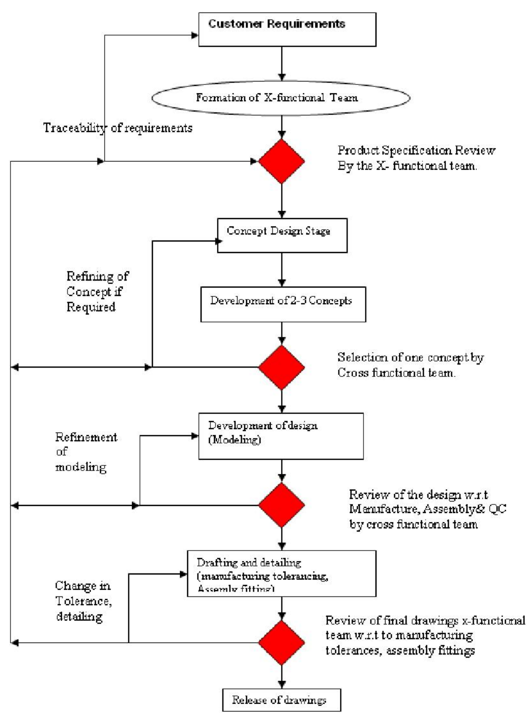

Figure 12 CE Based Documented Design Process

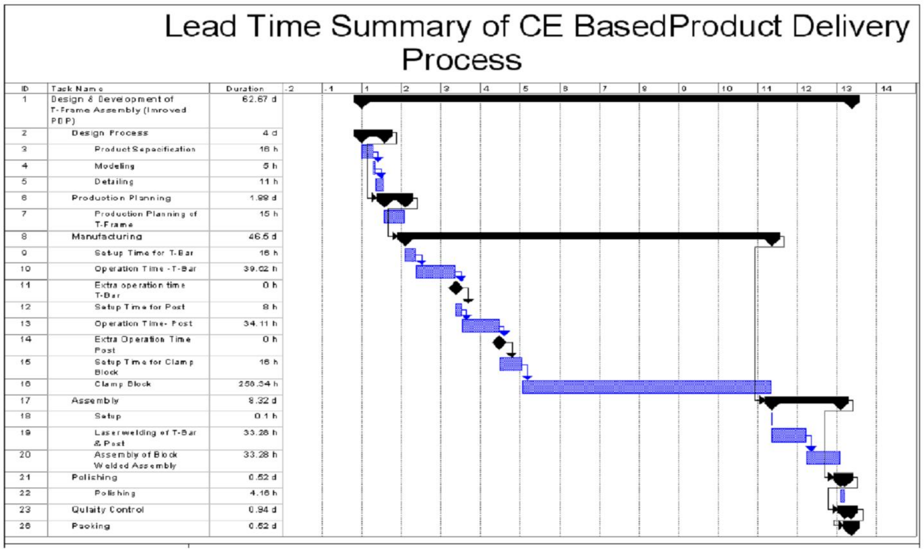

Figure 13 Lead Time Summary of CE based Product Delivery Process

The costing of the T-Frame Assembly is computed using the standard costing techniques used in industry and labor rate of Rs. 72 / Hr is used; direct labor cost Rs 536.856, indirect cost Rs 362.293, which gives total cost equal to Rs 899.149 (1 US$= Rs. 98).

4. Comparisons and Results

The improvements in the overall times are given in figure 14. Increase in design time is due to the introduction of design process model. This will increase the product launch time, but manufacturing time will be reduced by the removal of unnecessary operations due to tight tolerances and due to better design of the product. This resulted in time savings of about 198 hrs (lead time).Planning time has reduced by one hour. The comparative values are given in table 1 and 2.

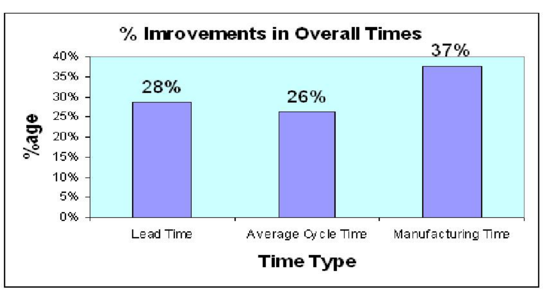

Figure 14 Improvements in Overall Times

In design and planning times comparison, most of the manufacturing cost is committed at the design stage; an improvement in design process (one part of “development of product” CE area) results in large saving in manufacturing times which is a step towards implementation of required approach of CE based on ‘program approach’ and values given in table 1.

Table 1 Design & Planning Times Comparison

Time Type	Existing PDP Times (Hrs)	Improved PDP Times (Hrs)
Design	24	32
Planning	16	15

These times are reduced due to the removal of extra operations on T-bar & Post is due to relaxation in tolerances as result of use of technical standards. However this reduction in manufacturing time is also contributed by technological advancement in manufacturing and given in table 2.

Table 2 Manufacturing Operation Times Comparison

Part Name		Existing PDP Times (Hrs)	Improved PDP Times (Hrs)
T-Bar		52.3	39.5
Post		91.1	34.1
Clamp Block		401.6	258.3
Extra Operated Time	T-Bar	5.6	0
	Post	4.2	0

The company was lacking in “organization and development of product” areas of CE as per CE based analysis. As a result of improvement of these areas (particularly use of standards, new esign process consisting of review stages and cross functional teams and technological advancement (computer integration plus CNC) an overall improvement in manufacturing operation times is witnessed. The improvement of manufacturing operation time is shown in figure 15.

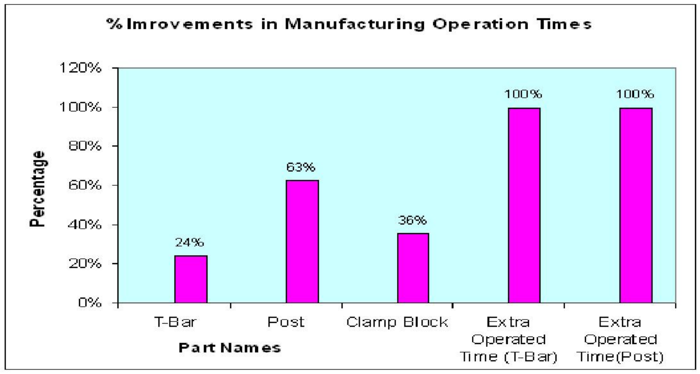

Figure 15 Improvements in Manufacturing Operation Times

Increase in assembly time is due to addition of laser welding process to join post and the block. This has resulted in reduction in manufacturing operation time. However polishing, QC and packing times are improved up to 5%. This improvement is due to reduction in rejections shown in figure 16.

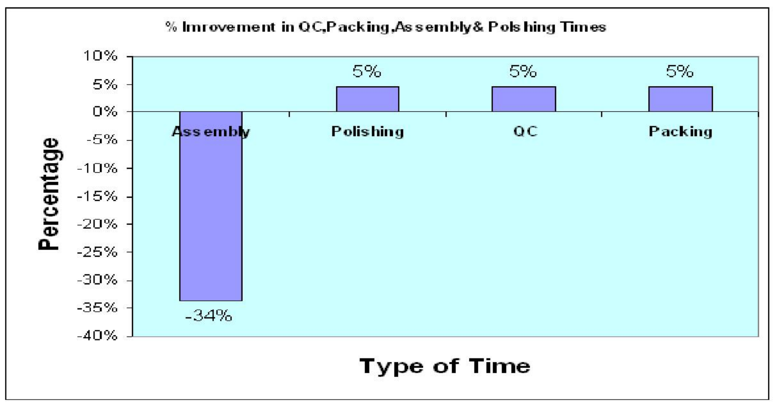

Figure 16 Improvements in QC, Packing and Assembly Times

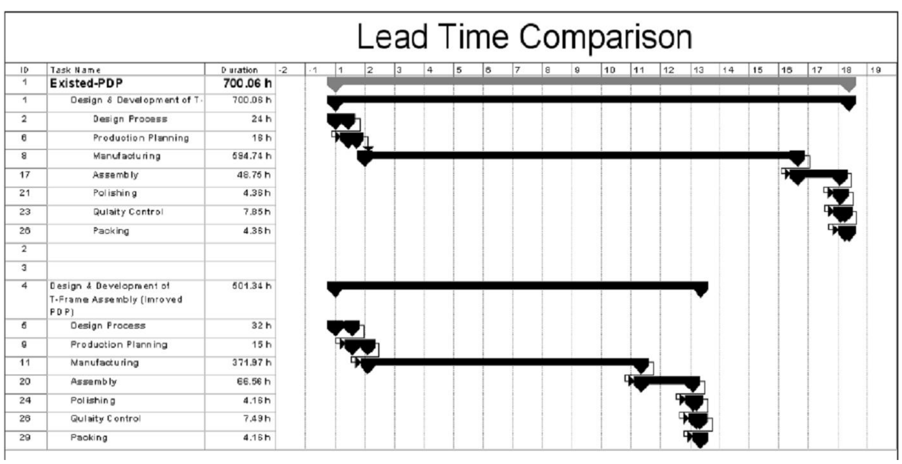

Figure 17 Lead Time Comparison

As a result of improvement in weak areas of CE ("organization and product development") an improvement is observed in all most all the areas of product delivery process (which is actually required to reach 'program approach' of CE). However in few areas an increase in time is observed, but this increase has resulted in large improvement in manufacturing times, the lead time comparison is shown in figure 17.

Reduction in cost is mainly indirect and this shows the reduction in overheads. These costs are mainly contributed by the reduction in times of manufacturing operations shown in figure 18. These reductions are observed due to overall improvements in product delivery process of the organization.

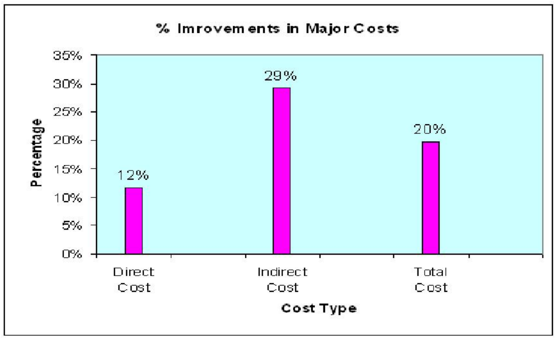

Figure 18 Improvements in major costs

Reduction in rejection is due to improvement in education and training (organization area of CE), while reduction in extra operated part is due to relaxation in tolerances due to use of standards and miscellaneous comparison as shown in figure 19.

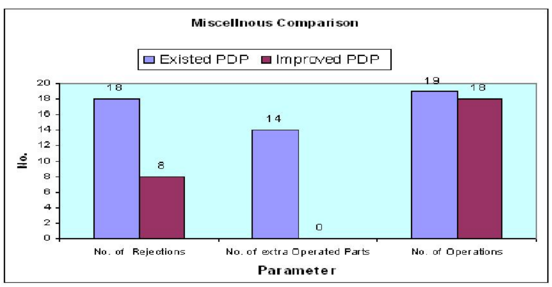

Figure 19 Miscellaneous Comparison

5. Recommendations

- It is found that manufacturing companies particularly in local surgical instruments manufacturing companies are surrounded by typical problems worst are product delivery time and cost of the product. To cope with these problems, it is recommended to implement CE concepts using CE based modified analysis tool. One of the weakest areas is Design Process (One Part of Development of Product CE area). As improvements in design process, following measure are recommended a) Input from representatives of Design, Manufacturing, QC, and Marketing and Assembly department before the start of design, b) Selection of Concept Design by Cross Functional Team, c) Intermediate reviews of Design and d) Design review after the completion of Design activity.
- It is found that due to walls between the departments the company was lacking in Team Integration (which is one of part of organization CE area). To cope with this problem, it is recommended that multidisciplinary team or cross functional team should be formed to carry out the whole design process as well as development process.
- The use of standards in the case company is very limited as found from CE based analysis. Initially following two standards are recommended to be used: i) ISO 2768-1 Medium grade Standard" for tolerance and ii) ANSI B 4.1 for Limits and Fits.
- There is another area known as Computer integration (which is one of the part of "Development of Product" CE area) is found weak during CE based analysis. This area is also highlighted as top priority for improvements. For computer integration it is recommended to model the product in Del-CAM Power SHAPE and use Del-CAM Power Mill for tool path generation.
- Training and education (which is one of the part of "Organization" CE area) is also marked as weakest area during the CE based analysis. It is recommended that two types of training & education of the employees is required; a) the training on software (Del-CAM, Power SHAPE-MILL) and training on machines of the workers. b) the training of multidisciplinary team or cross functional team is required.
- The technological up-gradation of the company to be done in phases. In first phase use of Del-CAM Power SHAP and Power MILL software may be adopted and CNC Lathe and Milling Machines may be introduced. However in future CNC Wire cut, five axis milling machines etc may be introduced.
- The first assumption which we have done that reworks are also considered as rejections. This area can be more explored and this assumption can be removed by separately calculating time and cost for rework and for rejections. This area can be used for future work in this regard.
- The work is done using the concept of batch production and formulas used for calculation of lead time are from batch production environment.
- More effect of "Simultaneous working" can be added if parallel working of all departments can be done by using the concept of mass customization. This means high variety high volume production (HVHV).
- A Single product has been selected to test CE, however work can be expanded to entire product and this paper focuses only to surgical manufacturing company and work can be

expanded to other similar companies. It will be equally beneficial to other manufacturing organization as whole and surgical instruments manufacturing companies particularly.

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