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Concurrent engineering implementation assessment: A case study in an Indonesian manufacturing company

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Abstract

Concurrent Engineering or Simultaneous Engineering has been utilized by companies since 1980s as an approach to design a new product in integrative manner. It replaces traditional product development method which is a serial process with little coordination between different functions and lack of product life cycle perspectives. Concurrent Engineering (CE) offers opportunity for creating new products in short time while maintaining the highest quality at lowest cost which is considered to answer today's market demand. While benefit of CE is promising, implementing CE is not easy. There are a vast amount research that uncover difficulties during CE implementation. However, study of CE implementation in Indonesian company is only a few. One of them is conducted in 1998 at company X, one Indonesian high technology industry. Thus, this research aims to re-evaluate progress of CE implementation in company X today. In this research, CE implementation achievement level in company X is assessed by using Simultaneous Engineering Gap Analysis (SEGAPAN) and Analytical Hierarchical Process (AHP) . The result shows that management's role, cultural change, and the cross functional team are three factors that have the least level of CE implementation compliance. In other words, these three factors are the most difficult barrier to implement CE successfully in company X. Next, Five Whys method is utilized to investigate the root cause of these impediments and some recommendations are proposed to reduce or to eliminate these CE implementation impediments accordingly.

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1. Introduction

Concurrent Engineering is a collaborative approach to develop product and processes which is conducted concurrently by cross functional team including external organization representatives, and by taking into consideration the whole stage of product life cycle [1]. Concurrent Engineering (CE) has been seen as a better approach for developing a new product due to its promising benefits (i.e. shorter time to market while maintaining the highest quality at the lowest cost). Reference [2] stated that Concurrent Engineering is comprised of three fundamental elements namely: collaboration, process and information technology. Since market needs become more complex, rapid development of technology capability and globalization, has made CE gaining a broad acceptance in industries since 1980s. CE had been implemented for developing various types of products, from electronics to aircraft and from domestic household to military equipment [3,4].

Eventhough CE has been implemented in many industries around the world for almost 30 years, it is not easy for any company to change its product development process from a serial to parallel activities by involving of several inter and intra organisational divisions. According to [5,6,7,8] there are several difficulties in CE implementation, namely: (1) Lack of in-house expertise, (2) Lack of training, (3) Lack of management support, (4) Lack of communication, (5) Inadequate reward system, (6) Improper company culture, etc.

There are many studies of CE implementation in USA [4,9], Europe [10,11,12,13], Australia [14,15]. However, there are only few study of CE implementation in industries located in Asia including Indonesia . One of them is conducted by [16] that present some findings from CE implementation in company X, an Indonesian industry that manufactures aircraft as well as aircraft components. This study is published approximately 17 years ago when this company starting using CE approach to develop a new product which is a mid sized civil aircraft. Preliminary finding of this research shows some problems in CE implementation which most of them are similar with result of other studies, such as: poor communication, and shortage of competent specialist/resources limitation. Yet, there is a specific issue that is happened in this company during that time; that is incomplete of company restructurization. Futhermore, methodology to gather information in this study is not elaborated.

In this research, implementation of CE in company X today is re-examined by using Simultaneous Engineering Gap Analysis (SEGAPAN) method and Analytical Hierarchical Process (AHP) . The objectives of this study are three folds, they are: (1) to quantify CE implementation level in company X after approximately 15 years of practicing this approach, (2) to identify difficulties in CE implementation facing by company X today, and (3) to provide a case study in CE implementation in Asian/Indonesian industry setting.

2. Literature review

2.1. Concurrent Engineering and its implementation

Concurrent Engineering (CE) is defined as ‘integrated, concurrent design of products and their related processes, including manufacture and support’ with the ultimate goal of customer satisfaction through the reduction of cost and time-to-market, and the improvement of product quality” [1]. According to [17], there are 8 basic elements in Concurrent Engineering. They are categorized into two main aspects namely: (1) Man and Management aspect, which includes team development, leadership and organization philosophy, and (2) Technological aspect, which includes technology to design, communication, coordination and develop a standard.

Some potential benefits can be expected when a company implement CE, for instance: less development time and time to market, fewer engineering changes, reduction of defect, rework and scrap, higher quality and return on assets [18]. Moreover, [19] reports that CE implementation in three companies (Boeing's Ballistic System Division, NCR, McDonnell Douglas) has successfully improving manufacturing cost around 40%. As implementation CE in any company is not an straight forward process, some factors should be available to ensure successfullness of its implementation, for example: (a) Top management support, (b) Conducive company culture, (c) Provide training and education for employees at all levels, (d) Effective project management, and (e) Multidisciplinary teamwork [20, 21].

In general, there are seven steps to implement CE in an organization according to [22]. These steps are as follows (figure 1): Step 1: Develop a strategy by top management; Step 2: Assessment organization's existing condition by using a particular assessment tools such as benchmarking, questionnaires and performance metrics; Step 3: Create a

supported company culture to increase awareness to CE method and provide related CE implementation training; Step 4: Prioritise improvements based on result from assessment in step 2; Step 5: Plan the change by involving every person in charge, setting milestones/targets, and analysing required resources in CE project; Step 6: Implement improved situation; Step 7: Support Implementation. These seven steps follows a repetitive cycle, since to implement CE a continuous improvement is required.

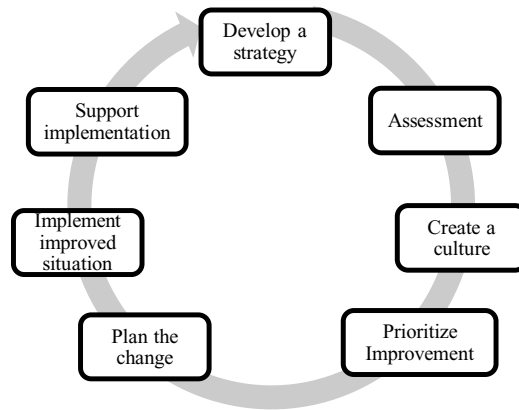


Fig. 1. CE implementation steps

2.2. Concurrent Engineering assessment

Reference [23] present an extensive studies of several tools that can be used to assess CE implementation in an organisation which are as follows:

- RACE (Readiness Assessment for Concurrent Engineering)
- PMO (The Process Model of Organisation)
- PMO-RACE (A Combination of PMO & RACE)
- PRODEVO (A Swedish Model Based on RACE)
- CMM (Capability Maturity Model)
- SPICE (Standardized Process Improvement for Construction Enterprises)
- Project Management Process Maturity (PM)² Model
- SIMPLOFI (Simultaneous Engineering through People, Organization and Functional Integration) Positioning Tool

Similar but more recent study is conducted by [24]. In this study, CE assessment tools are divided into two dimension which are: logic of assessment (i.e. conformity, coherence, causality) and knowledge base incorporated in tools (i.e. high level of abstraction, low level of abstraction). Moreover [23] develops a special assessment method which is called Benchmarking and Readiness Assessment for Concurrent Engineering in Construction (BEACON) Model to support CE implementation in Construction company.

Reference [25] compares five assessment tools, namely: RACE, Simultaneous Engineering Gap Analysis (SEGAPAN), Practical Approach to Concurrent Engineering (PACE), Extended RACE, and Mentor Graphics according to percentage of complied requirement. This study suggested that SEGAPAN has the highest total proportion (more than 80%). Reference [26] use SEGAPAN to assess and compare level of CE implementation compliance in Italian and Belgium companies. Due to its advantages, SEGAPAN is selected to be utilized in this research accordingly. SEGAPAN is developed by [27]. It is a self assessment which has 6 domains namely: (1) Management role, (2) Corporate Culture, (3) Cross-functional teams, (4) Co-design, (5) Communication infrastructure, (6) Tools and techniques. Each domain has one or more factors. There is 22 factors (subjects) in total which relates to CE practices (table 1). For each section, it consists one or more yes-no types of questions and with

the total number of questions are 302. This questionnaire is filled by company's representative. After all of these questions have been filled, CE compliance rate then could be determined. CE compliance rate represents application level of CE implementation (in percentage) and is calculated based on weighted average of scores of 6 domains. Each domain has the same weight which is one sixth, while for each factor may have different weight which depend on company's preference. Since company's preference is closely related to decision making activity, therefore one popular decision making tool, Analytical Hierarchical Process (AHP), could be utilized to quantify the weight for each factor under each domain [28]. Rate of CE compliance can be divided into three levels [29], they are: (a) more than 60% which is an excellent of CE implementation, (b) between 30% to 60% which is average of CE implementation, and (c) less than 30% which is poor of CE implementation.

3. Self Assessment of CE implementation in company X

In the 90's, Company X realized that it took a long time to develop a new product. There was one type of aeroplane that took almost 10 years to build. After learning about successful implementation of CE for supporting product development at Boeing and Airbus, company X sent several employees to learn about CE from those companies. Finally, company X started to implement CE in the late 90's for developing new aeroplane based on the knowledge that has been gathered from Boeing and Airbus.

Reference [16] investigates implementation of new product development project in company X, namely Project Z. Concurrent Engineering is selected as an approach to assist this project with technology support. Based on his study, there are two important findings. Firstly, while sometimes it is difficult to implement CE effectively in western companies, the same situation also applies for Indonesian manufacturing (company X). Secondly, several problem in implementing CE in company X have been identified. These impediments are: (1) lack of expertise, (2) inadequate communication, (3) improper organization structure, (4) lack of knowledge about CE approach, (5) unsupported corporate culture.

Prior to this study, a preliminary observation is conducted to gather understanding about how CE application in company X currently after almost 20 years of implementation. There are many changes that has occurred in company X which may lead to different problem in CE implementation. First of all, number of employee is significantly reduced by a quarter. Company X now only has around 4,200 people from roughly 17,000 people. Next, company X applies a new organization structure which support company's regular operations and a special structure for big project . Moreover, at the time of this study, company X is installing a new Enterprise Resource Planning (ERP) to replace their paper based system, namely System Application Product (SAP). This conversion process is not without any problem. However, benefits of SAP utilisation may support company X in daily operations and new product development project in the future (e.g. communication).

To assess level of CE application in company X, SEGAPAN check list is distributed to four company's X representatives. The basic compliance of each factor (table 1) is calculated based on number of "positive" answer (supporting CE implementation) for the questions divided by total questions in each factor. For example, "General scope of the knowledge base" factor consist of seven questions and the respondent responds five questions with "positive" answer, therefore raw achievement is 5/7 (71%).

Table 1. SEGAPAN check list and results

Domains/ factors	Basic compliance	Initial Weight	Final Weight	Final compliance
I. Management Role				
1. General scope of the knowledge base	71%	75.00%	12.500%	8.875%
2. Management's role	57%	25.00%	4.167%	2.375%
II. Corporate Culture				
1. Departmental Interface Management	100%	3.50%	0.583%	0.583%
2. Cultural Change	57%	18.80%	3.133%	1.786%
3. Pilot Project	91%	36.80%	6.133%	5.581%
4. Training	60%	13.00%	2.167%	1.300%

Domains/ factors	Basic compliance	Initial Weight	Final Weight	Final compliance
5.Continuous Improvement	75%	9.00%	1.500%	1.125%
6.Employee Involvement	80%	18.90%	3.150%	2.520%
III.Cross Functional Team				
1.The Cross-Functional Team	59%	83.33%	13.888%	8.194%
2.Purchasing's Role	78%	16.67%	2.778%	2.167%
IV.Co-design				
1.Suppliers' Involvement	61%	25.00%	4.167%	2.541%
2.Customers' Involvement	64%	75.00%	12.500%	8.000%
V.Communication Infrastructure				
1.Computerized Tools	100%	15.30%	2.550%	2.550%
2.Product Data Management	92%	31.50%	5.250%	4.830%
3.Organizational Structure	71%	17.55%	2.925%	2.076%
4.Monitoring And Controlling Progress	75%	17.55%	2.925%	2.193%
5.Value Analysis	100%	7.40%	1.233%	1.233%
6.Electronic Data Interchange	64%	10.70%	1.783%	1.141%
VI. Tools and Technique				
1.Design Aids	86%	5.80%	0.967%	0.831%
2.Design For Manufacture And Assembly	71%	22.60%	3.767%	2.674%
3.Variety Reduction	100%	3.10%	0.517%	0.516%
4.Design To Cost	83%	22.10%	3.683%	3.057%
5.Visualization Tools	67%	5.20%	0.867%	0.580%
6.Computer-Aided Engineering	100%	14.50%	2.417%	2.416%
7.Computer-Aided Manufacturing	80%	9.20%	1.533%	1.226%
8.Statistical And Quality Methods	67%	3.50%	0.583%	0.390%
9.Logistics Support	100%	4.80%	0.800%	0.800%
10.Group Technology	100%	9.20%	1.533%	1.533%
Compliance Rate				73.101%

While, overall weight for each domain is the same (one sixth), company's X preference is required to determine weight of each factor within one domain. The weight of each factor is quantified using AHP methodology. One expert from company X who is in top management position and has a long experience with CE projects is selected as respondent to fill AHP questionnaire. This expert compares and determines the relative importance between two factors within the same domain through pairwise comparisons type of questions. Furthermore, the consistency level of the expert judgement is also measured by using Expert Choice software. The result shows that inconsistency ratio for expert feedback are all less than 0.1, which means that the company's X respondent judgement is consistent. As a result, initial weight for each factor is determined from this step. As the weight for each domain is already set at one-sixth, thus final weight for each factor is established by multiplying initial weight with one-sixth. This final weight then is multiplied with basic compliance to get final compliance for each factor (table 1). For example, Initial weight of "General scope of the knowledge base" factor is 75%, then the final weight is $75\% \times 1/6$ which equal to 12.5%. Then its final compliance is attained from 71% (basic compliance) multiple with 12.5% equal to 8.875%. Finally, compliance rate for company X is obtained by summing up final compliance of all factors, which is 73.101%.

4. Result and Discussion

Compliance rate of company X is more than 60%, thus company X could be categorized as a company who has an excellent level of CE implementation. In spite of this, based on data of basic compliance of each factor from table 1, there are three factors that still have less than 60% of basic compliance rate (figure 2), they are: (1) II.2. Cultural Change, (2) I.2.Management's Role, and (3) III.1.The Cross-Functional Team. Hence, further analysis is conducted for these three factors to uncover the root cause of these problems. Firstly, tracing back to related SEGAPAN questionnaires to know which questions that have "negative" answer so it could lead to lower initial compliance rate.

These questions are seen as impediments of CE implementation. Second, utilizing Five Whys, a simple yet powerful tools, for investigating root cause of this problem . Besides utilizing five whys, discussion and brainstorming with Company's X representatives is also conducted to get deeper understanding of CE implementation barrier in company X.

Table 2. Root cause analysis

SEGAPAN Factor	Related impediment	5 Whys Analysis	
		Why 1	Why 2
Cultural Change	<ul style="list-style-type: none"> Engineers feel sceptical about CE Employee feel that CE is long and arduous process Inadequate internal expertise that required to implement change 	Inadequate implementation preparation	Lack of top management knowledge on CE implementation
Management's role	<ul style="list-style-type: none"> Management does not set up specific time to market targets Company does not use benchmarking to develop strategic objectives No top management willing to accept responsible as champion of CE 	Lack of awareness from top management during CE implementation	Lack of top management knowledge on CE implementation
The Cross-Functional Team	<ul style="list-style-type: none"> No representatives from suppliers, customers Team does not include (fully involve) marketing, finance, and procurement All team member is specialist 	Unavailability of clear policy on who should involve in CE team Most of recruited employee is specialist	Lack of top management knowledge on CE implementation

After several iterations of developing 5 Whys, root cause of CE implementation problems in company X is identified which is lack of top management knowledge on CE implementation (table 2). Further discussion with company X representative uncovers reason behind this root cause. In late of 90s, Indonesia heavily affected by global monetary crisis. As company X is state owned company, thus funding from government during that difficult time also became limited. Company X is forced to alter its focus, from technology development based company into profit oriented company. Moreover, company X also should reduce the number of its employee up to 25%. At the same time, company X started to implement CE after their employees have returned back after learning about CE from several companies that has already implement CE successfully (e.q. Boeing and Airbus). Due to the financial difficulties and substantial change of company policy, a structured strategic plan to convert from traditional product development into Concurrent Engineering is very limited. Moreover, as only several employees that is sent to learn about CE implementation overseas, there is only limited number of internal expertise to well support CE implementation. Furthermore, lack of dissemination and training for all employee about CE and its benefits leads to lack of support and commitment from all employee including top management in implementing CE. As a result, lack of knowledge about CE lead to unsupportive policy such as recruiting specialist employee and not involving suppliers and customers in CE team project.

Considering that today company X is in a more financially stable with increasing number of demand and also number of employees, it is suggested that company X could start to re-develop a better CE implementation strategy based on today environment. One methodology to manage change management is Change Acceleration Process (CAP) which has been in General Electric during Lean SixSigma implementation [30]. It consists of seven stages, which are: setting up project team, leading change, creating a shared need, shaping a vision, mobilizing commitment, making change last, monitoring progress, dan changing systems and structures. As company X has started currently implementing Lean Manufacturing to improve their operations efficiency since 2013, using CAP may supports this company to implement CE as well as Lean Manufacturing better. CAP stages includes trainings and knowledge sharing about CE for all employees including top management and changing in recruitment process that give more support CE implementation.

5. Conclusion

This research presents a recent study of CE implementation in company X, an Indonesian manufacturing industry, which has implemented CE for almost 17 years. Although, compliance rate of CE implementation of company X has achieved excellent level (more than 60%), there are three CE implementation impediments that need to be improved. These problems (i.e. Cultural Change, Management's Role, and Cross-Functional Team) are caused by inadequate top management knowledge on CE implementation. This is originated from lack of clear structure and strategy to implement CE at the beginning of CE implementation in the late 90s due to financial crisis. Company X now is in better financial conditions due to greater demand yet also facing increasing competition which pushes this company to improve their operations and product development process. Since CE is a methodology has proven to benefit in improving and accelerating new product development, thus company X should re-started CE implementation with a better and well structured strategy such as using Change Acceleration Process (CAP) approach.

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