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Concurrent Engineering: Practice and Performance

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Abstract

By using concurrent engineering (CE) practitioners expect that design alternatives and their related process and technology alternatives are dealt with simultaneously and interactively at the early stages of product development. The focus is on both product and process by involving all related internal and external stakeholders. This study is intended to investigate the process of implementing concurrent engineering, tools used, level of implementation, and its impact on users' performance. Related literature was reviewed including major elements, activities, tools and techniques, benefits and barriers to success, best practices, and latest trends. Based on that, a survey was conducted, that included a representative sample of industrial firms, to study the level of awareness of concurrent engineering, practices and implementation levels, and its impact on different performance levels. A sample of 80 organizations (manufacturing and services) in UAE was taken. Major findings include that there is a relatively good awareness of concurrent engineering practices, the working culture supports early involvement of all stakeholders but lack the needed team building and training, and most CE practices are based on the experience and the initiatives of related employees and not based on a disciplined process. Moreover, they use integrated information technology tools without paying the same attention to supporting tools and software, and top management role in settling disputes and conflict resolution got the highest score, whereas empowering teams got the lowest. Finally, the study concluded that concurrent engineering has a clear impact on improving performance. Specifically, communication, cooperation, integration, and information sharing between different functions at the company-wide level, improving customer satisfaction, reducing after-design engineering changes, improving the overall quality, improving competitiveness/market share, improving productivity, reducing development time and time to market, and increasing return on investment. People-related practices had the highest correlation with performance followed by those related to used tools.

Keywords
Concurrent Engineering, CE Practices, CE Implementation, Improving Performance, Statistical Analysis.

1. Introduction
In the traditional product cycle, designs and drawings are produced before continuing the analysis and preparation of manufacturing instructions. Concurrent engineering aims to overcome such limitations, by having a collaborative approach to product development that integrates design, manufacturing, and other relevant processes from the outset, aiming to streamline the development lifecycle, reduce time-to-market, enhance product quality, and minimize costs. This methodology emphasizes parallelism and interdisciplinary communication among different teams and stakeholders, enabling simultaneous progress across various stages of product development (Huang et al., 2024), (Ghazilla et al., 2021), (Siregar et al., 2015), (Kusiak, 2009). Traditionally, product development followed a sequential model where each stage was completed before moving on to the next. However, CE allows for iterative progress and early consideration of factors such as manufacturing constraints, cost implications, and user requirements, leading to more efficient decision-making (Li et al., 2023), (Matsumoto et al., 2020), (Huang et al., 2012), (Pahl et al., 2008).

Key principles of Concurrent Engineering include the early involvement of stakeholders, utilization of advanced tools and technologies like computer-aided design (CAD) and simulation, and a focus on collaboration and integration throughout the development process (Zhang et al., 2022), (Sangwan et al., 2018), (Wang et al., 2010), (Kim et al., 2007). By adopting Concurrent Engineering practices, organizations can adapt more swiftly to market changes, innovate more effectively, and deliver products that better meet customer needs and preferences. The objective of this paper is to review related literature including major elements, activities, tools and techniques, benefits and barriers to success, best practices, and latest trends. Based on that, a survey will be conducted, that will include a representative sample of industrial firms, to study the level of awareness of concurrent engineering, practices and implementation levels, and its impact on performance.

2. Literature Review

Although the term "concurrent engineering" was only coined in 1987, it has now become institutionalized as a concept with a dedicated journal, many conferences, numerous books and other publications, industry awards, and several dedicated research centers around the world. It is an approach that has its conceptual roots in both management and engineering literature and that offers valuable guidelines for firms seeking to improve their product innovation capability. Before firms can obtain any benefits from this approach, they need to understand what exactly CE is and need to come to terms with the very real and problematic details of implementation. Implementation is not simply a matter of introducing new tools and practices "off the shelf" (Badham et al., 2000).

Bhuiyan et al. (2006) reported that concurrent engineering can be defined as the integration of interrelated functions at the outset of the development process to minimize risk and reduce effort downstream in the process, and to better meet customers' needs. Moreover, it is defined as a systematic approach to creating a product design that simultaneously considers all elements of the product life cycle, from conception through disposal (Lightfoot, 2002). A requirement to develop new products in a short time due to the current great market competition needs systems that can design and produce with minimum risk of failure, where teams are often pressured to compress or skip over proven processes and check points to reduce the systems development life cycle. Tools such as rapid prototyping, virtual product development, use of CAD/CAM for 3D modeling, and selective tolerance management have helped to make the process of CE more approachable and comfortable to use with highly integrated and complex systems (Lightfoot, 2002).

Since the late 1980s, in academia and industry, concurrent engineering has been recognized as one such strategy for improving the design process. This involves performing as many activities as possible in the design process simultaneously, enabled by cross-functional teams working cooperatively and effectively on separate aspects of the overall product development. Many issues have been identified as essential requirements about ensuring that CE is effective when implemented and operated in a large engineering organization or complex design process. The most prominent issues of CE are coordination, communication, cooperation (teamwork), integration, information sharing, multi-functional teams, planning, scheduling, discipline and productivity. Moreover, the size and nature of a business needs to be considered when deciding how, and to what extent, CE could be employed within the organization (Coates et al., 2002).

Gatenby et al. (1994) addressed the basic elements of CE as cross-functional teams, concurrent product realization process activities, incremental information sharing and use, integrated project management, early and continual supplier involvement and customer focus. By its very definition, requirements and specification must be conveyed to the designers and developers as soon as they are generated. Market impact information, development constraints, integrated issues, and operational requirements all must be shared among engineers, developers, users, maintenance personnel, vendors, and other constituents and be acted upon as soon as they are known (Lightfoot, 2002). Furthermore, Rouibah (2002) stated that concurrent engineering requires designers to share information that can be incomplete or contradictory early during product development. Information sharing is even more important when it crosses company borders to include customers and suppliers in the development of complex products.

Recent research emphasizes the integration of digital technologies such as artificial intelligence (AI), machine learning (ML), and virtual reality (VR) into CE processes. These technologies enable real-time collaboration, virtual prototyping, and predictive analytics, facilitating faster decision-making and enhanced product quality (Ribeiro et al., 2023). Research indicates a growing reliance on information and communication technologies (ICTs) to support CE practices. Scholars examine the role of ICT tools such as computer-aided design (CAD), product data management (PDM), and collaborative platforms in facilitating real-time communication and data sharing among team members (Liang et al., 2014). There is a growing focus on integrating sustainability considerations into CE practices. Scholars highlight the importance of considering environmental impacts, resource efficiency, and lifecycle assessments throughout the product development lifecycle. Sustainable CE frameworks are proposed to guide organizations in balancing economic objectives with environmental and social responsibilities (Hassini et al., 2022).

Effective cross-functional collaboration remains a central theme in CE literature. Studies explore strategies for enhancing communication and coordination among diverse teams, including the use of collaborative tools, shared repositories, and interdisciplinary training programs. Successful collaboration is identified as a key driver of innovation and competitiveness (Cheng et al., 2019). The literature underscores the significance of integrating suppliers and external partners into the concurrent engineering process. Collaborative supply chain frameworks are proposed to enhance coordination, reduce lead times, and improve product quality through early supplier involvement and joint decision-making (Nagel et al., 2013). Studies emphasize the importance of integrating design, manufacturing, and other functions in the product development process. Scholars explore various approaches to achieve seamless coordination among different departments, highlighting the benefits of early involvement and cross-functional teams (Mota et al., 2016). Scholars explore strategies for enhancing communication and cooperation among diverse teams involved in product design, manufacturing, and other functions. Effective collaboration is identified as a key driver for achieving concurrent development goals (González-Zamora et al., 2009), Integration of agile and lean principles into CE methodologies is gaining traction. Researchers advocate for iterative development, rapid prototyping, and continuous improvement to respond to changing customer needs and market dynamics. Agile CE frameworks are proposed to streamline processes and enhance adaptability in fast-paced environments (Lu et al., 2021),Researchers develop metrics and frameworks to assess the performance of concurrent engineering initiatives. Key performance indicators (KPIs) such as time-to-market, cost reduction, and product quality are analyzed to evaluate the effectiveness of CE implementation strategies (Hong et al., 2012).

Knowledge management emerges as a critical factor in successful CE implementation. Studies examine approaches for capturing, sharing, and leveraging knowledge across different stages of the product lifecycle. Knowledge management systems and tools are proposed to facilitate information exchange and decision-making in concurrent engineering environments (Wang et al., 2008). Integration of Design for Manufacturing and Assembly (DFMA) principles into CE processes gains attention. Researchers explore methodologies and tools for designing products that are easy to manufacture, assemble, and maintain. DFMA is seen to reduce production costs, improve product quality, and accelerate time-to-market (Yang et al., 2007).

Risk management emerges as a critical aspect of CE research. Scholars investigate approaches for identifying, assessing, and mitigating risks associated with concurrent development projects. Risk management frameworks are proposed to enhance decision-making and minimize potential disruptions throughout the product lifecycle (Karvonen et al., 2011).

Bouikni et al. (2008) reported that Product Lifecycle Management (PLM) is an approach for controlling and exploiting product-related information throughout its lifecycle as needed by various business functions. Concurrent engineering (CE) integrates several disciplines contributing to product design. Both PLM and CE involve information sharing amongst disciplines having a specific point of view regarding the product. While each discipline exerts its own expertise and methods on the definition of the product and its related processes, information must remain consistent for all disciplines and throughout the evolution of the product definition. Therefore, being able to efficiently manage multiple views fulfilling the needs of multiple disciplines is an important issue. Moreover, the current ultra-competitive manufacturing arena demands that a multitude of factors be considered during product design and manufacturing, in addition to core concerns such as product performances, product qualities, and manufacturing costs. Safety aspects, environmental impact, recycling issues, and the satisfaction of product consumers and users must all be addressed for a product design to be successful. Optimum system technologies that can concurrently consider a broad range of factors pertaining to product manufacturing and streamline decision-making for product design and manufacturing are required (Yoshimura, 2007).

Ainscough et al. (2003) conducted a review of various tools for assisting organizations to implement concurrent engineering. A workbook style tool was proposed, which was based on a self-assessment model to enable the implementation of CE through a change management strategy. The developed self-assessment model was based on six main practice components of CE (formal new product introduction process, teamwork, information technology, tools and techniques, supply chain management, and project management). The combination of self-assessment and change management enabled the simultaneous measurement and deployment of practices, which can assist organizations in the project management of product development, and lead to the identification of further improvements to rigorously manage the transition to CE. The tool described was implemented at London Taxis International (a large sized UK based automotive company) and led to the creation of a formalized new product introduction process, implementation of a project management system, and enhanced teamworking at the company.

Khalfan et al. (2001) discussed the development of a CE readiness assessment model for the construction industry. They also included a comparative review of existing readiness assessment tools and models that have been specifically developed and successfully used in the manufacturing and IT sectors. Moreover, they concluded that implementing CE within the construction industry has the potential to contribute towards client satisfaction by improving quality, adding greater value, reducing cost, and reducing construction schedules. It is also necessary to carry out CE readiness assessment of the industry before CE implementation to ensure that maximum benefit is achieved. Culler and Garcia (2004) reported that CE does not work well when there is high uncertainty and many changes in the design. Moreover, the benefits of CE are more dependent on interpersonal than inter-technological communications. People are always the key to the success or failure of a project.

Bhuiyan et al. (2006) discussed the use of concurrent and sequential engineering for new product development. It was compared in one technology-intensive company. The study established a framework for the systematic implementation of CE, involving process, people, tools and technology, metrics, organizational support, buy-in, and benefits and barriers to success. They concluded that benefits of CE implementation include schedules reduced for all CE projects, delivery of defect-free prototypes accelerated, production yields improved, and time to market shorter. Such benefits were achieved because of early involvement, risks identified, and tradeoffs made earlier, specifications mostly correct because all functions present, constant involvement of operations delivered correct prototypes on time, operations and testing assisted in finding design problems before layout began, and production issues resolved early. Whereas barriers to success include lack of business unit and top management support, requirements hard to set at concept stage, lack of control of project resources, lack of interaction between hardware and software groups, lack of involvement by marketing at project start, and CE not well understood. Such barriers can be overcome by creating a multifunctional team at project outset, defining member responsibilities clearly, dedicating necessary resources, improve new product development process, defining requirements earlier, improving team communication, improving interaction between hardware and software groups, training members better: skills, IT tools and CE methods, improve IT tools, and increasing use of simulation tools. Furthermore, concurrent engineering has been successfully implemented in many companies, including Texas Instruments, Hewlett-Packard, Motorola and General Motors.

Chen et al. (2007) reported that allied concurrent engineering (ACE), which combines the concepts of virtual enterprise and CE, is a highly promising business strategy for enterprises in facing global competition. ACE is designed to integrate the activities, resources, information, and organization of enterprises via enterprise alliances, thus minimizing cost, increasing competitiveness, and achieving rapid response to customer expectations. However, the success of ACE depends on effective and close cooperation among allied enterprises. Selecting cooperative partners in the context of ACE thus becomes pivotal in enhancing the efficiency of ACE.

3. Research Tool

Based on the literature survey and with the benefit from the framework for CE implementation developed by Bhuiyan et al. (2006), the research tool (questionnaire) was designed. It consists of three parts. Part one presents demographic questions, mainly: the organization's name, category and number of employees, and respondent e-mail, gender, age, qualification, position and experience. Part two asks the respondent based on his/her experience and the level of implementation of CE in his/her company to rate each of its 23 statements of CE using a scale from 1 to 5, where 5 stands for strongly agree while 1 stands for strongly disagree. The first 6 statements address the practices related to people, followed by 5 statements addressing the practices related to process, followed by 5 statements addressing the practices related to used tools and the last 7 statements address the practices related to leadership. Finally, in part three, using the same scale, CE benefits are assessed. People, Process, Tools, Leadership, and Benefits are treated as study variables.

3.1 Research Sample

The study was conducted within United Arab Emirates (UAE). A total of 80 organizations were included; 35 of them were manufacturing companies, while 45 were in services. UAE was selected to represent the practices in this part of the world (Middle East) and in developing countries, in general.

4. Research Results and Discussion
Data analysis of collected data including reliability and demographic results, descriptive statistics of data, correlations, and testing hypotheses are presented and discussed.

4.1 Reliability and Demographic Results
Reliability less than 60% are generally considered to be poor, these in the 70% range to be acceptable and those over 80% to be good (Sekaran, 2003). Table 1 shows the Cronbach's alpha corresponding to each of the study variables that supports the reliability of the questionnaire. The demographic data about respondents showed that most respondents were male, being managers or supervisors, with 75% of the respondents from organizations of size of more than 100 employees.

Table 1: Cronbach's Alpha for Study Variables

No.	Variable	No. of Items	No. Cases	Cronbach's Alpha
1	People	6	80	0.715
2	Process	5	80	0.708
3	Tools	5	80	0.797
4	Leadership	7	80	0.824
5	Benefits	11	80	0.856

4.2 Descriptive Statistics of the Data
The frequencies, the mean and the standard deviation for the responses of each statement were calculated. The same was calculated for the average of each CE dimension (variable) and the grand average for all practices. Similar calculations were done to the responses related to CE benefits. This was done for responses of manufacturing organizations as well as that of service organizations.

Tables 2 and 3 provide the summary of the descriptive statistics of the responses. From Table 2, there is a relatively good awareness of concurrent engineering practices supported by the average of responses (level of implementation) of its different practices. The average values range from 3.90 to 3.33 out of 5.00, in general, while it got a 3.70 grand average score. Moreover, it is evident that both People and Leadership practices had higher scores (means) compared to both Process and Tools practices, with the Process practices being the lowest. Within the People practices, the practice, or the statement, "The CE teams include design and manufacturing/operations personnel, external customers and suppliers, and the marketing function" got the highest score while the practice "Team members receive the needed training to be effective team players" got the lowest which support the culture of early involvement but lack the needed team building and training.

For the Process practices, the practice "Your company has a disciplined CE process" got the lowest score which supports that the CE practices are based on the experience and the initiatives of related employees and not based on a disciplined process. Similarly, the use of integrated information technology (IT) tools got the highest score within the Tools practices which assures the need for coordination, communication, integration, and information sharing as core practice for the success of CE implementation. Whereas, using some tools such as quality function deployment (QFD), design failure modes and effect analysis (DFMEA), value engineering, CAD/CAM, 3D modeling, and simulation received the lowest scores. This reflects the concentration of coordination and integration of efforts without paying the same attention to supporting tools and software. Moreover, the scores of the Leadership practices show that the top management role in settling disputes and conflict resolution got the highest score whereas empowering teams got the lowest score.

Similarly, Table 3 displays the impact of CE in improving the performance of organizations. Respondents agreed on CE impact on improving communication, cooperation, integration, and information sharing between different functions at the company-wide level, improving customer satisfaction, reducing after-design engineering changes by identifying problems, risks, and tradeoffs earlier, improving the overall quality, improving competitiveness/market share, improving productivity, integrating efforts to finalize customer requirements more quickly, reducing development time and time to market, and increasing return on investment. The above results agreed with related literature and similar studies.

Table 2: Summary of Descriptive Statistic for First Four Variables

	Mean (Manufacturing)	Mean (Services)	Mean (All)
People:			
1. The CE teams include design and manufacturing/ operations personal, external customers and suppliers, and the marking function.	3.88	4.33	4.13
2. The CE process includes establishing such multifunctional teams early.	3.88	3.77	3.82
3. CE teams are chosen to be composed of highly skilled individuals who could communicate well.	3.82	4.20	4.03
4. Team members receive the needed training to be effective team players.	3.77	3.44	3.58
5. Resource planning is a critical issue for completing projects on time and on budget.	3.77	4.13	3.97
6. The working environment and culture support team work activities.	3.82	3.53	3.66
People Average	**3.82**	**3.90**	**3.87**
Process:			
1. Your company has a disciplined CE process.	3.40	3.24	3.31
2. The CE process activities are scheduled with the overlapping activities of the CE process are clearly defined.	3.57	3.33	3.43
3. The CE process owner (responsible position/employee) is always appointed for the CE process.	3.60	3.40	3.48
4. The CE process is documented.	3.94	3.26	3.56
5. There is always a set of clear and quantitative goals for the CE process. Goals focus on process improvement, product/service quality, and deliverables.	3.85	3.44	3.62
Process Average	**3.67**	**3.33**	**3.48**
Tools:			
1. Teams identify tools and technology that enable CE activities.	3.85	3.60	3.71
2. The use of integrated information technology (IT) tools to ensure coordination, communication, integration, and information sharing.	3.97	4.02	4.00
3. Use of some tools such as Quality Function Deployment (QFD), Design Failure Modes and Effect Analysis (DFMEA), Value Engineering, CAD/CAM, 3D Modeling, etc.	3.57	3.37	3.46
4. Use simulation modeling or prototypes built early.	3.28	3.51	3.41
5. Train people/team members to properly utilize the used tools.	3.71	3.64	3.67
Tools Average	**3.68**	**3.63**	**3.65**
Leadership:			
1. The company's business strategy supports the CE and product/service innovation projects.	4.05	3.95	4.00
2. Top Management allocates enough resources to support CE activities and continuous training.	3.71	3.73	3.72

3. Top management participation (involvement) in some CE activities in appropriate way and at the right time.	3.77	3.66	3.71
4. CE teams are empowered to make related decisions.	3.54	3.46	3.50
5. An effective recognition and reward system is adopted to motivate CE teams.	3.57	3.62	3.60
6. Top Management plays a major roll in settling disputes and conflict resolution.	3.85	3.68	4.26
7. Use of some performance measures to monitor progress and achievements like development time, rework levels, and total costs.	3.74	4.04	3.91
Leadership Average	**3.75**	**3.86**	**3.81**
Grand Average	**3.73**	**3.67**	**3.70**

Table 3: Summary of Descriptive Statistic for "Benefits" Variable

	Mean Manufacturin g	**Mean Services**	**Mean All**
1. Reduce development time and time to market.	4.05	3.86	3.95
2. Integrated efforts to finalize customer requirements more quickly.	3.97	4.02	4.00
3. Reduce after-design Engineering changes by identifying problems, risks, and tradeoffs earlier.	4.34	3.91	4.10
4. Reduce scrap and/or rework.	3.97	3.62	3.77
5. Improve the overall quality.	4.17	4.00	4.07
6. Improve productivity.	4.05	4.00	4.02
7. Reduce manufacturing/operating costs.	3.94	3.64	3.77
8. Increase return on investment.	3.94	3.91	3.92
9. Improve customer satisfaction.	4.28	4.02	4.13
10. Improve competitiveness/market share.	4.05	4.04	4.05
11. Improve communication, cooperation, integration, and information sharing between different functions at the company-wide level.	4.20	4.17	4.18
Benefits Average	**4.09**	**3.92**	**4.00**

4.3 Correlation between CE Practices and Performance:

To test the correlation between the CE practices and the related performance, Pearson correlation coefficients were calculated as shown in Table 4. All practices were significant at the 0.01 level and the People practices had the highest correlation with performance followed by the Tools practices that assures the crucial impact of people in the achieved benefits which agrees with the findings of Culler and Garcia (2004). Leadership practices have the lowest correlation with the achieved benefits which could highlight the need to give more attention to the related practices.

Table 4: Correlation Matrix for Study Variables

	People	Process	Tools	Leadership	Benefits
People	1				
Process	0.423(**)	1			
Tools	0.552(**)	0.563(**)	1		
Leadership	0.440(**)	0.401(**)	0.515(**)	1	
Benefits (Performance)	0.667(**)	0.514(**)	0.573(**)	0.447(**)	1

** Correlation is significant at the 0.01 level (2-tailed).

4.4 Hypotheses Testing:

To test the variation in responses in different CE practices and resulted performance (benefits) between manufacturing and service organizations, and with respect to the size of the organization (number of employees), the following hypotheses have been tested for $\propto = 0.05$.

1. Testing hypotheses related to service and manufacturing organizations:

Hypothesis No (1a)

Ho: There is no variation between service organizations and manufacturing organizations with respect to People practices.

Ha: There is a variation between service organizations and manufacturing organizations with respect to People practices.

Hypothesis No (2a)

Ho: There is no variation between service organizations and manufacturing organizations with respect to Process practices.

Ha: There is a variation between service organizations and manufacturing organizations with respect to Process practices.

Hypothesis No (3a)

Ho: There is no variation between service organizations and manufacturing organizations with respect to Tools practices.

Ha: There is a variation between service organizations and manufacturing organizations with respect to Tools practices.

Hypothesis No (4a)

Ho: There is no variation between service organizations and manufacturing organizations with respect to Leadership practices.

Ha: There is a variation between service organizations and manufacturing organizations with respect to Leadership practices.

Hypothesis No (5a)

Ho: There is no variation between service organizations and manufacturing organizations with respect to CE Benefits.

Ha: There is a variation between service organizations and manufacturing organizations with respect to CE Benefits.

Hypothesis No (6a)

Ho: There is no variation between service organizations and manufacturing organizations with respect to grand average practices.

Ha: There is a variation between service organizations and manufacturing organizations with respect to grand average practices.

Based on the related ANOVA analysis, Table 7 shows the summary of the related statistics (F and p values) and the conclusion to accept or reject each of the above null hypotheses. To illustrate the contents of Table 7, hypothesis No (1a) will be taken as an example. Table 5 shows the mean and standard deviation of sample with respect to People variable. Whereas Table 6 shows the ANOVA for People variable. Study hypothesis No (1a) states that there is no variation between service and manufacturing organizations with respect to people's practices. From Table 6 the null hypothesis is accepted at the 5% level of significance.

Table 5: Mean and Std. Dev of Sample Respect to People

Organization	Mean	Std. Deviation
Manufacturing	3.8286	.80793
Services	3.9037	.51061

Table 6: ANOVA for People Variable

Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.111	1	0.111	0.257	0.613
Within Groups	33.665	78	0.432		
Total	33.776	79			

Table 7: Summary of Testing Hypotheses Related to Manufacturing and Service Organizations

Hypothesis No	Variable	F	p	Accept/Reject
1a	People	0.257	0.613	Accept
2a	Process	4.181	0.044	Reject
3a	Tools	0.095	0.759	Accept
4a	Leadership	0.291	0.591	Accept
5a	Benefits	1.271	0.263	Accept
6a	Grand Average	0.276	0.601	Accept

Table 7 shows that there is no variation between manufacturing and service organizations in the responses related to the practices related to People, Tools, Leadership, Benefits and the grand average. Whereas the hypothesis No (2a) related to Process practices has been rejected, which indicates that there is a difference in level of implementation of such practices between manufacturing and service organizations. Tables 8 and 9 show the details of testing hypothesis No (2a) with manufacturing firms have a higher response mean.

Table 8: Mean and Std. Dev of Sample with Respect to Process

Organization	Mean	Std. Deviation
Manufacturing	3.6743	0.81902
Services	3.3378	0.65341

Table 9: ANOVA for Process Variable

Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.229	1	2.229	4.181	0.044
Within Groups	41.593	78	0.533		
Total	43.822	79			

2. Testing hypotheses related to size of organization (No. of employees):

Hypothesis No (1b)

Ho: There is no variation between the size of organization with respect to People practices.
Ha: There is a variation between the size of organization with respect to People practices.

Hypothesis No (2b)

Ho: There is no variation between the size of organization with respect to Process practices.
Ha: There is a variation between the size of organization with respect to Process practices.

Hypothesis No (3b)

Ho: There is no variation between the size of organization with respect to Tools practices.
Ha: There is a variation between the size of organization with respect to Tools practices.

Hypothesis No (4b)

Ho: There is no variation between the size of organization with respect to Leadership practices.
Ha: There is a variation between the size of organization with respect to Leadership practices.

Hypothesis No (5b)

Ho: There is no variation between the size of organization with respect to CE Benefits.
Ha: There is a variation between the size of organization with respect to CE Benefits.

Hypothesis No (6b)

Ho: There is no variation between size of organization with respect to grand average practices.
Ha: There is a variation between size of organization with respect to grand average practices.

Table 10 shows the summary of the related statistics (F and p values) and the conclusion to accept or reject each of the above null hypotheses based on the related ANOVA analysis. It shows that there is no variation due to the size of the organization (number of employees) in the responses related to the practices related to People, Process, Tools, Leadership and the grand average. Whereas the hypothesis No (5b) related to Benefits has been rejected which indicates that there is a difference in the impact of implementing CE practices (Benefits) between different sizes of the organizations. Tables 11 and 12 show the details of testing hypothesis No (5b) with large organization (more than 1000 employees) have a highest response mean.

Table 10: Summary of Testing Hypotheses Related to the Size of Organization (No. of Employees)

Hypothesis No	Variable	F	p	Accept/Reject
1b	People	0.474	0.625	Accept
2b	Process	2.639	0.078	Accept
3b	Tools	1.739	0.182	Accept
4b	Leadership	1.135	0.327	Accept
5b	Benefits	5.337	0.007	Reject
6b	Grand Average	1.871	0.161	Accept

Table 11: Mean and Std. Dev of Sample with Respect to Benefits

Size of Organization	Mean	Std. Deviation
Less than 100	3.6727	0.74289
100 – 1000	3.9527	0.53081
More than 1000	4.2208	0.56656

Table 12: ANOVA for Benefits Variable

Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.904	1	1.952	5.337	0.007
Within Groups	28.162	78	0.366		
Total	32.066	79			

5. Conclusions

There is a relatively good awareness of concurrent engineering practices. People and Leadership practices had higher scores compared to both Process and Tools practices, with the Process practices being the lowest. The working culture supports early involvement of all stakeholders but lacks the needed team building and training. Most CE practices are based on the experience and the initiatives of related employees and not based on a disciplined process. The use of integrated information technology tools got the highest score that assures the need for coordination, communication, integration, and information sharing as a core practice for the success of CE implementation, unfortunately, without paying the same attention to supporting tools and software. The top management role in settling disputes and conflict resolution got the highest score, whereas empowering teams got the lowest in Leadership practices. Concurrent engineering has a clear impact on improving communication, cooperation, integration, and information sharing between different functions, improving customer satisfaction, reducing after-design engineering changes, improving the overall quality, improving competitiveness/market share, improving productivity, integrating efforts to finalize customer requirements more quickly, reducing development time and time to market, and increasing return on investment. People's practices had the highest correlation with performance followed by the Tools practices. There are no variations in responses of different CE practices and resulted performance between manufacturing and service organizations, and with respect to the size of the organization, except for Process practices between manufacturing and services, and the "Benefits" between different sizes of organizations, with the benefit to high-sized ones.

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