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Full Length Research Paper

New product development in multi-location R&D organization: A concurrent engineering approach

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Relocating organization functional units geographically to an economically advantage location is one way for multi-national companies to improve competitive advantage. Change of company operation environment from co-location to multi-locations influences way of new product development management. This research reviewed new product development process in a multi-located research and development organization and examine elements for an efficiency new product development process. The research applied concurrent engineering approach to form a concept of concurrent new product development engineering. Seven concurrent engineering main constructs and 49 concurrent engineering critical attributes were identified. Using 98 survey data from a multi-location research and development organization, the research suggested there was no significant difference in new product development process of co-location and multi-location research and development organization. The research also revealed that efficiency concurrent new product development engineering process in multi-located research and development organizations were driven by "application of concurrent engineering tools", followed by "top-down concurrent engineering approach" and "continuous improvement". However, concurrent engineering "team" related attributes, which suggested by other researchers as main driver for efficiency new product development in co-located research and development organization was found less important in multi-located research and development environment

Key words: New product development, concurrent engineering, research and development, multi-location.

INTRODUCTION

The increasing challenge of competing in the global rival market environment is forcing organizations to reconsider and often revise their business development strategies (such as innovation, operation strategy and marketing strategy) in order to improve competitive advantage (Michael, 2008). To create distinct competitive advantage, some organizations relocated their design and manufacturing entities partially from their origin ground to new locations. The move is to promote geographically and economically advantages in the form of cost reduction in product development and manufacturing related activities, as well as being closer to their customer or material and components supplier (Liker et al., 1996). As the result, in the multinational organization, new product development (NPD) process is the coordination of activities from multi-location teams, where NPD efficiency is devoted to the effectiveness of solutions integration by the teams from multi locations.

An effective NPD process is the key impact factor in an organization's ability to develop and manage innovation (Marisa et al., 2008). Competitive and hostile business environments make NPD process more important to business to ensure the business stays ahead of present or potential competition (Michael, 2008). This research review one of the most cited techniques for developing

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Abbreviations: CNPDE, Concurrent new product development engineering; **CEMC**, concurrent engineering main constructs; **TR,** technology ready; **OI,** opportunity identified; **IA,** identity approved; **TI**, technology integrated; **DC**, design completed; **SA**, specification achieved; **PL**, product launch; **LR**, launch review; **PT**, project transfer.

successful new product development process in multi-location organization, which is concurrent engineering (CE) process (Salomone, 2005; Cooper, 2002; McCarthy, 2006; Merle and Anthony, 2006). Smith (1998) defined concurrent engineering as the systematic approach to integrate concurrent design of products and the related processes, including manufacture and support. The intention of this approach is to encourage designers to consider all elements of the product life cycle at the beginning of the NPD phase, which includes product quality, cost, schedule, user requirements as well as product disposal (Ken, 2006). The simultaneous performance of product design and process design in concurrent engineering involves the formation of cross-functional teams' communication. This allows engineers and managers of different disciplines to work together simultaneously in developing product and process design (Foster and Thomas, 2001).

Many studies in NPD literature focus on investigation and presenting the positive effect of CE on developing new products at centralize location (Belassi, 2006; Han, 2003). However, the implementation of CE in multi location R and D organization, and factors that lead one organization success, while another not remain overlooked (Belassi, 2006). This study aims to close the gap and complements the current research by investigating the determinants of CE with the aim to assess NPD process in a multi-location organization and to identify contributing factors for an effective NPD process in a multi-location organization from CE perspective.

To address the aforementioned problem, three research objectives are identified and formulated:

1.) To assess the perception among employees in a multi location R and D organization in regard with importance phases for an effective NPD process.

2.) To identify the importance constructs for concurrent engineering in NPD process within the multi location R and D organization.

3.) To investigate the implementation level of concurrent engineering in NPD process within the multi location R and D organization.

Research scope

This research focuses on assess the perception on importance phase for an effective NPD process in a multi location R and D company. This research is also aims to identify the importance constructs for implementation of CE on NPD, and to evaluate the level of CE implementation in the multi-location R and D Company. The company under this study has a high reputation for extensive research and development activities, with headquarter located in United Kingdom, and other operation in Malaysia, USA, Europe, Australia, Japan, China and Singapore.

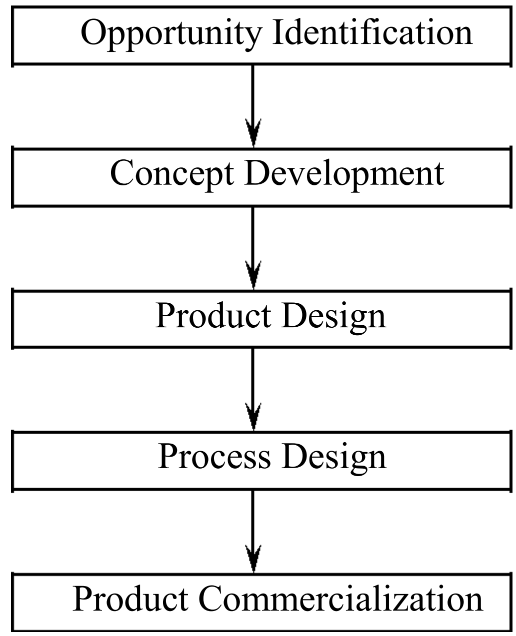

Figure 1. Standard NPD process flow.

Theoretical background

This section reviews elements and frameworks of NPD processes gathered from a series of NPD literature reviews, as well as the main constructs for CE in NPD.

New product development (NPD) Process

A typical NPD process is comprised of five distinct phases, opportunity identification, concept or idea development, product design, process design, testing or validation and product lunch or commercialization (Cooper, 1993; Merle and Anthony, 2006; Dariush, 2006; Lioukas, 2007; Roxana et al.,, 2009) as shown in Figure 1.

Opportunity is a business or technology gap that a company uncovers that exists between the current situation and an envisioned future in order to respond to a threat, solve a problem and capture competitive advantage (Cooper, 2002). Opportunity Identification is the phase where new product opportunities spin out of the ongoing business operation through market research (Merle and Anthony, 2006). At the concept development phase, the identified new product opportunity is transformed into an initial product concept, followed by detail product and process design and development at the product design and process design phases. The newly developed product should be put through series of tests prior to product launch at the product commercialization phase (Lioukas, 2007). Each NPD phase accomplishes specified objectives toward the success of NPD

Table 1. Milestone (MS) Process.

Standard NPD process	MS process
Opportunity Identification	Technology Ready Opportunity Identified
Concept Development	Technology Integration Identify approved
Product Design	Design Completed
Process Design	Process Design
Product Commercialization	Product Launch
-	Launch Review
-	Project Transfer

(Dariush, 2006).

The new product development process in the company under study is named as Milestones (MS) process. The MS process expanded the standard NPD process to nine steps or milestones as shown in Table 1.

In the MS process, opportunity identification phase is spitted into technology ready (TR) and opportunity identified (OI) milestones. Technology ready (TR) milestone focuses on new technology development, while opportunity identified (OI) milestone subsequently pull together the proven new technologies into a new product idea proposal that should demonstrates business potential prior to proceed to the next milestone. Concept development phase is also divided into two milestones, which are technology integrated (TI) and identity approved (IA) milestones. At TI, new idea and technology is integrated into new product, this is followed by IA milestone where the product identity (look, colour, sound, feel) and targeted performance specification are defined and approved. Product design phase is named as design completed (DC) milestone. Product development phase is completed at the end of DC milestone, where product design is finalized, prototype is made and tested. Subsequently, specification achieved (SA) milestone focus on tooling design and outlining manufacturing methods and proving that product meets specification prior to the agreement of product commercialization, which is at product launch (PL) milestone. The uniqueness of the MS process is the process expands beyond the common NPD process with two additional milestones, launch review (LR) and project transfer (PT) milestone. LR takes place six months after product launch. Review is done based on customer feedback, review of specification changes between opportunity Identified and Launch Review, as well as review of issues between PL and LR. PT milestone refer to transferring of project and project ownership from one geographical location to another. The distinctive part of PT milestone is it is “floating” milestone where project can be transferred in between OI and SA milestone, as shown in Figure 2.

Opportunity identified (OI), technology integrated (TI), development completed (DC) and specification achieved (SA) are the four key millstones for the entire milestone process. Key milestones demotes to milestone that required comprehensive reviews of key commitments, where required top management team to review the project and consequently make major business affecting decisions

Concurrent engineering in new product development

CE refers to the bringing of the design and manufacturing engineers together early in the design phase to simultaneously develop the product and processes for producing the product (Stevenson, 1999). The basic concept of CE is to take the product design process out of the isolated world of design engineers and incorporate the other functional requirement that have, or should have, influence over the design (Farrington and Martin, 1995). CE promotes early involvement of a cross-functional team to simultaneously plan product, process and manufacturing (Hartley, 1997). It is typically manifested through concurrent work-flows, product development team and early involvement of constituents (Koufteros, 2001).

Pawar and Riedel (1994), Dariush (2006) believe that the application of CE on NPD process will lead to the development of better, simpler and cheaper product in lesser time. In order to improve the competitive capabilities of the firms, manufacturability issues need to be brought into light and also to reduce lead time from design conception to delivery of the product by involving manufacturing early in the design stage (Dean, 1992).

Critical success factors in concurrent engineering

The core concept for concurrent engineering lays on the removal of functional barrel and whilst forming a cross

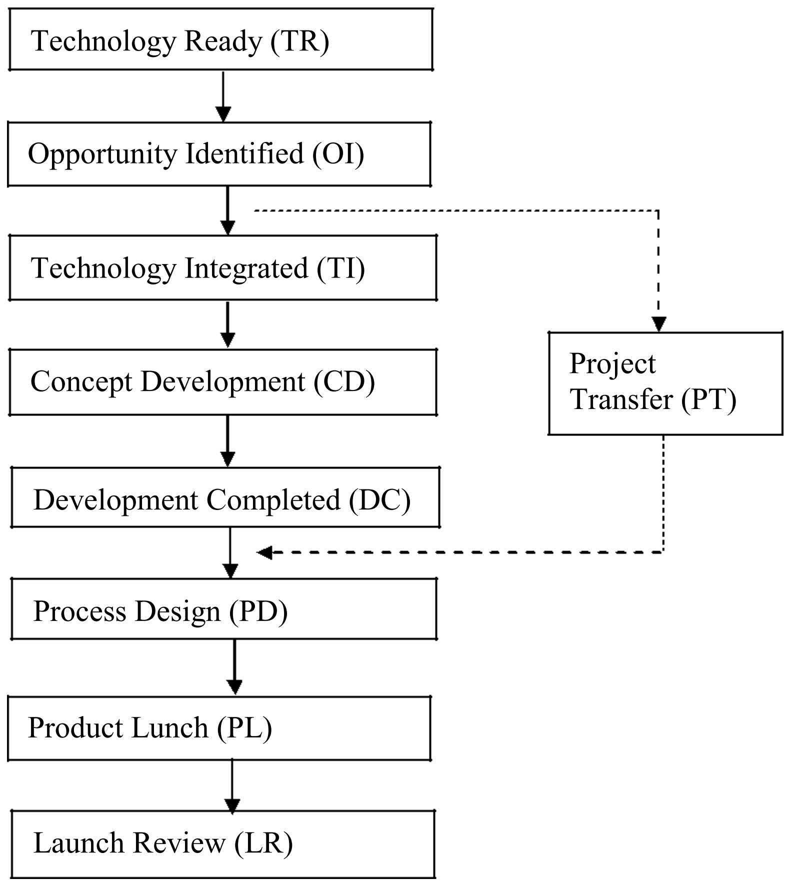

Figure 2. Milestone process flow.

functional CE team (Hans, 2003). According to Cleland (1998), an effective CE teams are characterized by the following:

a.) The team contains not more than ten members.
b.) Team members serve from the beginning to the end of the project.
c.) Team members participate on full time basis.
d.) Team structure is clearly defined.
e.) Team consist of member from varies key functional department, such as marketing, engineering and manufacturing.
f.) Team members are co-located within conversational distance of each other.

Schrage (1993) evaluated critical CE success factors in NPD from holistic business point of view. Schrage (1993) identified ten characteristics that lead to the successful implementation of CE in NPD. The ten characteristics cover team related aspect, business and engineering approaches and business process elements.

1.) A top down design approach based on a comprehensive engineering system process.
2.) Strong interface with the customer.
3.) Multifunctional and multidisciplinary teams.
4.) Continuity of the teams.
5.) Practical engineering optimization of product and process characteristics.
6.) Design benchmarking and soft prototyping.
7.) Simulation of product performance and manufacturing and support process.
8.) Experiments to conform/change high risk predictions found through simulation.
9.) Early involvement of subcontractors and vendors.
10.) Corporate focus on continuous improvement and lesson learned.

In addition, Schrage (1993) has also identified activities that will accelerate the formation of the 10 characteristics. Rudha et al. (2000) conducted an examination of successful concurrent engineering transformations in industry and revealed the presence of the interaction between three underlying elements known as the three T's of concurrent engineering: Tools, training and time. The three T's of concurrent engineering are dynamic by nature and can exist in the following forms:

(1) Type of tools used throughout the NPD process, such a computer aided design (CAD), computer aided

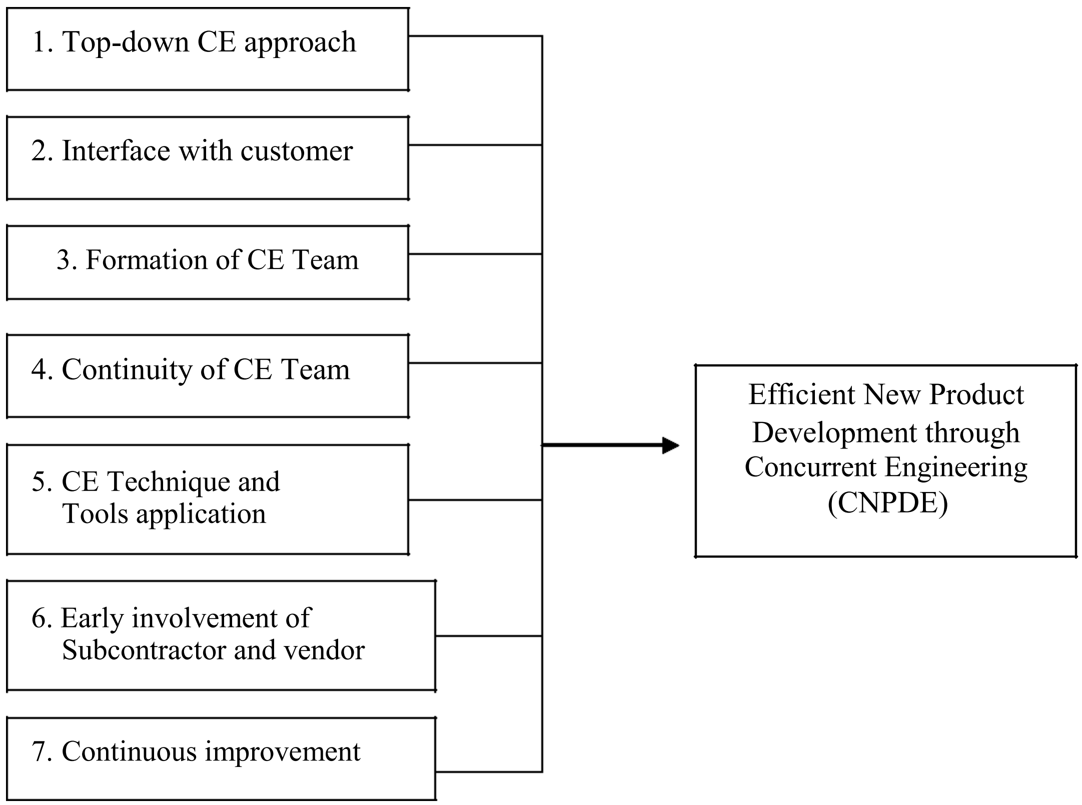

Figure 3. Factor model for efficient NPD through CE process.

manufacturing (CAM) and computer aided engineering (CAE).

(2) Training, area of training including both human development aspect, such as communication and interaction training, as well as technical training that related to CE skills and techniques.

(3) Time; realistic estimation of time for project deadline setting as well as reduction of product development cycle time.

The studies by Rudha (2000) and his colleagues were further developed by Robert (2008) who described three main areas to focus for successful concurrent engineering as "people", "process" and "technology". "People" represents the formation of teams and training, "process" refers to a clear definition of NPD process and to be open to changes and "technology" stand for the application of software, hardware and networking systems such as CAD and CAM. In addition, Irini (2008) pointed out that the influencing agents of CE are tasks (parallel task); teams (inter-disciplinary work group); techniques (design for manufacture techniques); technology (CAD/CAM/CAE); time (reduction of the product design and manufacturing cycle time); tools (software, hardware and networking) and talent (learning the new work model).

Shields (1994) conducted a study on fourteen commercial new product developments process, and subsequently reviewed and analyzed to understand factors that affecting efficiency of NPD process. According to Shield (1994), functional interaction process and continuity of project are driven by collocation of team and maintainability of team. The same observation noted by Smarts (1997). Smarts (1997) reveal that the critical factor for efficiency NPD process in collocated industries were mainly driven by "team" related attributes; which included team structure (multi-disciplinary team), formal team selection process, full time core team and leader, as well as permanent collocation of core team. Base on the aforementioned literature review, this study will primarily exploit Schrage's (1993) ten CE main charac-teristics as the fundamentals of research framework while integrating with CE critical success factors derived from other researchers to produce a research framework comprising of seven main CE constructs with 49 attributes which are deemed as critical agents for an efficient NPD through CE process (Figure 3 and Table 2). As "Team" is commonly recognized as main attribute for CD in NPD (Cleland, 1998; Shields, 1994, Smarts, 1997; Rudha, 2000; Irini, 2008), in the research framework, two out of the seven CE main constructs are allocated to "team" related attributes, which are "forming of CE team" and

Table 2. CE Critical success factor

Critical success factors	
1.0	**Top down concurrent engineering approach**
1.1	Top management commitment and involvement on CE
1.2	Company mission, strategies and policies which promote CE activities
1.3	Clear definition of NPD process flow, tracking method and NPD management system
1.4	NPD process which promotes identification of concurrent activities
1.5	Existent of driving force for new product development
1.6	Computer integrated information environment that allows automated configuration management and control
1.7	Effective communication and teamwork between different levels and departments throughout NPD process
1.8	A team approach (e.g., quality circles, cross-functional teams) in problem solving and continuous improvement
1.9	Team learning and knowledge sharing among employees
1.10	Management openness to change
2.0	**Interface with customers**
2.1	Understanding of the definition of customer (external and internal customer)
2.2	Involvement of customers at the early stage of NPD
2.3	Methods for translation of the “voice of the customers” into key product and process characteristics (e.g., QFD)
2.4	Integrates customer specification into product and process specification
2.5	Continuous feedback to the internal customer as the process evolves
3.0	**Formation of CE team**
3.1	Teams formed at the early stage of NPD phase
3.2	Optimum team size (number of team members)
3.3	Staffing of the team (team members from all disciplines: design, manufacturing, marketing and support)
3.4	Members participation in the team on full time basis
3.5	Team structure and reporting line that is members report solely to team leader, and leader reports to management)
3.6	Team leader’s skill and capability
3.7	Team members’ skill and capability
3.8	Involvement of supplier in the team
3.9	Motivation of the team members
3.10	Training for members to improve soft skills (for example communication, effective meeting, empowerment and leadership)
3.11	Location/distance among members (members are co-located within conversational distance of each other)
4.0	**Continuity of CE team**
4.1	Identify key team members
4.2	Key team members transit with the product (serve from beginning to the end of the project)
4.3	All team members serve from the beginning to the end of the project
4.4	Incentive scheme for team members who serve from beginning to the end of the project
4.5	Training provided for team members in transition (from 1 team to another; or from one location to another)
4.6	Organizational acceptance for team members in transition (from 1 team to another, or from 1 location to another)
4.7	Incentive scheme for team members in transition (from 1 team to another; or from 1 location to another)
5.0	**CE technique and tools application**
5.1	Application of Design for Manufacturing (DFM)
5.2	Use of Computer Aided Design (CAD) and Computer Aided Engineering (CAE)
5.3	Use of prototyping techniques on design benchmarking (Benchmarking of design options via prototyping models)
5.4	Use of Failure Mode and Effect Analysis (FMEA) for identifying high risk product and process characteristics

Table 2 Contd.

5.5	Validation and verification of critical components/parts/technologies at different NPD stages
5.6	Consideration of produce ability and process capability in product design process (for example Cpk and Ppk studies)
5.7	Simulation of product manufacturing and support process (for example engineering build, preproduction)
5.8	Use of design of experiments for variability reduction procedures throughout NPD process
5.9	Selection of optimization values for key product and process characteristics based on sensitivity analysis or DOE
6.0	**Early involvement of subcontractors and vendors**
6.1	Identify critical paths, schedules, and required concurrency of subcontractors and vendors activities
6.2	Top management peer acceptance of early subcontractor/vendor participation
6.3	Good communication channels with suppliers
6.4	Involvement of suppliers in product development process
7.0	**Corporate focus on continuous improvement and lessons learned**
7.1	Methods used for design tracking and feedback of lessons learned
7.2	Leaders assume active roles as facilitators of continuous improvement and creating conducive environment
7.3	Storage method or repository of lessons learned and accessibility to team members

"continuity of CE team".

METHODOLOGY

The research design for this study is deductive theory based. Deductive approach begins with an abstract, logical relationship among concepts; subsequently moving towards concrete empirical evidence (Neuman, 2007).

Research tool

This research adapts quantitative based research tools, where quantitative data is collected through survey questionnaires and Delphi method. The questionnaire is designed and structured based on the extensive literature review of concurrent engineering success factors in NPD. Section 1 of the questionnaire attempts to access the perception of importance ranking placed by project managers and designs managers on the nine NPD milestone phases. Section 2 of the questionnaires attempts to check the degree of importance placed by the engineers and managers on the seven CE critical constructs and 49 CE attributes. In the same questionnaire, the respondents are also requested to judge the level of CE implementation in NPD. Both CE importance and implementation level are rated through two sets of five point scales ranging from (1) `Not important' or 'No implementation' to (5) `Extreme important' or 'Full implementation'.

Sampling design

The total population for the survey questionnaire is 159 respondents; they are design engineers, technical development engineers, test engineer, tooling engineers, quality engineers and commercial executives who have involved in the CE base NPD practices. A random sampling technique group is deployed of which 98 personnel is identified. In addition, for the Delphi method, 12 managers are invited to rank the importance level of the company's nine NPD milestone phases.

Analysis tools

On the Delphi method, Kendall's coefficient of concordance is applied to determine the consistency of ranking by the managers. While descriptive statistic technique is used on analyzing the importance and implementation level of the CE based NPD system.

RESULTS AND DISCUSSION

Based on the research objectives formulated earlier, this section presents the analysis of the empirical evidence.

Reliability test

The reliability coefficients for the seven constructs range from 0.8447 - 0.9484 (Table 3). This implies that the data is statistically significant and could be further analyzed (Sekaran, 2005).

Assessment of the perception of importance of NPD phases

Response from the first round of the Delphi method and the Kendall's coefficient of concordances (W) analysis are summarized in Table 4.0. From Table 4, the Kendall's coefficient of concordances and p-value for scored ranking were 0.194 and 0.017 respectively. Since the p-value is less than 0.05, the findings were deemed to be significant; thus implying that the ranking of the 12

Table 3. Reliability analysis.

Constructs	Detail	Alpha
1	Top down CE approach	0.8447
2	Interface with customer	0.8871
3	Formation of CE team	0.9484
4	Continuity of CE team	0.8916
5	CE technique and tools application	0.8777
6	Early involvement of subcontractor and vendor	0.8972
7	Continuous improvement	0.8978

Table 4. Summary of first round Delphi method.

Overall ranking	**1**	**2**	**3**	**4 or 5**	**4 or 5**	**6**	**7**	**8**	**9**
Milestone process:	**DC**	**OI**	**SA**	**TR**	**IA**	**SP**	**TI**	**LR**	**PT**
Respondent 1	5	1	6	2	4	7	3	8	9
Respondent 2	4	1	5	7	3	8	2	9	6
Respondent 3	2	8	1	6	5	3	9	4	7
Respondent 4	5	1	6	2	4	7	3	8	9
Respondent 5	6	4	5	3	8	2	9	1	7
Respondent 6	1	8	2	9	6	3	7	4	5
Respondent 7	1	2	3	5	4	7	6	9	8
Respondent 8	6	3	8	2	1	9	4	5	7
Respondent 9	1	4	7	3	6	2	8	9	5
Respondent 10	1	5	2	6	3	7	4	8	9
Respondent 11	1	8	3	9	4	5	7	6	2
Respondent 12	3	4	5	2	8	1	7	6	9
Total	36	49	53	56	56	61	69	77	83
Average	3.00	4.08	4.42	4.67	4.67	5.08	5.75	6.42	6.92

Kendall's W [a]= 0.194; Df=8; Chi-Square=18.644; Asymp. Sig. = 0.017

managers are consistent. However, the first round survey did not presented a comprehensible idea on the important ranking as two of the milestones scored the same means of 4.67, namely TR (Technology Ready) and IA (Identity approved) milestone. Therefore, the survey result was presented to the respondents for reevaluation. Five out of the six managers had made a change on initial ranking which forms a second round of survey result.

Results of the second round of the Delphi method and the Kendall's coefficient of concordances (W) analysis are presented in Table 5. According to Table 5, the Kendall's coefficient of concordances and p-value for scored round has improved tremendously to 0.248 and 0.002 respectively.

Since the p-value is less than 0.05, once again, the findings were deemed to be significant, implying that the ranking of the 12 managers were consistent. The higher value of Kendall's W implied a higher level of consistency of ranking by the 12 managers.

As described in literature review, the unique element of the MS process was with the additional LR and the "floating" PT milestone, where project transfer timing can be floated between OI to DC milestone. From the ranking survey, both LR and PT milestones were ranked as the least important milestone in the MS process; this suggested that the uniqueness of LR and PT milestones did not significantly distinguish the MS process with common NPD management process practiced by other collocated R and D companies. From the same ranking survey, DC, OI, SA, TR and IA were rated as the top five importance milestone. The finding reinforces studies of Cooper, (1993); Merle and Anthony, (2006); Kotles et al., *(*2006); Dariush, (2006); Roxana et al., (2009) and Lioukas (2007) where standard NPD process involves five common phases; opportunity identification (which is equivalent to OI and TR of the MS process); concept development (corresponding to IA of the milestone process); product design (comparable with DC of the milestone process); process design and commercial production (correspondent to SA of the milestone process). Once again, the finding revealed that there is no

Table 5. Summary of second round Delphi method.

Overall ranking	1	2	3	4	5	6	7	8	9
Milestone Process:	**DC**	**OI**	**SA**	**TR**	**IA**	**SP**	**TI**	**LR**	**PT**
Respondent 1	4	1	6	2	7	5	3	8	9
Respondent 2	3	1	5	7	8	4	2	9	6
Respondent 3	3	8	1	6	2	7	5	4	9
Respondent 4	4	1	6	2	7	5	3	8	9
Respondent 5	2	6	5	4	1	7	8	3	9
Respondent 6	1	8	2	9	3	6	7	4	5
Respondent 7	1	2	3	5	7	4	6	9	8
Respondent 8	6	3	8	2	9	1	4	5	7
Respondent 9	1	4	7	3	2	6	8	9	5
Respondent 10	1	5	2	6	7	3	4	8	9
Respondent 11	1	8	3	9	5	4	7	6	2
Respondent 12	3	4	5	2	1	8	7	6	9
Total	30	51	53	57	59	60	64	79	87
Average	2.50	4.25	4.42	4.75	4.92	5.00	5.33	6.58	7.25

Kendall's W [a] = 0.248; Df = 8; Chi-Square = 23.844; Asymp. Sig. = 0.002.

Table 6. Ranking on the importance of CE Constructs.

Ranking	Constructs	Means score
1	CE technique and tools application	4.25
2	Top-down CE approach	4.07
3	Continuous improvement	3.97
4	Interface with customer	3.90
5	Formation of CE team	3.87
6	Continuity of the CE team	3.87
7	Early involvement of subcontractor and vendor	3.82

significant different between NPD process involved in multi-located R and D company (that is the milestone process) as compare with common NPD management process practiced by other industrial.

Identify the important constructs on implementing CE

From the results of the survey, Table 6 ranked the CE constructs based on level of importance for a multi-location R and D organization.

From Table 6, “CE technique and tools application” was ranked as the most important construct with a mean score of 4.25. While “early involvement of sub-contractor and vendor” was ranked at the last position however with a relatively high importance mean score of 3.82. In over-all, the data suggested that the respondents regarded all of the CE constructs as important to NPD.

From literature, “team” related attributes are the main constructs for effective NPD process from CE point of view (Cleland, 1998; Shields, 1994, Smarts, 1997; Rudha, 2000; Irini, 2008). Finding from the research suggested for multi located R and D organization, as discontinuity of team took place when project transferred from one location to another, team related attribute became relatively less important constructs for NPD process in multi location organization. Alternately, “CE tools and technique” had substituted “team” related elements as the main driver for an effective NPD process.

Investigate the level of implementation on CE

Table 7 exhibits the implementation level of CE constructs in the NPD process as rated by respondents. Based on Table 7, “CE technique and tools application” and “top-down CE approach” were rated high (3.46 and 3.30 respectively), while the rest of the constructs were rated at the average level of implementation with “continuity of the CE team” ranked at the lowest position (mean score 2.67).

It is interesting to note that “CE technique and tools application”, “top-down CE approach”, “continuous

Table 7. Ranking of implementation level of CE Constructs.

Ranking	Constructs	Means score
1	CE technique and tools application	3.46
2	Top-down CE approach	3.30
3	Continuous improvement	3.16
4	Interface with customer	3.15
5	Early involvement of subcontractor and vendor	3.13
6	Formation of CE team	2.90
7	Continuity of the CE team	2.67

Table 8. Ranking of CE constructs importance and implementation level.

Rank	Importance level (from highest to lowest)	Implementation level (from highest to lowest)
1	CE technique and tools application	CE technique and tools application
2	Top-down CE approach	Top-down CE approach
3	Continuous improvement	Continuous improvement
4	Interface with customer	Interface with customer
5	Formation of CE team	Early involvement of subcontractor and vendor
6	Continuity of the CE team	Formation of CE team
7	Early involvement of subcontractor and vendor	Continuity of the CE team

improvement" and "interface with customer" were ranked as the top four constructs in terms of both importance and implementation level of CE constructs. However, for the following three constructs: "Formation of CE team", "continuity of the CE team" and "early involvement of subcontractor and vendor" were ranked differently based on importance and implementation level (Table 8). The differences could be traced to the company's CE and NPD policy.

Formation and continuity of CE team are implemented at lower level as the company's NPD policy did not promote continuity of team. Team was dismissed in headquarter prior to project transfer and a new team was formed locally with minimum team members transiting with the project. "Early involvement of subcontractor and vendor" is ranked as the least importance construct as the company is dealing with new technology of high confidentiality. Involvement of suppliers and vendors at the early stage of NPD process was inadmissible until intellectual property right of the new technology was granted. However the construct was implemented at higher level, perhaps geographical factor was the main dispute behind the scene. As example, the R&D facility in Malaysia was far apart from the rest of global functional departments, however closer to contractors and vendors as majority of them were located in South East Asia region

Conclusion

The research evaluated the importance level of NPD activities in multi located R and D organization. Finding from the survey suggested the core elements for NPD process in multi-located R and D organization had no significant different as compare to collocated R and D Company. Where, in the case of the company under study, design completed, opportunity identified and specification achieved are the most importance NPD phases. The major findings of the research were the identification of critical CE constructs for an effective NPD process in multi-located R and D Company, which is dissimilar to co-located R and D organization. Efficiency of NPD process in multi-located R and D organization through CE approach is driven by application of CE tools and techniques, followed top-down CE approach and continue improvement. Finding from this research reveals that CE team related attributes, which suggested by other researchers as main driver for efficiency NPD in collocated R and D Company, however, was less important in multi-located R and D organization.

As implication, a revised CNPDE model in multi-located R and D organization is developed base on the responses of research survey questionnaires. The revised model is illustrated in Figure 4 where CE constructs are ranked according to the importance level (from the most important to the least important). The model can be applied on other multi-located R&D organization in the study of CE in NPD.

Future research

Future research could be conducted in other sectors such

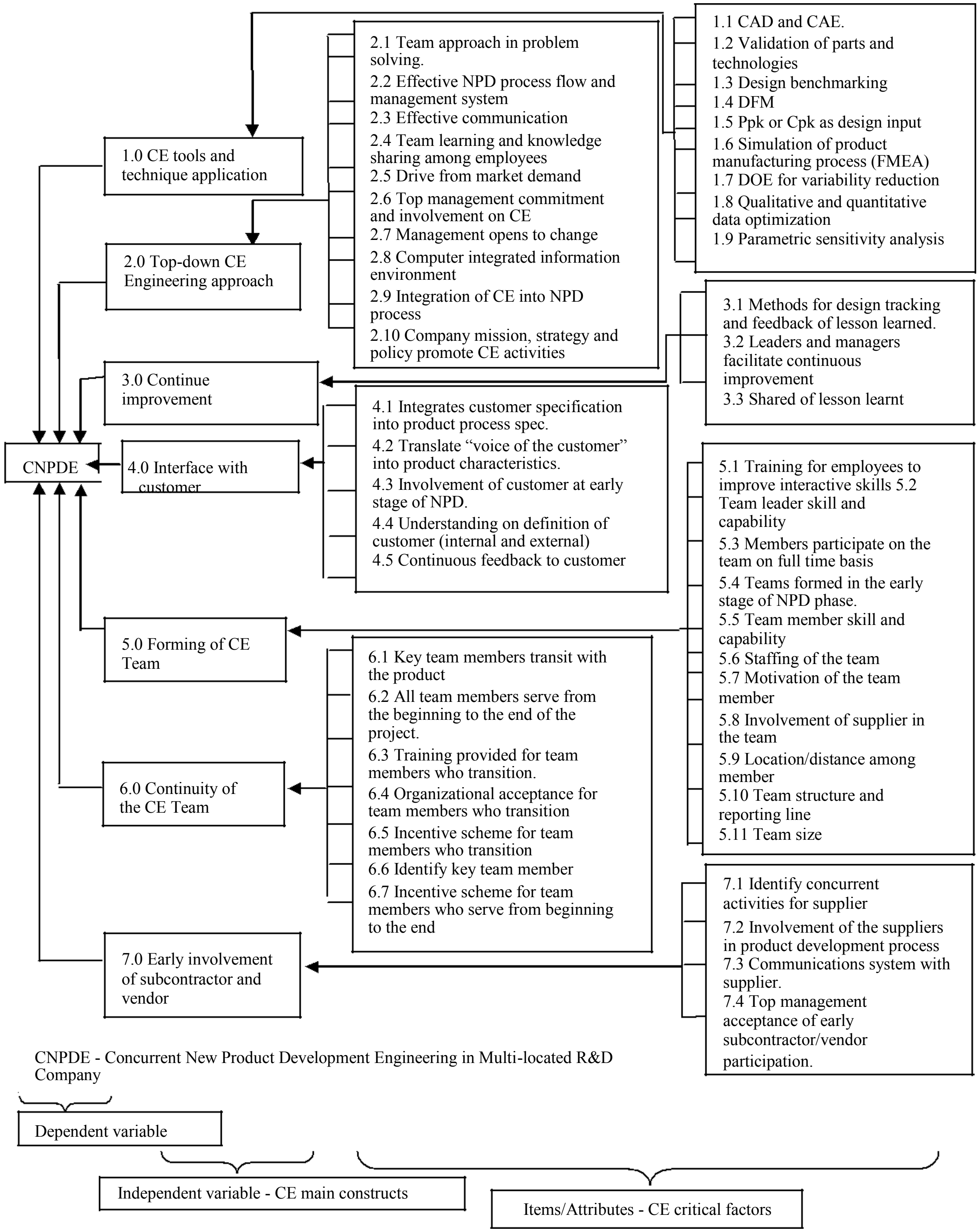

Figure 4. Revised framework.

as multi location R and D in semi-conductors, pharmaceutical, food industrial and medical. As different sectors of business might have different approach on CE implementation. Research on other sectors will acquire an overall picture of CE in NPD of multi location R and D. Besides this, studies in other firms involved in consumer products can also be carried out to compare and reinforce findings discussed in this research. A future research could also look into the implementation framework towards achieving CE in R and D with the steps and processes modeled from this study. In addition, as expansion of this research, future research could be done on the detail of CE tools and techniques application, such as type of CE tools, application, and degrees of usefulness of CE tools on non- R and D; co-located R and D as well as multi location R and D organization. If the long term viability of CE depends on effectively developing and deploying CE tools, the assumptions about how CE design tasks are most successfully performed and the roles of tools in facilitating that work should be carefully reviewed (King and Majchrzak, 1996).

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