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# Implementation of critical success factors in construction research and development process

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## Abstract

Construction research and development (R&D) process has a number of issues that affect its success. These issues imply that Critical Success Factors (CSFs) of construction R&D process are not properly addressed. Not knowing CSFs could lead to not implementing them and not paying proper attention for them. The study investigates CSFs of construction R&D process and their implementation/consideration during the R&D process. A comprehensive literature review was used first to develop construction R&D process. CSFs and their implementation/consideration were evaluated by a questionnaire survey. Construction R&D process was derived with four phases namely Initiation, Conceptualizing, Development and Launch and Management activities that support coordination and resourcing of R&D process. Study revealed that, as a whole there is a gap between the importance of success factors against their implementation/consideration as majority of CSFs are not properly implemented compared to the importance attached to them.

*Keywords:* Construction R&D process, Critical success factors, Implementation, Consideration

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## 1. Introduction

Research and Development (R&D) has been identified as an overarching strategy for construction industry to address its challenges (Barrett 2007; Hampson and Brandon, 2004) such as to improve the efficiency and effectiveness of construction processes and materials; address growing concerns of environmental considerations and health and safety issues; comply with sustainable development requirements; and address cost, time, and quality parameters of construction projects. Fairclough (2002) suggests that innovation driven by R&D as a way forward if the society needs to be benefited from a modern, efficient, high quality construction industry. Not limiting the importance within the UK, R&D is being identified as a key factor which develops the construction industries worldwide (Fox and Skitmore, 2007).

Despite the importance of R&D activities for the growth of the construction industry, there are number of issues, which affect its success. A low level of investment can be identified for UK construction R&D when compared with countries like France, Japan and Scandinavia (Gann, 2000) and when compared with other sectors like manufacturing (Department for Business Enterprise and Regulatory Reform, 2007; Institute of Civil Engineers, 2006; DTI, 2006; Dulaimi et al, 2002; Fairclough, 2002; Seaden and Manseau, 2001; Laing, 2001; Egan, 1998). One of the main reasons for low investment is improper reporting of R&D expenses (Seaden and Manseau, 2001) and inadequate mechanisms to evaluate the successfulness of activities (Lorch, 2000). People question the value of R&D when clear links between its benefits and the financial commitments are not established. Further, when the expectations of the participants of construction R&D activities are not met, a low level of contribution from industrial partners is evident (Barrett and Barrett, 2003). Moreover, lack of feedback on the progress and success of R&D activities and lack of communication between the parties involved (Dulaimi et al, 2002) have reduced the interest and attraction for contributors to ongoing construction R&D activities. It is being evident that construction R&D activities lack effective communication, feedback and validation procedures, and coordination between the parties involved in the process (Gann, 2001; Lorch, 2000).

Above issues imply that factors that are critical for the success of construction R&D process are not properly addressed. Lack of knowledge and understanding of Critical Success Factors (CSFs) could lead to repercussions of paying insufficient attention on them. Further, not knowing the CSFs could result in focusing on factors which are less important for the success of construction

R&D process. This highlights the value of proper identification of CSFs. Studies carried out in other disciplines suggest that there could be a gap between the factors that are important and those that are implemented (Sun and Wing, 2005) as lack of knowledge of the success factors could lead to lack of implementation/consideration in practice. Even though there are a number of studies carried out on identifying CSFs related to R&D in other disciplines (see Cooper and Kleinschmidt, 2007; Sun and Wing, 2005; Roberts, 2002; Sawhney and Prandelli, 2000; Cooper, 1999; Lester, 1998), paucity of studies is evident in evaluating CSFs of construction R&D process and their actual implementation/consideration. Therefore, this study explores the implementation/consideration of CSFs in construction R&D process.

The paper is structured as follows. Firstly, the paper derives phases of construction R&D process via a comprehensive literature review. Secondly, it provides the research methods used for the study. Following this, CSFs of construction R&D process are presented. Implementation/consideration of CSFs is analyzed next followed with a discussion based on the importance and implementation/consideration of CSFs of construction R&D process.

## **2. Construction Research and Development Process**

The life cycle of a new venture (new product/process/services) can be divided into a number of distinct phases. The exact division of these phases is governed by the complexities of the final output, management structure of the organization etc. (Aw, 2005). The development of a new venture can involve a number of activities which are carried out by multidisciplinary teams, different departments and are influenced by various decisions. By considering these factors Saren (1984) identifies five types of models that represent life-cycle of a new venture.

- departmental stage models: based on the departments or functions which hold responsibility for the tasks carried out in the innovation process;
- active stage model: based on the activities that are performed;
- decision stage model: represent the innovation process as a series of evaluation points to decide if the work should go ahead or be abandoned;
- conversion process model: based on the concept that the innovation process is a conversion of inputs to outputs; and
- response model: focuses on the individuals' or organisations' response to change of ideas or project proposals in terms of acceptance or rejection of ideas or proposals.

There are strengths and weaknesses within the above models. The departmental stage model has the disadvantage of handling the idea in isolation within departments, and is characterized by the lack of ownership of the idea (Lim et al, 2006). The involvement of cross functional expertise and activities carried out during each stage is identified in the active stage model. However, this model assumes straightforward progression without indicating any alternative paths available (Saren, 1984). Further, the activities are supported by relevant departments thus passing the tasks from one department to the next (Takeuchi and Nonaka, 1986). The activities are seen, therefore, as the responsibility of the departments, creating similar drawbacks to the departmental stage models. The decision stage model consists of specific decision points to evaluate the success of activities and can be incorporated in the department stage and active stage models. Saren (1984) claims that the aforementioned models indicate that the new venture moves in a rational manner. The conversion process model takes the standpoint that conversion of inputs to outputs avoids assigning the responsibility to separate departments (Hart and Baker, 1994), avoids the sequential approach and the presence of activities (Saren, 1984). The response model is based on the responses to a change of idea/proposal thus evaluating the factors which influence the decision to move ahead or to reject (Hart and Baker, 1994).

In addition to the above models which represent the involvement of different decisions, activities, departments, and responses, the life cycle of a new venture can be divided into number of distinctive phases. Pillai et al (2002) divide it into three phases: project selection phase (initial screening, detailed evaluation, project selection); project execution phase (effective resource management to accomplish project goals within the stipulated time and cost); and project implementation phase (focusing on customer satisfaction and return on investment). Further, there are number of models proposed by various authors depicting various activities in a new venture development (see Table 1). It is noticeable that the phases of those models proposed by different authors follow a similar pattern, whilst activities coincide with one another.

**Table 1:** Phases and activities involved in new venture development

	Snelson and Hart (1991)	Theije et al. (1998)	Loch and Tapper (2000)	Cooper (2001)	Price (2004)	Moultrie et al. (2006)
<b>Initiation</b>	Idea generation Screening ideas	Concept stage	Generate idea	Discover scope	Opportunity recognition	Project generation
<b>Conceptualisation</b>	Concept development Business analysis	Specification stage Basic design stage Detail design stage	Select fund Generate concept Define specs	Business case	Opportunity focusing Commitment of resources	Requirement capture Concept design
<b>Development</b>	Product development Test marketing	Engineering stage	Design Test	Develop Test and Validate	Market entry	Implementation
<b>Launch</b>	Commercialisation		Launch	Launch	Full Launch and Growth	
<b>Maturity</b>					Maturity and expansion Liquidity event	

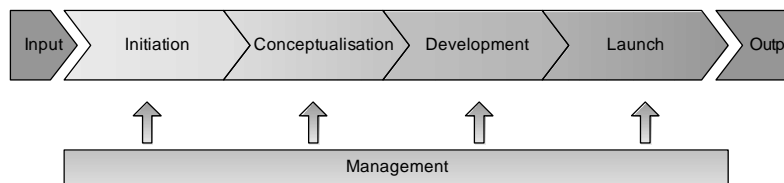
By reviewing the characteristics of the models, the authors categorize the phases of development of new venture into four categories as Initiation, Conceptualization, Development and Launch (Figure 1).



**Figure 1:** Phases of a new venture

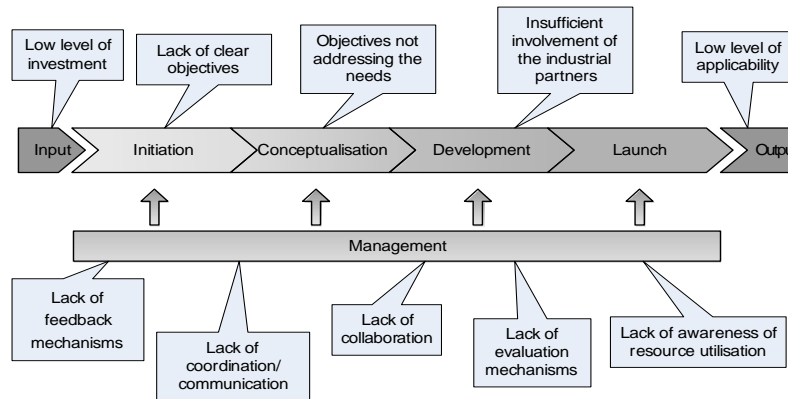
The initiation phase involves idea generation regarding the new venture. This is followed by the conceptualization phase, which involves identifying the requirements of the parties involved and available resources and carrying out an analysis to check the feasibility of the new venture. The third phase involves the actual development and piloting of the new venture to test its validity. Finally the product will be launched at the launch phase. Some models consider a maturity phase where they examine the effect of the new venture on the market (see Price, 2004). Table 1 summarizes leading models of new venture development in relation to the identified four categories.

For the new venture to be successful within its life cycle, it requires a number of management roles, such as effective coordination of activities, communication, resource management and evaluation of output against the goals. By combining the phases of the new venture with the management activities that R&D process needs for its success, authors derived R&D process as shown in Figure 2.



**Figure 2:** Construction R&D process

When designing the R&D process pertaining to this study, the concepts of “*active stage*” and “*conversion*” models were used (see Saren, 1984). Agreeing with Saren (1984) the authors also believe that the R&D process should not be a rational or sequential one. Nevertheless, the authors believe that the identification of activities involved within the phases of R&D process would help to prioritize them and lead to the successful accomplishment of them. The identification of activities involved during different phases would facilitate effective controlling and monitoring of the activities. It ensures the establishment of milestones and short term goals for their accomplishment, during a particular phase, and direction of the team members towards those goals. Though it is recommended to overcome the phase based approach and to integrate the phases, Sun and Wing (2005) comment that such integration could dilute the essential activities involved in R&D work. Thus, the model designed for this study combines the characteristics of the active stage and conversion process models acknowledging the iterative processes, while representing the activities involved within each phase for ease of understanding of the R&D work. Below diagram shows the issues (Refer Section 1) mapped against the construction R&D process.



**Figure 3:** Issues within the construction R&D process

Having identified the construction R&D process, next section discusses the research methodology used from the study.

**3. Research Methodology**

*3.1 Data Collection*

The scope of the study is based on collaborative construction R&D activities carried out between universities and industry. University-industry partnerships are acknowledged as a better way of carrying out construction research activities as they blend theory with practice to gain much success for the research effort (Gilkinson and Barrett, 2004; Calvert and Patel, 2003). During the first stage of the study, a comprehensive literature review was carried out to derive construction R&D process. The development of the R&D process critically evaluated new product development models and their characteristics (Refer Section 2). During the second stage of the study, identification of CSFs of construction R&D process and their actual implementation/consideration was evaluated. To identify CSFs related to construction R&D process, 13 semi-structured interviews were carried out (five principal investigators, five researchers and three industrial partners). By using NVivo software, the interview transcripts were coded to identify the success factors revealed by the interviewees. In addition to the semi-structured interviews, an extensive literature review was carried out on the CSFs in other disciplines. Success factors gathered from empirical investigation via semi-structured interviews and literature review were combined to prepare the questionnaires (Refer Table 2 for the response rate of the questionnaire survey). Within the questionnaire, the success factors were structured according to the phase of the construction R&D process derived from the literature review namely Initiation, Conceptualization, Development, Launch and for Management.

**Table 2:** Response rate for the questionnaire survey

Category	Number of questionnaires sent	Number of responses received	Response rate
<b>Principal Investigators:</b> represent the university and manage and lead the R&D process & <b>Researchers:</b> represent the University and carries out research work related to the project	55	34	62%
<b>Industrial Partners:</b> representatives from construction organizations who contributes to the R&D process	74	26	35%

Both importance and implementation/consideration of success factors during their lifecycle was gathered from the questionnaire by using five scale Likert scales (Refer Table 3). The Likert scale to evaluate importance of success factors comprised of Very Important, Important, Moderately Important, Of the little Important and Unimportant where as the Likert scale to evaluate implementation/consideration of success factors comprised of Always, Very Often, Sometimes, Rarely and Never (Refer Table 3). In addition to the above values, no opinion/not applicable columns were added to both Likert scales to avoid respondents giving incorrect answers due to lack of knowledge or opinion for a particular question (Krosnick, 2002).

**Table 3:** Sample of the questionnaire survey indicating the format and values assigned for Likert scale

1. <i>Initiation Phase: This involves the idea generation to select the most suitable option for a research project</i>													
The extent of importance						The extent of consideration/ implementation							
Unimportant	Of little importance	Moderately important	Important	Very Important	No Opinion N/A		Never	Rarely	Sometimes	Very often	Always	No Opinion N/A	
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Understand the market and its dynamics	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Establish the research problem clearly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Selecting a competent team	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Leadership of the principal investigator	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Commitment of the principal investigator	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Consider funding bodies' requirements	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Consider industrial partners' requirements	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Consider researchers' requirements	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Other (please specify)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

3.2 Data Analysis

CSFs of construction R&D process were evaluated by considering the responses received regarding the importance of success factors. Responses received for the questionnaire survey regarding the importance of success factors were subjected to two filtering stages to evaluate CSFs of construction R&D process. During the first filtering stage, success factors that received an overall mean value (total mean value received from principle investigators, researchers and industrial partners) less than four were excluded from further analysis. This filtering was done on the premise that mean value less than four indicates unimportant (value 1), of the little important (value 2) or moderately important (value 3) success factors (refer Table 3 for the values assigned for the questionnaire survey). For those success factors obtained an overall mean value including four and above were subjected to the second filtering stage by using the Wilcoxon signed rank test. The Wilcoxon signed rank test is a non-parametric method to test the differences of two related variables when the subject (dependant category) is measured on two occasions or under different conditions (Hill and Lewicki, 2007; Pallant, 2001). By taking a consecutive pair of data, the Asymptotic significance was calculated. The Asymptotic significance shows an estimate of the significance of differences within attributes being tested (Pallant, 2001). Generally, Asymptotic significance less than 0.05 is considered as indicating a significant difference between the attributes being tested. Accordingly, the paired data which showed an Asymptotic significance < 0.05 was considered as responses having a significant difference regarding the importance of the success factors, hence such factors were considered as not critical for the success of construction R&D process (refer to Table 4 for total mean values and Asymptotic significance of CSFs).

After identifying the CSFs, their implementation/consideration during the construction R&D process was done by analyzing the total mean values obtained from the questionnaire regarding the “implementation of success factors” (refer to Table 4 for the mean values obtained for the implementation/consideration of success factors). The above section discussed the research methodology used for the study. Section below provides the CSFs of construction R&D process.

4. Findings

4.1 Critical success factors of construction research and development

The study developed a number of CSFs for construction R&D process by analyzing the questionnaire survey. Summary of CSFs of construction R&D is presented in Table 4.

**Table 4:** CSFs and their implementation/consideration during the R&D process

Initial Phase	Importance of the success factors			Implementation/consideration of the success factors	
	Mean	Rank	Asymptotic Significance	Mean	Rank
Establish the research problem clearly	4.79	1	N/A	3.97	2
Commitment of the principle investigator	4.56	2	0.06	3.80	3
Select a competent team	4.48	3	0.51	3.59	8

**Table 4 (cont'd):** CSFs and their implementation/consideration during the R&D process

Initial Phase (cont'd)	Importance of the success factors			Implementation/consideration of the success factors	
	Mean	Rank	Asymptotic Significance	Mean	Rank
Leadership of the principle investigator	4.28	4	0.08	3.69	6
Consider industrial partners' requirements	4.27	5	0.99	3.72	4
Consider funding bodies' requirements	4.26	6	0.87	4.02	1
Understand the market and its dynamics	4.13	7	0.45	3.72	5
<i>Consider researchers' requirements</i>	3.79	8		3.66	7

**Conceptualising Phase**

Check the feasibility of the project	4.75	1	N/A	3.82	3
Commitment of the principle investigator	4.57	2	0.07	3.77	5
Committed and cooperative team members	4.53	3	0.55	3.60	9
Establish clear and realistic goals/ deliverables/ milestones	4.51	4	0.99	3.79	4
Adequate resources/financial support	4.44	5	0.52	3.75	6
Allocation of responsibilities to team members inline with competencies	4.39	6	0.61	3.44	12
Establish a plan to disseminate research results	4.39	7	1	3.90	2
Leadership of the principle investigator	4.31	8	0.58	3.67	7
Having a skilled team	4.30	9	0.76	3.66	8
Establish clear method to measure success	4.30	10	1	3.20	16
Consider industrial partners' requirements	4.30	11	0.95	3.52	10
Consider funding bodies' requirement	4.28	12	0.97	3.98	1
<i>Absence of lengthy bureaucracy</i>	4.00	13	0.03	2.93	18
<i>Early involvement of industrial partners</i>	4.00	14		3.34	13
<i>Comprehensive briefing process</i>	3.98	15		3.33	14
<i>Recognition for team members</i>	3.92	16		3.21	15
<i>Consider researchers' requirements</i>	3.84	17		3.46	11
<i>Fast decision making process</i>	3.72	18		3.18	17

**Development Phase**

Committed and cooperative team members	4.59	1	N/A	3.64	6
Commitment of the principle investigator	4.57	2	0.83	3.93	2
Adequate resources/financial support	4.56	3	0.91	3.79	3
Having a skilled team	4.51	4	0.55	3.57	7
Meet funding bodies' requirements	4.51	5	0.99	3.93	1
Share a common understanding about the work	4.41	6	0.29	3.52	8
Well establish operational procedure	4.39	7	0.91	3.36	12
Meet industrial partners' requirements	4.39	8	0.98	3.46	9
Momentum/ motivation of the team	4.38	9	0.91	3.39	10
Flexibility and responsiveness to change	4.38	10	1	3.38	11

**Table 4 (cont'd):** CSFs and their implementation/consideration during the R&D process

Development Phase (cont'd)	Importance of the success factors			Implementation/consideration of the success factors	
	Mean	Rank	Asymptotic Significance	Mean	Rank
Leadership of the principle investigator	4.38	11	0.94	3.72	5
<i>Absence of lengthy bureaucracy</i>	4.11	12	0.02	3.08	15
<i>Meet researchers' requirements</i>	4.08	13		3.75	4
<i>Recognition for team members</i>	4.02	14		3.21	13
<i>Fast decision making process</i>	3.95	15		3.10	14
<i>Having a risk mitigation strategy</i>	3.95	16		2.78	17
<i>Testing the market</i>	3.92	17		3.00	16

**Launch Phase**

Effective dissemination of the results	4.52	1	N/A	3.54	4
Meet funding bodies' requirements	4.49	2	0.73	3.90	1
Having a well established dissemination/ marketing plan	4.48	3	0.88	3.33	6
Meet industrial partners' requirements	4.40	4	0.46	3.64	2
Launch the output within the planned time frame	4.36	5	0.93	3.41	5
<i>Comprehensive project review and feedback</i>	4.05	6	0.03	3.28	7
<i>Meet researchers' requirements</i>	3.89	7		3.56	3
<i>Refinement of the output after launch</i>	3.84	8		3.00	8

**Management**

Effective communication	4.70	1	N/A	3.59	2
Effective collaboration	4.62	2	0.28	3.52	4
Effective planning, controlling, and organising of activities	4.52	3	0.29	3.54	3
Continuous reviews	4.48	4	0.53	3.66	1
Effective resource management	4.34	5	0.19	3.31	6
Effective management of the people	4.33	6	0.85	3.38	5
<i>Having an external person to do reviews</i>	3.98	7		3.16	7
<i>Evaluating post delivery success</i>	3.95	8		2.98	8
<i>Having a separate project administrator</i>	3.43	9		2.89	9

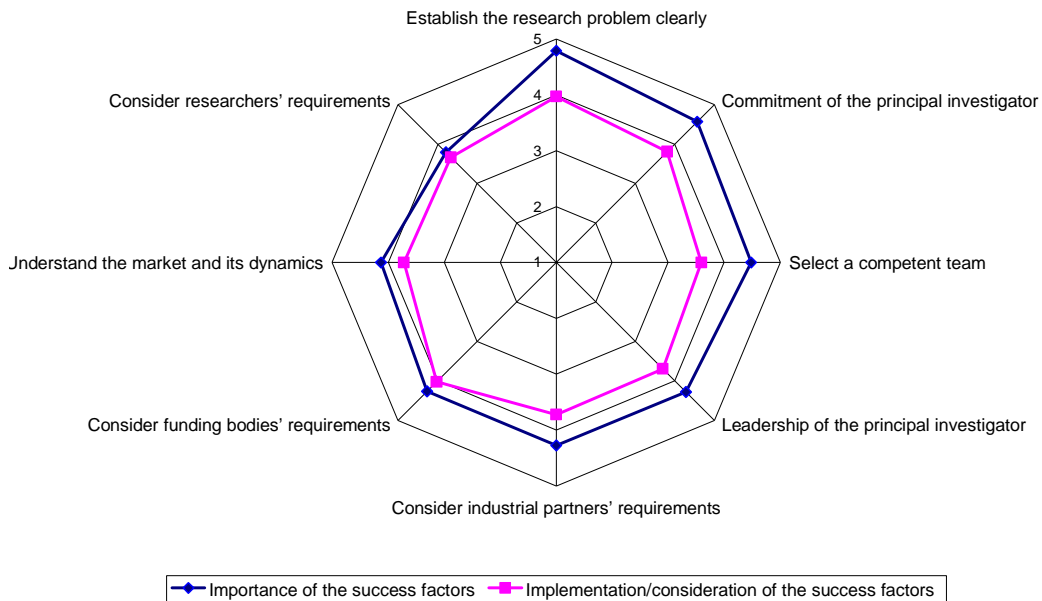
\* Success factors written in Italic letters are none-critical factors  
Asymptotic Significance values are not shown for non-critical factors

For the detail descriptions about above CSFs, please refer Kulatunga et al. (2009).

**4.2 Implementation/consideration of critical success factors**

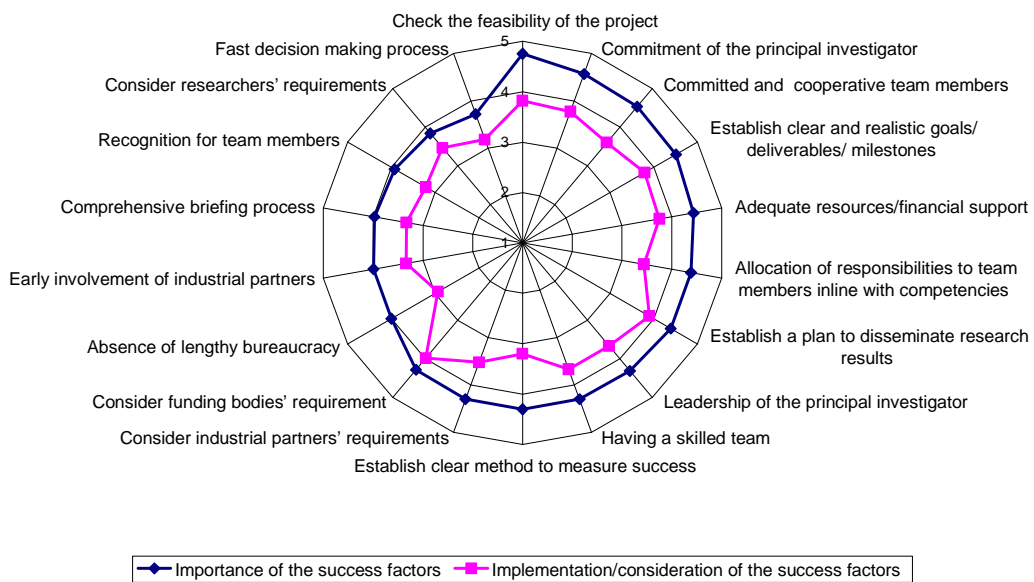
By considering overall mean values (Table 4) of CSFs and their implementation/consideration during the R&D process Radar diagrams were prepared (Figure 4 to Figure 8). These figures compare the importance and implementation/consideration of success factors during initiation, conceptualizing, development and launch phases and at management.





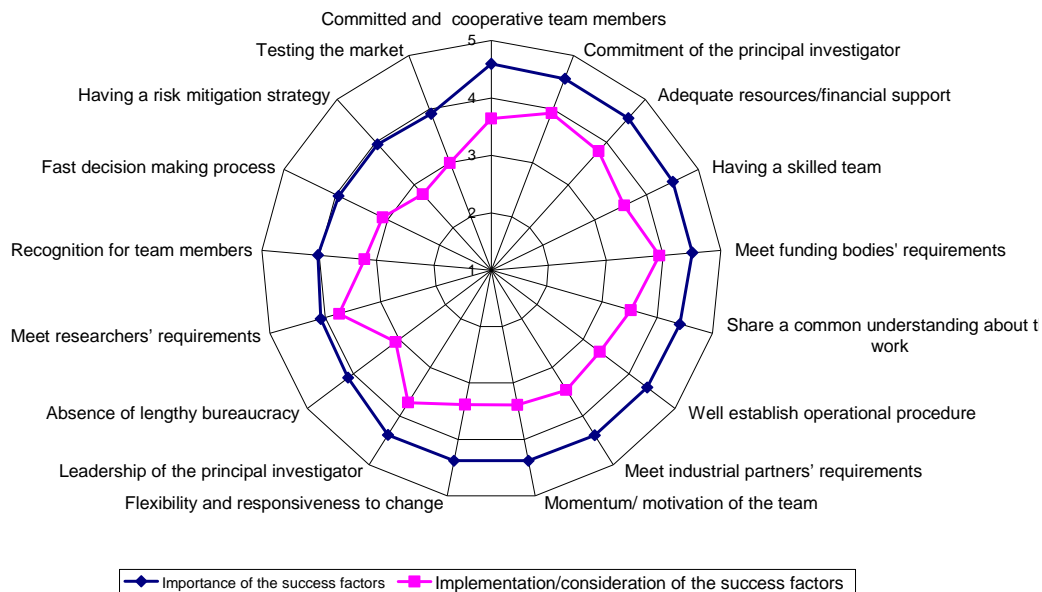
**Figure 4:** Comparison of the importance of success factors against their implementation/consideration at the initiation phase

At the initiation phase all the success factors except for “considering funding bodies’ requirements” have obtained mean values less than 4 for their implementation/ consideration. It can be noted that “considering the funding bodies’ requirements”, “establishing the research problem clearly” and “commitment of the principal investigator” are being identified as the most implemented/considered factors while “selecting a competent team” and “considering researchers’ requirements” as the least implemented/considered factors. Figure 5 illustrates the importance and implementation/consideration of success factors at the conceptualizing phase. Within this phase, all the success factors have acquired a mean value less than 4 for their implementation/ consideration. Nevertheless, similar to the initiation phase, “considering funding bodies’ requirement” has been ranked as number one indicating higher consideration given it. “Establishing a plan to disseminate research results” and “checking the feasibility of the project” is ranked second and third respectively, while “a fast decision making process” and “absence of a lengthy bureaucracy” as the least implemented/considered factors.



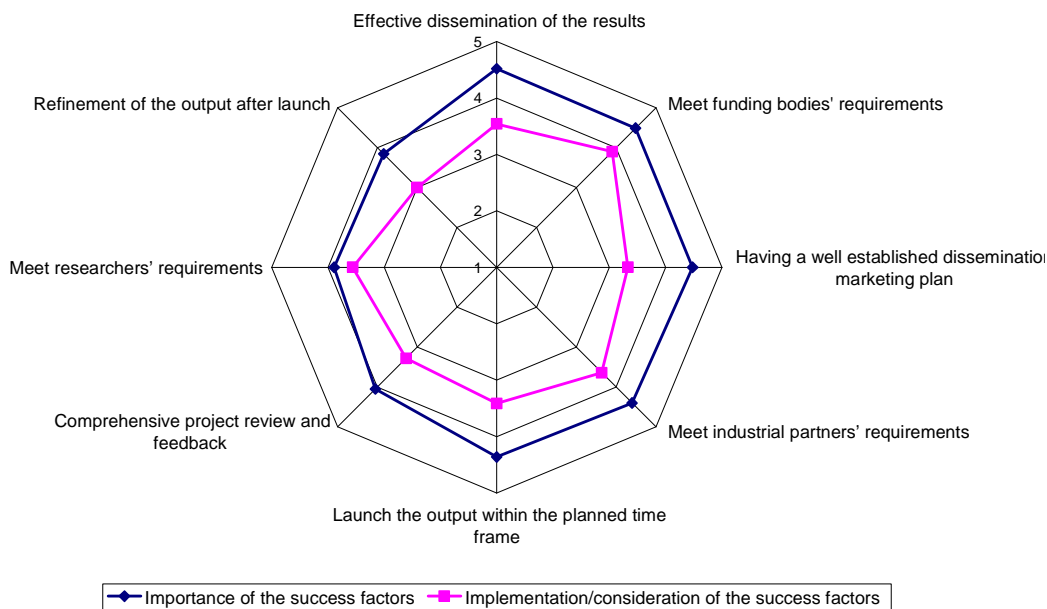
**Figure 5:** Comparison of the importance of success factors against their implementation/consideration at the conceptualizing phase

Similar to the initiation and conceptualizing phases, all the success factors have obtained mean values of less than 4 at the implementation/consideration during the development phase (see Figure 6). Again, “addressing the requirements of the funding body” has been ranked number one, while “commitment of the principal investigator” and “having adequate resources” have been ranked two and three according to their implementation/ consideration.



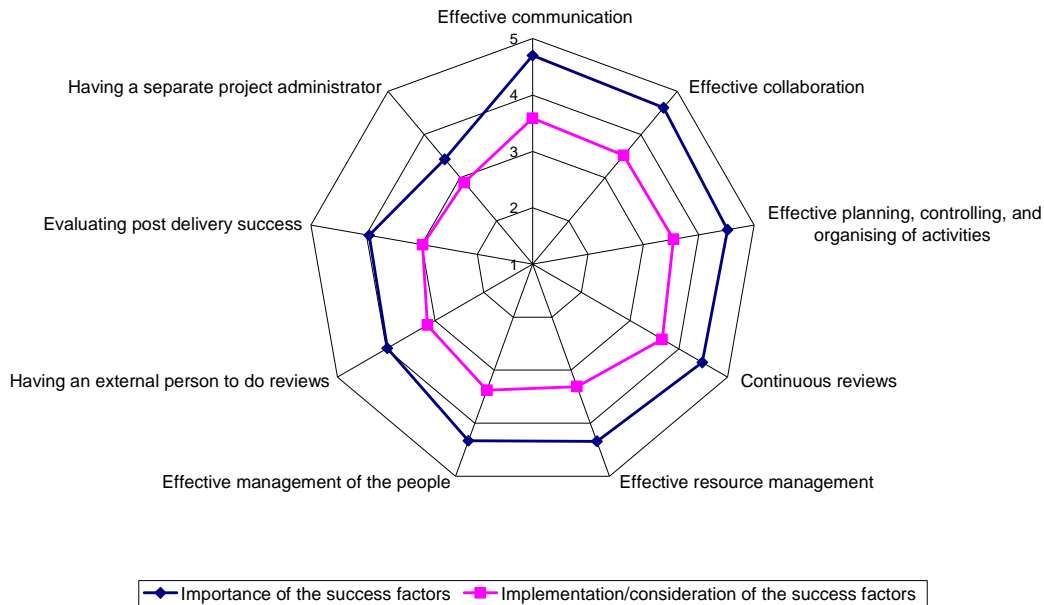
**Figure 6:** Comparison of the importance of success factors against their implementation/consideration at development phase

At launch, addressing the funding bodies’ and industrial partners’ requirements have been selected as the factors that were mostly implemented/ considered (see Figure 7). The success factors “refinement of the output after launch” and “carrying out project reviews and feedback” are identified as being the least implemented/considered factors. Corresponding to the other phases, at the launch phase also all the success factors obtained their mean values less than 4.



**Figure 7:** Comparison of the importance of success factors against their implementation/consideration at the launch phase

Carrying out continuous reviews and effective communication are identified as being the most implemented/considered success factors when managing the R&D process (see Figure 8). “Engaging a separate person to undertake project administration work” and “evaluation of post delivery success” has been selected as the least implemented/considered factors.



**Figure 8:** Comparison of the importance of success factors against their implementation/consideration at project management

### 5. Discussion

Overall, the empirical data indicates that the majority of success factors (except for “considering the funding bodies’ requirements”) are not very often (value 4) or always (value 5) implemented/considered during the construction R&D process but are implemented sometimes (value 3). This indicates that CSFs are not adequately implemented/considered during the actual process even though they are identified as important for the success of construction R&D process. The success factors identified as non-critical (refer to Table 4), have generally been ranked low at the implementation/consideration (except for “meeting the researchers requirements” during the development and launch phases). This gives a positive correlation between the importance and implementation/consideration of non-critical success factors.

During the actual implementation of the R&D process, the funding bodies’ requirements were taken as the most considered factor (Refer Table 4). This indicates the prominence given in fulfilling the requirements of funding bodies as the satisfaction of funding bodies leads to safeguarding of future funding opportunities for construction R&D projects. Though the empirical investigation of this study highly valued the importance of commitment of principal investigator for the R&D process (Rank 2 at initiation, conceptualization and development phases), during the implementation stage of the R&D project, the commitment of the principal investigator was not ranked highly when compared to its importance. In contrast to the findings of the empirical investigation of this study, Peansupap and Walker (2006) identify the influence of senior management for proper diffusion of innovation. Selecting a competent team during the initiation phase and having a skilled team during the conceptualizing and development phases obtained ranks below 7 (Refer to Table 4) indicating they are not given sufficient implementation/consideration during construction R&D process. Similarly, having a multi-skilled team in order for a construction organization to be innovative was not given much attention in the study carried out by Manley and McFallan (2006).

Although “selecting a competent team” has been ranked third according to its importance at the initiation phase, it has been ranked eighth at the implementation. Similarly, factors “committed and cooperative team members” at the conceptualizing and development phases (rank 3 and 9, 1 and 6 respectively), “allocation of responsibilities to team members in line with competencies” at the conceptualizing phase (rank 6 and 12) have taken higher rankings for their importance when compared with their implementation. This indicated that these factors are not given due consideration during the implementation when compared to their importance. Accordingly, some factors showed an inconsistency between the importance and implementation based on their assigned ranks. Such inconsistency of CSFs based on the importance and implementation was identified in the study carried out by Sun and Wing (2005).

## 6. Conclusions

The study investigated the CSFs and their implementation during construction R&D process. Despite the importance of R&D to construction industry, there are number of issue that hinders its success. This study suggests the identification of CSFs and evaluation of their implementation during the R&D process as a way forward to enhance success of construction R&D process. The study argued that identification of CSFs and their actual implementation/consideration during R&D process could lead to giving proper attention for the factors that are highly important for the success of construction R&D process. Study identified a number of CSFs of construction R&D process from inception, conceptualizing, development and launch phases and at management. The results revealed that, when compared with the importance, it is seldom that almost all the CSFs are given enough attention during the actual implementation of the construction R&D process. Identification of CSFs from the study provides a good foundation for their effective management of them to provide required resources and attention by concentrating on few critical factors that are required for the success of construction R&D process. The fact revealed from the study that prominence attached to the importance of success factors were not given when it comes to their implementation during the construction R&D process will also help to pay more attention for the success factors during their actual implementation stage. As a way forward, it can be suggested to link CSFs with performance measures so that addressing performance measurement targets can ensure implementation of CSFs to enhance construction R&D activities. Even though there are a number of studies carried out on identifying CSFs, they are based in other disciplines such as manufacturing etc. Thus, this study contributes to the theory by deriving construction R&D specific CSFs and integrating them with the phases of the R&D process from initiation, conceptualising, development to launch and at the management of R&D activities. Evaluation of the actual implementation/consideration of CSFs contributed to management and practice by identifying the CSFs that are not implemented/considered properly during the construction R&D process. The scope of the study is based on collaborative construction R&D activities carried out between universities and industry. The findings derived from the study therefore can be generalized within collaborative construction R&D activities between universities and industry. This can be identified as a limitation of the study.

## References

- Aw, K. C. 2005, Integrating quality and reliability assessment into product development process, *International journal of quality and reliability management*, Vol. 22 No. 5, pp. 518-530
- Barrett, P. 2007, Revaluating Construction: a holistic model, *Building Research and Information*, Vol. 35 No.3, pp. 268-286
- Barrett, S. P., and Barrett, L. C. 2003, Research as a kaleidoscope on practice, *Construction management and economics*, Vol. 21 No. 7, pp. 755-766
- Calvert, J., and Patel, P. 2003, University- industry research collaborations in the UK: bibliometric trends, *Science and public policy*, Vol. 30 No. 2, pp. 85-96
- Cooper, R.G. 1999, From experience: the invisible success factors in product innovation, *Journal of Product Innovation and Management*, Vol. 16 No. 2, pp. 115-133
- Cooper, R.G. 2001, *Winning at New Products: Accelerating the Process from Idea to Launch*, 3<sup>rd</sup> edition, Perseus publishing, Cambridge
- Cooper, R.G., and Kleinschmidt, E.J. 2007, Winning businesses in product development: the critical success factors, *Research Technology Management*, Vol. 50 No. 3, pp. 52-66
- Department for Business, Enterprise & Regulatory Reform, 2007, *Draft Strategy for Sustainable Construction*, A consultation paper, (accessed: Feb 2008), available online at: <http://www.berr.gov.uk/files/file40641.pdf>
- Dulaimi, M F., Ling, F.Y.Y., Ofori G., and De Silva N. 2002, Enhancing integration and innovation in construction, *Building research and information*, Vol. 30 No. 4, pp.237-247
- Egan, J. 1998, *Rethinking construction: Report from the construction task force*, Department of the environment, transport and regions, UK
- Fairclough, J., 2002, *Rethinking construction innovation and research: A review of government R and D policies and practices*, Department of Trade and Industry, London
- Fox, P., and Skitmore, M. 2007, Factors facilitating construction industry development, *Building Research and Information*, Vol. 35 NO. 2, pp. 178-188
- Gann, D. M. 2001, Putting academic ideas into practice: technological progress and the absorptive capacity of construction organisations, *Construction management and economics*, Vol. 19 No.3, pp. 321-330
- Gann, D.M. 2000, *Building innovation*, Thomas Telford, London
- Gilkinson, N., and Barrett, P. 2004, The unanticipated impacts of research on practice, *CIB world congress*, 2<sup>nd</sup> - 7<sup>th</sup> May, Canada
- Hampson, K., and Brandon, P. 2004, *Construction 2020: A vision for Australia's property and construction industry*, CRC Construction Innovation, Australia
- Hart, S. J., and Baker, M .J. 1994, The multiple convergent processing model of new product development, *International marketing review*, Vol. 11 No. 1, pp. 77-92

- Hill, T., and Lewicki, P. 2007, *STATISTICS Methods and Applications*. StatSoft, Tulsa, (accessed: February 2008), available from: <http://www.statsoft.com/textbook/stathome.html>
- Institute of Civil Engineers, 2006, *Infrastructure research priority*, (accessed: March 2007), available from: <http://www.ncrisp.org.uk/Publications/Infrastructure%20Research%20Priorities.pdf>
- Krosnick, J.A. 2002, The causes of no-opinion responses to attitude measures in surveys: They are rarely what they appear to be. In R.M. Groves, D.A. Dillman, J.L. Eltinge, & R.J. A. Little (Eds), *Survey nonresponse*, John Wiley & Sons, New York
- Kulatunga, U, Amaratunga, D, and Haigh, R 2009, Critical Success Factors of Construction Research and Development, *Construction Management and Economics*, Vol. 27. No. 9, pp. 891-900
- Laing, M. 2001, Yesterday, today and tomorrow - lessons from the past we can take forward into the future, *Reading construction forum*, Oxford
- Lester, D.H., 1998, Critical success factors for new product development, *Research Technology Management*, Vol.41 No.1, pp.16-21
- Lim, L. P. L., Garnsey, E., and Gregory, M. 2006, Product and process innovation in biopharmaceuticals: a new perspective on development, *R&D Management*, Vol. 36 No.1, pp. 27-36
- Loch, C. H., and Tapper, U. A. S. 2000, *R&D performance measurement that are linked to strategy*, working paper, INSEAD, (accessed 5<sup>th</sup> March 2005), available from: <http://ged.insead.edu/fichiersti/inseadwp2000/2000-14.pdf>
- Lorch, R. 2000, *Improving the communication of academic research to the construction industry*, Construction research and innovation strategy panel, (accessed 20<sup>th</sup> February 2006), available online from: <http://ncrisp.steel-sci.org/Publications/9916frLo.pdf>
- Manley, K. and Mcfallan, S., 2006, Exploring the drivers of firm-level innovation in the construction industry, *Construction Management and Economics*, Vol.24 No. 9, pp.911-920.
- Moultrie, J., Clarkson, P. J., and Probert, D, 2006, A tool to evaluate design performance in SMEs, *International Journal of Productivity and Performance Management*, Vol. 55 No. 3/4, pp. 184-216
- Pallant, J. 2001, *SPSS survival manual. A step by step guide to data analysis using SPSS for windows (Version 10-11)*. Open University Press, Buckingham
- Peansupap, V. and Walker, D.H. T. 2006, Innovation diffusion at the implementation stage of a construction project: a case study of information communication technology, *Construction Management and Economics*, Vol. 24 No.3, pp. 321-332
- Pillai, A. S., Joshi A., and Rao, K. S. 2002, Performance measurement of R&D projects in a multi-project, *International Journal of Project Management*, Vol. 20 No. 2, pp. 165-177
- Price, R. W. 2004, *Road map to Entrepreneurial success: powerful strategies for building a high profit business*, AMA-COM, New York.
- Roberts, G. 2002, SET for success: The supply of people with science, technology, engineering, and mathematics skills, HM Treasury, UK
- Saren, M. 1984, A classification of review models for the intra-firm innovation process, *R&D management*, Vol. 14 No.1, pp.11-24
- Sawhney, M., and Prandelli, E. 2000, Communities of creation: managing distributed innovation in turbulent markets, *California Management Review*, Vol. 42 No.4, pp.45-69
- Seaden, G., and Manseau, A. 2001, Public policy and construction innovation, *Building research and information*, Vol. 29 No.3, pp. 182-196
- Snelson, P.A., and Hart, S. J. 1991, Product Policy: Perspectives on Success, in Baker, M. J. (Ed.), *Perspectives on Marketing Management*, Vol. 1, pp.193-225.
- Sun, H., and Wing, W. 2005, Critical success factors for new product development in the Hong Kong toy industry, *Technovation*, Vol.25 No.3, pp.293-303
- Takeuchi, H., and Nonaka, I. 1986, The New Product Development Game, *Harvard Business Review*, Vol. 64 No.1, pp. 137-46
- Theije, S. M., Sander, P.C., and Brombacher, A. C. 1998, Reliability tests to control design quality: a case study, *International Journal of Quality & Reliability Management*, Vol. 15 No. 6, pp. 599-618

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