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Critical success factors for multidisciplinary engineering projects

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CRITICAL SUCCESS FACTORS FOR MULTIDISCIPLINARY ENGINEERING PROJECTS

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Project success is an attractive idea but what factors lead to success remains an area of conjecture. In the project management literature the success has often been defined in terms of better control of timescales, budgets and resource planning. Yet these are impoverished terms for conceptualising success, which is both multi-dimensional and contextual. The study explores the perceptions of critical success factors (CSFs) in a multi-disciplinary engineering practice. Project success is seen to be related to five dimensions of work: *individuals, teams, process, project* and *product*. Understanding these elements and their interdependence may enable managers to identify strengths and weaknesses in current work practices. An important insight is that CSFs is a form of knowing, which needs to be articulated and communicated more effectively within the project community, emphasising the role of social capital and social networks.

Keywords: consulting engineering, critical success factors, multidisciplinary projects, project success, organisational behaviour, social capital, success factors,

1. Introduction

In an era when projects have become a means of enhancing organisational performance and competitiveness, defining and assessing project success is more relevant than ever (Shenhar, 2001), especially so in engineering and construction. Current success frameworks do not seem to apply in these project based environments where conflicting priorities exist between different projects and professional groups as well as the number of interfaces between the projects and their surrounding environments (Fong 2005). The success of individual projects impacts on the wider organisation in several dimensions and has a bearing on the future direction of project management (Jugdev & Muller 2005) as well as organisational longevity. Yet, project success appears to be something of an enigma. This is perhaps not surprising, since the terminology surrounding success has been widely criticised as both confusing and simplistic (see Guss 1998). Initially, the concept of critical success factors (CSFs) was used to identify information systems needs of managers and engineers in various industries (Daniel 1961; Rockart 1979). In this context, critical success factors were defined as "the critical key areas where 'things' must go right for the business to flourish" Rockart (1979: 85).

Nevertheless, while CSF may be useful in pinpointing important for achieving desired goals, as a method it fails to fully answer the question: What factors really lead to successful projects? Over the past 20 years or so textbooks maintain that there are three critical factors that define project success, often referred to as the priorities of project management: a definite due date, a limited budget (including personnel resources), and a specified set of performance goals. However, academics and practitioners alike now recognise that there is more to success than fulfilling the goals of the project manager (Shenhar et al 2001; Meredith & Mantel 2006). From this perspective, two different aspects of projects are deemed essential in determining whether a

project is a success or failure: 1) the internal characteristics of the project organisation such as time cost and performance goals, and 2) the external characteristics, such as customer satisfaction (Shenhar 1997; Agarwal & Rathod 2004; Meredith et al 2006). Additionally, empirical research has shown that perceptions play a strong role of a project and therefore projects success should be 'perceived project success' (Baker, Murphy & Fisher, 1988). Put differently, success means different things to different people; 'trying to pin down what success means in the project context is akin to gaining consensus from a group of people on the definition of good art' (Jugdeev & Muller 2005:19). Consequently, a project can be both a success and a failure. The Millennium Dome in Greenwich, London, for example was hailed as a success in engineering terms, but was more widely perceived to be a failure within the public and political domain (Cook 2005).

An important finding is that the factors associated with project success are different for different industries (Baker et al 1983) as well as depending on the cultural context (Diallo & Thuillier 2004). At the very least, success factors and their relative importance are idiosyncratic to the project type and the firm. Generalising a 'checklist' of factors derived from one project environment to another is therefore hardly worthwhile. In their retrospective look at the evolving understanding of project success, Jugdev et al (2005) contend that project managers still have to answer the question 'How is your project doing?' which inevitably puts pressure on them to define success (p.19). In light of this, they stress that a diversified understanding of project success is necessary, particularly in settings where practitioners must manage multiple projects at various stages of their life cycles and face competing priorities on a daily basis (Jugdev & Muller 2005).

According to Cooke-Davies (2002) a comprehensive answer to the question which factors are critical to project success depends on answering three separate questions: 'What *factors lead to project management success?*', 'What *factors lead to a successful project?*', and 'What *factors lead to consistently successful projects?*'. Drawing on empirical research he makes two major distinctions to explain the theory behind the proposition. Firstly, he distinguishes between *project success* (measured against the overall objectives of the project), and *project management success* (measured against traditional measures of performance such as cost, time and quality). Secondly, he distinguishes between *success criteria* (the measures by which success or failure of a project will be judged) and *success factors* (those inputs to the management system that lead directly to the success of the project). The most notable observation concerns the human dimension as embedded in the 'real' factors that lead to project success (Cooke-Davies 2002: 189). The 'discovery' that performance and success is achieved through people draws attention to the very core of what constitutes organisations: human and social capital. Empirically based findings in construction, although preliminary, support the notion that 'successful relationships' are key to overall project success (Abeysekera & McLean 1991). However, the link between project success and relationships between the project stakeholders remains under explored.

For purposes of clarity, this paper builds on Cooke-Davies (2002) assumptions on success factors by exploring the cornerstones of successful multidisciplinary engineering projects. This particular setting is characterised by the uniqueness and temporality of multi-project arrangements. So far there is little knowledge, if any, on project success in multi-project settings. The challenges that the various project participants (including engineers, architects, clients, contractors) in design projects face are many and varied. For example, there is a high degree of complexity and interconnectedness of tasks, a high dependence on diverse skills and collective knowledge and little time to find out where relevant knowledge resides (Cicmil 2004). It is suggested that teams such as these often have difficulty developing a shared project vision since

they tend to create their own understandings of the project reality based on their background and world view (Dogherty 1992). By capturing the perceptions of project success as experienced by the team members themselves, it is possible to make explicit the context specific CSFs that underpin consistent project success. This may be an effective framework to better understand the dynamics of project success; how different factors reinforce or impede each other during project stages. The initial findings serve as a basis for further investigation of CSFs and how they behave and function in actual construction project setting. It also responds to the expressed need for broader research methods in construction (Bresnen et al 2005).

2. Methodology

This study was analysed within a grounded theory framework. This inductive methodology enables issues relevant to the field of enquiry to emerge from the data and for theory to be generated by being grounded within the data itself. The methodology includes systematic open and axial coding (analysis), questioning of data, explanation of categories, their properties and the relationships among them (Strauss & Corbin 1998).

2.1 Participants

Twenty two engineers and technicians (thirteen male and eight female) took part in this study, which was conducted in a UK based multidisciplinary engineering practice over a two month period. Specifically, it was located in one of the integrated business groups (IBGs), which employs more than 90 people. Since the aim was to reflect a broad spectrum of beliefs and values across the group, the sample was stratified to include individuals from different disciplines such as structural, building services and façade engineering, but also CAD-technicians. Six job levels were represented: group manager, associates, senior engineer, engineer, graduate engineer and CAD-technician. There were eight structural engineers, three façade engineers, nine building services engineers and two CAD-technicians. The sequence of the data collection was as follows: (1) interviewing twenty two individuals in the unit, (2) organising and implementing six workshops accommodating 4-6 people in each session, and (3) sending an electronic survey to all staff (100 people).

2.2 Data collection

Interviews

A series of semi-structured interviews were conducted with questions focusing on the informant's job role, experience of project work and examples of successful and less successful projects. The selected informants were e-mailed beforehand and asked to identify examples of a 'successful' and a 'less successful' project as the basis for discussion in the interviews. As part of the interview process, informants were asked to brainstorm critical success factors in project work. This was aimed to encourage individuals to 'make free associations' without being prompted, about factors they perceive as critical to project success. The exercise was useful because it helped to reveal two things: 1) some of the specific meanings that individuals attach to factors and, 2) their significance in context. The interviews were audio-recorded and transcribed verbatim.

Workshops

The 175 categories identified were subsequently validated through work. Due to the high number of categories (some overlapping) they were grouped into a number of high level categories and named to reflect the emerging themes, for example, communication, leadership, team work and

so on. The selected individuals, 36 in total, were put in to groups of 4-6 people according to their job level to allow data comparison across job levels. The informants were asked to group all of the initial categories (175) under larger categories so they would end up with a number of core categories. Each group was given 45 minutes to complete the task. The categorisation made by all six groups was then compared with the grounded analysis of the interview material. The analysis of the data included open coding (labelling segments of the interview material); asking questions such as ‘What is going on here?’ and ‘What category does this incident indicate?’; axial coding to link categories and sub categories together, e.g. the category ‘integration of disciplines’ was placed under the larger category ‘communication’; and selective coding to generate of core categories. A list of 19 CSFs was distilled from the interviews and workshops: culture communication, project management, teamwork, technology, motivation, technical skills, social skills, social activities, leadership, roles and responsibilities, listening and feedback, trust shared values, office environment, resources, client focus, creativity and innovation, knowledge management. The data reduction, in terms of minimising the amount of high level categories, was made by comparing and contrasting the initial grouping of the 175 factors with the groupings made by the staff in the workshops.

Survey

The main focus of the survey was to establish whether there are any differences in perception of factors important for project success between different project members. Specifically, the respondents, 40 in total, were asked to review the 19 CSFs and select one factor that they think is of supreme importance and rate it 10, then choose the least important factor and rate it 1 (only using these values once); then rate the remainder of the factors on the list using a 2-9 rating scale. See survey results in Figure 1 below.

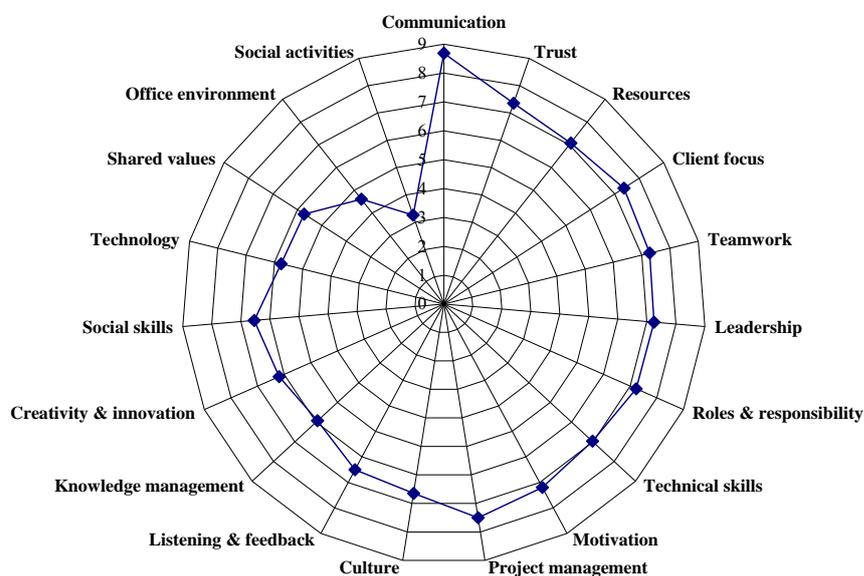


Figure 1. Response pattern from the CSFs survey..

3. Results

Analysis of the interview material (brainstorming exercise), workshops and survey results revealed five central constituents of project success: *individuals*, *teams*, *process*, *project* and *product*. An illustrated summary is provided in Figure 2 below. These primary (core) categories, labelled in the final analysis, summarise the project team's perceptions of what is considered 'critical' in delivering successful projects or, more specifically, what needs continuous attention in day to day project implementation. From a managerial point of view the project organisation need to have skilled, motivated and passionate *individuals* to carry out the task or the challenge; these individuals have to work together as a *team* to accomplish collaborative design that satisfy the client; the individuals and the teams need appropriate *processes*, including technology (tools and workspace) and effective project management (planning, support and definition of roles and responsibilities) to operate in a structured way; and all these influence the central outcome of the *project*, the *product* itself.

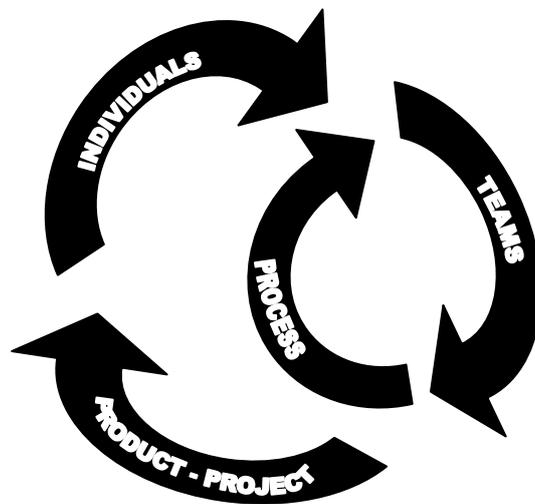


Figure 2. The dynamics of the five primary CSFs derived in the study.

The model shows that project success relies heavily on the ability and behaviour of team members to work well together, but also how these relationships may be reinforced or impeded by other factors such as planning, availability of resources and style of leadership. Inherent in this way of thinking is the recursive interplay between the actors, e.g. project members, and the structure, e.g. organisational hierarchy and prevailing culture, which offers some important insight into how to understand project success. The interviews formed the basis for developing a preliminary hypothesis of core CSFs, which could be mapped onto the core categories created in the workshops. It is important to point out that these two sets of data are based on the open coded factors (175) elicited from the initial brainstorming exercise. In both instances, the primary task was to cluster the open coded CSFs into higher level categories and label them. The analytical process of the workshop data is explained elsewhere (Koutsikouri et al 2006). In sum, the workshop outcomes can be summarised as follows:

1. Project success is seen as a *process* rather than an end-state across group levels.
2. There is a preference to view success factors as *interrelated* and *mutually interdependent*; 'they cannot exist without each other'.

3. Project success is seen as dependent on appreciating what lies beneath the exterior of the so called golden triangle, 'cost, time and to specification'.
4. Success factors relating to *leadership/management, team work* and *competency/skills* were common to all groups.
5. There is a high degree of consensus across groups on factors such as *communication, motivation* and *culture*. Communication which is usually seen as a top success factor in other studies, is not a consistent factor across the groups. Instead it was talked about as an overall important factor. For example, technicians talk about communication seemed to be related to being more integrated in the project process. The senior engineers across all disciplines summarised it as follows: 'communication is the catalyst in all good project work'.
6. Variations between the groups appear to be a consequence of job roles rather than professional disciplines, indicating that junior levels (e.g. graduate engineers) perceive supportive as more critical than resource planning. Similarly, senior levels seem to place more focus on having the right people and manage the different and sometimes conflicting project demands rather than 'time to play with ideas'. Contrary to recent studies of CSFs in project work, client focus does not emerge as a consistent factor across the groups. There was little reference to 'the client', 'client satisfaction' or 'end-user'.

The most striking observations indicate that project participants, regardless of background or role, hold an inward looking attitude of project success, mainly focusing on their own concerns such as timetables, their contribution to the project and so forth. This reflects the continuous regime of 'getting things done', or what has been termed the 'tyranny of projects'; a mentality that governs much of the work in the construction industry (Koch 2004). One senior, male building services engineer expressed an important part of this condition: '*You just work, work, work, busy, busy, busy you know. I can organise my time but then somebody throws something in... something is coming from nowhere, which should not happen really*'. The situation is further complicated by the difficulty in juggling the demands of being involved in many projects which is common in consulting engineering (Koch & Bendixen 2005). This presents a challenge that goes beyond time management; it is a matter of knowing where to direct attention. The results of the survey validate the findings from both the interview study and workshops emphasising the importance of 'soft' factors in achieving project success. See Diagram, p x. These are all related to the notion of social capital which is key in understanding how work really gets done in organisations (Cross & Parker 2004). Using descriptive statistics the survey outcomes show that there is variability in responses both within and across job levels and engineering disciplines, confirming that success means different things to different people even in a project where people may seemingly share the same background and organisation. However, there are extremely few significant differences between job levels and disciplines as to what factors are of supreme importance. There is a significant difference between job levels with regard to the factor *creativity and innovation*. This factor is rated higher among junior than senior job levels, with senior engineers scoring highest and associate director scoring lowest. The difference may be due to different responsibilities associated with each job level in that more senior staff must spend most of their time overseeing and managing the project level whereas more junior staff usually has more time at hand to be creative and express innovative thinking. But this should not be interpreted that senior staff has a lack of interest in creativity and innovation rather for this group it does not seem to be imperative in achieving project success. Overall, the statistical analysis reveals that there is variability in responses both within and across job levels and engineering disciplines, confirming that success means different things to different people even in a project where people may seemingly share the same background and organisation

Discussion

The aim of the study was to explore project success as perceived by engineers and technicians in a multidisciplinary engineering consultancy. It presents an ideal opportunity to make comparisons with existing literature on success factors drawn from other project settings. Five core success factors were distilled through a combined analysis of the interview, workshop and survey data: *individuals*, *teams*, *processes*, *project* and *product*. Analysis of these high level factors shows that they both reinforce and impede each other in an iterative manner during the different stages of the project life cycle. In this way, the data confirms that there is a need to take a much wider view of project success, linking it to individual motivation, organisational culture and leadership. By understanding how project performance can be impeded and reinforced by individual's abilities, motivation and appropriate management support project success is dependent on structure. This will assist in setting up criteria for measuring project success and promote greater sensitivity among project managers and project members what really matters for project success. However, it must be stressed that the model represents a way of thinking about success rather than a prescriptive framework. The assumption is that the concept of success is dynamic rather than static which means that it changes across time and space. The benefits of the intermediate model for articulating project success through primary categories grounded in qualitative and quantitative data thus provides a better understanding of the hard and soft dimensions of success and how they may 'play out' in project work. These findings support recent findings in the project management literature that there is a need for a more multidimensional view of success is needed (Baccarini 1999; Shenhar 2001). Specifically, suggested model implies that human as well as contextual factors contribute to the perception of project success. The most striking observation in the study was that when given the freedom to state any success factor the majority of interviewees emphasised variables relating to internal characteristics of the project process such as maintaining good relationships, passion for the project, and a clear understanding of their role. External characteristics of the product or service itself such as customer focus or product performance were not emerging as critical. This pattern of responses occurred in the subsequent workshop where the participants were asked to group the success factors derived from the in-depth interviews. This is surprising considering the many published articles and books on the importance of the customer satisfaction in project success (e.g. Meredith et al, 2006), and brings attention to the somewhat inward-looking attitude of what matters in achieving successful project work. Clearly, this internally focused attitude of what constitutes success is also found in contexts such as software development. While it appears possible to meet both internal (e.g. cost, time and to specification) and external goals (client satisfaction) when faced with pressure, project participants pursue their own goals sometimes without regard to the customer (Agarwal & Rathod 2005). Assessment of these observations suggest two concurrent events: 1) engineers and technicians are more focused on getting the design right than focusing on product performance which can only be measured when the building is ready to use, and 2) the naturalised culture in construction seem to emphasise 'getting things done' rather than reflecting on 'what is getting done'. These observations are to a great extent in line with conclusions based on a number of different project environments and industries (e.g. Baker et al, 1983; Slevin & Pinto, 2004). While the pressure to deliver on time and on budget are still dominant within the project organisation, team members themselves are more interested in whether a project is worthwhile doing, satisfying and is a good learning experience (i.e. they are focused on psycho-social outcomes). The problem seems to lie in the realities of working in intense multi-project environments such as engineering, where each project is unique in its design and construction. The workshops demonstrate that the differences in perception of project success, is a result of job role, rather than what professional group one

belongs to. This was an expected outcome, but worth investigating since professionals cultures seems to be seen as major problem in multidisciplinary work (Dougherty, 1992). An important insight provided by this research is that CSFs is a form of knowing, which resides within the psyche of each project member but seldom commonly articulated within the project community. Indeed, while communication was singled out as being the 'catalyst' for all CSFs, failure to communicate seems to be the root of many project failures. Thus CSFs must be made explicit in an organisation to have any effect on performance. The constraint lies in the nature of design work; the involvement of architects and other subcontractor that represent organisations that operate outside of the engineering consultancy. Construction project work is communication based; efficient collaboration relies on effective diffusion of information throughout the project (Baiden, Price & Dainty, 2006, in press; Winch, 2001). What is required is a radical change in the way CSFs are conceptualised and measured for them to be useful for practitioners looking for ways to improve current project performance. Key in the evolving understanding of what leads to project success is that they are socially constructed among individuals and depend on the relationships that are created through the project stages. In this way, project success can hardly be understood in the same way by everyone. Consequently, success in a multidisciplinary practice depends on the socialisation of the project members in the different projects as well as the quality of interactions between team members across time and space as put forward by researchers in the social constructivist tradition (see Fong 2005; Cicmil, 2004). This draws attention to the very core of what constitutes organisations: human and social capital. Social capital, generally understood as the property of the group rather than the property of the individual (Halpern, 2004), has potential to provide important insights to the complex and social realities of work, not the least in project based organisations such as engineering and construction. It may help answer the question *why* success is more likely to occur in some settings and not in others. Clearly, there is a need to understand the dynamics of project structure in terms of informal and formal social networks, especially in multi-project environments, for project success. Exploring the quality of relationships in such organisations; how well individuals communicate, how much they trust each other and their senior manager, how they function as teams, whether effective cooperation exists (Zohar, 2004) and how this relates to individual and collective success presents a new interesting research topic worth investigating within construction management.

Conclusions

Project success is an attractive idea but what factors lead to success remains an area of conjecture. However, because there is no agreement what factors exactly contribute to success, and because its measurement continues to defy simplification, debates regarding its conceptualisation continue. Clearly, CSFs continue to be regarded as an important method of improving performance in project work. The main conclusions from this study are that: 1) project success appears to be related to the opportunities and constraints of organisational behaviour, existing work processes and structures, causing an inward-looking view of success among project participants 2) CSFs are interrelated and mutually dependent and are likely to change across time, and 3) project success is a process rather than a static concept which relies on effective communication between individuals at all levels. Despite this, it is impossible to claim that all dimensions of project success in a multi-disciplinary project environment have been captured. Further empirical studies are needed to evaluate and further develop the presented intermediate model as basis for appropriate support to practitioners in the construction industry. Exploring the hidden powers of social capital in complex project environments could further evolve current understanding of what really leads to project success in complex project environments.

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