Development of a Tool to Measure Competencies of Software Project Managers : A Confirmatory Factor Analytic Study

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Abstract

The production of high quality computer software and the efficiency of the software development process are key issues facing academics and practitioners today. With the importance placed on the successful accomplishments of software projects, stakeholders and customers have looked to project managers for leadership. Consequently, many studies have been conducted to determine the characteristics or skills associated with competent and effective project managers. This study presents the steps involved in construction and validation of an instrument for evaluating competencies required for software project managers.

Key Words : Competencies, Unidimensionality, Convergent Validity, Reliability.

Competitive Global Environment and the Software Industry

The growing global economy for software products and services has forced many organizations to redefine the very standards by which they operate. The customer base to which they serve is becoming much larger and more demanding and there is a necessity for reduced cycle time. Coupled with this, the growing complexity, and the increased mission-critical status of these software systems are pressurizing organizations to deliver higher quality and more complex software products.

Researchers have examined the software development problem and concluded that management is the most important factor determining the success or failure of a project (Dale 1973, Hertel, 1977). Researchers and practitioners suspect that a great majority of project managers are weak on certain required skills, and their weakness contributes to the problems encountered on many projects (Drucker, 1980; Peters, 1987, 1992).

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Recruitment and selection have been long-running problems in the Information Technology (IT) industry. Project managers are rarely selected because they have been nurtured and developed for the role. It is common for technical specialists in the organization to be promoted to the rank of project managers. Once promoted, they are expected to carry out their new roles without formal training. The only immediate support the PMs receive for their new role is a literature of project management procedures ranging in their complexity plus some software tools ranging from the simple to very complex. The importance of active skills such as vendor management and public relations are often completely overlooked.

Some companies prefer to recruit rather than develop their own project managers. In a tight labour market, this leads to rapid turnover with project managers often not seeing projects through to completion before accepting a better offer. This results in weak identification of IT project managers with their projects (sauer et al, 2001).

It is therefore important for IT management to understand the characteristics and behaviours of high performing IT project managers in order to identify them as early as possible and to create an environment conducive to their development and retention (Wynekoop and Walz, 2000).

Previous Research

Competence is a term which is widely used but which has come to mean different things to different people. It is generally accepted, however, as encompassing knowledge, skils, attitudes, and behaviors that are causally related to superior job performance (Boyatzis 1982).

This paper first presents a review and analysis of research based literature concerning the knowledge, skills and personal attributes of project managers that are expected to lead to achievement of successful project outcomes. Then it reviews the instruments that have been used to assess these competencies. Finally, it discusses the steps involved in the development and validation of the scale to evaluate Software project managers' competencies.

Research based literature on the aspects of project management competence draws primarily upon the opinions of project managers and others concerning the knowledge, skills and personal attributes required by an effective project personnel (Posner 1987a; Thamhain1991; Turner1993, Meredith et al., 1995; Wateridge1996; Zimmerer and Yasin1998).

Posner (1987), was among the first authors to publish an empirically grounded study listing the characteristics of an above-average project manager. His research used an open-ended questionnaire, and identified six core skill areas, which he linked to critical project problem areas. He concluded that the training requirements for project managers were mostly interpersonal as opposed to technical in nature. He recommended that project managers should improve their ability to communicate, organize, build teams, provide leadership and deal comfortably with change (Posner, 1987). Zimmerer & Yasin (1998), and Jiang, Klein & Margulis (1998), arrived at similar conclusions.

Thamhain (1991), conducted a study using personal interviews, and identified three principal competency groups for project managers interpersonal, technical and administrative. He concluded that a project manager's effectiveness depends on the ability to understand the people, the tools and the organization.

Turner (1993), has proposed six traits for effective project managers: problem solving ability and results orientation, energetic and initiative, self assured leadership, broad perspective, communicating and negotiating abilities. Knowledge and learned skills also make important contributions.

Meredith et al. (1995), have categorized the skills needed for a project manager into six skill areas: communication, organizational, team building, leadership, coping, and technological skills. Katz[1991], suggested that effective administration rests on three basic developable skills. These are human skill, conceptual skill and technical skill. Although these skills are interrelated, they can be developed independently. There is surprisingly little agreement among educators and training program directors of many leading universities and institutions on what makes a good project manager (El Sabaa, 2001).

Some researchers focused on project manager job characteristics and attempted to generate a list of recommended activities for IS project managers (Nadler & Tushman, 1990; Pinto & Kharbanda, 1995a). Such studies found that the critical project management tasks include recognizing project team conflict, understanding who the stakeholders are and what they want, determining project implementation policy and leading from the front.

According to a survey of HR directors of Fortune 1000 firms, the top ten skills needed for managers to achieve organizational success are as follows: interpersonal, listening, persuasion and motivation, presentation, small-group communication, advising, interviewing, conflict management, writing, and reading.

Birkhead, Sutherland and Maxwell's (2000), survey of

128 PMs from the sectors of IT, Construction and Engineering Projects in South Africa resulted in a rank ordered list of competencies based on 28 constructs derived from the literature. The 7 factors of competencies that emerged from the ranking were: (1) Planning and controlling (2) Personal Influence (3) Goal Focus (4) Problem Solving (5) Team Leadership (6) Project Team Development and (7) Project Context.

Wateridge (1997), from an analysis of Advertisements for project managers in the trade and national press drew the conclusion that a competent project manager must have administrative, technical, inter-personal, business and political skills. However, not all of the skills will be necessary on every project.

What emerges from the work of all the specialists in terms of the requirements of Project Managers? First, they all seem to agree on the importance of wider management skills: Planning, Organization, Follow-up, Decision Making, Team Supervision and Human Aspects. Many of them also emphasized the need for a global vision of the project, or a multidisciplinary orientation that could embrace the technical, managerial, political, legal and environmental aspects. Finally, a certain number of personal characteristics were also identified among which, analytical ability, creativity, decisiveness, the ability to adapt, stability, energy and persistence recurred most frequently.

A review of above literature shows that the studies on project manager competencies have considered opinions of project managers from different industry and project types. These competencies are generic in nature and not industry specific. Then, there exists considerable literature on the subject but most of it is still qualitative in nature (Anderson, 1992).

Artto (2000), argues that more research and development would be needed to define competence profiles that would be appropriate for different organizational positions in different environments. Kooyman & Sargent (1998) have also raised the need to address the differences between project managers operating in different cultural environments. It has also been suggested by Pettersen (1991), that additional competencies would be required by a project manager working in a developing country. Although limited research has been done within particular organizations to identify the competencies required for project managers in India, no publicly available research has been conducted.

This research studies the role of the project manager in software service firms and identifies the skills, knowledge, attributes, and behaviours,(collectively termed as competencies) these are particularly important for software project managers to manage their projects successfully. The paper then presents the steps involved in construction and validation of a scale/instrument based on these competencies. It then suggests the uses of the instrument for developing software project managers, and gauging training requirements for those managing all types of software projects.

Methodology

The investigator began by reviewing questionnaires and list of skills used in other studies. Most of the studies reviewed, had generated a list of characteristics, that the ideal project manager should have and had asked respondents managing various types projects to rate or rank those skills according to their importance. A comprehensive instrument that could systematically measure the level of importance and the extent of competencies present among the software project managers could not be found in literature.

Of the studies reviewed, the most comprehensive analysis of behavioral skills based on extensive pilot research was Green's (1989), work involving 18 behavioral skills (Table 1). These skills, not related to any particular type of system development, apply to any project development, environment (Frame, 1994).

The international project manager's competence research of Crawford(1997, 1998, 2000), had investigated project managers in different industries and project types. The project manager's competencies are measured by a questionnaire that subdivides competencies into four component parts: Knowledge, qualifications and experience (measured by curriculum vitae); core personality; and demonstrable performance (indicated by actual actions and doings of the project manager).

Software-engineering books and Project management books were read in order to understand the models and process of software development, and the various activities performed by the project managers. A list of Items comprising of the competencies used in other studies was made. It included the various project management activities and tasks. Further, items were identified from advertisements placed in job classifieds on web and dailies for the appointment of project managers. These specified the level of knowledge, the qualifications, and experience, skills and personality characteristics that software companies sought for in the project managers they wished to hire. The HR departments of a reputed company provided their metrics/parameters that they used to evaluate their personnel' eligibity for promotion as a project manager.

A list of 141 constructs was derived from the literature

and personal interviews of project personnels. These were then grouped under the broad categories of Project Management Business Skills, Technical Expertise, Managerial and Administrative Skills/Tasks, Human Resource Management Skills, Client Management Skills and Personality Characteristics and Attributes, as these covered all aspects of project management. (Table 1)

Using these 141 items, a questionnaire was prepared that also included the 18 behavioral skills validated previously by Green (1989). A 5- point Likert scale was provided each on either side of the items. The aim was to simultaneously elicit from the respondent, his/her opinion on importance as well as evidence of project manager competencies. The Likert scale on the left hand side of the items, required the respondents to indicate how strongly they believed each listed competency was important for project managers during software project development. The Likert scale on the right hand side of the items required the respondents to indicate the extent to which they believed that the project managers possessed those competencies.

This questionnaire was then given to 2 project managers and 2 senior managerial personnel (a director and a vice-president of different software firms) for their judgement on the appropriateness of the items. The collective items, which were declared as unfit by more than three judges, were discarded. Therefore 8 items, which were seen either, redundant or not falling under the category of project manager's responsibility, were removed. Two new items were added on their suggestion.

This reviewed questionnaire was then shown to 3 academicians in the filed of research and behavioral psychology for further refinement in terms of sentence construction, language, clarity of meaning of the items. On their advice, a few items were re-framed and modified in language and style. One item, which represented two different but similar aspects, was split into two in order to remove its ambiguity. Hence, the questionnaire with 136 items was administered to a group of 5 project personnel in the level of project leaders for a mock response to see if items conveyed their intended purpose and to check for any further ambiguity. The purpose was also to check the amount of time required completing the questionnaire. Four items belonging under the head of personality characteristics received low rating in terms of their importance and so were dropped from the questionnaire. The final questionnaire retained only 132 items.

Questionnaires were administered through personal interviews and through soft copies attached to e-mails. Although 540 respondents were contacted, only 250 usable responses were obtained.

Respondents' Profile

The respondents' profile was as follows

- 40% were Project Leaders, 40% were Project Managers and 20% were Business Managers
- 50% were in the age group of 30-40 years, 50% were above 31 years of age.
- 81% were male.
- 57% were engineering graduates.
- 49% have undergone training in private institutes that offer training related to software development

Table I : Competencies and Their Explanation

Competencies	Explanation of Competencies
Business Skills	• Understanding of business environment of own organization and client's organization. • Knowledge of own organization's business goals, and the project's business objectives. • Knowledge of the client organization's functional or business processes and ability to conceptualize necessary technology solutions related to clients, business needs. • Expertise with financial tools and techniques for project estimates.
Technical Expertise	• Technical expertise or knowledge, and skills in managing technology include understanding of the technologies involved, the engineering tools and techniques employed, product applications, knowledge of programming languages and understanding the relationship among supporting technologies.
Managerial and Administrative Skills	• Skills required in coordination resources for various project tasks and activities in project management. • Understanding own and client's organizational processes, practies, procedures and governing regulations. • Delegating work among project personnel and ensuring that they adhere to the rules and standards.
Human Resources Management Skills	• These include the competencies required to manage a software project team. • Ability to delegate work among team members. • Empowering project team members, building their morale, encouraging them to accomplish project goals. • Recognizing the need for, and implementing suitable training programmes for the project team, and developing members.
Client Management Skills	• These include the competencies that are required by the project manager in managing clients. • Ensuring clients' cooperation from the beginning of the project. • Ability to elicit information from clients, etc.
Personality Characteristics and Attributes	• These include the behavioral, emotional and temperamental traits, the distinctive qualities that distinguish a person from others. • Includes competencies such as 'Ability to work hard' 'Critical reasoning' 'Assertiveness' 'Adaptability' 'Problem-solving ability' etc.

and personality development.

- The most frequent type of projects had worked in, were Application Development Projects, followed by Maintenance Projects and Product Development Projects.

Scale Refinement and Validation

A critical aspect in the evolution of a fundamental theory in any management concept is the development of good measures to obtain valid and reliable estimates of the constructs of interest. Without establishing the reliability and validity, it is difficult to standardize the measurement scales, and hard to know whether they truly measure what they intend to measure.

Conventionally, exploratory factor analysis (EFA) is used for the situation, where the relationships between the observed and latent (factors) variables are unknown or uncertain. The approach proceeds in an exploratory manner to unearth the underlying factors, thereby illustrating the relationship between the latent factors and the observed variables. The purpose is to come out with the minimum number of factors that will explain the co-variation among the observed variables. Nonetheless, this approach suffers from certain limitations. The primary limitation of this approach is that in EFA, it is assumed that the correlations between the variables are due to one or several underlying hidden factors that generate the raw data. But, the researcher may have only an imprecise but not an explicit idea about these correlations or factors. Moreover, even if he/she is fairly sure about the presence of a particular factor, he/she may not know which variable influences the factor (Byrne, 1994). Therefore, the investigator may lack any sound evidence on which to make his/her interpretations. Furthermore, items are assigned to those factors on which they load to a significant extent.

Therefore, it is possible for an item to load substantially on more than one factors and hence, the distinctiveness of the factors is affected. Besides, in pure EFA, items are loaded only on a statistical basis, and not any theoretical justification, thereby affecting the valid identity of the items. And, at last the concept of unidimensionality (i.e. the extent to which items on a factor measure one single construct) has not been taken care of in EFA approach (Ahire et al., 1996). Essentially EFA is particularly useful only in the absence of a sufficiently detailed theory about the relationships of the observed variables to the latent constructs (i.e. only for the constructs that are at a very nascent stage of research).

On the contrary, the CFA approach, to a very great extent, overcomes the above mentioned limitations, and addresses the situation, wherein, the researcher specifies a model, a priori, and tests the conjecture that a relationship between the observed and latent variables does in fact exist. In short, the hypotheses that form the constraints are an integral part of the CFA technique. This is due to the fact that the researcher has reasonably good knowledge of the factors that are required to explain the intercorrelations among the measured variables. In addition, he/she knows which factors account for the co-variation among the observed variables. The proposed model is built on logic, research and theoretical findings, and if the researcher has a reasonably good idea about the observed variables that are likely to be the reliable indicators of a particular factor, CFA is more appropriate than EFA (Bentler, 1995). The present work chosen to adopt the factor analysis (for scale refinement and validation) in a confirmatory fashion.

Unidimensionality Analysis

A highly mandatory condition for construct validity and reliability and checking, is the unidimensionality of the measure (Anderson and Gerbing, 1991). It refers to the existence of a single construct/trait underlying a set of measures. The usefulness of the items within a measure depends on the extent to which they share a common core (Nunnally, 1988). The concept of unidimensionality enables us to represent the value of a scale by a solitary number (Venkatraman, 1989). In order to check for unidimensionality, a measurement model is specified for each construct (Ahire etal., 1996). A comparative fit index (CFI) of 0.90 or above for the model, has been said to imply that there is a strong evidence of unidimensionality (Byrne, 1994). However, this value has often been disputed and so disregarded. (Bollen 1989, Marsh, Balla and McDonald 1988, Tanak 1993, Hoyle and Panter 1995). The values below 0.90 have been accepted as appropriate fit. Cohen 1988, for example, suggested a minimum of 0.80. Bollen (1989), observed that cutoffs are arbitrary and stated that a more salient criteria may be to compare the fit of one model to the fit of another, prior model of the same phenomenon. For example, a CFI of 0.85 may represent progress in a field where the best prior model had a fit of 0.70. As the literature points out that there is no such thing as "good fit" (Bentler & Bonnett 1980, Hoyle & Panter 1995). The aim is to find a meaningful pattern of loadings (and Paths) to best produce the original co-variances. The emphasis thus is on the meaningfulness. A model with a fit index of 0.8 may be the very best that can be achieved-given the status of the theory, given the adequacy of the measures, and

given the representativeness of the sample. On the other hand you can bet a fit index of 0.95 simply by over-factoring the data. The aim of fit indices is to assist in the development of meaningful theory. The CFI indices for all the six competency constructs are shown in Table 1. All the CFI values are above the suggested minimum fit (0.80) of Cohen 1988, implying that there is strong evidence of unidimensionality for the scales.

Reliability Analysis

Unidimensionality alone, although a prerequisite, is not sufficient per se to establish the usefulness of a scale. Once unidimensionality of a scale is established, its statistical reliability should be assessed before it is subjected to any further validation analysis (Ahire et al., 1996). Reliability of a measure is the ability to yield consistent results (Nunnally, 1988). Even a highly unidimensional scale will be of very little use if the resultant aggregate score is ascertained basically by measurement error, with the values of the score broadly fluctuating over repeated measures (Gerbing and Anderson, 1988).

Several measures of reliability can be ascertained in order to establish the reliability of a measuring instrument. These include test-retest method, equivalent forms, split-halves method and internal consistency method. Of all the above methods, the internal consistency method requires only one administration and consequently is supposed to be the most effective, especially in field studies. Moreover, this method is considered to be the most general form of reliability estimation (Nunnally, 1978). In this method reliability is operationalized as internal consistency, which is the degree of intercorelations among the items that constitute a scale (Nunnally, 1988). Internal consistency is estimated using a reliability coefficient called Cronbach's alpha (Cronbach, 1951). An alpha value of 0.60 and 0.70 or above is considered to be the criteria for demonstrating internal consistency of new scales and established scales respectively (Nunnally, 1988). The Cronbach's alpha values for all the six scales are shown in Table 2. All the values exceed the minimum requirements, thereby demonstrating, that all the six scales are internally consistent and have acceptable reliable values in their original form.

Validity Analysis

Confusion appears to prevail in the methodological literature with respect to the extensive variety of labels/tags, and the way they are organized to describe the validity of scales and measures. Different validity terms are used to illustrate various aspects of construct validity. A comprehensive list of validity types that are typically mentioned in texts and research works includes face, content, convergent, discriminant and criterion-related validity.

Face Validity

Face validity is the mere appearance that a measure is valid (Kalpan and Sucuzzo, 1993). In face validity, one looks at the measure and sees whether "on its face" it seems a good reflection of the construct. Although face validity is probably the weakest way of demonstrating the construct validity, it does not in any way mean it is wrong, as the researcher on most occasions relies on subjective judgment throughout the research process. As the six competency constructs are identified from the literature, their selection is justified, thereby ensuring the face validity of the instrument.

Content Validity

Content validity is the degree to which the instrument provides an adequate representation of the conceptual domain that it is designed to cover. Apart from face validity, content validity is the only type of validity for which the evidence is subjective and logical rather than statistical (Kalpan and Sucuzzo, 1993). If the items representing the various constructs of an instrument are substantiated by a comprehensive review of the relevant literature, content validity can be ensured (Bohrnstedt, 1983). The present instrument has been developed, based on a detailed analysis of the prescriptive, conceptual, practitioner and empirical literature. Moreover, the content validity of the instrument was also ensured through a thorough review by experts (both academia and practitioners) in the field.

Convergent Validity

Convergent validity refers to the degree to which the different approaches to construct measurement are similar to (converges on) other approaches that it theoretically should be similar too. When there is high co-relation between a measure and other measures that are believed to measure the same construct, convergent evidence for validity is obtained. (Kaplan and Sucuzzo, 1993). Convergent validity is based on the co-relation between responses obtained by maximally different methods of measuring the same construct (Ahire etal., 1996). By this method, the convergent validity can be established using a coefficient called Bentler Bonett coefficient1980. A scale with values of 0.80 or above is an evidence of strong convergent validity (Bentler and Bonnet, 1980). The values of convergent validity for all the scales are summarized in Table 2. All the scales have a value of more than 0.80, thereby demonstrating strong convergent validity.

Criterion-related Validity

The basic idea of criterion related validity is to check the performance of the measure against some criterion. In the present study, a five-point Likert scale at the end of the questionnaire asked the respondents to rate the impact of each competency on performance of the project. This served as a criterion for measuring the importance of competencies. The criterion-related validity is established by co-relating the 'importance'-scales scores with this criterion. The co-relations are shown in Table II. All the scales show significant positive co-relations.

Table II

Convergent Validity, Unidimensionality and Reliability Indices for the Six Competency Scales.

Competencies	Bentler Bonett Coeficient	Confirmatory Fix Index (CFI)	Cronbach Alpha (α)
Business Skills	0.853	0.873	0.913
Technical Expertise	0.822	0.840	0.943
Managerial and Administrative Skills	0.802	0.814	0.968
Human Resources Management Skills	0.804	0.824	0.940
Client Management Skills	0.929	0.953	0.870
Personality Characteristics and Attributes	0.835	0.845	0.962

Inferences

To sum up, all the six factors of competencies have shown strong evidence of unidimensionality, reliability, convergent, and criterion-related validities. Furthermore, the overall model CFI and the Bentler-Bonett coefficient (4) have exceeded the obligatory requirements. Therefore, it can be stated that competencies of software project managers can be considered a six-factor structure consisting of the above identified six structures.

Uses of the Scale

This scale to measure the software project manager's competencies could aid the human resource personnel in the selection, recruitment and development of Project Managers. Software service firms could assess their Project Manager's level of competence and employ the ones with the right mix of skills on important projects. It could be used for the regular performance evaluation in the organization. Since the scale items are framed in impersonal statement form, they can be administered to the Project Manager's subordinates, self/peers and superiors, thereby enabling a 360-degree evaluation of the Project Manager in focus. It would help in identifying the skills considered most crucial. The results can then help in determining the training needed to develop those skills. Improving project manager's competence would improve project performance and the probability of project success.

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