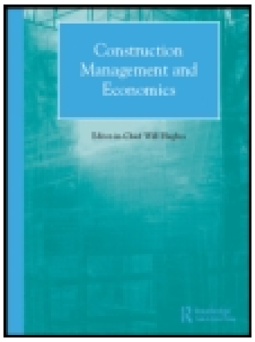

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# Structural equation model of project planning effectiveness

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# Structural equation model of project planning effectiveness

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Previous research studies investigating the impact of situational variables on project planning effectiveness have not examined how the situational variables work together to influence planning effectiveness. A structural equation model (SEM) has been developed for describing and quantifying the influence of situational factors in project environments and organizational characteristics of performing organizations on project planning effectiveness. The individual effects of directly-observable variables on the project planning process were evaluated using regression analysis. The SEM approach enables the modelling of multiple factors as latent not-directly-measurable variable sets, thus providing a theoretical insight into how individual influence factors work together to determine the effectiveness of project planning efforts. The project environment has a dominant significant influence on the potential effectiveness of project planning efforts. In contrast, the influence of organizational characteristics is relatively insignificant.

*Keywords:* Project management, project planning, planning effectiveness, structural equation modelling, Australia

## Introduction

Project planning is the process of determining optimal methods, sequence and timing of project activities, and required resources to maximize the chance for a successful project. Project planning effectiveness can be conceptualized as the extent to which a project achieves its planned objectives. Decisions taken during the planning process have been found to have a significant influence on the probable outcome of a project (Arditi, 1985; Clayton, 1989; Syal *et al.*, 1992). Planning efforts conducted prior to the commencement of project execution when expenditures are relatively small have also been shown to have a much higher level of influence on the probable outcome of a project in comparison to efforts undertaken after a project has commenced when expenditures may be significant (Laufer and Cohenca, 1990; Faniran *et al.*, 1994; Hamilton and Gibson, 1996). However, while efforts to improve the effectiveness of project planning efforts often focus on the development of analytical tools and models for scheduling project tasks and resources, an understanding of the characteristics of the project planning process itself and the modes of interactions between the planning process and its environment can provide a conceptual framework for formulating strategies for improving project planning effectiveness.

Faniran *et al.* (1998) identified and measured directly-observable variables with the potential to influence the effectiveness of project planning efforts, and evaluated the individual effects of these variables on the project planning process. The study work done in the previous study is extended by: (1) examining how individual situational variables work together to influence planning effectiveness; and (2) identifying conceptual not-directly-measurable determinants of project planning effectiveness. Modelling the indirect effects of the situational variables provides a better understanding of how situational factors in project and organizational environments interact and work together to influence project-planning effectiveness. The identification of conceptual constructs would also be potentially useful for developing a classification scheme or taxonomy which can be incorporated into a model for assisting in organizing project planning activities

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and predicting the effectiveness of project planning efforts in different situations.

## Research gap

The limited research studies reported in the management literature that have addressed the problem of improving the project planning process have focused mainly on examining the individual impacts of a variety of influence factors on the effectiveness of project planning efforts. For example, Cohenca *et al.* (1989), Laufer and Cohenca (1990) and Laufer (1991) examined the effect of eight situational variables (classified into three project dimensions – project complexity, project uncertainty and attitudes towards planning) on the efforts invested in construction project planning. Findings from the studies showed how these situational variables individually influence project planning. Faniran *et al.* (1994) and Faniran *et al.* (1998) evaluated the influence of situational factors in project environments and organizational characteristics of performing organizations on project planning efforts and project planning effectiveness. As in the studies of Cohenca *et al.* (1989), Laufer and Cohenca (1990) and Laufer (1991), significant relationships were also found between the variables representing the individual situational factors and the variables representing project planning efforts and effectiveness in the studies of Faniran *et al.* (1994) and Faniran *et al.* (1998). More recently, Dvir *et al.* (2002) evaluated the relationship between three measures of planning efforts (development of functional requirements; development of technical specifications; and implementation of project management processes and procedures) and four measures of project success (meeting planning goals; end-user benefits; contractor benefits; and overall project success). Findings from Dvir *et al.*'s study supported previous research findings which found a significant positive relationship between the amount of efforts invested in the project definition and technical specifications functions of the project planning process on one hand, and project success on the other.

Although the studies highlighted above (and other related studies) have contributed to understanding how the project planning process interacts with its environment, the potential applications of the findings to the development of strategies for improving project planning effectiveness is limited by inherent deficiencies in the methodologies applied. Firstly, the methodologies used in the previous studies have focused mainly on measuring directly-observable influence variables, and assessing the effects of these variables on the project planning process. However, the methodologies have not considered the interrelationships that exist within the variable sets of the influence factors in order to understand how individual influence factors work together in influencing planning effectiveness. A second major limitation of the previous studies is that the findings were drawn mainly from a multiple regression analysis of qualitative data that had been converted into abstract numerical scales. The conversion of qualitative data (typically obtained from a questionnaire survey of the subjective judgements of respondents) to quantitative data (in the form of abstract numerical scales) leads to a large potential for error in the measurement of a variable. Regression analysis cannot accurately account for the errors in measurement that occur as a result of the transformation of qualitative data into quantitative data.

## Structural equation modelling

Structural equation models are ideally suited to address the methodological limitations identified above. The structural equation modelling (SEM) technique was originally developed by sociologists and psychologists and can be used to describe relationships between two types of variables: observed and latent. Observed variables have data that can be directly measured by a researcher, for example numeric responses to a rating scale item on a questionnaire. Latent variables, on the other hand, are variables that are of interest to a researcher but are not directly observable. To observe latent variables, models need to be constructed expressing the latent variables in terms of observed variables. SEM involves two procedures: a measurement component and a structural component (Byrne, 1994). The measurement component specifies how latent variables are measured in terms of observed variables. The structural component expresses relationships among the latent variables. SEM enables the development of a causal indicator model in which a latent theoretical construct of interest is represented by measured variables. SEM also accounts for measurement errors, thus producing more accurate representations. Molenaar *et al.* (2000) have previously applied SEM to model factors that affect contract disputes between owners and contractors in the construction industry.

## Research model and hypotheses

The research model is shown in Figure 1. The model provides a framework for exploring the relationships between the research variables. There are four latent variable constructs in the research model. Project

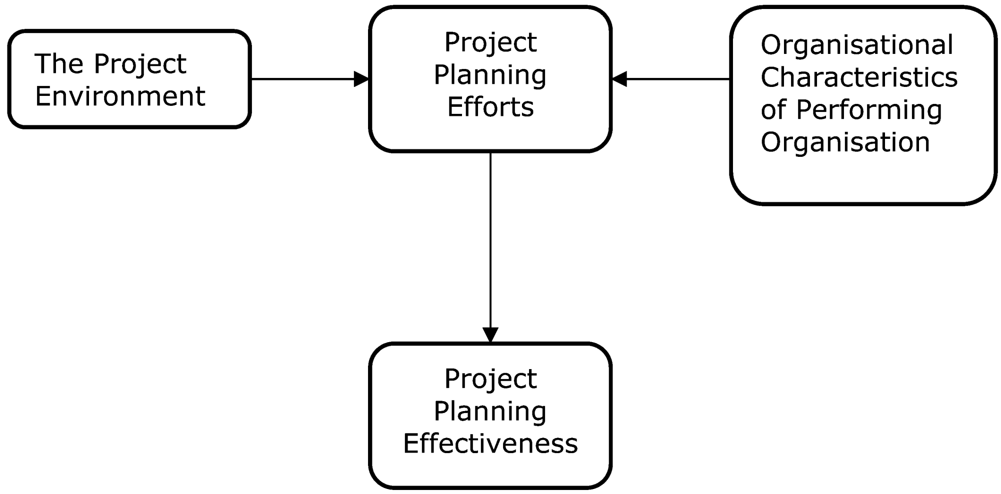


**Figure 1** The research model

planning efforts is the primary independent variable with project planning effectiveness as the dependent variable. The project environment and organizational characteristics of the performing organization are moderator variables that induce change in the relationship between the independent and dependent variables.

The research model can be expressed in the form of the following mathematical function:

Project Planning Effectiveness (PRPE)=*f*(Project Planning Effort (PPE))

i.e. $PRPE=\lambda_1\gamma_1 PPE_1+\lambda_2\gamma_2 PPE_2+ \ldots\ldots\ldots +\lambda_n\gamma_n PPE_n$

where: $\lambda_i = i^{th}$ Organizational Characteristic (OC)

and: $\gamma_i = i^{th}$ Project Environment Variable (PE)

The basic proposition which the research model examines is:

P1: The project planning process can be improved and made more effective by adjusting planning efforts to cope with different situations in the project environment, and structuring the organizational environment in which planners operate to facilitate effective planning.

Proposition P1 establishes the basis that the particular actions of adjusting planning efforts to cope with different situations in the project environment, and structuring the organizational environment in which planners operate to facilitate effective planning, will improve the project planning process and make it more effective. In order to examine the basic proposition, it is expressed in the form of the following specific hypotheses:

H1: The project environment has a direct causal effect on project planning efforts and an indirect causal effect on project performance as mediated by project planning efforts.

H2: Organizational characteristics of performing organizations have a direct causal effect on project planning efforts and an indirect effort on project performance as mediated by project planning efforts.

H3: Project planning efforts have a direct causal effect on project performance.

The latent variable constructs used to test the hypotheses are discussed below.

## Project planning efforts

Although it is widely accepted in the project management literature that the project planning process has a significant impact on the successful achievement of desired project outcomes, there is a divergence of opinion on the extent of effort that should be invested in project planning activities, and how project planning efforts should be organized to maximize the probability of achieving project success. Cohenca *et al.* (1989) evaluated three dimensions project planning efforts – planning time, control time and frequency of revision – and concluded that planning efforts should be adjusted to meet varying situations. Faniran *et al.* (1994) and Faniran *et al.* (1998) also undertook an empirical analysis of project planning efforts and identified adequate allocation of time for planning activities prior to project implementation, and an emphasis on methods planning during the project planning process, as key requirements for maximizing project performance. Faniran's studies also identified an overemphasis on scheduling and control at the expense of methods and action planning as being a major deficiency in project planning practices.

### Project planning effectiveness

Project planning effectiveness can be conceptualized as the extent to which a project achieves its planned objectives. Ashley *et al.* (1987) evaluated project-planning effectiveness using four criteria: budget performance, schedule performance, functionality, and stakeholder satisfaction. Pinto and Slevin (1988) provided a general description of project success and suggested that the outcomes of a project can be measured in terms of utilization of: time, cost, performance, applicability or usage of project product, and user satisfaction. Laufer and Cohenca (1990) evaluated project-planning outcomes by measuring the extent of schedule variance, man-hour variance, and level of usage of plans.

### The project environment

The project environment can be described as the combined characteristics of a project which have a direct impact on its performance. Attributes which have been used in previous research studies to characterize projects include: size (e.g. Bennett, 1983), degree of uncertainty (e.g. Laufer (1991), degree of complexity (e.g. Bennett and Fine, 1980) and degree of competition at tender (e.g. Ireland, 1985).

### Organizational characteristics of performing organizations

The influence of situational factors in an organizational environment on the decision-making process has been extensively researched in the general management literature (Galbraith, 1977; Butler, 1991), and it is now widely accepted that the organizational environment in which decisions are made affects the performance of decision-makers. Previous studies undertaken by researchers in construction management also indicate that organizational characteristics of construction firms may have an influence on the effectiveness of construction planning efforts (e.g. Cohenca *et al.*, 1989; Kabasakal *et al.*, 1989; Laufer and Cohenca, 1990).

## Methodology

### Data collection

As stated earlier, this study is an extension of a previous study reported in Faniran *et al.* (1998). The data collected for the previous study was also used in this study. The original data was collected through a questionnaire survey of planners and contract management personnel in a sample of construction firms in Australia. The survey instrument has been described fully in Faniran *et al.* (1994), and more briefly in Faniran *et al.* (1998). The questionnaires were distributed to 85 different construction firms located in the state of New South Wales, Australia. Fifty-two of the firms responded, giving a 61% response rate. Tables 1 and 2 show the profile of the sample.

**Table 1** Profile of sample – project size distributions

| Project characteristics | Range | | Mean |
|---|---|---|---|
| | Minimum | Maximum | |
| Project cost (Australian Dollars) | 350 000 | 240 000 000 | 17 400 000 |
| Project duration (weeks) | 13 | 135 | 57.5 |

**Table 2** Profile of sample – size of construction firms

| Size of construction firms (average annual volume of work in Australian dollars) | Percentage of respondents (%) |
|---|---|
| Less than $1 million | 0 |
| $1 million – $10 million | 29 |
| $10 million – $30 million | 35 |
| $30 million – $50 million | 12 |
| Above $50 million | 24 |

### Operationalization of constructs

The survey instrument contained 49 variables representing the four latent variable constructs that were used in the study to evaluate the project planning process (i.e. the project environment, organizational characteristics of performing organizations, project planning efforts, and project planning effectiveness). Selection of appropriate research variables from such a vast number of items is a most difficult but essential part of building a reliable structural equation model. The original 49 variables were reduced to 15 variables considered to maximally discriminate across the behaviour of the theoretical domain, and to also be compatible with the framework of structural modelling. The reduction of the number of variables was performed on the basis of a Pearson product-moment correlational analysis. Variables found to have insignificant associations, at a 95% confidence interval ($p<0.05$), with other variables within a latent variable construct and with other variables across the entire set of variables were excluded from the model. Table 3 shows the 15 variables included in the final model within the four latent construct variables. Details of how the variables were measured have been described in detail in Faniran *et al.* (1998).

**Table 3** Research variables

| Latent construct | Observed variables |
|---|---|
| Project environment | Contract type |
| | State of design |
| | Construction experience |
| | No of trades |
| Organizational characteristics | No of branches |
| | No of workers |
| | Formalization |
| | Centralization |
| Planning efforts | Planning time |
| | Focus on methods planning |
| | Proportion of planning time spent analysing information |
| Planning effectiveness | Cost variance |
| | Time variance |
| | Man-hour variance |
| | Client satisfaction |

### Model development

The structural equation model was developed using the AMOS (version 4.0) statistical computer programme. The model consists of a measurement component and a structural component. The measurement component determines how well exogenous variables measure latent variable constructs. The structural component models the relationships between latent variable constructs, allowing for direct, indirect and correlative effects to be explicitly modelled. A base model was developed by incorporating the latent constructs with their corresponding measures into an initial structural equation model on the basis of theoretical expectations and past empirical findings. Model improvements were then performed over several iterations to arrive at a final model specification by using a combination of modification indices (Hoyl, 1995) and theoretical justifications until a final satisfactory model was identified. *t*-statistics and R-square measures were used to assess and improve the fit of the model during the model refinement stage. Competing models were then compared using a range of goodness-of-fit measures, and a final model was selected on the basis of compliance with both theoretical expectations and goodness-of-fit measures.

## Results

### Model specification

Figure 2 shows the final model. The observed, or measured, exogenous variables are shown in rectangles. The unobserved latent variable constructs are shown in ellipses. The arrows in the figure represent the direction of hypothesized influence. For example, the influence of the *Project Environment* is presumed to be reflected in the observed measures of the variables: Type of Contract, State of Design Completion, Construction Experience and Number of Trades; as depicted by the directional arrows. *Project Planning Effectiveness* was hypothesized to be influenced by a combination of both latent endogenous and observable exogenous variables. Error terms are included for each exogenous variable that is an indicator for a latent variable construct. For example, State of Design Completion does not perfectly describe *Project Environment*, and so an error term is needed to represent the error of measurement. This error term, e2, is an unobserved entity that consists of the portion of the measured value of State of Design Completion that does not reflect the influence of *Project Environment*. Squared multiple correlations ($R^2$ values) are also shown in Figure 2. The regression of *Project Environment*, *Organizational Characteristics* and *Planning Efforts* on *Project Planning Effectiveness* results in an $R^2$ value of 0.57, or 57%. Thus, the Structural Equation Model explains about 57% of the variability in *Project Planning Effectiveness* for the sampled data. Similarly, the $R^2$ value for Planning Efforts is 0.54 indicating that the exogenous constructs: *Project Environment* and *Organizational Characteristics* together account for 54% of the variability in *Planning Efforts*.

### Assessment of model

Multivariate normality, an underlying assumption necessary for obtaining unbiased estimates by the structural equation modelling technique was checked using the multivariate kurtosis, a measure of multivariate normality. This was found to be small (15; z-value of 2.39), suggesting that the research variables do not exhibit any extreme departure from the criteria of normality. Multicollinearity and singularity, another required assumption, was also investigated through factor analysis. The determinant of the correlation matrix was found to be 0.0086, which is greater than the threshold value of 0.00001 indicating the research variables are free from the danger of multicollinearity or singularity (Kinnear and Gray, 1993).

The parameter estimates for the measurement model are presented in Table 4. Standard errors for the parameter estimates do not exhibit any extremely large or small values. The *t*-values for all the parameter estimates are also statistically significant. The path coefficients for the influence of the observed variables on the latent variables range from 0.34 to 0.91 (see Figure 2), indicating that the research variables extensively characterize their unobserved constructs. Hence, it can be inferred that the latent variable constructs

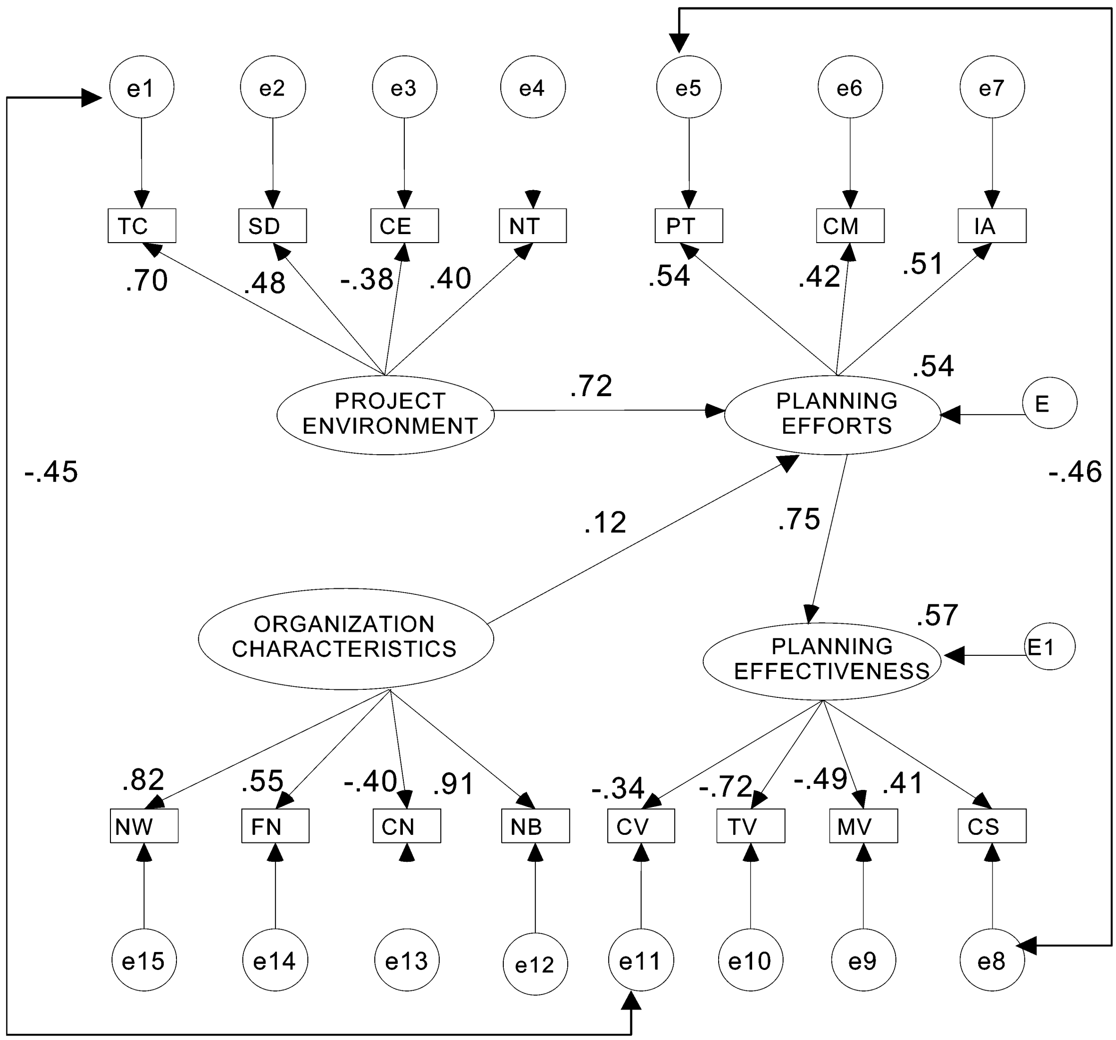


**Figure 2** Final model specification

**Table 4** Parameter estimates of measurement model

| Latent variables | Indicators | Factor loadings | Standard Error | t-value | $R^2$ value |
|---|---|---|---|---|---|
| Project environment | Contract type | 1.00 | – | – | 0.50 |
| | State of design | 1.05 | 0.42 | 0.014** | 0.24 |
| | Construction experience | −0.27 | 0.13 | 0.041** | 0.14 |
| | No of trades | 0.42 | 0.19 | 0.032** | 0.16 |
| Organizational characteristics | Total workers | 1.00 | – | – | 0.69 |
| | No of branches | 1.01 | 0.18 | 0.000*** | 0.83 |
| | Formalization | 0.29 | 0.07 | 0.000*** | 0.30 |
| | Centralization | −1.72 | 0.62 | 0.006** | 0.16 |
| Planning effort | Planning time | 1.00 | – | – | 0.29 |
| | Construction method | 0.30 | 0.14 | 0.036** | 0.18 |
| | Analysis information | 1.16 | 0.50 | 0.020** | 0.26 |
| Planning potential | Client satisfaction | 1.00 | – | – | 0.12 |
| | Cost variance | −0.14 | 0.08 | 0.096* | 0.52 |
| | Time variance | −0.73 | 0.33 | 0.031** | 0.24 |
| | Man-hour variance | −0.24 | 0.12 | 0.045** | 0.17 |

*Note*: *p<0.1; **p<0.05; ***p<0.001.

**Table 5** Goodness of fit indices for structural model

| Fit index | Value |
|---|---|
| $\chi^2$ | 89.02 |
| p-value | 0.217 |
| GFI | 0.83 |
| CFI | 0.93 |
| RMSEA | 0.048 |
| PCLOSE | 0.51 |

have requisite validity, at least in the specific empirical setting of the sample studied.

The overall fit of the structural model was assessed using a number of goodness-of-fit tests which included the chi-square test, the Goodness of Fit Index (GFI), the Comparative Index (CFI), Root Mean Square Error of Approximation (RMSEA), and the fit index PCLOSE. Table 5 shows the results of the goodness-of-fit tests for the SEM model. Unlike traditional hypothesis testing, the goal of Structural equation Modelling analysis is to produce a non-significant result at a $\alpha$ level of 0.05 because it is generally acknowledged that most models are useful approximations that do not fit in the populations (Arbuckle *et al.*, 1999). Hence, a *p*-value above 0.05 for the chi-square test was considered to be the minimum threshold for acceptable goodness-of-fit. All the fit indices for the structural model are higher than minimum acceptable levels cited in literature (Hu and Bentler, 1999).

Table 6 shows the parameter estimates for the structural model. The path coefficient for the influence of the project environment on planning efforts is statistically significant (at $p<0.05$). Hence, hypothesis H1 is strongly supported by the data. On the other hand, the path coefficient for the influence of planning effort on project planning effectiveness has a *p*-value that is slightly above the 90% significance level. However, it should be noted that small samples usually produce a conservative probability level, and if the obtained probability is around the standard p-value, it can be inferred with confidence that the true probability level is much higher than what is reflected in the model. (Kline, 1998). Hence, hypothesis H3 is marginally supported by the data. In contrast, the *p*-value for the path coefficient for the influence of organizational characteristics on planning effort has a *p*-value that is much higher than the significance level. Hence, the model does not support hypothesis H2.

## Discussion of results

### Measurement component of SEM model

The *Project Environment* variable construct is measured in the SEM model by the contract type, state of design completion prior to construction and previous construction experience (both indicators of uncertainty), and the number of construction trades (an indicator of complexity). The contract type had the most influence in characterizing the *Project Environment* (coefficient: 0.70) followed by state of design completion (coefficient: 0.48) and number of construction trades (coefficient: 0.40). Past construction experience had the least influence in characterizing the *Project Environment* (coefficient: −0.38).

The *Organizational Characteristics* variable construct is measured in the SEM model by the firm's number of branch offices and the total number of workers that a firm has on its various construction sites (both indicators of organizational size), centralization and formalization (both indicators of organizational structure). The number of branch offices had the highest influence in characterizing *Organizational Characteristics* (coefficient: 0.91) followed by number of workers on construction sites (coefficient: 0.82) and formalization (coefficient: 0.55). Centralization had the least influence in characterizing *Organizational Characteristics* (coefficient: −0.40).

The *Planning Efforts* variable construct is measured in the SEM model by the planning time, focus on methods planning, and proportion of planning time spent analysing information. The time invested in planning prior to commencement of site work had the highest influence in characterizing *Planning Efforts* (coefficient: 0.54), followed by proportion of planning

**Table 6** Estimates of structural parameters

| Exogenous construct | Endogenous construct | Factor loadings | Standard error | p-value | Squared multiple correlation, $R^2$ |
|---|---|---|---|---|---|
| Project environment | Planning efforts | 0.93 | 0.41 | 0.023** | 0.54 |
| Organizational characteristics | Planning efforts | 0.06 | 0.08 | $0.471^{ns}$ | 0.54 |
| Planning efforts | Planning effectiveness potential | 0.13 | 0.08 | 0.106* | 0.57 |

*Note*: *p<0.1; **p<0.05; ns: not significant.

**Table 7** Direct and indirect influences on planning effectiveness: standardized estimates of path coefficient values

| Factors | Planning effectiveness potential | | |
|---|---|---|---|
| | Direct effect | Indirect effect | Total effect |
| Project environment | – | 0.54* | 0.54 |
| Organizational characteristics | – | $0.09^{ns}$ | 0.09 |
| Project planning efforts | 0.75* | – | 0.75 |
| $R^2$ | – | – | 0.57 |

*Note*: *p<0.05; ns: not significant.

time spent analysing information (coefficient: 0.51). Focus on methods planning had the least influence in characterizing *Planning Efforts* (coefficient: 0.44).

The *Project Planning Effectiveness* variable construct is measured in the SEM model by the cost variance, time variance, man-hour variance, and satisfaction of client with final building quality. Time variance had the highest influence in characterizing *Project Planning Effectiveness* (coefficient: −0.72), followed by man-hour variance (coefficient: −0.49) and client satisfaction (coefficient: 0.41). Cost variance had the least influence in characterizing *Project Planning Effectiveness* (coefficient: −0.34).

### Structural component of SEM model

The implication of the hypothesized research model (see Figure 1) is that the *Project Environment* and the *Organizational Characteristics* of the performing organization indirectly influence *Project Planning Effectiveness*, being mediated by planning efforts. Only the *Project Environment* was found to have a statistically significant direct influence on *Planning Efforts* (path coefficient: 0.72). In contrast the *Organizational Characteristics* of the performing organization was not found to have any statistically significant direct influence on *Planning Efforts*. Table 7 shows the direct and indirect influences of the three hypothesized predictors of *Project Planning Effectiveness*. *Project Planning Efforts* was found to have a significant direct influence on *Project Planning Effectiveness*, while the *Project Environment* also had a significant indirect influence on *Project Planning Effectiveness*. The *Organizational Characteristics* of the performing organization was not found to have any significant indirect influence on *Project Planning Effectiveness*.

An implication of the findings of the study is that the organizational environment in which the project planning process is undertaken does not appear to have any significant influence on the outcome of the process. Any interpretation and comparison of this particular finding with previous studies needs to be done within the context of the specific variables being studied in the different studies. The study reported here has focused on examining the impact of the organizational environment on the project planning process and its outcomes, in contrast to studies such as Kabasakal *et al.* (1989) that investigated the relationship between organizational dimensions and the use of specific management systems (e.g. programming techniques, operations research techniques, quality control of materials and techniques, cost controls) and organizational.

Another implication of the findings of the study is that any strategy developed to improve project planning effectiveness should not only focus on improving project planning efforts, but should also focus on identifying and eliminating (or at least minimizing) potentially adverse impacts which the project environment might have on project plans. The use of appropriately designed project control systems (specifically tailored to the project environment) is one way of minimizing potentially adverse impacts of the project environment on project plans.

## Conclusion

The intention was to provide an insight into how situational factors in project and organizational environments interact and work together to influence project-planning effectiveness. The focus was on the relative influence of three latent variable constructs: planning efforts, project environment, and organizational characteristics of construction firms on the dependent construct: project planning effectiveness. The findings suggest that while the organizational environment in which the planning process is undertaken has almost no effect either directly on planning efforts or indirectly on planning effectiveness, the project environment has a significant direct influence on planning efforts and a significant indirect influence on planning effectiveness. Individual effects of observed variables on the constructs were also evaluated. Time variance was found to be the factor with the highest influence in characterizing project-planning effectiveness, while cost variance was the factor with the least influence. The amount of time invested in project planning activities and the contract type were also found to be the factors with the most influence in characterizing planning efforts and the project environment respectively.

A limitation of this study is the relatively small sample size, as the structural equation modelling is a large sample technique. Nevertheless, this is the first study to our knowledge that examines the interrelationships existing within observable variables affecting project planning in order to understand how the individual variables work together in influencing planning effectiveness. Furthermore, despite the relatively small size of the sample, the hypothesized model provided a good explanation of how the project planning process interacts with its environment, and how these interactions influence project-planning effectiveness. Further work will focus on cross-validating the developed covariance structure model using data drawn from a larger sample, and data collected from other geographical locations.

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