PAPERS

A Comprehensive Framework for Sustainable Project Portfolio Selection Based on Structural Equation Modeling

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ABSTRACT

Project selection problems are inherently complex problems with multiple and often conflicting objectives. The complexity of project selection problems is due to the high number of projects from which a subset (portfolio) has to be chosen. Various analytical methods, ranging from the simple weighted sum to complex mathematical programming have been proposed to solving these problems. We propose an integrated approach for strategic and sustainable project portfolio selection, which is composed of two distinct but interrelated modules. In the first module, we use the strategic planning and sustainability concepts to select a set of promising projects. In the second module, we use a project portfolio selection procedure to choose among the promising projects identified in the first module. A structural equation model is used to analyze and explain the relationships among different factors in the proposed framework. More specifically, we investigate the effects of: (1) *strategic level performance* on *sustainability, post-implementation,* and overall performance; (2) *implementation performance on post-implementation and overall performance;* (3) *portfolio selection performance* on *implementation* and *overall performance*; and (4) *post-implementation performance on overall performance*. A case study in investment banking is presented to demonstrate the applicability of the proposed model and exhibit the efficacy of the procedures and algorithms.

KEYWORDS: project portfolio selection; structural equation modeling; sustainability; strategic planning; financial service

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INTRODUCTION

The project selection problem is an important and recurring problem in many organizations, and establishing a systematic and comprehensive selection model is an important concern. However, project selection problems are inherently complex problems with multiple and often conflicting quantitative and qualitative factors, such as business goals, financial costs and benefits, and limitations in available resources. In spite of the importance of project selection problem research, a framework that integrates the strategic themes of the organization with the portfolio selection procedure has rarely been presented in the project selection literature.

Selecting projects and optimizing the project portfolio that best aligns with the organization's strategic priorities is the essential focus of project portfolio selection. Morris and Jamieson (2004) and Dey (2006) argue that project portfolio management is a "bridge between strategy and operation" and enables organizations to transform the organization's vision into realities or successfully implement their corporate strategies. Iamratanakul, Patanakul, and Milosevic (2008) have summarized the project selection problem models into several groups, including: scoring methods, economic methods (i.e., payback period, net present value, and internal rate of return), simulation and heuristics models, mathematical programming methods, and real options, among others. They reported that each methodology alone does not address all of the aspects of project portfolio selection because each method has its own advantages and disadvantages.

For example, although scoring methods are simple and easy to use, they assume that scores are precise, which is not always the case. The economic methods also have their own drawbacks. Payback period does not take time value of money into consideration or net present value, and internal rate of return requires data that may not be readily available or easy to estimate. Simulation models are well-suited for selecting projects in dynamic organizations; however, they are not suitable for organizations that do not have well-established standards and flow of information. Mathematical programming models are widely used in the literature but they are not suitable for alignment problems that are based on the central tendency approach. The

Researcher(s)	Description: Theme(s)/Considered Factor(s)/Methodology/Application
Ahn et al. (2010)	Framework/portfolio management approach/differentiating, prioritizing, selecting investment/project and portfolio/product innovation
Castillo & Pitfield (2010)	Framework/evaluative and logical approach to sustainable transport indicator compilation multi-criteria decision making (MCDM), analytic hierarchy process (AHP)/transport, and English Regions UK.
Howell et al. (2010)	Framework/uncertainty, complexity, urgency, team empowerment, criticality/project process selection, tuning of processes, project risk assessment.
Joumard & Nicolas (2010)	Framework/sustainability/multi-criteria decision making/transport project
Liu et al. (2010)	Framework/sustainability/grounded theory/water resource management
Shehu & Akintoye (2010)	Framework, implementation and practice of program management/success factors/survey, and interview/construction industry
Shen et al. (2010)	Framework, feasibility study/economic, social, and environmental/survey/construction
Williams et al. (2010)	Framework/political, rational/case-study/public project Norway and UK.
Doloi et al. (2011)	Framework, project success/soundness of business and workforce, planning and control, quality performance, past performance/structural equation modeling/43 construction firms in Australia.
Eriksson & Westerberg (2011)	Framework/procurement indices, cost, time, quality, and environmental, innovation/critical survey

Table 1: The project selection problem: Framework development research highlights.

real options approaches can translate project options into visualizing effects but they require extensive data and analysis.

We propose a comprehensive framework for a sustainable strategic project selection problem. The proposed framework aligns the strategic themes of the organization (i.e., mission, vision, and values) with the tactical and operational considerations. The proposed method consists of two modules. The first module considers sustainability (i.e., economic, environmental, and social) criteria, which are strategic, and the second module considers project portfolio selection (financial, semi-financial, and non-financial) criteria, which are tactical and operational.

Our framework helps the decision makers to (1) think systematically about complex project selection problems; (2) decompose the project selection problems into manageable steps and integrate the results to arrive at a solution consistent with organizational goals and objectives; (3) carefully consider the elements of uncertainty within a structured framework; and (4) consider sustainability within a strategic context. Managerial judgment and accurate data are integral components of project selection problems and portfolio selection decisions. Our approach enables decision makers to assimilate project-related judgments and data in a formal and systematic approach.

The remainder of the paper is organized as follows. A brief review of the project selection problems literature is presented in the second section. The project selection problem framework proposed in this study, along with the associated factors and measurements are presented in the third section. A structural equation model described in the fourth section is used to analyze and explain the relationships among different factors in the model. In the fifth section, the applicability of the proposed framework is demonstrated in the investment banking industry; finally, the sixth section draws the conclusive remarks and future research directions.

Review of the Relevant Literature

There are three different types of project solution problems: (1) accept–reject problems, where the goal is to decide whether a project is acceptable or not; (2) single-project selection problems, where the goal is to select the best project from a set of mutually exclusive projects; and (3) multiple-project selection problems, where the goal is to select a set of projects from a set of non-mutually exclusive projects. The project selection problem research can be classified into five general categories: (1) framework development research, (2) decision support system development research, (3) criteria and indices development research, (4) methodology development research, and (5) application development research. The framework development research literature and the decision support system development research literature are highlighted in Tables 1 and 2, respectively.

For more information about the project portfolio selection models, the interested reader is referred to Graves and Ringuest (2003) and Iamratanakul et al. (2008).

The Proposed Strategic Framework for Sustainable Project Selection

The framework proposed for project selection problems should support the strategic themes of an organization in an essential way. It is important to assess whether the portfolio of projects support strategic goals or not; therefore, the organizational strategies should be

Researcher(s)	Description: Theme(s)/Considered Factor(s)/Methodology/Application
Sen et al. (2009)	DSS/financial and non-financial: quality, technology, socio-economic/fuzzy sets, MCDM/software selection
Khalili-Damghani et al. (2011)	DSS, investment selection/cost, budget, profit, rate of return, resources/fuzzy mathematical programming, fuzzy rule based/simulated benchmark instances

Table 2: The project selection problem: Decision support system (DSS) development research highlights.

used to properly align projects with the organizational goals. For each project, a question should be asked: "*To what extent does this project enable us to reach organizational goals?*" These screening questions are designed to test each project's fit with the organizational goals. Poorly selected criteria could hinder an organization in reaching its goals and objectives. Projects that merely keep the organization active and provide some value still may not be essential enough to move the organization forward toward achieving its goals and strategies.

The proposed framework has two main modules. The first module is concerned with the integration of the sustainability criteria in the strategic planning process. The sustainability criteria (i.e., economic, social, and environmental effects) are considered as an essential component of a comprehensive strategic planning process. The output of the first module is a set of projects that support the strategic goals and objectives of the organization. In the second module, a portfolio project selection procedure that considers financial, semi-financial, and non-financial criteria is proposed. The outputs of the first module are treated as inputs for the second module. The second module is assumed to deliver a set of projects, which not only support strategic and sustainability themes, but is also aligned with the financial, semi-financial, and non-financial criteria. The two sequential modules are graphically depicted in Figure 1.

Module I: Sustainable Strategic Planning

The sustainable strategic planning module contains the following three sub-modules: strategic level, sustainability considerations, and strategic planning (Robèrt et al., 2002).

Strategic Level

The organizational vision, mission, and values are considered at the strategic level (Kölbl, Niegl, & Knoflacher, 2008; Wong, Ng, & Chan, 2010).

Sustainability Considerations

Although economic analyses are the most commonly used criteria in project selection procedures, sustainability, which considers a balance between the economic, social, and environmental factors associated with an investment, is a more modern paradigm. *Our Common Future*, also known as the *Brundtland Report*, from the United Nations World Commission on Environment and Development (1987), is viewed as a major political turning point for the concept of sustainable development. The first formal definition of the sustainability concept appeared in the United Nations World Commission on Environment and Development (1987, p. 8) as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The balance of economic, social, and environmental effects (also referred to as the three pillars or objectives of sustainable development) is interpreted as sustainability in the project life cycle management of an organization (Mebratu, 1998).

Labuschagne and Brent (2005) proposed the concept of sustainable project life cycle management. They described three goals for sustainable development (i.e., social equity, economic efficiency, and environmental performance) in various project life cycle management problems. They showed how manufacturing facilities can achieve true sustainable project life cycle management. Table 3 presents some examples of sustainability criteria and indices.

Sustainability Trade-off

A trade-off plan and a preference on the priority of the three dimensions of sustainability (i.e., economic, social, and environmental) are generally required before analysis. Hahn, Figge, Pinkse, and Preuss (2010) have argued that the trade-off and conflict between the sustainability aspects are not an exception but a rule; they argued that these conflicts are often experienced in the sustainable development environment. They also

Economic	Social	Environmental
• Taxes paid • Ethical investments • Capital investments • Infrastructure investments • Cultural investments	• Provision of employment • Health and safety (employees, contractors, customers, citizens) • Nuisance (odors, noise, visual) • Public acceptability (process, product)	• Raw material • Energy • Emissions (air, water, land) • Impacts (global warming, ozone depletion, acidification, human toxicity, eco-toxicity, summer smog, and eutrophication)

Table 3: Examples of sustainability criteria and indices.

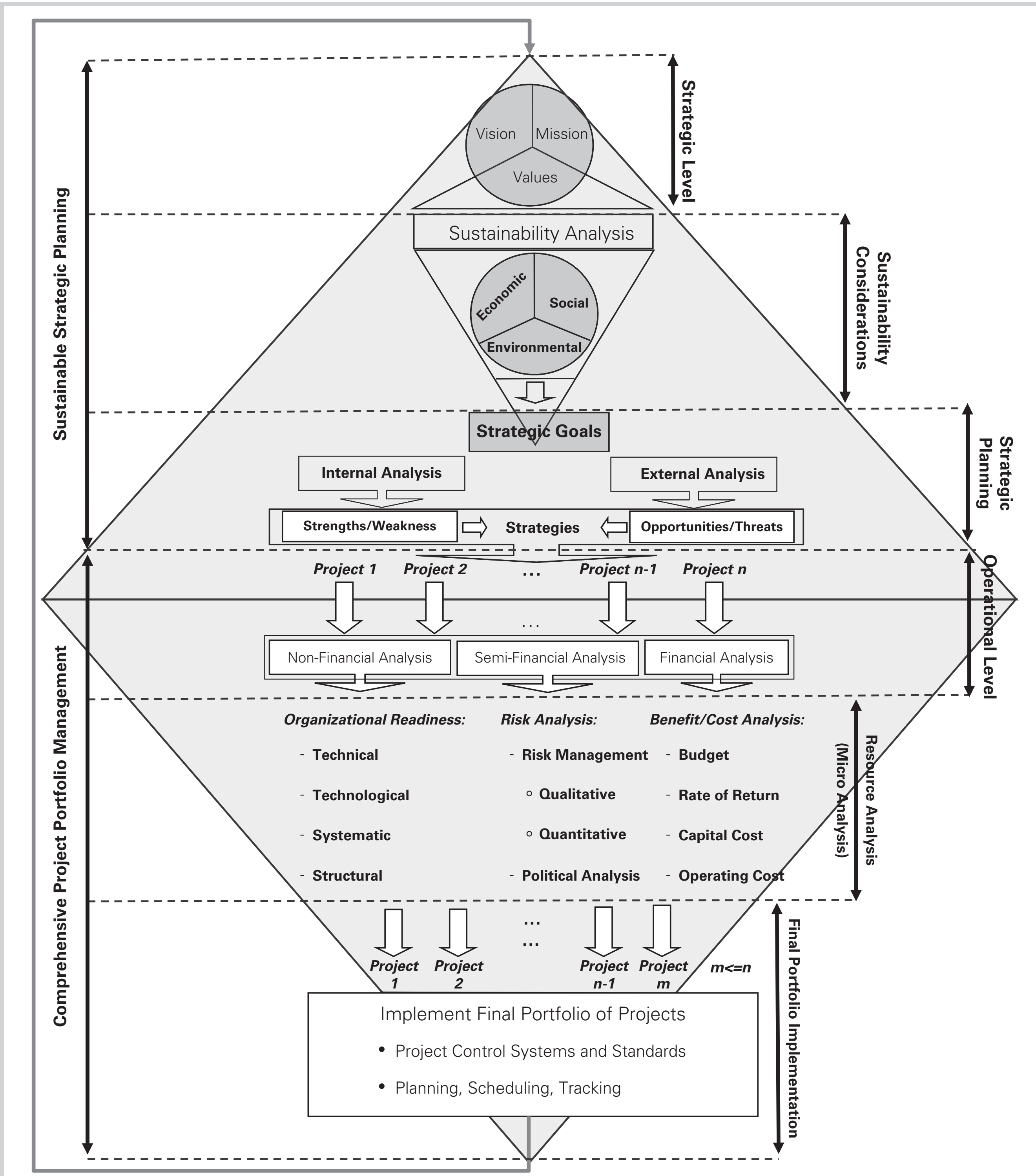

Figure 1: The conceptual framework for sustainable project portfolio selection.

showed that neglecting these trade-offs usually results in a limited perspective on corporate contributions to sustainable development. They discussed the limitations of the win–win paradigm with regard to sustainable development.

In the trade-off situations, it is impossible to achieve two or more desirable objectives simultaneously; rather, decision makers need to weigh a loss in at least one dimension against a gain in other dimensions. Given the fundamental transformation that it requires, it is most probable that sustainable development entails multiple conflicts. Hence, the sustainability planning and policy literature has stressed that a purely consensus-driven approach will water down sustainable development strategies to the lowest common denominator. The same problem applies to win–win approaches to corporate sustainability: corporate sustainability based on the win–win logic will be restricted to conflict-free solutions with little ambition to fundamentally change core business practices for the sake of sustainable development.

Trade-off situations have been defined as 'compromise situations' when a sacrifice is made in one area to obtain benefits in another. Trade-off situations are thus in stark contrast to win–win situations, where it is assumed that benefits in two or more areas of corporate sustainability can be achieved simultaneously. Rather, trade-offs in corporate sustainability address those situations in which corporate contributions to sustainable development can only be achieved if one accepts a compromise between at least two sustainability dimensions that are in conflict with each other. As shown here, however, this does not imply that trade-off situations necessarily result in inferior corporate contributions to sustainable development compared with win–win situations. For example, accepting a relatively small loss in corporate economic performance to generate a substantial social or environmental benefit might well result in a greater positive corporate contribution to sustainable development compared with a situation of minor gains in economic performance alongside modest improvements in environmental or social performance.

Strategic Planning

Strategic planning involves internal and external analyses:

Internal Analysis: Analyzing the inbound situation of the organization by estimation of weakness and strength points.

External Analysis: Analyzing the outbound situation of the organization by estimation of threats and opportunities.

A proper combination of vision, mission, values, and strategic goals develops the perspective of an organization's desired ends:

Strategic Goals: Provide very specific, measurable goals for achieving different aspects of the vision, mission, and values.

While strategies are assumed to be approaches to achieving the ends, projects are treated as action plans:

Strategies: The approaches that provide the framework that an organization uses to achieve its goals.

Projects $(1,. . .,n)$: The operational activities, which should support the vision, mission, values, strategic goals, and strategies.

Module II: Comprehensive Project Portfolio Selection

Project portfolio selection is a general procedure used to select a set of projects using operational resource analysis in order to find the best approach for implementing its strategic goals:

Operational Level

The operational level is assumed to attach the outputs of the sustainable strategic planning module to the project portfolio management module. The main themes of this sub-module are action plans and screening the selected projects of the first module.

Resource Analysis

Resource analysis involves a careful consideration of a set of financial, semi-financial, and non-financial factors as follows:

- *Financial criteria*: Factors that can be directly converted into monetary values (i.e., costs, revenues).
- *Semi-financial criteria*: Factors that can indirectly be converted into monetary values (i.e., risks, political situations).
- *Non-financial criteria*: Factors that are difficult to convert into monetary values (i.e., organizational readiness factors such as systematic and technical considerations).

Structural Equation Modeling

Statistical methods are a major tool for data analysis in social science research (Nachmias & Nachmias, 2008); however, most multivariate techniques share a common limitation: they can only investigate one relationship at a time (Hair, Black, Babin, Anderson, & Tatham, 2006). Structural equation modeling is a technique that effectively subsumes a wide range of standard multivariate analysis methods, including regression, factor analysis, and analysis of variance. Among the strengths of structural equation modeling is the ability of the method to construct latent variables: variables that are not measured directly, but are estimated in the model from several measured variables. Technically, structural equation modeling estimates the unknown coefficients in a set of linear structural equations. Variables in the equation system are usually directly observed variables and unmeasured latent variables that are not observed but relate to observed variables. Structural equation modeling consists of two components: a *measurement model* and a *structural model*. The measurement model comprises the relationships between the latent factors and the observed values of the questionnaire items. The structural (construction) model represents the path direction and strengths of the relationships of the latent variables. The structural model is used to assess the hypothesized relationships among latent factors. Recognizing the objectives of the present study—to examine the pattern and interrelationships of multiple independent and dependent variables in project selection problems—structural equation modeling is regarded as the most effective analytical

Researcher(s)	Field Application
Cao & Zhang (2010)	Supply chain collaborative advantage
Danese & Kalchschmidt (2011)	Cost and delivery performance
Doloi et al. (2011)	Contractor's performance
Golini & Kalchschmidt (2011)	Supply chain management
Han et al. (2011)	Quality management practices
Nusair & Hua (2010)	E-commerce (tourism management)
Punniyamoorthy et al. (2011)	Supplier selection
Ramanathan & Muyldermans (2010)	Demand structure
Ray et al. (2010)	Backordering cost structure and stochastic demand
Su & Yang (2010)	Effect of management systems (ERP and SCM)
Yazan et al. (2011)	Bioenergy production chain
Yee et al. (2010)	Employee loyalty, service quality, and firm performance

Table 4: Recent structural equation modeling applications.

instrument (Byrne, 2001; Hair, Anderson, Tatham, & Black, 1998; Hair, Anderson, Tatham, Black, & Babin, 2006). Table 4 presents some recent applications of structural equation modeling.

The literature reports on a few applications of structural equation modeling in project selection problems. Kim, Black, Babin, Anderson, & Tatham (2009) developed a structural equation model to predict the project success of uncertain international construction projects considering economic, social, and environmental aspects. A comparative analysis showed that structural equation modeling outperformed multiple regression analysis and artificial neural networks. Structural equation modeling showed a more accurate prediction of performance because of its intrinsic ability to consider various risk variables in a systematic and realistic way. In addition, the use of structural equation modeling allowed for visually depicting the paths and showing how those complicated variables were interrelated. Cho, Hong, and Hyun (2009) investigated the effect of project characteristics on project performance in construction projects based on structural equation modeling. Their study aimed at analyzing the overall relationship between project performance and a project's characteristics. They studied the degree of influence between 17 project characteristics and five project performance indices.

In this study, a structural equation model is used to analyze the relations among different components of the proposed framework for sustainable project selection. We first define the appropriate modules/sub-modules and criteria in the proposed framework and then propose a set of hypotheses in the form of a structural model. The flowchart for sustainable project portfolio selection is presented in Figure 2.

Sustainable Project Selection Modules

Based on the primary framework proposed in the previous section, the modules/sub-modules and criteria/factors related to the sustainable project selection

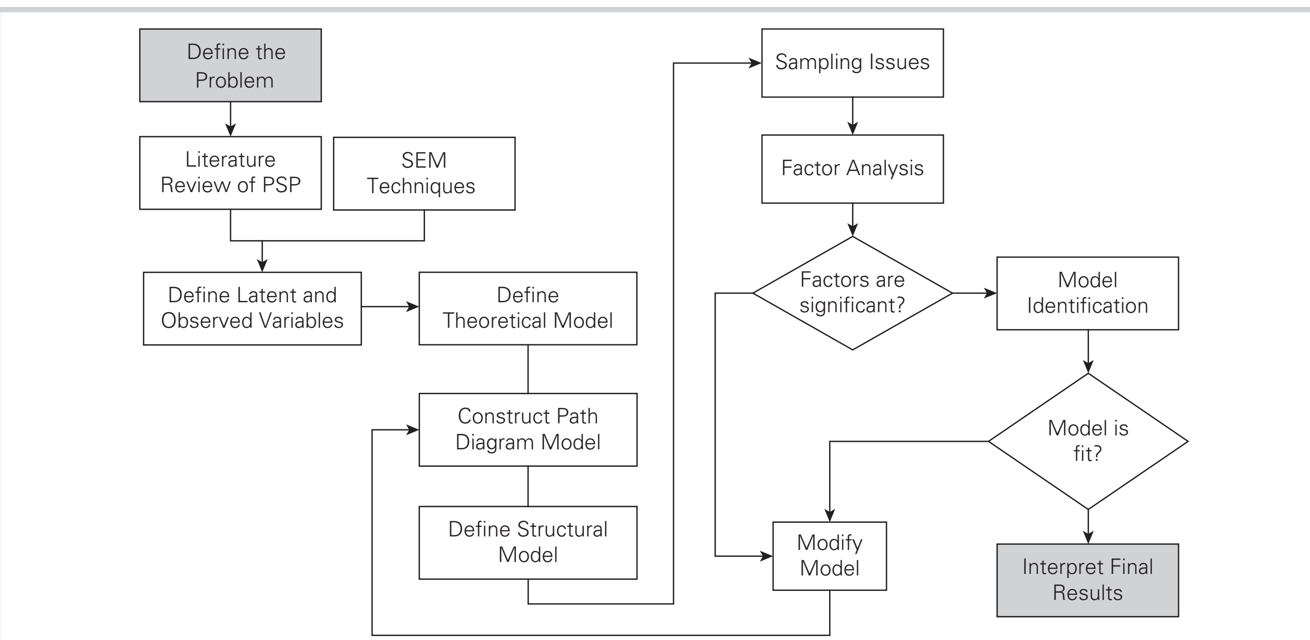

Figure 2: The flowchart for sustainable project portfolio selection.

Phase	Module	Sub-modules	Factors	Instances of Criteria
Planning	Sustainable strategic planning	• Strategic level • Sustainability analysis • Strategic planning	• Mission, vision, values • Economic, social, environmental • Internal/external analysis	In *Table 3* In *Figure I*
Selection	Project portfolio management	• Non-financial analysis • Semi-financial analysis • Financial analysis	• Organizational readiness • Risk analysis • Benefit/cost analysis	In *Figure I* In *Figure I* In *Figure I*

Table 5: The definitions of the phases, modules, sub-modules, and criteria of the sustainable project selection framework.

Latent Variable	Observed Variables	Definition
Sustainability Performance (SP)	• Economic portfolio (Y_1) • Social portfolio (Y_2) • Environmental portfolio (Y_3)	The capability of the selected portfolio to balance economic, social, and environmental criteria in the macro level
Strategic Level Performance (SLP)	• Feasible strategies (X_1) • Strategic portfolio (X_2) • Transparent objectives (X_3)	The capability of strategic level to supply feasible and transparent strategies and select a portfolio to support the main strategic goals, mission, vision, and values
Portfolio Selection Performance (PSP)	• Organizational feasible (X_4) • Risk feasible (X_5) • Benefit/cost feasible (X_6) • Integrated selection (X_7)	The capability of the selected portfolio to be executed considering the micro level criteria such as organizational readiness, risk analysis, and cost/benefit analysis
Implementation Performance (IP)	• Integrated portfolio (Y_4) • On scope portfolio (Y_5) • On time portfolio (Y_6) • On budget portfolio (Y_7) • On quality portfolio (Y_8) • HRM portfolio management (Y_9) • Communication portfolio management (Y_{10}) • Operational risk (Y_{11}) • Procurement portfolio management (Y_{12})	The capability of the project control system to implement the selected portfolio of projects based on the *PMBOK® Guide* requirements, such as on time, on budget, and in a predetermined quality with minimum operational risk
Post-implementation Performance (PIP)	• Financial issues (Y_{13}) • Customer issues (Y_{14}) • Implementation methods (Y_{15}) • Implementation innovations (Y_{16})	The capability of the framework to provide performance measurements
Overall Framework Performance (OFP)	• Universalism (Y_{17}) • Simplicity (Y_{18}) • Flexibility (Y_{19}) • Robustness (Y_{20}) • Accuracy (Y_{21})	The overall capability and performance of the sustainable project selection, implementation, and evaluation framework

Table 6: The latent and observed variables.

framework are represented in Table 5. The basic factors in the proposed structural equation model are latent variables that cannot be measured; therefore, the observed variables in Table 6 are considered for measuring the latent variables.

Main Hypotheses and Path Diagram

Based on the factors defined in Table 5, the following research hypotheses are formulated:

- **Hypothesis 1.** The Strategic Level Performance (SLP) has an effect on Sustainability Performance (SP) (Joumard & Nicolas, 2010; Kölbl et al., 2008; Liu, Zhang, & Zhang, 2010; Mebratu, 1998; Robèrt et al., 2002; Shen, Tam, Tam, & Ji, 2010; Wong et al., 2010).
- **Hypothesis 2.** The Strategic Level Performance (SLP) has an effect on Post-implementation Performance (PIP) (Graves & Ringuest, 2003; Kölbl et al., 2008; Punniyamoorthy, Mathiyalagan, & Parthiban, 2011).
- **Hypothesis 3.** The Implementation Performance (IP) has an effect on Post-implementation Performance (PIP) (Doloi, Iyer, & Sawhney, 2011; Shehu & Akintoye, 2010).
- **Hypothesis 4.** The Portfolio Performance Selection (PPS) has an effect on Implementation Performance (IP) (Doloi et al., 2011; Iamratanakul

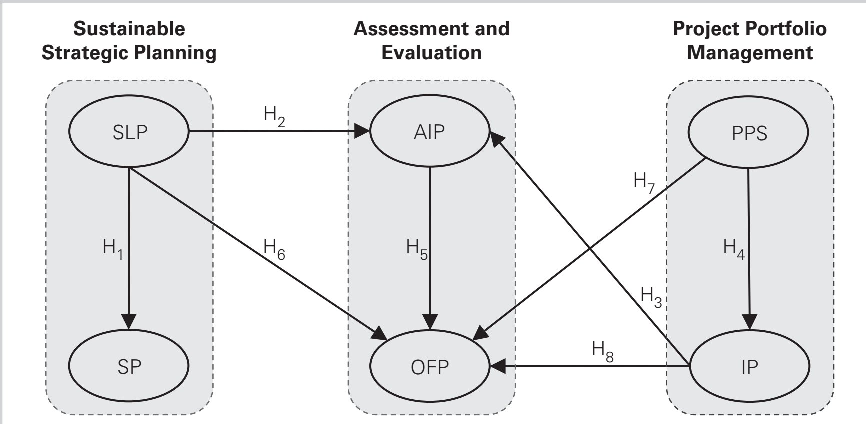

Figure 3: The hypothetical construct equations for the structural equation modeling.

et al., 2008; Eriksson & Westerberg, 2011).

- **Hypothesis 5.** The Post-implementation Performance (PIP) has an effect on Overall Framework Performance (OFP) (Eriksson & Westerberg, 2011; Williams, Klakegg, Magnussen, & Glasspool, 2010).
- **Hypothesis 6.** The Strategic Level Performance (SLP) has an effect on Overall Framework Performance (OFP) (Williams et al., 2010; Eriksson & Westerberg, 2011).
- **Hypothesis 7.** The Portfolio Performance Selection (PPS) has an effect on Overall Framework Performance (OFP) (Iamratanakul et al., 2008; Williams et al., 2010; Doloi et al., 2011; Eriksson & Westerberg, 2011).
- **Hypothesis 8.** The Implementation Performance (IP) has an effect on Overall Framework Performance (OFP) (Graves & Ringuest, 2003; Williams et al., 2010; Eriksson & Westerberg, 2011).

The goal here is to investigate the direct and indirect effects of the factors on the overall performance of sustainable project selection, implementation, and evaluation framework. Based on the aforementioned hypotheses, the construct equations of the proposed structural equation model are represented in Figure 3. The complete model representing the relationship between the observed variables and the latent factors is presented in Figure 4.

Experimental Results

A considerable amount of resources are usually at stake in capital investment planning and identifying the "best" subset of investment portfolios is often of major importance. The proposed framework was used at the

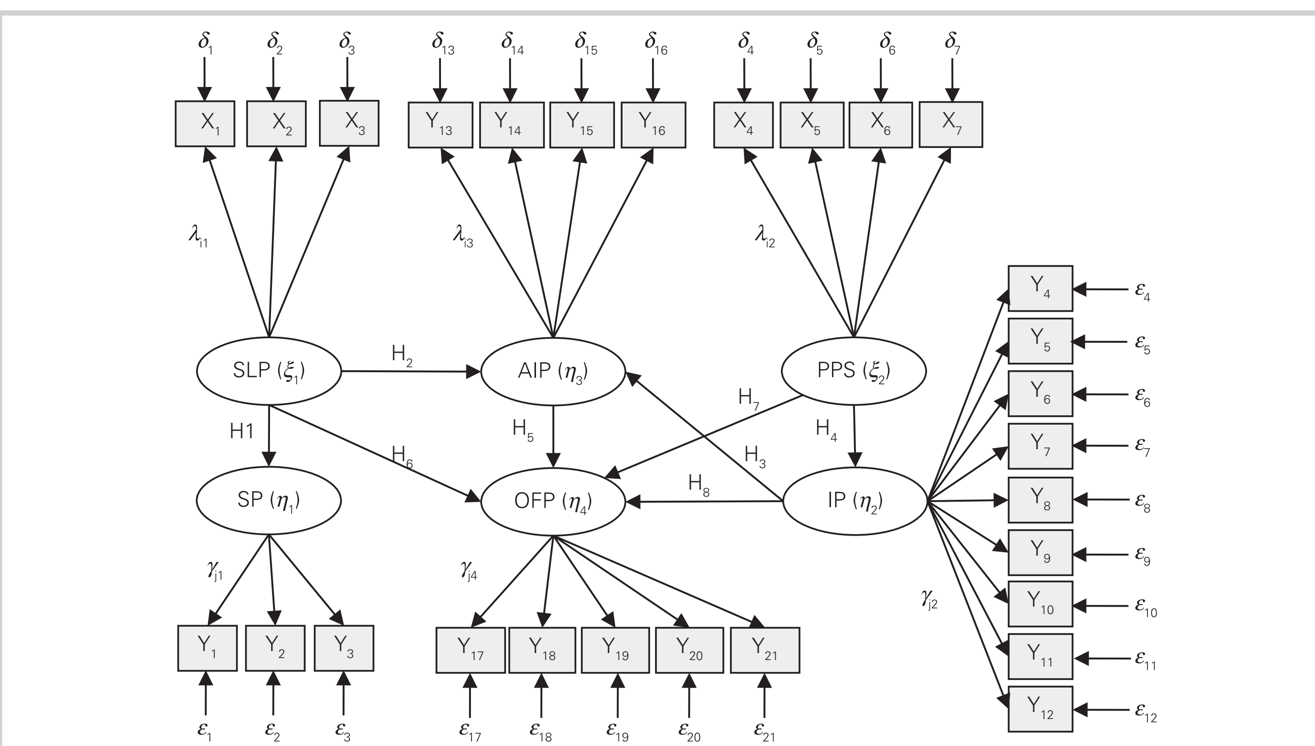

Figure 4: The complete hypothetical measurement and structural model.

Latent Variable	Observed Variables	Factor Loadings	Cronbach's Alpha Test
Sustainability Performance (SP)	• Economic portfolio (Y_1) • Social portfolio (Y_2) • Environmental portfolio (Y_3)	0.97 0.93 1.00	0.775
Strategic Level Performance (SLP)	• Feasible strategies (X_1) • Strategic portfolio (X_2) • Transparent objectives (X_3)	1.00 0.91 0.77	0.846
Portfolio Selection Performance (PSP)	• Organizational feasible (X_4) • Risk feasible (X_5) • Benefit/cost feasible (X_6) • Integrated selection (X_7)	0.89 0.83 1.00 0.94	0.835
Implementation Performance (IP)	• Integrated portfolio (Y_4) • On scope portfolio (Y_5) • On time portfolio (Y_6) • On budget portfolio (Y_7) • On quality portfolio (Y_8) • HRM portfolio management (Y_9) • Communication portfolio management (Y_{10}) • Operational risk (Y_{11}) • Procurement portfolio management (Y_{12})	0.27 0.31 0.85 0.89 1.00 0.92 0.33 0.46 0.27	0.701
Post-implementation Performance (PIP)	• Financial issues (Y_{13}) • Customer issues (Y_{14}) • Implementation methods (Y_{15}) • Implementation innovations (Y_{16})	0.94 1.00 0.73 0.87	0.924
Overall Framework Performance (OFP)	• Universalism (Y_{17}) • Simplicity (X_{18}) • Flexibility (Y_{19}) • Robustness (X_{20}) • Accuracy (Y_{21})	0.93 0.88 0.92 1.00 0.95	0.931

Table 7: The confirmatory factor analysis.

Manhattan Group,[1] an American multinational financial services corporation headquartered in New York City. The Manhattan Group was hired to select an optimal portfolio of investment projects for Horizon Oil Company,[2] a multinational oil and natural gas producer in the Middle East, based on several financial and non-financial criteria. Manhattan Group's analysts were considering 34 investment projects for Horizon over a 30-year planning period, with an available budget of US$120 million per year and expected annual production of at least 70,000 barrels. Over the past 60 years, Horizon Oil Company has drilled more than 50,000 wells around the world in hopes of striking oil. Before Horizon puts a drill to soil or the seabed, they use topographical maps, aerial photography, sound waves, 3D projections, and other tools to help them form an educated guess about the size, shape, and consistency of the oil or natural gas that lies underneath. The 34 investment projects were all oil-well exploration projects with known estimated sizes and shapes. A survey was devised and used by the Manhattan Group analysts to evaluate a pre-established set of factors used to evaluate investment projects for multinational oil and natural gas producers. A total of 493 investment bankers, with an average tenure of 9.75 years, participated in the assessment process to evaluate investment projects at oil and natural gas companies. All the variables given in Table 6 were measured using a five-point Likert scale, where the higher numbers represented better performance or higher satisfaction; 195 usable questionnaires were returned. The load factors for the 195 responses are presented in Figure 4.

Confirmatory Factor Analysis

Confirmatory factor analysis evaluates a priori hypotheses and is largely driven by theory. As such, confirmatory factor analysis allows for the explicit constraint of certain loadings to be zero. The analysis in confirmatory factor analysis is driven by the theoretical relationships among the observed and unobserved variables. When a confirmatory factor analysis is conducted, the researcher uses a hypothesized model to estimate a population covariance matrix that is

[1]The name of the investment firm and the data are changed to protect the anonymity of the firm and its clients.
[2]The name of the oil company is changed to protect its anonymity.

compared with the observed covariance matrix. Technically, the researcher wants to minimize the difference between the estimated and observed matrices. Confirmatory factor analysis was accomplished using MINITAB 15.0 to validate the relationships among observed and latent variables. The factors were rotated using Vari-Max rotation to maximize the variance of the squared loadings for each factor and to produce the clear factor loadings. The results are shown in Table 7.

The loading factors in Table 7 represent the correlations between the common factor and the associated observed variables. One of the parameters is assumed to be equal to unity in each category and others have been estimated using the maximum likelihood estimation (MLE) method. For example, for the sustainability performance (SP) factor as a latent variable, the observed variables are economic portfolio (Y_1), social portfolio (Y_2), and environmental portfolio (Y_3). The associated parameter of Y_3 has been assumed to be fixed and the correlations between economic portfolio (Y_1), and social portfolio (Y_2) and sustainability performance have been calculated using MLE method as 0.97 and 0.93, respectively. Therefore, these observed variables can properly describe the associated latent variable sustainability performance. Similar interpretations can be represented for the other parts of Table 7.

The reliability of the research instrument was tested with Cronbach's alpha. If Cronbach's alpha for some subsets falls below 0.7, normally the decision is to delete the relevant question in the subset in order to increase Cronbach's alpha above 0.7. The results showed that every factor had more than 0.70 as shown in Table 7. This confirmed the reliability of the relationships among all of the observed variables and the latent variables (Cronbach, 1951).

Model Identification and Test of Hypotheses

We have used path analysis in this section. Path analysis is a causal modeling approach used to explore the correlations within a defined network. Historically it is an approach that is more often used as a confirmatory (hypothesis testing) method than an exploratory (descriptive or model searching) method, more model-driven than data-driven, and more "causal" than correlative. The hypothetical model in path analysis usually involves two kinds of variables: observable/manifest (endogenous) variables and latent (exogenous or non-observable) variables. Observable variables serve as indicators of the underlying construct, and latent variables are usually theoretical constructs that cannot be observed directly. There are two goals of path analysis: (1) understanding patterns of correlations among the regions and (2) explaining as much of the regional variation as possible with the model specified. Different from statistical testing in other techniques (e.g., multiple regression and ANOVA), the focus in path analysis is usually on a decision about the whole model: reject, modify, or accept it.

The structural equation model was established based on the covariance matrix. A well-known approach for calculating the covariance in structural equation modeling is maximum likelihood estimation (MLE) (Hair et al., 2006). LISREL was used to analyze the level and the value of the causal relationship among the variables (Jöreskog & Sörbom, 2001). Table 8 represents the results of path analysis for latent variables. Figure 5 presents the results of the structural equation modeling analysis and the associated load factors.

Path coefficients are not correlation coefficients. Suppose we have a network with a path connecting from latent variable A to latent variable B. The meaning of the path coefficient theta (e.g., 0.81) is as follows: if the latent variable A increases by one standard deviation from its mean, the latent variable B is expected to increase by 0.81 its own standard deviation from its own mean while holding all other relevant latent variables connections constant. With a path coefficient of –0.16, when latent variable A increases by one standard deviation from its mean, latent variable B is expected to decrease by 0.16 its own standard deviation from its own mean while holding all other relevant latent variable connections constant.

Fitness of the Model and Modification

Column (a) in Table 9 presents the goodness of fit measures for the primary structural equation model.

Absolute Fit Indices

The absolute fit indices determine how well a priori model fits the sample data (Jöreskog & Sörbom, 2001) and demonstrate which proposed model has the most superior fit. These measures provide the most fundamental indication of how well the proposed theory fits

Path (Latent-Latent)	Hypothesis	Point Estimation	P-Value	Hypothesis (P-Value < 0.05)
SLP → SP	H_1	0.78	0.043	☑
SLP → PIP	H_2	0.13	0.172	☒
IP → PIP	H_3	0.91	0.00	☑
PSP → IP	H_4	0.61	0.034	☑
PIP → OFP	H_5	0.69	0.045	☑
SLP → OFP	H_6	0.72	0.012	☑
PSP → OFP	H_7	0.89	0.011	☑
IP → OFP	H_8	0.84	0.00	☑

Table 8: The hypothesis testing results.

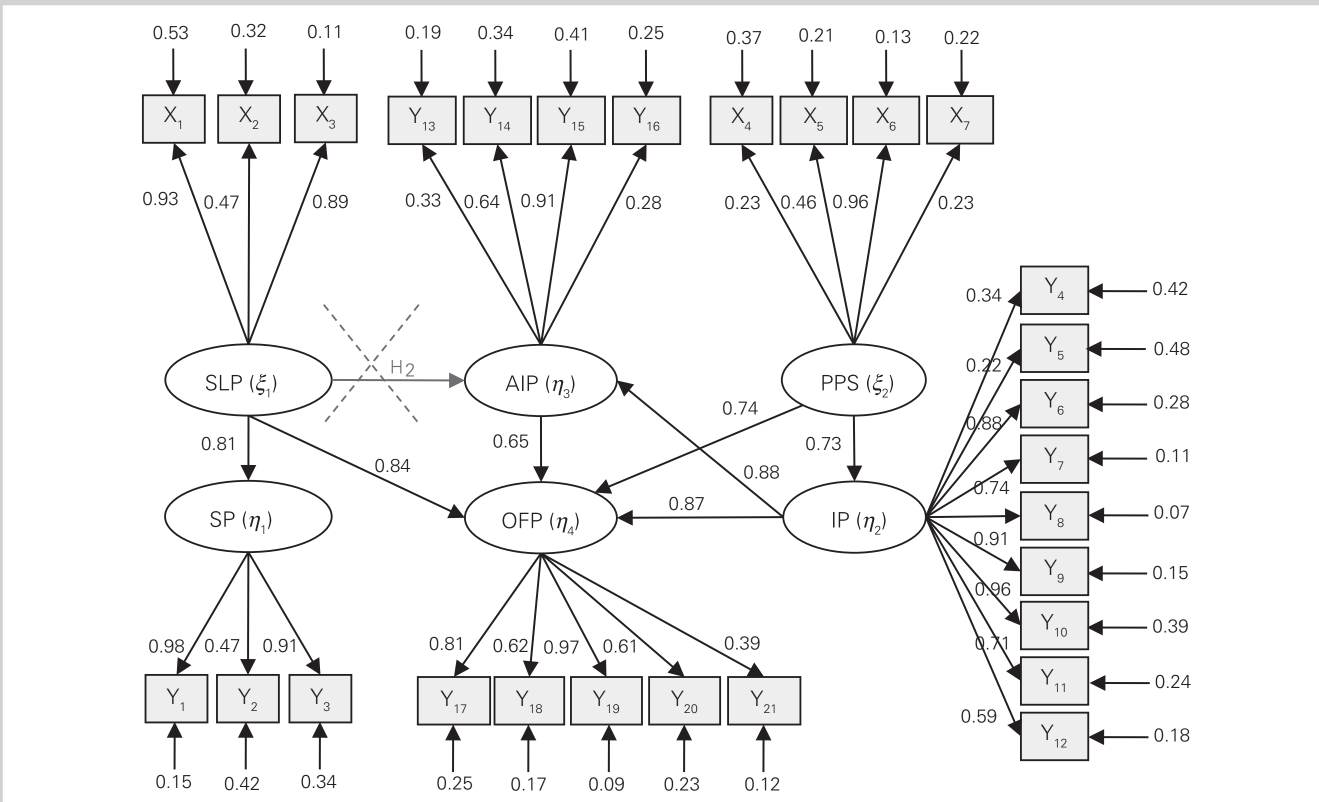

Figure 5: The revised structural equation model.

Measurement	Acceptable Region	(a) Primary SEM	(b) Revised SEM	(c) Final SEM
χ^2/df	From 1 to 2	10.327	2.138	1.37
GFI	0 (No fit) to 1 (Perfect fit)	0.593	0.802	0.937
CFI	0 (No fit) to 1 (Perfect fit)	0.631	0.834	0.941
RMSEA	< 0.1	0.279	0.097	0.049
NFI	0 (No fit) to 1 (Perfect fit)	0.617	0.897	0.963

Table 9: The goodness of fit measurements for the primary, revised, and final structural equation models (SEMs).

the data. Unlike incremental fit indices, their calculation does not rely on comparison with a baseline model but is instead a measure of how well the model fits in comparison with no model at all (Jöreskog & Sörbom, 2001). Included in this category are the chi-squared test, root mean square error of approximation (RMSEA), incremental fit indices (IFI), normed-fit index (NFI), and comparative fit index (CFI).

Chi-Squared test (χ^2)

The chi-square value is a traditional measure for evaluating the overall model fit and for assessing the magnitude of discrepancy between the sample and fitted covariance matrices. A good model fit would provide an insignificant result at a 0.05 threshold; thus, the chi-square statistic is often referred to as either a 'badness of fit' or a 'lack of fit' measure.

Root Mean Square Error of Approximation (RMSEA)

The RMSEA is the second fit statistic reported in the LISREL. The RMSEA shows how well the model, with unknown but optimally chosen parameter estimates, would fit the population's covariance matrix. In recent years it has become one of the most informative fit indices due to its sensitivity to the number of estimated parameters in the model. In other words, the RMSEA favors parsimony in that it will choose the model with the lesser number of parameters. A RMSEA in the range of 0.05 to 0.10 is considered an indication of fair fit and values above 0.10 indicate poor fit.

Incremental Fit Indices (IFI)

Incremental fit indices, also known as comparative or relative fit indices (Jöreskog & Sörbom, 2001), are a group

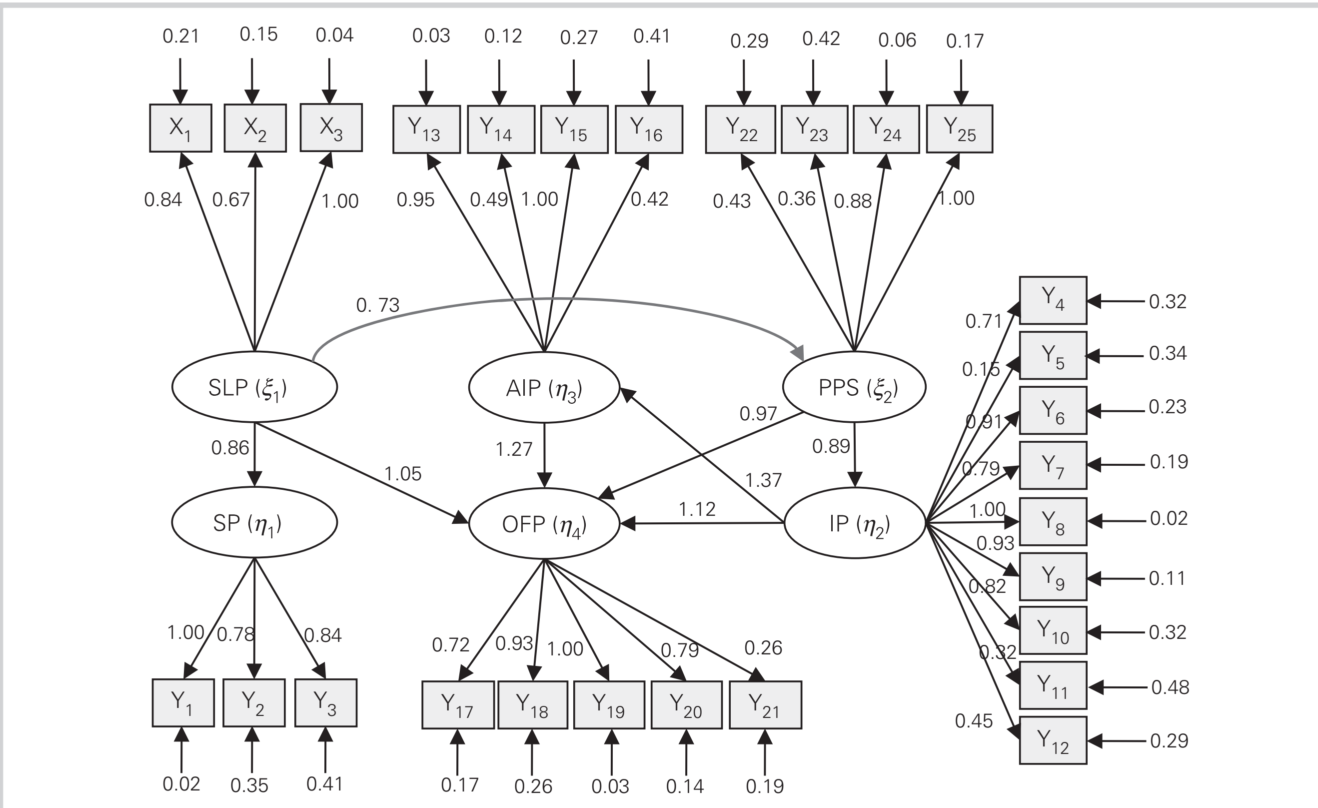

Figure 6: The final structural equation model.

of indices that do not use the chi-square in its raw form but compare the chi-square value with a baseline model. For these models, the null hypothesis is that all variables are uncorrelated.

Normed-Fit Index (NFI)

The first of these indices to appear in LISREL output is the normed-fit index (NFI). This statistic assesses the model by comparing the χ^2 value of the model with the χ^2 of the null model. The null/independence model is the worst-case scenario because it specifies that all measured variables are uncorrelated. Values for this statistic range between 0 and 1, and values greater than 0.90 indicate a good fit. More recent suggestions state that the cut-off criteria should be NFI $\geq$ 0.95.

Comparative Fit Index (CFI)

The comparative fit index (CFI) is a revised form of the NFI, which takes into account sample size that performs well even when the sample size is small (Jöreskog & Sörbom, 2001). Like the NFI, this statistic assumes that all latent variables are uncorrelated (null/independence model) and compares the sample covariance matrix with this null model. As with the NFI, values for this statistic range between 0.0 and 1.0, with values closer to 1.0 indicating a good fit.

It is clear that the ratios report low fitness; hence, a hypothetical model was revised to achieve a model with a proper level of fitness. By deleting the path of the second hypothesis, which has a low causal relationship, we obtain a revised structural equation model with a better level of fitness. The associated fitness measurements for the revised structural equation model are summarized in column (b) of Table 9. We continued the modification process by adding a new causal relationship. The final results are reported in column (c) of Table 9 and Figure 6.

Column (a) in Table 9 shows that the primary hypothesis is not fully supported by the structural equation model. Additional confirmatory factor analysis reveals that hypothesis 2 is not supported by the model because its loading factor is less than the acceptable threshold.

Hypothesis 2 indicates that the strategic level performance (SLP) has a direct effect on the post-implementation performance (PIP). Although, we cannot assume that SLP and PIP are completely independent, the effect of SLP on PIP is so small, implying that dependence cannot be accepted and generalized. On the other hand, the collected data in our case do not support this hypothesis. The accuracy of SLP seems to be measured in terms of the accuracy of PIP. Therefore, if the strategic goals are accurately defined, the project portfolio selection is properly accomplished based on these strategic goals, and if the projects are implemented properly (i.e., on time, on budget, and on quality), the PIP should improve. In other words, a high value for SLP does not result in a proper PIP. The portfolio selection phase has a central role. If the strategic goals are defined properly and accurately, but the portfolio selection module is not implemented properly, the organization is misled and the final targets (i.e., sustainable development) are not achieved. In summary, the relationship between SLP and PIP is not a direct relationship but a type 2 relationship with an intermediary part called PPS.

Therefore, hypothesis 2 is diminished and the confirmatory factor analysis is repeated. Column (b) in Table 9 shows the results for the revised structural equation model analysis after diminishing the second hypothesis. As shown in Column (b) in Table 9, although the fitness measurements are improved, the minimum requirement is not met yet. There are two potential possibilities for reaching the proper fitness measurement in the model. The first proposal is to establish a hidden relationship between the existing structural factors in the model. The second proposal is to introduce a new structural factor to the model and establish its relationships to the existing factors in the model through exploratory factor analysis (EFA). The first proposal is concerned with the effect of strategic level performance (SLP) on portfolio performance selection (PPS) as shown in Figure 6. The CFA is re-implemented for the new structure shown in Figure 6. Column (c) in Table 9 shows that the fitness measurements are improved and the minimum requirement is met (the chi-square with the appropriate degree of freedom is equal to 1.37, both the GFI and CFT indices are larger than 0.9; the RMSEA index, which reports the overall error in the model is equal to 0.049, and the NFI index is equal to 0.963). As shown here, all the fitness indices are satisfactory and there is no need to check the second possibility for improvement.

Conclusions and Future Research Directions

Selecting the optimal projects in a competitive environment can be crucial in sustaining corporate competitiveness. The PSP (project selection problem) is a complex and knowledge intensive process, used in many organizations to make informed investment decisions. In most real-life situations, these informed investment decisions must be made in the presence of multiple objectives that are often conflicting. In this paper, a strategic framework was developed for project portfolio selection, implementation, and evaluation. A survey was used for the analysis of the cognitive relationships among project selection criteria, and a comprehensive framework was proposed for the strategic and sustainable project portfolio selection.

The proposed framework consisted of two modules. The first module involved strategic planning and comprehensive portfolio management. The strategic planning included strategic level, sustainability analysis, and strategic programming. In the strategic level, the mission, vision, and goals of the organization were defined. Sustainability analysis was also considered in this module. A balance of economic, social, and environmental factors was considered in the sustainability analysis. The strategic planning process involved internal and external analyses and a set of strategies was introduced to support the strategic goals of the organization. Finally, a set of potential projects was selected, which supported the strategic level and sustainability criteria.

In the second module, a portfolio analysis model was used to assess the potential projects selected in the first module. The financial, semi-financial, and non-financial considerations were integral parts of the portfolio analysis model. A set of projects, which supported portfolio analysis criteria, as well as the sustainability and strategic theme of the organization were selected. A structural equation model was used to measure the importance and effects of each module on the overall performance of the proposed framework. An application study in the investment banking industry with six latent variables and 28 observed variables were considered in the structural equation model analysis. Several hypotheses were proposed between the latent variables in a construction model. The hypotheses were tested using data collected from a large number of investment bankers. After revising the hypothetical model, the final structural equation model discovered the effects of the performance of the factors on the overall performance of the proposed framework.

The proposed framework integrates several pillars of an organization, including long-term macro and short-term micro level analyses and can be used to handle a wide range of management and engineering applications. A comparative study between the sustainable project portfolio selection approach proposed in this study and the competing methods in the literature is also another potential future research direction.

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References

Ahn, M. J., Zwikael, O., & Bednarek, R. (2010). Technological invention to product innovation: A project management approach. *International Journal of Project Management*, *28*, 559–568.

Byrne, B. M. (2001). *Structural equation modeling with AMOS: Basic concepts, applications, and programming*. Mahwah, NJ: Lawrence Erlbaum.

Cao, M., & Zhang, Q. (2010). Supply chain collaborative advantage: A firm's perspective. *International Journal of Production Economics*, *128*(1), 358–367.

Castillo, H., & Pitfield, D. E. (2010). A methodological framework for identifying and selecting sustainable transport indicators. *Transportation Research Part D*, *15*, 179–188.

Cho, K. M., Hong, T. H., & Hyun, Ch. T. (2009). Effect of project characteristics on project performance in construction projects based on structural equation model. *Expert Systems with Applications*, *36*(7), 10461–10470.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika, 16,* 297–334.

Danese, P., & Kalchschmidt, M. (2011). The impact of forecasting on companies' performance: Analysis in a multivariate setting. *International Journal of Production Economics*, *133* (1), 458–469.

Dey, P. K. (2006). Integrated project evaluation and selection using multiple-attribute decision-making technique. *International Journal Production Economics*, *103*(1), 90–103.

Doloi, H., Iyer, K. C., & Sawhney, A. (2011). Structural equation model for assessing impacts of contractor's performance on project success. *International Journal of Project Management*, *29*(6), 687–695.

Eriksson, P. E., & Westerberg, M. (2011). Effects of cooperative procurement procedures on construction project performance: A conceptual framework. *International Journal of Project Management*, *29*(2), 197–208.

Golini, R., & Kalchschmidt, M. (2011). Moderating the impact of global sourcing on inventories through supply chain management. *International Journal of Production Economics*, *133*(1), 86–94.

Graves, S. B., & Ringuest, J. L. (2003). *Models and methods for project selection: Concepts from management science, finance and information technology.* Dordrecht, The Netherlands: Kluwer Academic Publishers.

Hahn, T., Figge, F., Pinkse, J., & Preuss, L. (2010). Trade-offs in corporate sustainability: You can't have your cake and eat it. *Business Strategy and the Environment*, *19*(4), 217–229.

Hair, J. F., Anderson, R. E., Tatham, R. L., & Black W. C. (1998). *Multivariate data analysis* (5th ed.). Upper Saddle River, NJ: Prentice Hall.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2006). *Multivariate data analysis* (6th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Han, J., Trienekens, J. H., & Omta, S.W.F. (2011). Relationship and quality management in the Chinese pork supply chain. *International Journal of Production Economics*, *134*(2), 312–321.

Howell, D., Windahl, Ch., & Seidel, R. (2010). A project contingency framework based on uncertainty and its consequences. *International Journal of Project Management*, *28*, 256–264.

Iamratanakul, S., Patanakul, P., & Milosevic, D. (2008). *Project portfolio selection: From past to present.* In Proceedings of the 4th IEEE International Conference on Management of Innovation and Technology (pp. 287–292).

Jöreskog, K., & Sörbom, D. (2001). *LISREL 8: User's reference guide*. Lincolnwood, IL: SSI Scientific Software International, Inc.

Joumard, R., & Nicolas, J. -P. (2010). Transport project assessment methodology within the framework of sustainable development. *Ecological Indicators*, *10*, 136–142.

Khalili-Damghani, K., Sadi-Nezhad, S., & Aryanezhad, M. B. (2011). A modular decision support system for optimum investment selection in presence of uncertainty: Combination of fuzzy mathematical programming and fuzzy rule based system. *Expert Systems with Applications*, *38*(1), 824–834.

Kim, D. Y., Han, S. H., Kim, H., & Park H. (2009). Structuring the prediction model of project performance for international construction projects: A comparative analysis. *Expert Systems with Applications*, *36*(2), 1961–1971.

Kölbl, R., Niegl, M., & Knoflacher, H. (2008). A strategic planning methodology. *Transport Policy*, *15*, 273–282.

Labuschagne, C., & Brent, A. C. (2005). Sustainable project life cycle management: The need to integrate life cycles in the manufacturing sector. *International Journal of Project Management*, *23*(2), 159–168.

Liu, Ch., Zhang, K., & Zhang, J. (2010). Sustainable utilization of regional water resources: Experiences from the Hai Hua ecological industry pilot zone (HHEIPZ) project in China. *Journal of Cleaner Production*, *18*, 447–453.

Mebratu, D. (1998). Sustainability and sustainable development: Historical and conceptual review. *Environmental Impact Assessment Review*, *18*(6), 493–520.

Morris, P., & Jamieson, A. (2004). *Translating corporate strategy into project strategy: Realizing corporate strategy through project management.* Newtown Square, PA: Project Management Institute.

Nachmias, C. F., & Nachmias, D. (2008). *Research methods in the social sciences* (7th ed.). New York, NY: Worth.

Nusair, Kh., & Hua, N. (2010). Comparative assessment of structural equation modeling and multiple regression research methodologies: E-commerce context. *Tourism Management*, *31*, 314–324.

Punniyamoorthy, M., Mathiyalagan, P., & Parthiban, P. (2011). A strategic model using structural equation modeling and fuzzy logic in supplier selection. *Expert Systems with Application*, *38*(1), 458–474.

Ramanathan, U., & Muyldermans, L. (2010). Identifying demand factors for promotional planning and forecasting: A case of a soft drink company in the UK. *International Journal of Production Economics*, *128*(2), 538–545.

Ray, S., Song, Y., & Verma, M. (2010). Comparison of two periodic review models for stochastic and price-sensitive demand environment. *International Journal of Production Economics*, *128*(1), 209–222.

Robèrt, K.-H., Schmidt-Bleek, B., Aloisi de Larderel, J., Basile, G., Jansen, J. L., Kuehr, R., Price Thomas, P., … Wackernagel, M. (2002). Strategic sustainable development: Selection, design and synergies of applied tools. *Journal of Cleaner Production*, *10*, 197–214.

Sen, C. G., Baraçlı, H., Sen, S., & Baslıgil, H. (2009). An integrated decision support system dealing with qualitative and quantitative objectives for enterprise software selection. *Expert Systems with Applications*, *36*, 5272–5283.

Shehu, Z., & Akintoye, A. (2010). Major challenges to the successful implementation and practice of programme management in the construction environment: A critical analysis. *International Journal of Project Management*, *28*, 26–39.

Shen, L.-y., Tam, V.W.Y., Tam, L., & Ji, Y.-b. (2010). Project feasibility study: The key to successful implementation of sustainable and socially responsible construction management practice. *Journal of Cleaner Production*, *18*, 254–259.

Su, Y.-f., Yang, Ch. (2010). A structural equation model for analyzing the impact of ERP on SCM. *Expert Systems with Applications*, *37*, 456–469.

United Nations World Commission on Environment and Development (1987). *Report of the World Commission on Environment and Development: Our common future*. Retrieved from http://www.un-documents.net/our-common-future.pdf

Williams, T., Klakegg, O. J., Magnussen, O. M., & Glasspool, H. (2010). An investigation of governance frameworks for public projects in Norway and the UK. *International Journal of Project Management*, *28*, 40–50.

Wong, J. M.W., Ng, S. T., & Chan, A.P.C. (2010). Strategic planning for the sustainable development of the construction industry in Hong Kong. *Habitat International*, *34*, 256–263.

World Commission on Environment and Development (1987). *Our common future*. Oxford, England: Oxford University Press.

Yazan, D. M., Garavelli, A. C., Petruzzelli, A. M., & Albino, V. (2011). The effect of spatial variables on the economic and environmental performance of bioenergy production chains. *International Journal of Production Economics*, *131*(1), 224–233.

Yee, R.W.Y., Yeung, A.C.L., & Cheng, T.C.E. (2010). An empirical study of employee loyalty, service quality and firm performance in the service industry. *International Journal of Production Economics*, *124*, 109–120.

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