WJSTSD 13,3

174

A decision matrix approach to green project management processes

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Abstract

Purpose – The purpose of this paper is to develop a decision matrix for green project management processes (GPMPs) in commercial construction projects. GPMPs can assist in decoding all of the information required to make green-conscious decisions at various stages of a project.

Design/methodology/approach – Integrate the environmental factors into the traditional project management processes (PMPs) of major construction projects. The integrated product is worked into a process index, and the analytical hierarchy processes (AHP) method is used to prioritize the GPMPs according to pre-set criteria.

Findings – Research established the theoretical backing of green practices integration in the traditional PMPs, by creating an AHP weighted GPMP index that is linked to usable decision matrix. **Originality/value** – Develops a fresh methodology to facilitate green decision-making in the project management of commercial construction projects.

Keywords Environmental management, Analytical hierarchy processes, Decision matrix, Green indicators, Green project management processes, Project management process **Paper type** Research paper

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Introduction

Earth has limited resources that one day will be depleted if we continue to consume as rapidly as we do now. Therefore, we need to manage our resources and develop sustainable ways of living both to survive and to conserve resources for future generations.

In their 2009 conference paper, Ning *et al.* state that one way to solve this problem is to move toward a sustainable lifestyle such as applying green project management concepts, which is one of the techniques used to ensure a project's sustainability and to facilitate the challenges that face the building of green projects. Meeting the needs of today's civilization without jeopardizing the future needs of the next generation is the primary concept involved in adopting sustainable project management (Ning *et al.*, 2009). His 2010 journal article highlights the fact that environmental impacts, societal factors, and the economy are combined to develop green project management concepts that aim to achieve sustainability and harmony in nature (He, 2010). In their 2003 journal article, Czuchry and Yasin state that when applying green project management processes (GPMPs), managers are required to change their organizational culture by shifting toward open, horizontal communication systems and delegating responsibility to other team members (Czuchry and Yasin, 2003).

Furthermore, there is plenty of distinct research on project management or sustainability, but only a few authors bridge that gap (Tufinio *et al.*, 2013). The objectives of this study were to integrate green aspects into traditional project management



World Journal of Science, Technology and Sustainable Development Vol. 13 No. 3, 2016 pp. 174-180 CEmerald Group Publishing Limited 2012;5945 DOI 10.1108/WISTSD-01-2016-0009 processes (PMPs), to develop a GPMP index based on those integrated processes, to use the analytical hierarchy process (AHP) to prioritize the integrated GPMPs and to create a decision matrix based on the prioritized GPMPs. This work is an annex to the thesis effort by Al-Tekreeti and Beheiry at the American university of Sharjah in 2015.

Literature review

PMPs

Uppal (2004) states that PMPs are a series of actions or functions that must be executed to fulfill project objectives. To do so, one must continuously perform a sequence of systematic methods to execute and evaluate the project. Effective implementation of PMPs is the key factor for enhancing project efficiency, and by extension, the project successes rate will increase (Robert and Ralf, 2015). Hamilton indicates in his 1997 book that innovative thinking, technology, and problem-solving tools can be facilitated through PMPs (Hamilton, 1997). In their 2002 book, Lientz and Rea state that the following project elements should be included in an integrated project management process: the company strategy, the establishment of the project, project review, obtaining approval from the client and the regulatory institution, managing organizational resources, making decisions based on the project's progress, integrating the project with other work, and measuring the success or failure of the project.

Green management techniques and GPMPs

Tam *et al.* (2004) state that green construction assessment (GCA) provides the tools to continuously improve the construction process and to quantify environmental fulfillment. GCA will be based on what the client wants to measure, not what the assessment tools measure. Therefore, a pilot study will be conducted to identify the assessment criteria that concern green developers. To develop suitable weighting indicators for the complex, uncorrelated green assessment criteria involved in GCA, a scientific method should be used.

Korkmaz *et al.* in their 2010 report stated that the integration level in process delivery affect the outcomes of the project especially the sustainability goals. Project delivery attributes such as contract conditions, owner's commitment, and delivery process integration have an influence on the project outcomes. The report utilized case studies and methods of qualitative analysis to show that higher levels of design process integration will lead to a higher sustainability awareness level. Moreover, the report indicates that early immersion of the green strategies in the project design is a key factor in fulfilling the sustainability project outcomes.

Likewise, in their 2014 article, Tsai *et al.* specified that managing carbon emission from green building projects is a challenging problem that prompted their creation of the combined life cycle assessment and activity-based cost approach to develop an integrated model that assists the managers in pre-construction decision making on environmentally friendly construction projects bidding. This model helped construction companies to understand resources allocation and identify energy saving activities for each green building project through cost drivers.

The multiple criteria decision-making model helps to improve project environmental sustainability by selecting the suitable construction method and combines the decision-making trial and evaluation laboratory (DEMATEL), analytic network process (ANP) and zero-one goal programming (ZOGP) methods for evaluation process for each green project to obtain the optimal environmental sustainability level. DEMATEL

WJSTSD 13,3 visualizes the effects of different project perspectives and the relationship among different project teams. ANP calculates the priority of each project in the decision-making model. Finally, ZOGP selects the best construction method for the project (Tsai *et al.*, 2013).

Green project management is a relatively new field. Therefore, few research papers have addressed GPMPs. However, the increasing demand for green projects will prompt new research. Introducing green-thinking concepts in PMPs is the first step toward green projects, which is taken when we make decisions that consider environmental impact (Krasnoff, 2010). A deep understanding of the various project life cycles helps in addressing sustainability issues in project management (Marisa, 2015). Project managers have an essential role by integrating sustainable design and technology concepts into the construction project processes (Nannan *et al.*, 2014). The main purpose of green project management is not to convert every project-related decision to one that is environmentally friendly but instead to account for the environmental aspect when making decisions.

AHP

Complex problems require special multi-criteria decision-making techniques. One of these techniques is the AHP that handles both the complexity and uncertainty in decision making (Praveen *et al.*, 2015). AHP was developed by Saaty. The primary purpose of this analysis is to quantify a set of alternatives using a ratio scale approach according to the decision-maker's criteria. A decision-maker is judged on the alternatives depending on his knowledge and experience. Saaty states that an AHP analysis develops a framework for decision-making that arrives at effective decisions to resolve complex problems. The AHP method has the ability not only to convert decision-making processes into a systematic structure but also to synthesize those processes into mutually interacting parts by quantifying their impact on the ranking of those parts (Saaty, 2008). Accordingly, AHP analysis is the most relevant method to be used in this study.

Practical application for AHP. In their 2008 article, Wong and Li detailed that one of the applications for AHP analysis is the selection of intelligent systems for sustainable buildings. This should improve the performance of the buildings and reduce the energy and water waste. To define the criteria that provided the guidelines for planning the improvement for design, experts and professionals in the field of intelligent building (IB) technology were asked to fill out a questionnaire to identify the suitable and most effective criteria. Then, all the criteria were categorized and organized by using Saaty's consistency test to reach a suitable decision for the intelligent building systems selection through AHP matrix.

AHP analysis can be a powerful tool to integrate environmental factors for purchasing decisions and a helpful tool for managers to recognize the trade-offs among the environmental dimensions as well as to evaluate the performance of suppliers with different environmental traits. The AHP framework employs a variety of criteria for supplier environmental performance such as: public disclosure of environmental records, hazardous waste management, environmentally friendly product packaging and hazardous air emissions management environmental record to include in suppliers evaluation process. This framework does not only solve the problems due to the difference in the environmental criteria, but also integrates the environmental criteria with the decision-making process and addresses the environmental issues in this process (Handfield *et al.*, 2002). On the other hand, an AHP analysis is used to identify consumer rankings and specify the weights of green building categories rating systems such as leadership in energy and environmental design (LEED). The most important green building aspects which are cherished by consumers are highlighted, in order to develop effective marketing strategies (Attaran and Celik, 2013).

How AHP works. Before beginning to use this method, managers must collect all of the project-related information in as much detail as possible. Next, this information needs to be constructed into a hierarchy. For example, the objective for the project should be placed at the highest level of the hierarchy. The following level is composed of a set of criteria for evaluating the project's objective. The level after that is composed of a series of alternatives that have either negative or positive impacts on the project's objective. After the hierarchy is constructed, the managers' judgment is used to quantify the criteria by assigning a number from 1 to 9 to each criterion to highlight the important elements in the hierarchy. These judgments must be made by experts in the project field with the appropriate knowledge to facilitate the ranking process.

The priorities process in AHP. To solve the problems that may arise by applying the AHP analysis, a specific outline must be constructed. First, the problem and its desired solution must be identified. Second, a hierarchy must be constructed to solve any complicated problems; the brain usually tends to decompose problems into clusters, which are divided into small parts that share the same characteristics in the hierarchy. Third, priorities should be established by developing a pair-wise comparison matrix to compare two similar parts using specific criteria. To ensure the use of excellent judgment in the priority-setting process, everybody involved in the process must have a clear understanding of the project so that they can make the most effective decisions during the project's life cycle. The result of each weighted element should be collected and the most heavily weighted result should be selected. Next, the consistency of the judgment for each element should be tested; either the criteria are grouped in one coherent part that shares the same objective or they are grouped as inconsistent parts that have no relationship to one another. To estimate the consistency test for the entire hierarchy, each criterion is multiplied using a consistency index. Then, the products are added. To find the consistency index, the eigenvector λ max must be identified for each weighted criteria; next, the consistency index is calculated using the following equation:

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

where n represents the number of alternatives in the pair-wise comparison matrix.

Furthermore, Saaty states that to define the consistency ratio, the equation CR = CI/RI will be applied, where RI represents a random index that can be obtained by knowing the number of alternatives and matching that number with the corresponding random index (Saaty, 2008). Table I shows the RI for the consistency ratio (Saaty, 2008).

According to Saaty, if the consistency ratio is higher than 0.1, the test fails to find a consistency among the weighted criteria; otherwise, the ratio will be in the accepted zone.

Matrix size	1	2	3	4	5	6	7	8	9	Table I.
Consistency Source: Saaty (2	0 2008)	0	0.52	0.89	1.11	1.25	1.35	1.4	1.45	Average consistency with respect to matrix size

WISTSD What a decision matrix is?

A decision matrix is another tool used to facilitate the process of decision making. It has been applied broadly in various industrial areas. The primary purpose of this method is to ensure the contribution of all of the relative aspects related to the decision process and to arrange them into a matrix. A decision matrix will provide a clear understanding of all of the factors related to the decision to help the decision maker arrive at a suitable decision. Developing indexes that cover a wide range of project-related issues is essential for the effective implementation of the decision matrix, to support decision-making process and provide early warning signals to managers (Olli *et al.*, 2014).

How a decision matrix works in practical application?

In their 2000 journal article, Colwell *et al.* state that a decision matrix can be used as tool to assist a company in the process of selecting a vendor. The primary purposes of this matrix are to quantify a criteria weighting and to identify potential vendors by measuring successful key criteria for each of them (Colwell *et al.*, 2000).

In his 1995 journal article, Nicholls states that a decision matrix is used to manage a company scarce resources not only by determining the company strategic decisions and but also by arranging an organization portfolio for the selected project. A mission and core competences decision matrix is developed to support the core competences of the organization, to reallocate resources to the organization's activities, and to fulfill the company mission (Nicholls, 1995).

Research methodology

The novel research methodology facilitates green decision making in commercial building projects by creating a process index with a parallel algorithm and user-based decision matrix. The following steps highlight the research methodology: first, green indicators are comprehensively integrated into the traditional PMP; second, a GPMP index is created that is specially designed for commercial buildings; third, AHP and an expert panel are used to validate the Index algorithm; and fourth, a decision matrix is conceived for use by major project teams in assessing the degree to which green concepts are integrated into their PMPs.

The study integrates green factors into traditional PMPs to identify GPMPs and uses the AHP to discern green processes' priority according to feedback from an expert panel. The panel includes a committee of five members. Two members are academic experts and three members are from industry. The experts prioritize green processes based on specific, pre-set criteria by using pair-wise comparisons. The process' costs, risks and benefits to the project are the criteria used, to compare the green processes, in the AHP analysis. The AHP-driven processes' prioritization will be used to specify the weights in the decision matrix, which includes a process index that helps managers specify green processes. These indices must be rated by project teams according to project information. Green matrices translate into project percentile achievement that helps top managers identify the level of green concept integration in commercial building projects.

Integration of green indicators into traditional PMPs

The impact of the construction industry on the environment will vary according to its size, activities, people involved, and waste generated; therefore, it will be considered in this study due to its significant impact on the environment. In addition, the process

178

13.3

related to commercial construction projects will be considered (Khalfan, 2006). In his 2010 article, Kubba states that incorporating sustainable activities into traditional activities requires construction processes to be redefined and redesigned to ensure the effective adaptation of those practices into project objectives (Kubba, 2010). For the purposes of this study, green aspects were integrated into traditional PMPs and the result is shown below.

The first process of the initiation phase is the environmental impact assessment study (EIA-S). In their 2012 book, Jain *et al.* indicate that this process helps managers determine the environmental consequences for the entire project (Jain *et al.*, 2012). Those impacts may have either a positive or a negative impact on the environment. Assessments can be included in the environmental concerns section (El-Halwagi *et al.*, 2009). The second process is known as green stakeholder interest (GSI). In that process, stakeholders knowledge about green practices and their environmental impact must be identified; moreover, their tolerance of the risks of green projects must be specified. The third process is known as green organizational thinking (GOT), which is performed to enable the organization to cope with the green project's dynamic requirements and to prepare the organization to handle multi-dimensional criteria for the environmental factors.

The planning phase involves three processes. The first process is known as environmental impact assessment deliverables and activities (EIA-D), which involves defining the project's scope, activities that have a significant environmental impact, and the project environmental risks (Al-Tekreeti, 2015). Moreover, relevant activities should be specified. The second process is known as green integration (GI) across engineering sectors. That process requires cross-functioning between all of the engineering sectors (e.g. architectural, electrical, mechanical and civil engineers) to be included in the project plan to provide both a clear understanding of the project's green factors and guidelines for those factors. The third process is known as green project definition. During this process, all of the project specifications must be defined. In addition, all of the parties involved in the project must be identified, and the main guidelines for those specifications will be evaluated based on green factors.

The detail engineering design phase consists of the following processes. The first process is known as green design strategies (GDS). There are several strategies that help reduce the environmental and resource impact of building projects such as using less to achieve more by addressing effective design solutions to solve numerous needs using few elements. The second process is known as the green design code (GDC). In that process, the codes used must be specified, together with whether those codes are pursuing green certifications (such as LEED) or traditional ones. The third process is known as green design monitoring (GDM). In that process, both the stakeholder and the designer are required to schedule design review meetings. The main purpose of those meetings is to ensure that the project design meets the stakeholder's specifications and expectations.

The execution phase contains the following three processes. The first process is known as quality control (QC) assessment, which is conducted to establish green standards for procurements and the execution of project activities (Eccleston, 2000). The primary QC concept is to inspect the work to ensure that it meets quality standards. The second process is known as green construction management and coordination (GCMC). The primary idea of green construction management is to minimize project activities negative environmental impacts, such as noise pollution, water pollution, and waste pollution. The third process is known as resource

management on a green basis, which is performed to track the consumption of an organization resources during project execution in terms of environmental considerations such as waste management and demographic management, including urban, environmental and public health and safety (Glasson *et al.*, 1999).

The commissioning phase includes three processes that are responsible for ensuring that a building facility performs in accordance with its design documentation. The first process is known as energy management systems (EMS), which include all of the commissioning processes that control the usage and cost of the building energy, in addition, improvement opportunities for the project facilities must be identified, and effective upgrades must be implemented (Al-Tekreeti, 2015). The second process is known as system synergy; in it, a building facilities are functionally interrelated and their operations are integrated. All of the systems in the project must test at full capacity, and the system is subject to maximum overload to identify any faults that could lead to system failure and project shutdown because of the interrelation among the project's systems. The third process is known as guidelines for green commissioning. These guidelines aim to create a checklist for an environmental evaluation of the commissions for the building facilities.

The decommissioning phase includes all of the processes that can be performed during project shutdown. The first process is known as the recycling plan (RP), which pertains to how to reuse project materials after the shutdown process is complete. The company must prepare an effective RP to obtain the maximum benefit from the project resources. The second process is known as the environmental remedy. A project has two negative environmental impacts, one temporary and the other permanent. A project's temporary negative environmental impacts – for example, groundwater pollution, air pollution, and land use - must be reversed. However, treating a project permanent impacts will be difficult because to do so requires both more time and an additional budget. Examples include the Chernobyl reactor crisis, which caused severe environmental damage; the company involved in that incident is still spending money to reduce the damage (Kubba, 2010). The third process is known is managing hazardous materials (MHM). Some projects (e.g. nuclear reactors) will use hazardous materials that cannot be used again or recycled and that must be properly disposed of because if they are kept, they will damage the environment and contaminate the air and water. Therefore, companies must plan for those materials and reserve the budget necessary to dispose of them.

Result and discussion

The GPMP index

The index used to feed into the matrix will guide the manager through the green management process and help him/her to identify the most suitable processes for the project. The matrix index will raise the following questions, which must be answered. Those questions are as follows: what are those processes, why does the manager need those processes, and how can those processes be implemented. Following is the rating process index: (0) if the process is not applicable to the project; (1) if the manager has an initial idea about the process; (2) if the manager possesses some knowledge about the green process requirement; (3) if the manager has a reasonable level of knowledge about the required processes; (4) if the manager has a deep understanding of green processes and the actions that must be implemented during the project; and (5) if the manager begins to document actual steps that have been taken to address any concerns about the process and how to complete it. These indexes are treated

13.3

WISTSD

separately in each project phase. Following is a list of the process-specific indexes that address each project phase.

Initiation phase: the EIA-S includes the following indexes: recognition of the environmental consequences of the proposed project, identification of the need for an environmental impact assessment of the proposed project, and an assessment and prediction of the level of air, water, and noise pollution created by the project. The indexes included in the GISprocess include the following: definition of stakeholder concern about the green practices that may be used in the project, recognition of stakeholder tolerance of the risks occasioned by green practices, and identification (to the stakeholders) of both green specifications and green practices. The GOT process involves the following indexes: recognition of the company's green orientation, measurement of the organization's ability to manage the project's multi-dimensional tasks, and the provision of both employee training on green practices and employee incentives to adopt green practices.

Planning phase: the relevant indexes are included in the EIA-D processes. They include the recognition of the direct and indirect environmental consequences of particular activities in advance, the evaluation of the risks of environmental change caused by the proposed activities, and the recommendation of a set of changes to the proposed activities that will mitigate the environmental impact. Additionally, GI across engineering sectors includes the following indexes: the recognition of the collaboration level between cross-functional engineering sectors, the assessment and training of engineers to provide a solid level of understanding about green project factors, and the establishment of multidisciplinary teams to identify all project variables. Moreover, the following indexes are related to the green project definition process: the identification and definition of detailed green project specifications, the evaluation of the project specification's main guidelines related to green factors, and the correlation of environmental policies and governmental regulations to the project plan.

Detail engineering design phase: GDS contain the following indexes: the utilization of the best practices to maximize results in the building design, the evaluation of the strategy costs of green design in relation to its environmental benefits, and the specification of combinations of design strategies (i.e. controlled solar loads that utilize daylight, ventilation and natural cooling). Similarly, the next indexes are associated with the GDC process: the enhancement of building design using a variety of design concepts to reduce negative environmental impact; the improvement of the project's energy efficiency, indoor air quality, and site sustainability; and the revision of and compliance with the project's code requirements. GDM includes the following indexes: the assessment of the project's design progress; the identification of congruence among project design, stakeholder specifications and designer understanding; and the determination of the accuracy of cost estimates and the frequency of meetings between stakeholders and the project designer.

Execution phase: during the QC assessment process, the following indexes are used: the evaluation of the quality of the project execution, the identification and implementation of systematic activities to fulfill quality requirements, and the inspection of the execution of project activities. The indexes included in the GCMC process are as follows: the assessment of manager planning, coordination, and control that will be used to achieve project goals; the determination that the project is within its budget, that it is progressing according to schedule, and that all of its green goals have been satisfied; and the implementation of green management techniques such as lean construction, Monte Carlo, and just-in-time methods together with enhanced communication among the parties to the project. The resources management (RM)

on green basis process includes the following indexes: the efficient utilization of company resources, the measurement of company resource consumption during project execution, and the provision of enough physical resources and the assignment of people to tasks for project execution, and the assurance of the material vendors' commitment to the project delivery plan.

Commissioning phase: the next indexes are related to the EMS process. They include the identification of sets of computer systems that can be used both for energy monitoring and for controlling building systems; the checking, assessment, and testing of both building equipment and building systems to identify their reliability, efficiency, and performance level; and the development of tailored EMS software to control building operation sequences and to provide the owner's staff with proper training to operate the building systems. The systems synergy (SS) process use the following indexes: the integration of two or more systems to improve efficiency, to measure the efficiency of system recovery during power failure simulation and to identify the tolerance energy load for the building systems; the evaluation and testing of the function and operation of the building's hardware, software, and subsystems; and the assessment of end-to-end spotchecks on system integrity to identify any problems. Guidelines for green commissioning includes the following indexes: the definition of the processes that can be used to enhance building systems and by extension, to improve building value for the owner; the specification of the overall system efficiency and fulfillment of the project's environmental goals; and the identification of the number of systems that require commissioning, including specification of the detailed requirements for the commissioning test.

Decommissioning phase: in the RP process, the succeeding indexes are as follows: evaluation of the process of reducing project waste; specification of the efficiency of the RP and measurement of the preservation level for the project materials; and identification of a coordinator for recycling, waste auditing, and the determination of the project materials that will be recycled. The environmental remedy process includes the following indexes: assessment of the remedy for negative environmental impact caused by the project; mitigation of the project's temporary and permanent environmental impacts; and the utilization of remediation technologies such as thermal disruption, drilling, pumping and treating, and bioremediation. The MHM process uses the following indexes: identification of the process of collecting and treating the project's hazardous materials, the provision of health protection for both company employees and the public by effectively MHM, and specification of the legal requirements for storing, treating, transporting, and disposing of those materials.

The AHP analysis

AHP analysis is selected in this study to cope with multi-criteria in the decision-making process. In addition to systematically structuring the process, the AHP approach is able to quantifying the decision process that facilitates the ranking procedure and clearly justifies the decision. After the results from the panel of experts become available, development of the AHP analysis will begin. This process involves three steps:

- (1) Pair-wise comparisons for selected criteria will be developed to prioritize those criteria based on feedback from the experts.
- (2) Pair-wise comparisons for the green processes will be developed to prioritize and weigh those processes according to experts' feedback.

Saaty's nine-level scale will be used to evaluate the criteria and the green processes in both matrices. A vector of priorities will be calculated for each

182

13.3

WISTSD

pair-wise matrix and the sum of those vectors must be equal to 1. The vectors' rating will be from 0 to 1, where 1 represents the desirable alternative according to Saaty's rating system.

(3) A consistency test will be conducted to ensure that the process consistency falls within the accepted zone, which is less than 0.1.

The decision matrix will be developed after the result for the AHP analysis has been obtained. This matrix will represent the GPMPs and helps the project manager evaluate the level of project integration with respect to green concepts. A process index will be provided to facilitate the decision-making process. The AHPdriven processes prioritization will be used to specify the weights in the decision matrix. The primary reason for using a GPMPs matrix is to aggregate all of the information about the weighted processes from the AHP in this matrix together with their criteria.

Expert panel

The expert panel consisted of five members; three members from industry and two from academia. The members were selected due to their experience in the project management and green construction field. The experience panel members ranges from 10 to 20 years. Two industry experts occupy seiner project management position, and the third one is seiner technical engineer with PMP certification. On the other hand, the academic experts are associate professors with long expertise in construction engineering project management, green design and sustainable construction. Direct interviews were the method used to solicit the data from industry experts, and the data from academic experts was collected via email and follow up Skype interviews.

The expert panel analysis

The experts' pair-wise comparison has been analyzed to specify both criteria weighting and the priority of GPMPs. To identify the result for the expert judgment, Expert Choice software manufacturer by Expert Choice Inc. located in Arlington, Virginia, USA, will be used. This software is a powerful tool that can be used to evaluate a set of alternatives based on specific criteria. The Expert Choice results are shown below.

Criteria ranking for overall project: Based on the expert opinion, 80 percent of experts prioritized the "cost of applying green processes" criterion over the other criteria. The degree of risk in these processes was next in the priority ranking. This criteria ranking will be applied to all green process comparisons in all project phases. Figure 1 shows the overall criteria ranking.

Project phase 1 – initiation: in this phase, the processes will be ranked as follows: 67 percent of field experts prefer the GOT process to other processes. That notwithstanding, all of the academic experts designated the EIA-S to be the



Figure 1. Overall criteria priority

highest-ranking process. In total, 80 percent of the experts chose the GSI process to be second in the priority ranking. However, GSI holds the highest ranking when the experts' judgments are combined, thus relegating EIA-S to second place. Figure 2 shows the priority ranking for the initiation processes.

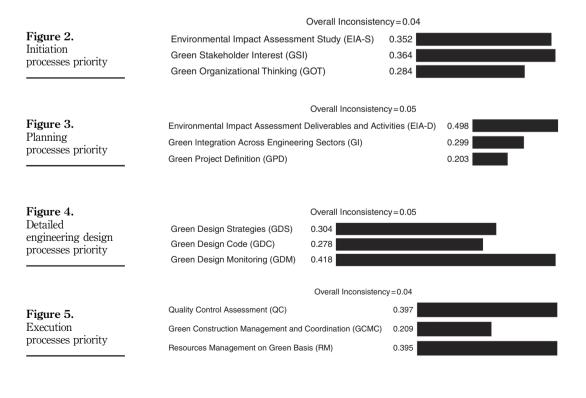
Project phase 2 – planning: in this phase, 80 percent of experts gave the highest ranking to EIA-D. GI across engineering sectors came in second. Figure 3 highlights the process rankings for the planning phase.

Project phase 3 – detailed engineering design: 67 percent of field experts ranked GDM as the first priority and the GDC process as the second priority. However, all of the academic experts ranked the GDS processes more highly than the other processes. When combined, the experts' judgment places GDM first and GDS second. Figure 4 shows all of the process priorities.

Project phase 4 – execution: in the context of project execution, 67 percent of field experts consider RM on green basis as the first priority and QC assessment as the second. However, there has been a major debate among academic experts on the subject of prioritizing execution processes. Because 50 percent of experts rank GCMC the highest, and 50 percent prefer RM to be the highest, combining the experts' input shows that to some extent, QC is more highly ranked than RM. Figure 5 shows these process priorities.

Project phase 5 – commissioning: in the commissioning phase, all of the experts agree that EMS processes are the highest priority in this phase and SS is the second priority. Figure 6 highlights the commissioning process priorities.

Project phase 6 – decommissioning: 80 percent of experts prioritize MHM over other decommissioning processes. When the experts' opinions are combined, MHM is the



184

13.3

WISTSD

highest priority in this project phase and RP is second. Figure 7 identifies the priorities for decommissioning processes.

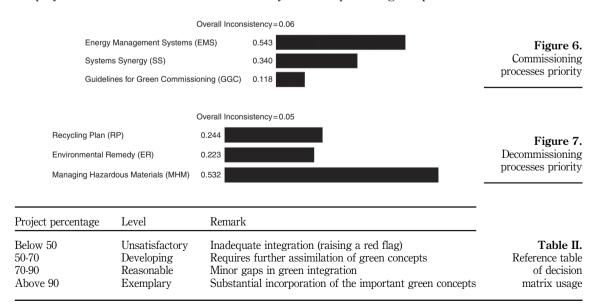
After a project manager finishes evaluating the processes index, he/she can assess the level of project integration with respect to green concepts by specifying a total "project percentile." Table II shows a reference table for matrix usage.

A hypothetical case study is used to demonstrate how the decision matrix can be applied in a construction project. In this case, a project manager needs to specify the rating index for all indices in each process according to the available information. The hypothetical data presents a project with a 61 percent integration level and recommends further assimilation of green concepts. Please refer to Figure 8.

For future work, it is important to consider other construction projects types such as transportation and infrastructure projects in the study. This will require further specialization of the green management processes and a more flexible framework. The major limitation that the study faced is the lack of similar research in the area and the thin literature to compare results. Ultimately, this study presents a fresh approach to building a decision framework for GPMPs. This novel theoretical approach facilitates green decision making in the project management of commercial building projects. The study is the first step toward new research in this field.

Conclusions

A matrix for GPMPs is important to facilitate the project manager's decision-making process. A green matrix can aggregate all of the necessary information for the manager to make a suitable decision. Two techniques were used: AHP analysis and the construction of a decision matrix. We utilized a panel of experts in the AHP analysis to specify the priority vector for the green processes. We used pair-wise comparisons to prioritize GPMPs, and experts weighted the processes based on the relative importance of each process in the construction industry. The process's costs, risks and benefit to the project are the criteria used in the AHP analysis to compare the green processes.



WJSTSD
13.3

186

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Orien Organization Theory (007) 0.34 Nonprise gene notation of the company 3 0 Measure organization capability to copy with null-dimensional tasks to the green project 5 0 Parson Organization Theory of the company 5 0 0 Parson Organization Theory of the company with null-dimensional tasks to the green project 5 0 Parson Organization Company Sectors 6.40 Nonprise dimensional tasks and task of the project administs from the company within the company and tasks and task of the project administs from the company sectors 6 0 Clean Theorem Diperson 0.40 Nonprise tasks and the entrymental dange due to the project administs from the company sectors 0 0 Clean Theorem Diperson 0.40 Nonprise tasks and the entrymental dange due to the project administs 0 0 Clean Theorem Diperson 0.40 Nonprise tasks to the project administs 0 0 Clean Theorem Diperson 0.40 Nonprise tasks to the project administs 0 0 Clean Theorem Diperson 0.40 Nonprise tasks to the project administs 0 0 0 Clean Theorem Dise and goverminist problem administs to the project administs<			Recognize stakeholder tolerance about risks in the green practices	3	1.092	Some knowledge about required processes
Green Organizational Theology (001) 0.34 Acceptual gene infertional of the company 3 0 Measure regretization capacity to capa with such dimensional tasks to the green project 5 0 Partners Places 6 0 0 Environmental project Assessment Diversion 6.44 0 0 Reservice (Comparison to the state) of the project Assessment Diversion 6 0 0 Reservice (Comparison to the state) of the project Assessment Diversion 6 0 0 Reservice (Comparison to the state) of the project Assessment Diversion 6 0 0 Reservice (Comparison to the state) of the project Assessment Diversion 6 0 0 Reservice (Comparison to the project Assessment Diversion to the project Asses			Specify the green specifications as well as green practices for the stakeholders	5	1.82	Reasonable knowledge about required proces
Number of the second						
Index experimental policy and products as well as taring or year particle. Image: Control employees notability to degram products as well as taring or year parts. Image: Control employee control employees notability to the product and the set of the s	Green Organizational Thinking (GOT)	0.284	Recognize green orientation of the company	3	0.852	Deep understanding of required processes a needed action
Index experimental policy and products as well as taring or year particle. Image: Control employees notability to degram products as well as taring or year parts. Image: Control employee control employees notability to the product and the set of the s						needed action
Instrume Total			Measure organization capability to cope with multi-dimensional tasks for the green project	2	0.568	Documented actual steps taken to address concerns and complete tasks
Instrume Total						concerns and complete tasks
Internet process Internet and process and and relative anomyonal consequences for particular activities tables they start Image: Consequence (Consequence) Image: Consequence) Imag			Provide employees incentive to adopt green practices as well as training on green practices	5	1.42	
Environmental page A seasoned Debesola and Achine (D.A.) Environmental and a set of charge and information to preproduce achines in the page of the seasoned preproduce achines in the page of the preproduce achines in the preproduce achines i			Total		10	
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Genen Intiguitani, Acons Englistering Sachar (c) 0.299 Recognize the collaboration time in braining an explosed activities to relappe the environment anguated space of Lacase are the implement an anguated and anguated anguate	and Activities (EIA-D)					
Overn Integrater, Across Engineering Sachers 0.20 Neograte the collaboration level basis best by a project and an exploration of a soft of an exploration of an exploration of a soft of an exploration of an exploration of a soft of a soft of an exploration of a soft o				4	1.99	
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(D) Tests and their engineem to a load for discriptional good green project lactors 2 1 Green Regist Delivities (DPD) 6.30 Refin field additions for green project additions 6 1 Green Regist Delivities (DPD) 6.30 Refin field additions for green project additions 8 1 Green Regist Delivities (DPD) 6.30 Refin field additions for green project additions 8 1 Green Regist Delivities (DDP) 0.30 Refin Refinance addition in a second addition of green project addition and green register basis 0 1 Green Regist Delivities (DDP) 0.30 Refinance addition in a second addition of green register basis 0 1 Green Regist Delivities (DDP) 0.30 Refinance addition in a second addition in a second in addition addit addition addition addition addition addition addition						
Green Project Definition (GPC) 6.20 and management provide strand great particulation and an analysis of particulation of parts before the project from t	sreen Integration Across Engineering Sectors	0.299		5	1.50	
Grave Project Debrits (GPT) 0.301 Early Mail administor for page product approximation 4 4 Counter Security Project S	(0)			2	0.60	
Exactly is man publicly specification or years balance 9 1 Contrastic for the project specification or years balance 0 1 Contrastic for the project specification or years balance 1 2 Sears Dasign Strategies (DD) 0.47 1 2 0 Contrast for the project specification or years balance 0 0 0 0 Contrast Strategies (DD) 0.47 1 1 0				4	1.20	
Conclusion in environmental policies and generalizations in the project plane. S Oracle Conclusion Research (COC)	Green Project Definition (GPD)	0.203	Identify detail definition for green project specifications	4	0.81	
Bits Economy Design Phone 101 12.20 Own Design Bessigner, RODS Grean Design Bessigner, RODS Grean Design Economy Designer, RoDS Grean Design Economy Designer, RoDS at a start and the start of the st			Evaluate the main guidelines for the project specification on green factors	3	0.61	
Sensiti Exercision Processor Control Co			Correlate the environmental policies and governmental regulations to the project plan	5	1.02	
Grean Design Boulgas (DS) 0.34 Mits the board puckeds to puckeds to an analysis and the display display for the property display of the display works and the display			Total		12.20	1
Gear Despin Biologies (GOS) 0.34 Kills the basis practices transmiss was in the subget gears 0 Gear Despin Code (GOS) 0.34 Kills the basis practices transmiss was used in the subget gears 0 Gear Despin Code (GOS) 0.37 Kills the basis practices transmiss was used in the control for the dispin strugget on the subget for the applice mappin and the dispin strugget on the subget for the applice mappin and the dispin strugget on the subget for the applice mappin and the dispin strugget on the subget for the applice mappin and the applice for the applice mapplice mappin and the applice for the applice mappin and the applice for the applice mappin and the applice mapplice mapplice mappin and the applice mappin and the applice ma	etail Engineering Design Phase				-	•
Exactlar grant fragment fragment of all models subtract and senders for all models and subtract for all models subtract and senders for all models and subtract and the project Image: Imag		0.304	Utilize the best practices to maximize results in the building design	0	0	1
Gene Deep Code (ISC) Bit Performance Statistical generation and a wareap of a single analysis of the magnet in regulation and the magnet in regulatin regulation and the magnet in			Evaluate green design strategy cost with respect to environmental benefit	0	0	1
Gene Deep Code (ISC) Bit Performance Statistical generation and a wareap of a single analysis of the magnet in regulation and the magnet in regulatin regulation and the magnet in			Specify design strategies combinations, (controlled solar load, utilizing the daylight, ventilation and	0	n/a	1
Image: constraint fragment problem in the image of the image	Green Design Code (GDC)	0.278	natural coornig) Enhance building design by using a variety of design concents in order to reduce the necestive import on		0.556	1
Orient and State R to description within this and in the population 9 5 Green Design Monitory (ISDM 4.14 Assess design programmes for the applications and designer understanding 4 1 Reson Design Monitory (ISDM 4.14 Assess design programmes for the applications and designer understanding 4 1 Reson Design Monitory (ISDM 4.34 Termination of the application of the applications and designer understanding 4 1 Quarky Control Assessment (ICD) 4.37 Termination of the application of the applications and designer understanding and meeting length quark programmes. The application of the			the environment	l	0.300	1
Orean Deeps Monkowy (KOM) 0.51 Assess design provide the sequence which will be added in the protect 0 0 0 Grean Deeps Monkowy (KOM) 0.51 Assess design provide the sequence setting and meeting frequency between stakeholders and designer understanding 4 0.1 Reset Deeps Monkowy (KOM) 0.51 Comparison for sequence settings and meeting frequency between stakeholders and designer understanding 4 0.1 Outsity Chercit Assessment (KOM) 0.27 Frequence settings and meeting frequency between stakeholders and the protect 5 2.23 Outsity Chercit Assessment (KOM) 0.27 Frequence settings and meeting frequency between stakeholders and the protect 2 0.0 Outsity Chercit Assessment (KDM) 0.20 Frequence settings and meeting frequency between stake to the fill gainty megatement 1 0.0 Reset Deeps Monkow (KDM) 0.20 Assess managed pationing, conducting and megatement operation and the protect green gaints 2 0.0 Green Deeps Monkow (KDM) 0.20 Assess managed pationing, conducting and megatement develops and the protect green gaints 2 0.0 Green Deeps Monkow (KDM) 0.20 Massess managed the themonkow (KDMM) 2 0.0			Improve energy efficiency , indoor air quality, and site sustainability for the project	2	0.556	1
Green Despris Monkoning (ISOM) 0.11 Asses despin progress for any specific density comparison between progress for any specific density. 4 1 Control Control Assessment (ISO) 0.11 Asses despin progress for any specific density. 5 1 Could Control Assessment (ISO) 0.31 Exercision and meshing tanguarcy balaxees statustications and desages understanding despin 5 1 1 0 Could Control Assessment (ISC) 0.31 Exercision and the specific desage of the spe			Bevise and follow the code requirements which will be used in the project	3	0.834	1
Resource before on project larger, tabeledite specification and disprese industration • 1 Resource of locate attribute and meeting frequency between stakeholders and the project 5 • 1 Outling Control Assessment (OC) • <td< td=""><td>Green Design Monitoring (GDM)</td><td>0.418</td><td></td><td>4</td><td>1.672</td><td>4</td></td<>	Green Design Monitoring (GDM)	0.418		4	1.672	4
Resch, Pa accuracy of colar dimension and meeting traguarcy balances status/balances and the project 6 Causing Control Assessment (CC) 0.397 Extended meeting traguarcy balances status to thill guily supplement 1 0 Causing Control Assessment (CC) 0.397 Extended meeting traguarcy balances status to thill guily supplement 1 0 Owner Control-ticution Management and Control Assessment (CCL) 0.397 Extende register status to admite to admite the status to admite and the status to admite admite admite to admite admite to admite admite to admite admite to admite	Green besign interneting (GDN)	0.410			1.672	4
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Control Prese 1 0 7.20 Guality Control Assessment (OC) 0.37 Extending implement replanding activity sequences 1 0 Dear Construction Management and Conditions (CDMR) 0.20 Assess manage project activities to Milling guarty regularities 2 0 Dear Construction Management and Conditions (CDMR) 0.20 Assess manage project activities to Milling guarty regularities 2 0 Resources Management and Conditions (CDMR) 0.20 Assess manages activities to Milling guarty regolarities 2 0 Resources Management on Green Bases (PM) 0.32 Utilities to company resource activities to Milling resources 0 0 Management on Green Bases (PM) 0.32 Utilities to company resource activities to Milling resources 0 0 Management on Green Bases (PM) 0.32 Utilities to company resource activities to Milling register taxeoform 0 Controllations, and protein diverse activities to Milling register taxeoform 0 0 Management on green diverse activities to Milling register taxeoform protein activities to Milling register taxeoform 4 2 Controllations, and prefination dinconte activities to Milling regreement sequence tactr			Specify the accuracy of cost estimate and meeting frequency between stakeholders and the project	5	2.09	1
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Conductor (dOUC) Image: project is within badget, meaning according to schedule, and that is project grave galaxies and the inductor is during the induced ind				4	1.588	
Systems Synary (SS) 3.3 Commission (SM) Commission (SM) <td>Green Construction Management and Coordination (GCMC)</td> <td>0.209</td> <td>Assess manager planning, coordination, and control which will be used to achieve project goal</td> <td>2</td> <td>0.418</td> <td></td>	Green Construction Management and Coordination (GCMC)	0.209	Assess manager planning, coordination, and control which will be used to achieve project goal	2	0.418	
Systems Systems (SMS) And Explorater guess manuagement to dropped an exploration. More a conductor, More Code, and just in fem Imagement information and an end-more communication drop project association. More Code, and just in fem Imagement information and an end-more communication drop project association. More Code, and just in fem Imagement information and an end-more communication drop project association. More Code, and just in fem Imagement information and information drop project association. More Code, and service information of the service communication of the project association, and an ensure communication of the service code of the project association, and an ensure information of the service code of the project association, and an ensure information of the project association, and an ensure of the project association, and an ensure information of the project association of the project association, and an ensure information of the project association of the project association, and an ensure information of the project association of the project association, and an ensure information of the project association of the project	,		Paraditrikat and at in which is data and data analysis is adaptic and that if and at any and		0.440	4
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Pleasances Management in Overs Basis (MI) 0.39 Utilizate a company security endows develop 4 project security. 0 Masca company security endows and project security. 0 0 0 0 Contractional plants 0			methods as well as enhance communication between project parties	-		
Bytem Synery (SD) Arry test compare sources constrained and pepter seaching sources to control table year sources and the propert seaching and control table year sources and the pepter sources and the perturbation of the perturbatis the perturbation of the perturbatis and perturbation	esources Management on Green Basis (RM)	0.395		0	0	1
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Systems Bysery (B) 4 Boddetes to Geen Commutation (GMD) 0.54 Landray starting starting to patient the same of a budding systems to benefity their relating to the same of a budding system to be set of a many monitoring and controlling budding. 2 1 Systems Bysery (B) 0.54 Landray starting starting systems that starting systems to benefity their relating systems to benefity their relating systems and starting systems to benefity their relating systems and starting systems to be set of a budding systems to be set of the systems and starting systems to be set of the systems and starting systems and s			Provide enough physical resources and assign people to tasks for project execution, and ensure	0	n/a	
Exergl Management Systems (EMB) 0.54 Modelly acid of compute systems which can be used for anary monitoring and controlling building 2 1 Order, assass, and test Subfrag support the same state of the anary monitoring and controlling building 4 2 Order, assass, and test Subfrag support the same state of the anary monitoring and controlling building 4 2 Systems Synary (SS) 0.34 Model and the signal frame of the signal building system states and building system states ananas			commitment of materials' vendors to the project delivery plan			
Exergl Management Systems (EMB) 0.54 Modelly acid of compute systems which can be used for anary monitoring and controlling building 2 1 Order, assass, and test Subfrag support the same state of the anary monitoring and controlling building 4 2 Order, assass, and test Subfrag support the same state of the anary monitoring and controlling building 4 2 Systems Synary (SS) 0.34 Model and the signal frame of the signal building system states and building system states ananas			Total		4	
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Deck trained and text building approximate as well as building systems to benefity their relation; •	Energy Management Systems (EMS)	0.543	toentry sets of computer systems which can be used for energy monitoring and controlling building systems	2	1.086	1
Description Description of annum programmer typem channes to control building quench sequences, and provide annum programmer typemer biological building quench sequences, and provide annum programmer biological building quench sequences, and provide annum programmer biological building quench sequences, and provide annum programmer biological building quench quench building quench building quench quench building quench building quench building quench building quench building quench building quench quench building quench building quench quench building quench building quench building quench quench building quench building quench quench building quench quench building quench quench building quench quench quench quench building quench quench building quench quench building quench quench building quench quencha quencha quench quench quench quencha quench quench quench quen					2.172	4
Description Description of annum programmer typem channes to control building quench sequences, and provide annum programmer typemer biological building quench sequences, and provide annum programmer biological building quench sequences, and provide annum programmer biological building quench sequences, and provide annum programmer biological building quench quench building quench building quench quench building quench building quench building quench building quench building quench building quench quench building quench building quench quench building quench building quench building quench quench building quench building quench quench building quench quench building quench quench building quench quench quench quench building quench quench building quench quench building quench quench building quench quencha quencha quench quench quench quencha quench quench quench quen			efficiency, and performance level	· *	21/2	1
Systems Synary (SS) 0.34 Images to set more actions to improve afficiency of system scores during on the set more actions and set of the set				4	2.172	1
Masses the difference of equation stroking and these simulation and dentify the bisances energy load for the building systems. 3 Evaluate and the building systems of equation of the building, and assess end-to and go cloads significant and and cloads the building, and assess end-to and go cloads significant and and cloads the building systems and, by extension, the building. 4 Guidatives for Green Commissioning (GOC) 0.114 Other the processes which can be used to enhance building systems and, by extension, the building value is a flow and the significant of the progents environmental goals 5 6 Building system discours of system of explanes (bits equation and speed) the distal significant of the progents environmental goal 5 6 Building system discours of system discours goal discours of system discours goal speed) the distalled regularements for significant of the speed to speed to building systems discours goal discours of system discours goal speed) the distalled regularements for significant of the speed to building system discours goal speed to be discload systements for significant of the speed to building system discours goal system					2.02	1
Masses the difference of equation stroking and these simulation and dentify the bisances energy load for the building systems. 3 Evaluate and the building systems of equation of the building, and assess end-to and go cloads significant and and cloads the building, and assess end-to and go cloads significant and and cloads the building systems and, by extension, the building. 4 Guidatives for Green Commissioning (GOC) 0.114 Other the processes which can be used to enhance building systems and, by extension, the building value is a flow and the significant of the progents environmental goals 5 6 Building system discours of system of explanes (bits equation and speed) the distal significant of the progents environmental goal 5 6 Building system discours of system discours goal discours of system discours goal speed) the distalled regularements for significant of the speed to speed to building systems discours goal discours of system discours goal speed) the distalled regularements for significant of the speed to building system discours goal speed to be discload systements for significant of the speed to building system discours goal system	Systems Synergy (SS)	0.34	Integrate two or more systems to improve efficiency	5	1.7	1
Evaluate and the factors and gravition of theolessic powers, and subsystem of the funding, and assass and the and pod clocks signifier integration powers. And subsystem of the funding and disabilities for Green Commissioning (GOC) 0.119 Others the processes which can be used to enhance building systems and, by extension, the building which is the overall blamping and the program of the program system metals improved building the overall blamping and the program of the stabilities of the program system metals of the commissioning last of explanes that regular commissioning and speedy the stabilities explanments for commissioning last 5 1			Measure the efficiency of system recovery during power failure simulation and identify the tolerance	3	1.02	1
Guidelines for Green Commissioning (IGC) Set (1) Daffers & processes which one has used terminal building variants multiply to instruction, the building Daffers & processes which can be used to sharehow building variants multiply to instruction, the building Daffers & processes which can be used to sharehow building variants multiply to instruction, the building Daffers & processes which can be used to sharehow building variants multiply to instruction, the building Daffers & processes which can be used to sharehow building variants Daffers & processes which can be used to sharehow building variants Daffers & processes which can be used to sharehow building variants Daffers & processes which can be used to sharehow building variants Daffers & processes which can be used to sharehow building variants Daffers & processes which can be used to sharehow building variants Daffers & processes which can be used to sharehow building variants Daffers & processes which can be used to sharehow building variants Daffers & processes which can be used to sharehow building variants Daffers & processes which can be used to sharehow building variants Daffers & processes which can be used to sharehow building variants Daffers & processes which can be used to sharehow building variants Daffers & processes Daffers & processes Daffers						1
Guidelines for Glesen Commissioning (GDC) 0.118 Dates the processes which can be used to wherein building systems and, by extension, the building used to great the temporal of the program and, by extension, the building used to great the temporal of the program and the temporal of temporal of the temporal of tempora of tempora of temporal of temporal of temporal of temporal of t			Evaluate and test function and operation of hardware, software, and subsystems of the building, and	4	1.36	1
Seedy need spann dispan dispany and dilibrari di se poperi annonneoli paini S					L	4
Seedy need spann dispan dispany and dilibrari di se poperi annonneoli paini S	Juiderines for Green Commissioning (GGC)	0.118	Define the processes which can be used to enhance building systems and, by extension, the building value for the owner will be improved	3	0.354	1
Seattly number of systems which require commissioning and specify the detailed requirements for commissioning test Total Total					0.59	4
commissioning test Total 11			opeous overal aysism encours and unimers or the project's environmental goals Identify number of systems which require commissioning and specify the datalled requirements for	5	0.59	4
Total 11			commissioning test	5	0.59	1
					11	1
Decommissioning Phase	ecommissioning Phase		Total			1
		0.244	Evaluate the process of reducing project waste	3	0.732	1
				3	0.732	1
						1
Identify a coordinator for recycling, waste auditing, and which materials will be recycled in the project 5 1.			Identify a coordinator for recycling, waste auditing, and which materials will be recycled in the project	5	1.220	1
					L	J
	Environmental Remedy (ER)	0.223		2	0.446	
				2	0.446	J
Utilize remediation technologies such as: thermal disruption, drilling, pump and treat, and 2 0.			Utilize remediation technologies such as: thermal disruption, drilling, pump and treat, and	2	0.446	1
bioemediation					L	4
	Managing Hazardous Materials (MHM)	0.532	Identify the process of collecting and treating project's hazardous materials	3	1.596	4
Provide protection for public health and company employees by effectively managing hazardous 4 2. materials			Provide protection for public health and company employees by effectively managing hazardous materials	4	2.128	1
				-	2.660	4
Specify the legal requirements for storing, treating, transporting, and disposing of those materials 5 2.			opeoxy one requirements for storing, treating, transporting, and disposing of those materials	5	2.660	1
Total 10					L	4
Petcentage			Total		10 61%	Level: Developing (Requires further assimi green concepts)

Figure 8. Hypothetical example of decision matrix for green project management processes

The experts' judgment indicates that the cost of applying green process criteria is the highest priority. In the initiation phase, the GSI process was prioritized over the other processes, whereas EIA-D had the highest ranking in the planning phase. In the detailed engineering design phase, experts highlight GDM as the highest priority; QC assessment has a superior ranking in the execution phase. In the commissioning phase, the EMS process is the most preferable. MHM has the highest ranking in the decommissioning phase. The decision matrix includes the process index to highlight essential information for each process. Three indexes have been developed for each process to help the manager decide which processes should be used. The process index

represents the following questions: what is the process, why is this process important, and how can this process be implemented? Green processes help the manager bring sustainability to the project. The construction industry is not only considered to be the largest contributor to environmental pollution but is also considered to be the largest consumer of natural resources. Therefore, implementing green practices to construction projects will help reduce both environmental pollution and the depletion of natural resources. Based on the results of this research, it is recommended that more indices be developed for other specialized types of projects such as industrial and heavy construction, etc.

Green project management processes

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