Insight into Decision Support Systems for Sustainable Geotechnical Engineering

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ABSTRACT

Geotechnical engineering has a significant role in sustainability, due to its early place in the construction process and thus with a higher possibility to limit the impact of the project. Nevertheless, there is a lack of methods for evaluating geotechnical developments considering the three core pillars of sustainability. A new decision support system DSS for the sustainability assessment in the construction of geotechnical infrastructures is indeed needed to evaluate and compare geotechnical alternatives by taking into account the environmental, social and economic parameters. This paper aims at presenting a preliminary insight into a new DSS for sustainable geotechnical infrastructures and presents an approach for the development of it.

Keywords: Decision Support System, MADM Method, Construction, Geotechnical Engineering, Sustainability Assessment

Introduction

The world is encountering unprecedented challenges related to energy resources, global warming, and waste material generation. Failure to overcome these challenges will inhibit the world development and will negatively impact the standard of living and security of current and future generations [1].

The construction industry is one of the largest exploiters of natural resources, both renewable and non-renewable, which is adversely changing the environment of the earth. It depletes two-fifths of global raw stone, gravel, and sand and one-fourth of virgin wood, and consumes 40% of the global energy and 16% of water annually [2]. A vast majority of the construction industry invariably involves geotechnical engineering as one of its components that has a huge potential contribution to the project sustainable development due to its early position in the construction process. The sustainable development should implement a holistic consideration of economic growth, social development and environmental protection (Fig. 1).
Consistent with the spirit of sustainable development, in recent years, plenty of assessment tools have been created for different categories of geotechnical projects, without though taking into account all the sustainability pillars and usually facing the lack of weighting system that might lead to misrepresentation of risk areas for certain types of projects (Fig. 2). Geotechnical engineering is a complex area because every engineering problem can be solved in different ways, considering a variety of parameters in a usually limited amount of time. Hence, geotechnical engineers are often dealing with the pressure of decision making, which might lead to a misleading interpretation of all available options and cause problems related to sustainability targets, deadlines, standards and budgets. The absence of frameworks for the evaluation of different geotechnical techniques through the prism of sustainability is hence considered extremely important. Yet, developing a sustainability assessment and performance-based management tool for geotechnical assets needs substantial effort [3]. Those sustainability evaluation problems can be overcome by developing a decision support system DSS, based on a Multiple Criteria Decision Making MCDM method, which helps decision makers to organise and synthesise information, allowing a complex comparison between available alternatives [4, 5].

Figure 1: Sustainability Pillars

Figure 2: Existing sustainability assessment tools and encountered issues
The objective of the present research is to develop a new DSS for sustainable geotechnical infrastructures based on a MCDM method. This paper gives a first insight into the main methods that will be used for the new DSS and highlights the importance of it.

**Development of a new decision support system**

The MCDM method has been developed as a part of operational research, concerned with designing mathematical and computational tools approaches. It is well known in the decision-making process for supporting subjective evaluations of performance criteria. In the present work, MCDM method has been selected due to its unique characteristics such as the presence of multiple non-commensurable and conflicting criteria, possible different units among the criteria, and the presence of different alternatives [5, 6, 7].

Two different methods are usually applied to solve the MCDM problems: the Multiple Objective Decision Making MODM method and the Multiple Attribute Decision Making MADM method. MODM method deals with many objectives to come up with an optimal solution to achieve prefixed objectives. Whereas in the MADM method, the decision-making process deals with alternatives that have a variety of performance attributes and factors, either qualitative or quantitative [8]. In this case, the MADM method has been chosen to allow the comparison among alternative methods.

The MADM method is a discrete method, which generally assigns numbers to all predetermined alternatives. It specifies how to process the attribute’s information to reach an ideal choice. To model those attributes, the MADM method will be presented through a decision matrix. This matrix consists of 1) alternatives, 2) criteria and 3) relative significance of criteria. Because a wide range of criteria can be considered during a sustainability assessment, depending on the type and the specific conditions of each project, it is considered critically important to define a core set of criteria to ensure that there is some level of consistency in the assessment process.

According to previous working experiences, as well as based on available published information and literature, Table 1 contains a list of the core criteria that will be implemented in the new DSS.

<table>
<thead>
<tr>
<th>Social</th>
<th>Environmental</th>
<th>Economical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply chain</td>
<td>Energy consumption</td>
<td>Material cost (removal, disposal, imported material)</td>
</tr>
<tr>
<td>Influence on surface area</td>
<td>Vibration pollution</td>
<td>Equipment cost (temporary, permanent)</td>
</tr>
<tr>
<td>Noise pollution</td>
<td>Waste material and usage</td>
<td>‘On site’ cost (site facilities, energy consumption, employees)</td>
</tr>
<tr>
<td>Vibration pollution</td>
<td>Emission of CO₂</td>
<td>Aid from government</td>
</tr>
<tr>
<td>Affection of existing structures and services</td>
<td>Environmental incidents and risk</td>
<td></td>
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<tr>
<td>Interaction/distribution of current transportations and services</td>
<td>Usage of recycled materials</td>
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<td>Duration of works</td>
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Some criteria (Table 1) are qualitative and need to be converted into quantitative scales for comparison purposes [9]. Commonly, the five-point Likert-type scales are used for this conversion. However, even though the five-point scales can convert qualitative criteria to numbers, they are not able to distinguish clearly the differences among close scores (e.g., good and very good). Because of that, a hierarchical scale consisting of 17 relative importance factors will be utilised for the comparison matrix among variable decisions. In general, there are various MADM techniques to be used during decision-making processes. In the present research, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method has been selected, for ranking all the available alternatives, due to its simplicity and ability to consider a non-limited number of alternatives in the decision making process. TOPSIS is a method of compensatory aggregation that compares a set of alternatives by identifying weights and normalising scores for each criterion, calculating the geometric distance between each alternative and the ideal one, which is considered the one with the best score.

Shanian and Savadago [10] noted that it is important to know the relative significance of each criterion in a MADM problem. For the determination of the weights, subjective fixed weight methods – such as the Delphi method, expert survey method, the analytic hierarchy process method (AHP), etc. – are usually used. However, those methods could eventually lead to deviations of indexes’ weights due to subjective factors. On the other hand, objective-fixed weight methods, based on the inherent information of indexes to determine weights of indexes, could eliminate man-made disturbances and increase the accuracy. Shannon [11] noted that the entropy method could also be used to objectively calculate the relative weight of information, except in the cases when data needs to be quantitatively estimated. The entropy weight method is one of the objective-fixed weight methods and it is based on the information determined by the index’s weights [11]. Also, Pratyush and Jian-Bo [12] believe that the entropy method can evaluate the amount of uncertainty represented by a precise probability distribution.

Due to the reasons above, in the integrated model that it is being designed, the entropy method has been chosen to calculate the relative weight of attributes and the TOPSIS method to compare a set of alternatives by normalising scores for each criterion and calculating the geometric distance between each alternative and the ideal one. As for the significance of each criterion with respect to others, the user will be able to introduce a specific value referring to a provided hierarchical scale. As a result, it is expected that DSS will provide flexibility to the user and adjustability according to the project requirements. Hence, the decision makers can be anyone involved in a geotechnical project and will be able to evaluate a project according to the core criteria.

CONCLUSIONS

It is extremely important to understand that decisions related to sustainability should not be based on the ‘we have always done it that way’ logic but should be adjusted and evaluated based on every project needs, by considering the multi-dimensional and multi-disciplinary aspects of sustainability.

Evaluation of geotechnical techniques by encompassing all the aspects of sustainability, from a multi-disciplinary point of view, while measuring their sustainability through each construction stage, is necessary for achieving all the sustainability credentials of a construction project. The current absence of frameworks for the evaluation of different techniques through the prism of sustainability needs to be urgently addressed.
The development of an integrated model that incorporates a DSS, can play a key role in predicting geotechnical impacts, as well as contributing to save time and reduce project costs. Such a model, on which the authors are currently working on, would help designers to select the most sustainable technique for proposed geotechnical projects, taking into account project limitations on one side and users’ requirements and preferences on the other.

The new DSS, which is under development, uses the MADM method to allow the comparison of alternative methods. It normalises values and applies weighting factors with the use of the TOPSIS and entropy methods, respectively. By doing so, with the new DSS, it will be possible not only to evaluate the amount of uncertainty, through the representation of a precise probability distribution, but also to determine the geometric distance between each alternative and the ideal one.

REFERENCES