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Automated multi-objective optimization system for airport site layouts

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ABSTRACT

Airport construction planners often face the problem of identifying optimal locations for temporary construction facilities on site, as the planned locations of these facilities usually influence important and conflicting planning objectives such as improving the efficiency of construction operations and maintaining safety on site. Careful evaluation of all feasible locations for temporary facilities and the selection of an optimal layout are needed in order to achieve these multiple important objectives. This paper presents the development of a practical automated system to optimize multiple conflicting planning objectives and provide all possible optimal tradeoff solutions among these objectives. The system is implemented and integrated in four main modules: (1) a comprehensive multi-objective optimization engine that integrates and optimizes construction work zone safety, construction-related aviation safety, construction-related airport security, and all relevant site layout costs; (2) a relational database that integrates planning data and stores all the generated optimal solutions; (3) an Input/Output module to facilitate specifying planning and optimization parameters and retrieving the generated optimal site layout solutions; and (4) a visualization module that communicates with external CAD software in order to support the visualization of the generated optimal site layout plans.

1. Introduction

In airport expansion projects, the planning of construction site layouts requires construction planners and decision makers to identify the best location of each temporary construction facility on site in order to achieve a number of important planning objectives. These objectives include (1) minimizing the cost of all the items influenced by the site layout; (2) maintaining the safety of airport operations during construction; (3) reducing construction-related security breaches; and (4) improving the safety of construction operations [1–4]. In order to assist construction planners in this important task, several methodologies have been adopted in the literature, aiming to develop site layout planning models. These methodologies included genetic algorithms [5–8], linear programming [9,10], knowledge-based systems [11–14], artificial neural networks [15], simulation [16,17], and ant colony optimization [31].

Over the past decades multi-objective genetic algorithms have evolved as powerful tools to solve problems that involve optimizing a number of objectives simultaneously. Some of these algorithms were also used in solving site layout planning problems [3,18,19,28]. For example, Soltani and Fernando presented a framework for supporting path planning analysis of construction sites based on multi-objective evaluation of transport cost, safety, and visibility [28]. Their work investigated the use of a fuzzy-based multi-objective optimization approach in making more informed strategic decisions regarding the movement path of workers and vehicles on construction sites, and detailed decisions regarding travel distance and operational paths on workplaces. The approach allows distance, safety, and visibility objectives to be combined and decision to be made on the preference given to a certain objective. El-Rayes and Said developed an approximate dynamic programming model that is capable of searching for and identifying global optimal dynamic site layout plans [30]. The model applies the concepts of approximate dynamic programming to estimate the future effects of layout decisions in early stages on future decisions in later stages. The model is designed to identify a global optimal location and orientation for each temporary construction facility on site, and is capable of considering and complying with practical site layout constraints such as operational and safety constraints.

Few research studies investigated the optimization of airport and other critical facilities construction sites. For example, El-Rayes and Khalafallah developed a model to maximize the safety of construction operations while minimizing the overall site layout cost [3]. Khalafallah and El-Rayes also developed a second model to minimize construction-related hazards and the overall site layout cost simultaneously [18]. The same researchers developed a third model to maximize construction-related airport security while minimizing the overall site layout cost [19].

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