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Conflict resolution-motivated strategy towards integrated construction site layout and material logistics planning: A bi-stakeholder perspective

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ABSTRACT

Efficiency of construction site layout planning (CSLP) and construction material logistics planning (CMLP) is of great significance for a successful project control. Despite considerable research undertaken to separately optimize the site layout plan or material logistics plan, the interdependencies and decision conflicts of the layout planner and the logistics planner are neglected in the construction planning and design phase. The ignorance of the decision conflicts and interdependencies can lead to an overrun cost, a delayed project or a worse quality. This research proposes a decentralized methodology based on a bi-level model and a Bi-PSO algorithm, enabling the layout planner and the logistics planner to optimize the CSLP and the CMLP in an integrated model. Fuzzy random parameters are utilized to deal with uncertainty in the data collection process. By utilizing the methodology, the stakeholders are capable of adjusting the respective decisions based on the changes of others. By iteratively adjusting the CSLP and CMLP solutions, the CSLP-CMLP decision conflicts are dealt with, accordingly, the bi-stakeholder conflict resolution-motivated CSLP-CMLP strategy is planned. To demonstrate the applicability of the proposed methodology, a real case study is conducted to optimize CSLP and CMLP simultaneously. The significance of optimizing an integrated CSLP-CMLP for the layout planner, the logistics planner and the general contractor is also justified. The contributions of this research include the capability of modeling the decision conflicts in a bi-level model, the ability of generating an integrated CSLP-CMLP solution and the practicality of guiding academic researchers and practitioners to optimize construction management from a global viewpoint. The research can be extended to other fields to explore the effects of decentralized decision making on other bi-stakeholder conflict resolution cases.

1. Introduction and research aim

Planning the site layout of mega or large-scale construction projects, such as bridges, dams, power plants, is a significant preplanning task that impacts the construction cost, safety, duration and environment [1,2]. Construction site layout planning (CSLP) includes the identification of site temporary facilities, sizes, locations of the facilities and on-site routes [3]. As large-scale construction projects have abundant site space, the positioning of facilities and the design of on-site routes will greatly influence the travelling cost, time and safety among any pair of facilities on construction sites [4]. For complying with practical site layout needs and computational convenience, the CSLP in this research focuses on the assignment of predefined facilities to a set of pre-identified locations on site as well as the design of on-site routes and the route connecting the external transport network and the construction site. Due to the complexity of the CSLP, designers and site layout planners (i.e. Southwest Electric Power Design Institute Co., Ltd) are often contracted to make detailed site layout plans on behalf of the project owners or the general contractors. Considerable research has been conducted to deal with the layout planning for the site layout planner [5–7] to determine facility locations and on-site transport routes. To bridge the gaps between academia and practice, existing CSLP models utilize previous experience, ad-hoc rules, common sense, adaptation of past layouts to the present project [4], GIS-based approaches [8], CAD-aided tools [7], expert systems [9] and mathematical techniques [10–13].

During the process of designing an efficient site layout plan, activities are organized among the construction supply chain stakeholders to guarantee a sound, safe and efficient construction [14]. *A significant impact factor of planning an efficient site layout is the efficient and effective*

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material logistics plan from the suppliers to the storage yards, to the processing centers, to the recycling centers, and finally to the structures under construction [15–17]. *Construction logistics is to manage resource flows (i.e. material, resource, funds, information) from the suppliers to the structure under construction based on the CSLP and the transport network between suppliers and the construction site* [18]. As the level of materials costs reaches up to 70% of the total construction cost estimates in many construction projects [19] and thus, planning the construction material logistics is another crucial preplanning task to guarantee smooth construction operations. Construction material logistics planning (CMLP) includes the identification of material items and quantities, the selection of material suppliers, the ordering quantities of the different items of materials, the transport of materials and the inventory control of various items of materials [15,16]. Due to the complexity of the CMLP, outsourcing the construction material logistics is considered to be an efficient method that is able to facilitate the overall project control, and accordingly, a material logistics planner, which is originated from supply chain management [20], is in charge of the task of construction material logistics planning to make an accurate procurement plan with detailed ordering quantities, delivery dates, storage locations and the inventory levels. Considerable research has been studied to arrange the construction material logistics for the logistics planner [15,16,18,19,21,22].

Both construction site layout planning problem and construction material logistics planning problem are vital to the successful completion of construction projects. In practical circumstances, the construction of mega or large-scale projects in mountainous regions involves multiple specialized stakeholders in different firms (contractors and subcontractors), who are considered as important parts of the respective specialty groups due to their responsibilities of pre-planning tasks, such as the development of schedule, the selection of construction methods, as well as the plan of procurement, workforce, material, equipment and transport routes. The various stakeholders are dealing with the respective tasks for their own objective optimizations [14,23], as demonstrated in the organizational structure in Fig. 1. For example, the project owners arrange for financing-related works of construction projects. The general contractors are responsible to the project owners to oversee and coordinate the work. The designers and the site layout planners interpret the owner's wishes into specifications to guide the practical construction. Contractors and subcontractors are authorized to provide materials, transportations and workforces. Safety professionals are awarded to supervise and control a safe construction. As multiple stakeholders are involved in the actual construction, conflicts are inevitable [4,8,13]. Conflicts are widely researched and categorized based on the various research objectives. When the decisions of one stakeholder are interfering or obstructing the actions/solutions of another stakeholder, the decision conflicts occur [24,25]. In the current study, as the CSLP and CMLP decisions are influentially interdependent (See details in Section 2), they are integrated into a CSLP-CMLP

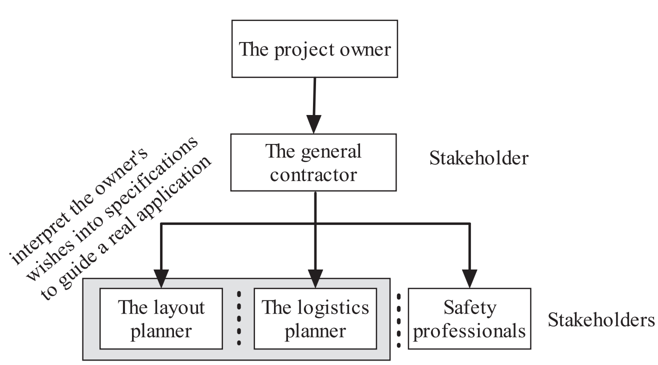

Fig. 1. The organizational structure in the present study.

decision. If the layout needs of the layout planner are not met, the CSLP and CMLP decisions are accordingly modified; and similarly, if the requirements of the logistics planner are not met, the CSLP-CMLP decision needs to be updated. Under these circumstances, when the CSLP decisions and the CMLP decisions are mutually interfering and obstructing, the CSLP-CMLP decision conflicts exist. To accomplish the goal of conflict resolution as well as manage practical site layout plan and material logistics plan, two project stakeholders, including the layout planner and the logistics planner are given priority to be modeled in a decentralized model for a simultaneous optimization.

In past decades, significant contributions have been made in both the CSLP and CMLP fields, however, there still remain a number of limitations, as shown in Fig. 2: (1) For the CSLP, mathematical methods [10], GIS techniques [8] and CAD tools [7] are widely applied to optimize the layout decisions for the planner. Similarly, supplier selection models, material inventory models or raw material procurement models have significantly contributed to the CMLP research for the logistics planner. However, most research has only focused on CSLP and CMLP as two separate planning tasks, and the significance of CSLP-CMLP decision conflicts is seldom addressed. Ignoring the decision conflicts may result in suboptimum CSLP or CMLP solutions for the layout planner or the logistics planner. As a result, the overall construction cost, duration and quality are negatively affected for the overall coordination of the general contractors. (2) Despite the fact that some previous studies have already recognized the integration significance of CSLP and CMLP [4,13,26], most of which focused on the integrated CSLP-CMLP from a centralized perspective for an overall coordination of the general contractor. However, the fact is often neglected that the CSLP decisions and the CMLP decisions are decided by two different stakeholders in many mega or large-scale construction projects. If the actions and reactions of one stakeholder from the planning phase are unsatisfactory to another stakeholder, conflicts tend to occur in the execution phase, which will delay the project, increase the costs or worsen the project quality. Therefore, an integrated research from a decentralized bi-stakeholder perspective is expected to address the interdependent CSLP and CMLP problems in the design and planning process before construction. (3) In real projects, re-planning activities are carried out before the implementation of construction operations, and thus, uncertainty has to be addressed to improve the robustness of the developed method for an integrated CSLP-CMLP solution.

To overcome the limitations, there is a pressing research need to investigate the CSLP and CMLP problems simultaneously for the layout planner and the logistics planner and develop a unified CSLP-CMLP model to interactively update the CSLP and CMLP solution to arrive at an overall equilibrium CSLP-CMLP solution. This study attempts to propose a methodology to accomplish the goal of conflict resolution between the layout planner and the logistics planner and search for an optimum integrated CSLP-CMLP solution from a bi-stakeholder conflict resolution perspective. The methodology can be employed for the general contractor to have a decentralized coordination of CSLP and CMLP as well as the layout planner and the logistics planner to search for the perspective optimal decisions.

Bi-level modeling techniques are extensively utilized to address bi-stakeholder problems in various research fields. For example, Anandalingam and Apprey utilized a a multi-level programming method to resolve conflicts of an arbitrator and a project owner [27]. Gang et al. resolved conflicts of the local authority and private stone enterprises in a bi-level mathematical model [28]. Min and Guo applied a bi-level method for designing a better transportation network [29]. A bi-level multiobjective optimization model is designed to resolve conflicts in a mill [30]. Ma and Xu used a bi-modeling equilibrium method to address the interdependencies of multiple stakeholders [31]. The excellent studies have validated the effectiveness and efficiency of bi-level models in addressing multi-stakeholder problems. In a bi-level model, stakeholders search for optimal solutions to achieve various planning objectives while complying with all environmental,