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Sharing of Temporary Structures: Formalization and Planning Application

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ABSTRACT

Sharing temporary structures minimizes the risks and costs associated with their set-up and break-down. Yet sharing makes temporary structure planning and re-planning more complex, as construction engineers need to understand the conditions of activities to determine the accessibility and sharing possibilities. BIM (building information modeling) technology can extract and process geometric and action data in 3D models. Using BIM can increase consistency and speed in identification of sharing solutions for temporary structures. At present, the construction industry does not leverage advances in BIM for planning temporary structures because it lacks formalization that defines key properties and relationship variables for sharing. In this paper, the geometric and action conditions affecting temporary structure sharing are examined to put forth a formalization for a computer application (a proprietary tool developed by the primary author) called the Temporary Structure-Planning Generator (TSPG). The formalization for the TSPG allows construction engineers to rapidly generate multiple temporary structure-sharing options with a selection consistency not yet seen in current construction practice.

1. Introduction

Ideally, the same temporary structure (i.e., scaffolding, shoring) can be utilized to support more than one construction activity. This minimizes risks involved in setting up and dismantling temporary structures and increases cost effectiveness. However, sharing makes temporary structure planning and re-planning more complex because construction engineers need to identify geometric and action conditions that affect temporary structure sharing. They need to analyze those conditions and relate them with the features of temporary structures. While selecting temporary structures to share, they need to validate whether the geometric conditions make the temporary structure being considered accessible, and that the action conditions are compatible for sharing the temporary structure.

With the advances of BIM technology, it is possible to easily store and extract the properties of geometric and action conditions of activities. Application of BIM technology can make temporary structure planning more robust, increasing consistency and speed of identification for temporary structures to share. However, without knowledge about how to *process* the data, property knowledge cannot give a complete picture of all the variables required to execute the sharing decision. For instance, knowing the distance between two building elements does not inform construction engineers which temporary structure is accessible and can be shared. Similarly, knowing the speed of the action of the activities does not tell whether those actions are compatible for sharing a temporary structure. The properties need to be qualitatively translated into formal languages (spatial relationships and action compatibilities) so that they can be used to determine accessibility of temporary structures and compatibility of actions. Without the formalization, current practice does not take advantage of computer-assisted approaches. In practice, planning decisions to share temporary structures using traditional manual process are inconsistent and prone to error, causing rework and cost-ineffectiveness.

So far, researchers have defined and formalized spatial relationships between activities [1,7,8]. These relationships describe geometric and

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topological relationships between building elements, such as column, beam, and roof. These definitions, however, focus on conveying spatial insights that are important only for sequencing activities and site-layout planning. Therefore, the relationships do not describe the geometric conditions that need to be considered to select the shareable temporary structures. Previous process modeling approaches have been focused on defining action relationships. The action relationships in the efforts focus on supporting process planning free of conflicts [2–4,9]. They do not convey information of actions to support selection of sharable temporary structures.

This research presents analysis of case studies of temporary structure sharing to identify geometric and action conditions that affect temporary structure sharing. From the analysis, we formalize spatial relationships and action compatibilities in support of identifying activities that can share temporary structures.

2. Motivating example

Here we introduce a motivating example of temporary structure sharing from the construction of an office building to discuss the formalization requirements. As shown in Fig. 1, an exterior wall was placed at the vestibule of the building. The ceiling of the vestibule was 18′–0″ high. A linear-type lighting fixture was placed in the ceiling. A storefront curtain system and a revolving door were embedded in the wall (Fig. 1, left). A steel-structured canopy was attached to the outside of the wall (Fig. 1, right). There were four activities to execute: spray paint the inside of the wall; install the interior lighting fixture; install the exterior metal panel above the store front curtain wall; install the lighting fixtures toward the edge of the canopy.

The construction engineer on this project planned to share a man lift for the wall painting and lighting fixture installation. He thought the man lift, a mobile access platform, is relevant for the geometric conditions of the activities (the lighting fixture was 4 ft away from the face of the wall). When selecting the temporary structure for the installation of the metal panel and canopy lighting fixture, he noticed that part of the surface of the floor on which the temporary structure is placed was recessed. So he decided to use sectional scaffold for the activities. As the canopy was sloped, making outer edge of it higher, he wanted to make sure that workers could reach the lighting fixture from the scaffold. Assuming the lighting fixture is in the middle of the canopy, he measured the distance from the wall to the center of the canopy before he decided to use the sectional scaffold.

The man lift worked well for the lighting fixture and wall painting. During the final coat of the paint he noticed that "paint spraying" was done in separate horizontal sections. The activity moves repetitively fast from left to right, requiring a temporary structure that provides an access platform covering the whole area of each horizontal section. The man lift moved fast enough to support the work. He realized that some temporary structures like ladders would not work for painting as they cannot be moved quickly. The sectional scaffold, however, could not be shared between the activities of metal panel installation and canopy lighting fixture installation because the distance between the face of the exterior side of the wall and the lighting fixture (located outside the center of the canopy), was longer than expected. He had to bring another set of sectional scaffold for it.

The motivating example describes situations where temporary structures can be shared, as well as the accessibility of the temporary structures, and calls attention to three geometric properties of *distance*, *angle*, and *orientation* to be matched to the features of temporary structures.

- The *distance* between workfaces of activities must be considered to tell whether the workspaces of the activities are close enough to share a temporary structure without moving or expanding the temporary structure. Also, horizontal and vertical distances must be considered separately as different temporary structures have different flexibilities in terms of expanding horizontally and vertically. For example, a rolling scaffold can be used for workfaces that are horizontally apart as it moves. Conversely, it is limited to expand it vertically to cover workfaces that are apart vertically.
- The *angle* between workfaces (i.e., the angle between the normal vectors of the workfaces) affects the accessibility of temporary

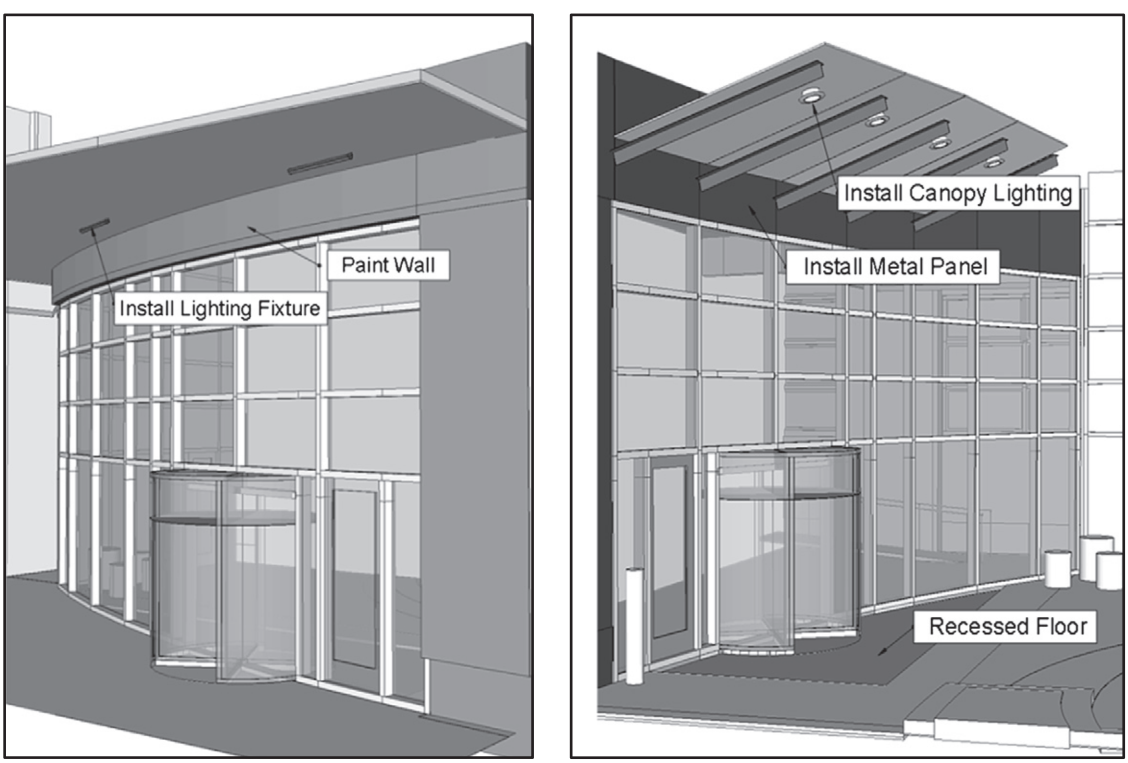

Fig. 1. Interior (left) and exterior (right) views of the vestibule.