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Socioeconomic impact assessment of highly dense-urban construction projects

Amir Ibrahim[a,*], Omar El-Anwar[b,c], Mohamed Marzouk[c]

[a] Civil and Environmental Engineering, University of Illinois at Urbana Champaign, Urbana, IL 61801, United States
[b] Department of Construction Management, University of Washington, Seattle, WA 98195, United States
[c] Structural Engineering Department, Faculty of Engineering, Cairo University, Egypt

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ABSTRACT

Dense-urban construction is reported to affect the social and economic welfare of surrounding residents and local businesses in various ways. However, research studies and practical methodologies aimed at assessing to what extent the choice of a construction plan that reduces such effect are very limited. The objective of this paper is to present the development of an automated assessment methodology to fill this research gap. To this end, two formulations are presented; one based on multi-attributed utility functions and the other based on monetary compensations for disruptions caused by construction operations. Both formulations assess the impacts of construction plans on (1) increased travel distance; (2) residents' relocation; (3) business loss; (4) business closure; and (5) noise inconvenience.

The proposed automated methodology is implemented in five sequential phases and utilizes Geographical Information Systems (GIS) and Visual Basic Application (VBA). Using the proposed implementation, the two alternative formulations are applied to an infrastructure upgrading project in Cairo, Egypt that had five possible construction scenarios. While the two formulations resulted in the same preference order for the five scenarios, they exhibited different performance in terms of their (1) assessment relative values; (2) required input data and robustness; (3) ease of results interpretation; and (4) comprehensiveness and scalability.

The developed framework shows promising results in terms of identifying and sorting the major root causes of the socioeconomic disruptions caused by dense urban construction. Results show that using the proposed methodology informs decision-making and planning at the early stages of a project, which in turn helps to reduce cost overruns and schedule delays.

1. Introduction

The growth of urban communities in relatively small areas leads to high concentrations of population. Such densely populated areas demand continuous investment in the form of new construction, upgrading and renovation projects aiming to maintain and elevate the standards of living. However, the presence of residents in proximity to construction sites introduces new challenges to project management and involved parties [1]. These challenges increase the number of non-traditional project variables, which in turn lead to higher project complexity and more associated risks.

Dense urban construction is associated with high density of population inhabiting the area surrounding construction sites. This condition introduces various unconventional socioeconomic challenges that affects construction projects' success and the livelihood of the surrounding population. For instance, excavation work generally interferes with subsurface utilities, disturbing related services. Another example is road closure and detours resulting from construction operations, which increases traffic congestion and leads to public dissatisfaction. This is in addition to the construction-related noise pollution that has severe impacts on the nearby residents.

It is reported that construction operations affect the social and economic welfare of the dense urban communities during most of the construction phases [2–4]. Ikioda [5] reported several social and economic adverse effects associated with a major highway construction project in Nigeria including blocking roads, relocating services and disturbing market activities. Adding to that, residents disrupted by construction activities intervene with the progress of construction operations leading to delays, additional costs or even project failure [6]. Accordingly, there has been a growing interest in studying the mutual interactions between construction operations in dense urban areas and the surrounding residents.

* Corresponding author.
E-mail addresses: aaelsay2@illinois.edu (A. Ibrahim), elanwar@uw.edu (O. El-Anwar).

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The term construction socioeconomic disruption in this paper refers to direct adverse effects caused by construction activities on the quality of life for surrounding residents, such as relocation and increased noise levels. It also encompasses other forms of socioeconomic disruptions that interfere indirectly with the surrounding human activities leading to the loss of business income and increased living and transportation expenses. Construction in planned urban areas - for instance highway construction and rehabilitation projects - commonly face dense urban construction challenges due to the high level of urban interference. [7–9].

Reducing disruption caused by construction is also a main topic in sustainable construction research. Ortiz et al. [10] used the Life Cycle Assessment (LCA) method to reduce construction material waste, reduce adverse environmental impacts and provide a responsible construction process. Santos et al. [11] investigated the lifecycle cost and environmental impact of pavement projects by studying different alternatives for asphalt mixtures and types of treatment. The later research focused mainly on improving pavement sustainability throughout the six phases of pavement lifecycle. Road construction is reported to cause many environmental, health and social disruptions [12–15]. These studies focus on deriving new designs, construction methods and techniques to reduce material waste and material transportation to minimize pollution emissions and energy consumption. However, research in sustainable construction focuses mainly on reducing projects' Life Cycle Cost (LCC) and minimizing environmental impacts which do not fulfill the need to assess the effect of construction projects on the surrounding social and economic activities.

A common dense urban developmental project in unplanned urban areas is to upgrade slums in order to address their rapid expansion and unhealthy living conditions. In such upgrading projects, the challenges associated with construction include (1) the temporarily relocation of dwellers, (2) the closure of businesses and other facilities, (3) the need for higher safety precautions, (4) the limited site accessibility and congested layout, (5) residents' opposition to the project, which can result in violence, and (6) the construction-related health issues due to high levels of noise and vibration [16,17]. While these challenges are very vivid in upgrading projects in unplanned areas, projects in planned urban areas also face these challenges [18].

Previous research contributions relevant to the challenges imposed by dense urban construction have managed to identify the main factors of disruptions. Gilchrist and Allouche [2] categorized the indicators of disruptions according to their impacts in four main areas; namely (1) traffic, (2) economic activities, (3) pollution, and (4) ecological, social, and health. To assess the disruptions, the authors used evaluation methods based on correlating the disruptions to several tangible and/or intangible factors. Nevertheless, the proposed methods require the availability of substantial amount of data that is not commonly accessible during the planning stages of dense urban projects. To such extent, the lack of available data hinders the identification and evaluation of possible socioeconomic disruption factors, which leads to poor construction planning decisions. Hence, in order to support planning for these types of projects, there is a need for an assessment methodology capable of quantifying and analyzing the major socioeconomic disruption factors associated with dense urban construction. While construction projects have socioeconomic impacts throughout their life cycle (e.g. during construction, operation, or disposal), the main focus of this paper is on the construction phase in order to fulfil the aforementioned research gap.

Our objective is to model the construction-related socioeconomic impacts of dense urban construction projects. The novelty of the proposed model stems from two main aspects. First, the model is capable of objectively quantifying the socioeconomic impacts of selected construction methods and execution phases on residents and businesses in proximity to the construction operations. Second, the model can receive input data as early as the project planning phase.

2. Model formulation

This paper presents two formulations for the socioeconomic assessment functions to reflect the different levels of data availability during the planning phase of the project. The first formulation requires the least amount of input data and utilizes multi-attribute utility functions to assess alternative construction plans. The second alternative offers a more accurate formulation that depends on less subjective data but requires input for the compensation rates for each of the socioeconomic impacts. In the latter formulation, a monetary-based assessment is applied based on the residents' experience during the construction process.

In the following sections, we present the first model formulation and its computational implementation before presenting the second formulation. The paper then presents a case study that demonstrates the application of the proposed models to assess alternative construction plans to a dense-urban construction project and discusses the models' capabilities and limitations.

3. First formulation: multi-attribute utility functions

The first formulation is designed to enable planners to assess the socioeconomic impact of possible construction plans on nearby residents and businesses. To this end, this formulation requires basic knowledge of the construction project and its surrounding area. The nature of this knowledge will depend on the socioeconomic metric being assessed, which can be(1) increased travel distance; (2) residents relocation; (3) business loss; (4) business closure; and (5) noise inconvenience.

The assessment of each of the aforementioned socioeconomic disruption metrics undergoes four main steps. First, a multi-attribute utility function is developed for each metric to assess its corresponding socioeconomic impact on each resident or business. This step results in a normalized impact decimal value that can range from 0 (indicating no experienced disruption) to 1 (indicating maximum disruption). Second, the socioeconomic impacts for each metric are aggregated for all affected residents or businesses. Third, a relative weight is assigned to each metric with respect to the other metrics. Finally, the weighted impacts are multiplied by a factor that accounts for the effect of the duration of the disruption. The following subsections present the formulation of each of the main socioeconomic metrics.

3.1. Travel distance metric

The travel distance metrics measure the increase in distance travelled by residents from their dwellings to surrounding services, increased travel distance originates from roads closure and detours due to construction operations. Generally, residents' travel patterns are disrupted where closure of roads and business impact residents' access to the most conveniently located providers of daily basic services. In this case the disruption can be inferred from the ratio of the new distances travelled by dwellers to the original distances travelled before construction.

Surrounding services include bus stops, schools, grocery shops, retail stores, etc. The travel distance computations require the following set of data about the studied area, (1) the locations and types of services to be included in the travel distance analysis; (2) the expected visiting frequency of each service based on its type (e.g. the expected number of trips to the grocery store per month); (3) the original distance travelled (D_o) by residents to each service; and (4) the corresponding new distance during construction operations (D_n).

These computations also require defining three parameters; namely (1) the shape of the utility function, whether linear, exponential, or logarithmic; (2) the minimum distance (ΔD_{min}) below which the increased travel distance has a negligible impact on residents; and (3) the maximum distance (D_{max}) that if reached the resident is assumed to