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Framework for Managing the Traffic Impacts of Building Construction Projects

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Abstract: Major building construction projects are important to the economic development of urban areas. However, such projects have negative impacts on their surroundings, particularly on traffic. This paper presents a framework for mitigating the traffic impacts of building construction projects in urban areas. The proposed framework consists of two stages: identification of the logistical construction requirements and development of an impact mitigation plan to control the negative effects of construction traffic on the road network and the surrounding community. The adopted methodology includes (1) a review of the available construction traffic management plans for twenty large building projects worldwide, (2) site visits to seven large building construction projects in urban areas and (3) multidisciplinary focus group sessions to extract knowledge and synthesise the proposed framework for managing the traffic impacts of building construction projects. The suggested framework provides systematic guidance for construction planners and site managers in developing a traffic management and impact mitigation plan for building construction projects. This framework could also help construction planners and site managers to better plan and manage construction activities to minimise the impact on the surrounding roads and minimise unnecessary delays by organising timely movement of resources to and from the construction site.

Keywords: Building construction, Project planning, Construction site, Impact mitigation, Traffic impact

INTRODUCTION

Construction activities in urban environments often have negative impacts on the communities surrounding the construction site, such as delays, negative environmental impacts, congested traffic conditions, safety hazards, and economic losses (Fuertes et al., 2013; Gangolells et al., 2011; Ahn et al., 2010; Gilchrist and Allouche, 2005; Chen, Li and Hong, 2004; Shen and Tam, 2002). These adverse impacts include (1) delays and traffic congestion caused by the additional traffic volume of construction traffic, (2) loss of parking spaces, (3) additional traffic conflict points at construction access and egress gates and (4) safety hazards associated with moving heavy equipment and oversized loads. Although avoiding those impacts may not be practical or even possible, they must be mitigated for the proposed construction project to earn an acceptable rating both environmentally and socially. Mitigating the impacts of construction projects on traffic conditions in urban areas is a major issue for construction managers, city officials and other regulatory bodies. The statutory requirements of many cities require that these authorities bear responsibility for mitigating the impacts and that provision for enforcing this responsibility be embodied in construction contracts so

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that the owners and engineering supervisory staff on construction sites can be held accountable.

In addition to being a legal requirement, proper management of construction traffic provides a number of advantages to construction companies, including (1) improved efficiency of construction operations by minimising unexpected delays in the movement of materials and equipment to and from the construction site, (2) improved company public image and public relations with the surrounding community by minimising the nuisance factor for residents and businesses in the neighbourhood and (3) minimised potential for accidents (i.e., enhanced safety) for workers as well as for local pedestrian traffic and road users.

A review of the literature related to traffic management and building construction reveals that there are two categories of reported research: (1) traffic impact assessment studies (Fang, Wenyu and Hui, 2009; Chen and Du, 2009; Hokao and Mohamed, 1999) and (2) studies on management of the impact of construction operations on traffic conditions (González and Echaveguren, 2012; Lee, 2009; Edara and Cottrell, 2007; Yu and Lo, 2005). However, construction traffic management (CTM) studies are different from traffic impact assessment (TIA) studies in the following ways: (1) TIA attempts to estimate the impacts of construction site activities on the surrounding road network after completion of construction (i.e., the operational phase), while CTM addresses the traffic problems generated by the building project during construction, (2) TIA forecasts the number of trips that will be generated as a result of operating the completed facility, while CTM estimates the number of trips that will be generated based on the scope of the construction work and the construction schedule, (3) CTM addresses traffic that includes a large percentage of heavy vehicles and oversized loads, which creates more risks for road users and (4) CTM personnel can proactively manage traffic patterns by construction staging, limiting the movement of materials and equipment to off-peak hours, restricting parking, using buses and establishing collection points for construction workers away from congested areas. The second category of reported research has received a great deal of attention from researchers, who have analysed the impact of construction operations on traffic conditions. However, almost all these efforts were limited to highway construction and maintenance operations (i.e., work zones), with little to no attention given to the impacts of building construction operations on traffic conditions.

Building construction operations significantly impact traffic, which is aggravated by the growing trend towards building skyscrapers and high-rise buildings in city cores, perhaps to create landmarks or to cope with the ever-rising cost and shortage of land in prime locations. Building skyscrapers and high-rises requires massive amounts of materials and involves large numbers of workers. For example, the Burj Khalifa in Dubai, which is the tallest man-made structure in the world, required 330,000 cubic meters of concrete, 39,000 tons of steel reinforcement, and 22 million man-hours to build (http://www.burjkhalifa.ae).

The objective of this paper is to propose a framework for managing the traffic impacts of construction projects. The proposed framework can be used at the planning stage of a project to prepare a construction traffic management plan (CTMP). This framework can also help site managers to better plan and more effectively direct construction activities for minimal impact on traffic conditions by organising the movement of materials and equipment to and from the site in a

timely fashion. To the best of our knowledge, this is the first study to address the mitigation of the traffic impacts of building construction projects. In this paper, we present our research methodology, the objectives of CTM, the contractual and legal enforcement of CTM responsibilities, and our proposed framework for developing a CTMP, which consists of two major stages: (1) identifying the logistical requirements of a construction project and (2) developing a plan to mitigate the traffic impacts of construction on road users and on local residents and businesses.

METHODOLOGY

The research methodology that we adopted to develop the proposed framework consists of three phases: In Phase I, we reviewed the available CTMPs for twenty large building construction projects worldwide. In Phase II, we visited a number of large building construction sites in urban areas: three projects in Abu Dhabi and four in Dubai. In Phase III, we took a knowledge engineering approach and held three multidisciplinary focus group sessions involving construction project managers, construction planners, traffic engineers from municipality and police traffic departments, and engineering consultants with construction monitoring responsibilities. The following sections provide a brief description of the conducted site visits and the organised focus groups.

Site Visits

This phase is intended to provide a better understanding of the traffic impacts of building construction projects, the different perceptions of project stakeholders on these impacts, and the areas of concern that should be addressed in the CTMP. We visited seven construction sites in May 2013. The seven selected construction sites were all large building construction projects located in central business districts in Dubai and Abu Dhabi. This project type was selected because the impact of construction activities on traffic conditions around such projects is obvious and significant. As such, it is possible to identify challenges and areas of concern that should be addressed in the mitigation plan. The management of each site was contacted in advance for an appointment and to obtain the necessary approvals for the planned visit. Prior to each site visit, a car tour was performed on the roads surrounding the site. Each site visit began with a meeting with the construction project manager, followed by a meeting with the safety supervisor/manager and a meeting with the consultant in charge of the construction phase monitoring. After the three meetings, the safety supervisor accompanied us on a walking tour within the site boundaries followed by a walking tour around the site. After performing the site visits, the themes to be discussed in the focus group sessions were identified and assembled in categories, as shown in Figure 1. Additionally, the visits provided us with a better understanding of the problem to ensure that the focus group sessions will address all the necessary elements of the CTMP.

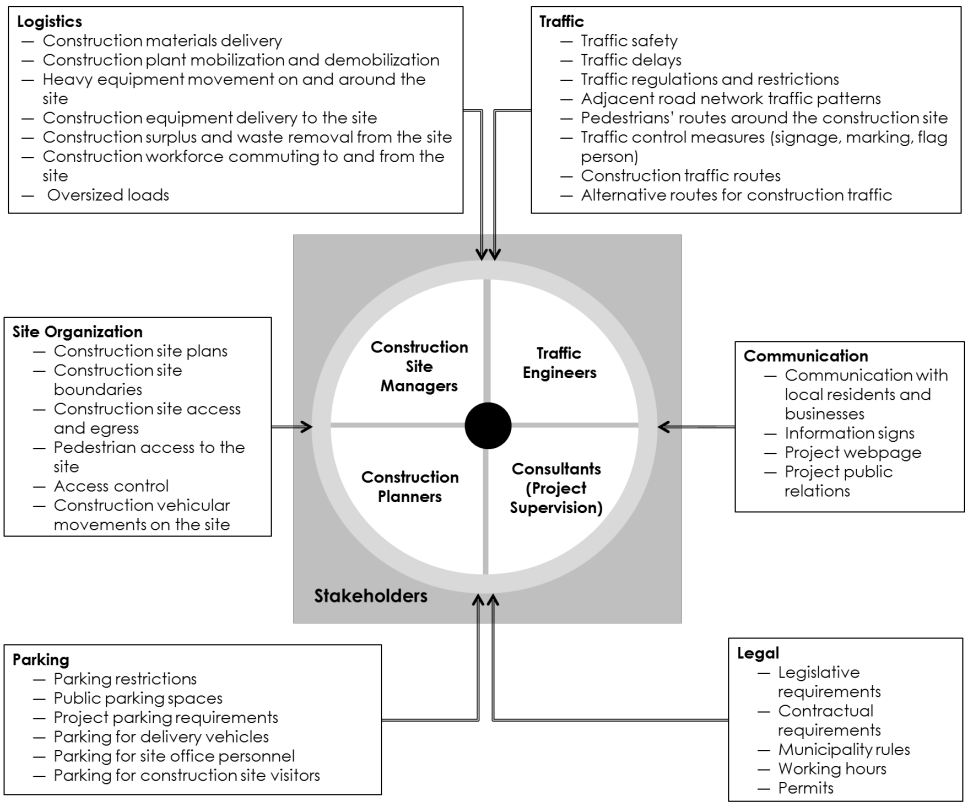

Figure 1. Focus Group Discussion Themes

Focus Groups

Focus groups can provide insight on different views and on the dynamics of the interaction within a group context. Although focus groups are used extensively in social sciences and marketing research, they are not commonly used in construction management research (Ereiba, Glass and Thorpe, 2004). Experience has shown that the use of the focus group technique in engineering management is fruitful and provides a way to rapidly collect the views of stakeholders and integrate them into a plausible theory (Brits and Plessis, 2007; Ereiba, Glass and Thorpe, 2004; Gillen et al., 2004). Three focus groups were conducted in the city of Abu Dhabi in November 2013. The first author served as the facilitator for the three sessions. Each session included six to eight professionals and lasted for approximately two hours.

Each session began by introducing the focus group participants to create a thoughtful, accommodating atmosphere. Afterwards, the ground rules for the session were presented to participants as follows: (1) each participant was assured of complete confidentiality, as the outcome of the research does not include any names or affiliations, (2) all the participants were urged to share their point of view, as there are no right or wrong answers but only differing points of view, (3) each

participant was told he does not need to agree with the others, but he must listen respectfully as others share their views and (4) the session was videotaped to ensure the accurate recording of all the comments.

The first session of the conducted focus groups was used as a forum for brainstorming and generating ideas, with participants discussing different angles of a problem. The agenda for the first session started with a brief introduction by the facilitator about the scope of the focus group and the difference between construction traffic management, traffic impact assessment studies and the research that studies the impact of highway work zones on traffic conditions. The introduction was followed by a short presentation outlining the conducted site visits. The presentation offered the members stimulus material to invite comments and questions to open the discussion. During the course of the discussions, participants were presented with a set of predetermined open-ended questions designed to yield powerful information. Examples of the open questions raised in the first session include the following: What are the main impacts of urban building construction projects on traffic conditions? How can the traffic impacts of building construction projects be minimised? What are the characteristics of projects that have the greatest impact on traffic conditions?

All the sessions were video recorded in addition to notes being recorded during the session. The recordings of the conducted sessions were watched after drafting the outcome of the session to ensure that all the raised issues and viewpoints were documented properly. Table 1 shows excerpts from the participants' responses to one of the questions in the first session. The facilitator concluded each session by providing a summary of the discussed issues, and participants were asked to comment on the summary and provide amendments or corrections. Finally, the participants were asked to suggest questions to be incorporated into subsequent focus group sessions. Session 2 of the focus group was similar to session 1; however, the questions posed were more specific and refined based on the responses obtained in the first session.

Note-based analysis was used to synthesise the factors that should be considered in preparing the CTMP. In addition to the notes recorded in the first two sessions, the videotapes of the sessions were reviewed again to glean more information and to verify the notes taken during the sessions. The second step in the analysis was identifying substantive parts in the discussion related to the research objectives, as well as any new topics or issues, and to classify these issues under common headings. The analysis revealed that the management of traffic impacts can be divided into two stages: identifying the impact of the construction project on traffic conditions and developing a plan to mitigate the identified impacts. The traffic impacts of building construction projects is not a controversial issue, as all participants agreed in general that such impacts should be mitigated. However, the participants differed in their perceptions regarding the extent to which construction projects should be allowed to affect traffic conditions. Such differences were expected and reflect the professional responsibilities of the participants and their priorities. The noted difference suggests a trade-off between site interests and road users' interests in managing the impacts of construction operations on traffic conditions. A draft framework for construction traffic management was synthesised and presented to the attendees of the third session. The proposed framework was then modified based on the feedback we received from the participants.

Table 1. Excerpts from the Responses to a Question in the First Session of the Focus Groups

Question: How can the traffic impacts of building construction projects be minimised?	
Member 1	**Member 2**
"Drivers are to obey all road rules both on public roads and within the construction compound. This applies to construction trucks as well as personal vehicles." "Use of an on-site concrete batching plant will reduce the number of trucks accessing the site and on the local road network." "The nature of some construction projects limit, to a great extent, the effectiveness of efforts to minimise traffic impacts. Some projects are located on small land lots in fully developed areas with neighbouring buildings on three sides, which makes it very difficult to mitigate the traffic impacts of the project." "Ensure construction vehicles queue and unload within the construction compound only."	"Construction access and egress gates should be designed to allow trucks to enter and leave the site in a forward direction to eliminate reversing vehicles movements." "Stockpile materials on site so that construction can continue without delivery vehicles constantly accessing the site." "Encouraging carpooling can reduce the demand for car parking spaces." "It is important to provide alternative parking arrangements for site staff and workforce if the construction site cannot accommodate the parking needs. The use of public parking spaces, especially in commercial areas, should be avoided entirely, as it creates negative feelings about the whole project among the surrounding community."
Member 3	**Member 4**
"Designers can have a role in mitigating traffic impacts by encouraging the recycling of materials in projects that involve the demolition of existing structures." "The CTMP should be regarded as a live document, reviewed at regular intervals and, where necessary, amended to reflect changes in the construction schedule or changes in the scope of work." "It is important that delivery trucks comply with using the designated haul route and enter the site using the designated entry and exit gates." "Provide a central designated point of contact for community and resident comments for the duration and hours of work." "The site truck movements can be evenly distributed over the day."	"The peak of staff vehicles entering and leaving the site should be arranged so that it does not coincide with the peak traffic hours in the adjacent roads." "Maintain all traffic control devices and other works provided for traffic control during the whole construction phase of work. Some contractors (projects) maintain such devices at the early stages of the project to obtain the necessary permits, then overlook the need to make the necessary maintenance during the construction." "All existing parking restrictions (No Stopping/No Parking) on the surrounding roads shall be maintained and respected." "Schedule major deliveries during night time hours when it is possible to do so."

(*continue on next page*)

Table 1: (*continued*)

Member 5	**Member 6**
"Traffic impacts can be added as a constraint when construction schedules are developed to avoid the overlap of activities that have large impacts on traffic conditions."	"There should be no deliveries or access to the site during the times of peak traffic hours or school traffic zones within the times of 7:30 am to 8:45 am and between 2:30 pm and 3:30 pm."
"Vehicle wash-down facilities should be provided, especially in the excavation phase of the project, and any material deposited on local roads should be removed within a reasonable time."	"Oftentimes, there is a cumulative traffic impact of construction operations from several construction projects in the precinct. The developed plan must take into consideration the cumulative impacts of known construction activity in the area."
"Coordinate deliveries to the site so that there are not two deliveries at one time to avoid construction vehicle bunching."	"The capacity of the local roads should be maintained."
"The vehicular traffic movements at each of the site entry or exit gates for traffic need to be controlled by a qualified flagman to ensure that no potential traffic safety conflicts occur between the site truck traffic and pedestrians on the adjacent footpath or road users."	"Have a plan to manage unplanned major incidents on the road network: provide a senior construction representative on-site to liaise with the traffic authorities and emergency service agencies; provide support to emergency services, including traffic control in the vicinity of the incident."
"The hours of operation for the construction site can be chosen to ensure that the site traffic movements are being generated mainly outside the normal commuter peak traffic periods."	

The focus group sessions were held in three stages to allow the researchers to assess the extent to which saturation has been reached. The outcomes revealed that three sessions were sufficient for the problem under consideration because an increasing occurrence of repetition was observed in the successive sessions, particularly in the last one. Therefore, conducting more sessions would have no additional interpretive worth.

OBJECTIVES OF CONSTRUCTION TRAFFIC MANAGEMENT

Construction traffic management in building construction projects has three main objectives: (1) to organise the transport and delivery of construction materials, plant and equipment to the construction site and the removal of surplus items and waste materials from the site, minimising and controlling the project's impact on road users, neighbours, the surrounding community, and the environment, (2) to organise the movement of the construction workforce onto and off of the site on a daily basis, minimising the impact on the available parking spaces on the roads around the site, minimising the impact on traffic volumes and congestion, and encouraging the use of public transportation and (3) to control construction vehicle movements on the site, maintaining both construction worker safety and road user safety by minimising the interaction, wherever possible, between road

user traffic and construction worker traffic and by segregating pedestrian routes and vehicle routes.

CTM AS A CONTRACTUAL AND LEGAL REQUIREMENT

Construction traffic management is a contractual and legal obligation of contractors, whose responsibilities for mitigating the impacts of construction traffic and the transportation of construction equipment and materials to and from the site are normally specified in the contract documents and enforced by ordinance or by government and municipal legislative authorities. The International Federation of Consulting Engineers (FIDIC) conditions for construction contracts, which are used worldwide, embody such responsibilities in several clauses. For example, sub-clause 4.15 (Access Route) in the FIDIC Redbook (FIDIC, 1999) states, "The Contractor shall use reasonable efforts to prevent any road or bridge from being damaged by the Contractor's traffic or by the Contractor's Personnel. These efforts shall include the proper use of appropriate vehicles and routes". It further states, "The Contractor shall provide all necessary signs or directions along access routes, and shall obtain any permission which may be required from the relevant authorities for his use of routes, signs and directions" (FIDIC, 1999).

Sub-clause 4.14 of the FIDIC Red Book (Avoidance of Interference) states, "The Contractor shall not interfere unnecessarily or improperly with…the access to and use and occupation of all roads and footpaths, irrespective of whether they are public or in the possession of the Employer or of others" (FIDIC, 1999).

The requirements of the Environment Agency in Abu Dhabi (EAD, 2010) are another example of CTM responsibilities. The EAD requires residential and commercial development projects to submit a Construction Environmental Management Plan (CEMP), which addresses traffic issues, for approval prior to the scheduled start of construction. No construction activity can begin on the site before a No Objection Certificate (NOC) has been obtained from the EAD. When the NOC is due for renewal (required on an annual basis), a revised CEMP should be submitted if new mitigation measures were adopted or impacts occurred over the last year. EAD (2010) states, "The Traffic Impacts section should provide a description of the traffic impacts produced from the construction activities. This information should include, but not be limited to, the following: A description of the potential impacts to traffic from construction related activities, including those from the closing of streets and those from increased vehicle usage for construction equipment, supplies, and disposal activities".

Many cities around the world have similar requirements. For example, the Melbourne City Council requires developers and builders to submit a construction management plan (CMP), which takes into account all the relevant aspects of demolition or construction. The CMP must address in detail traffic management related to the construction site and the adjoining community (Melbourne City Council, 2005). The Construction Management Plan Guidelines issued by Melbourne City Council in 2005 state, "The Traffic Management Plan (TMP) should cover all vehicle, pedestrian and cyclist access around the site, and all other roads where the impact of the construction work will be felt". These guidelines also state, "The traffic management of the site needs to be managed throughout the activity period, and periodic reports should be submitted to Council

demonstrating that the site is operating in accordance with the approved plan. Sites that do not provide periodic reports will be more frequently audited" (Melbourne City Council, 2005).

IDENTIFYING THE LOGISTICAL REQUIREMENTS OF CONSTRUCTION

A CTMP needs to address two logistical issues: (1) transportation, by road, of the plant, materials and equipment needed for the work onto the site and the removal of construction waste from the site to licensed disposal facilities and (2) the movement of a large number of workers, especially at peak times, onto and off of the site on a daily basis with minimum impact on the neighbourhood, especially on the available car parking spaces. The proposed procedure for identifying these two logistical requirements is presented below.

Construction Materials and Equipment Logistics

1. Identify the construction materials that will be delivered to the site (e.g., concrete, reinforcing bars, crushed stone, bricks, etc.). This information can be easily obtained from the bill of materials and the development plan for the project.
2. Identify the equipment to be delivered to the site (e.g., chillers, boilers, generators, high voltage switchgear, pumps, etc.). This information can be obtained in a similar manner to that step 1.
3. Identify the materials to be removed from the site (e.g., non-reusable demolition materials, excavated soils, and general waste that will not be useful in the completed project). This information can be obtained based on the site clearing and excavation requirements documentation and site surveys.
4. Identify any need to accommodate oversized loads. This requires consulting the lists of materials and equipment examined in the preceding three steps. Oversized loads have special transportation requirements, and their movement must be coordinated with traffic authorities in advance to ensure their safe transport.
5. Identify the locations of potential sources of materials and equipment needed for the work and of licensed facilities for waste disposal. Information on these locations should be readily available because the contractors need to consider location in the cost of construction in the bidding stage of the project.
6. Develop a construction materials traffic profile based on (i) the detailed schedule developed for the work (i.e., the scheduled start date and finish date for each major component of the work, such as site excavation, building the superstructure, etc.) and (ii) the estimated quantities of materials involved in each construction activity. Figure 2 provides a sample construction site traffic profile. The construction materials traffic profile will also be affected by other factors such as the availability of storage spaces at the construction site, the procurement schedule and material management policy, delivery arrangements with suppliers, the

geographic location of suppliers and the dynamic needs of the construction site.

7. Identify the main construction traffic patterns outlined in the construction site traffic profile.

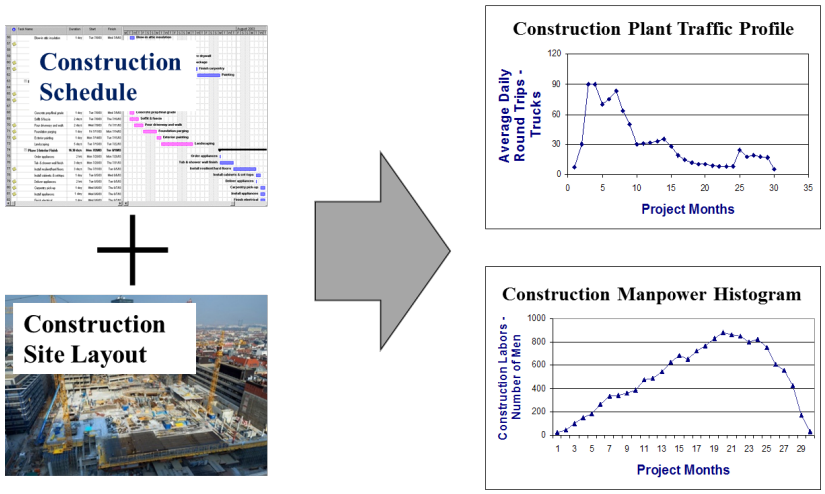

Figure 2. Identifying Logistical Construction Requirements

Construction Personnel Logistics

1. Develop a construction manpower histogram for the project based on (i) the detailed schedule for the project and the timelines for significant project components and (ii) the amount of work involved in completing each of these components. It is important to determine the labour requirements for each construction activity. This information should also be readily available because it provides the basis for scheduling resources and building resource histograms for all the trades involved in the project. Figure 2 provides a sample construction manpower histogram.
2. Estimate the number of site office personnel, and add them to the construction manpower histogram. Site office personnel includes (i) on-site project management, (ii) site management, (iii) engineering support and (iv) the owner's staff.
3. Identify the essential characteristics of the labour resources in a workforce profile. In building construction projects, the peak in the labour resources needed per day occurs in the second half of the project because this is when the finishing activities are performed, which are typically the most labour intensive.
4. Estimate the total number of parking spaces that will be required throughout the project's duration. In many projects, as construction proceeds, the number of available parking spaces required changes, as the new parking spaces for the newly constructed facility become available and can be used by construction personnel. The number of available parking spaces should take into account the spaces that will be

needed for site security personnel, site visitors and vendor representatives. The parking spaces available for workers can be obtained by subtracting the number of allocated spaces from the total number of parking spaces available.

The information generated at this stage will provide the necessary input to develop the second stage, which involves the preparation of a traffic impact mitigation plan that should meet the logistical requirements identified and include practical measures to minimise the construction impacts on the surrounding facilities and road users.

TRAFFIC IMPACT MITIGATION PLAN

The proposed methodology for preparing a traffic impact mitigation plan consists of the following major steps, as shown in Figure 3:

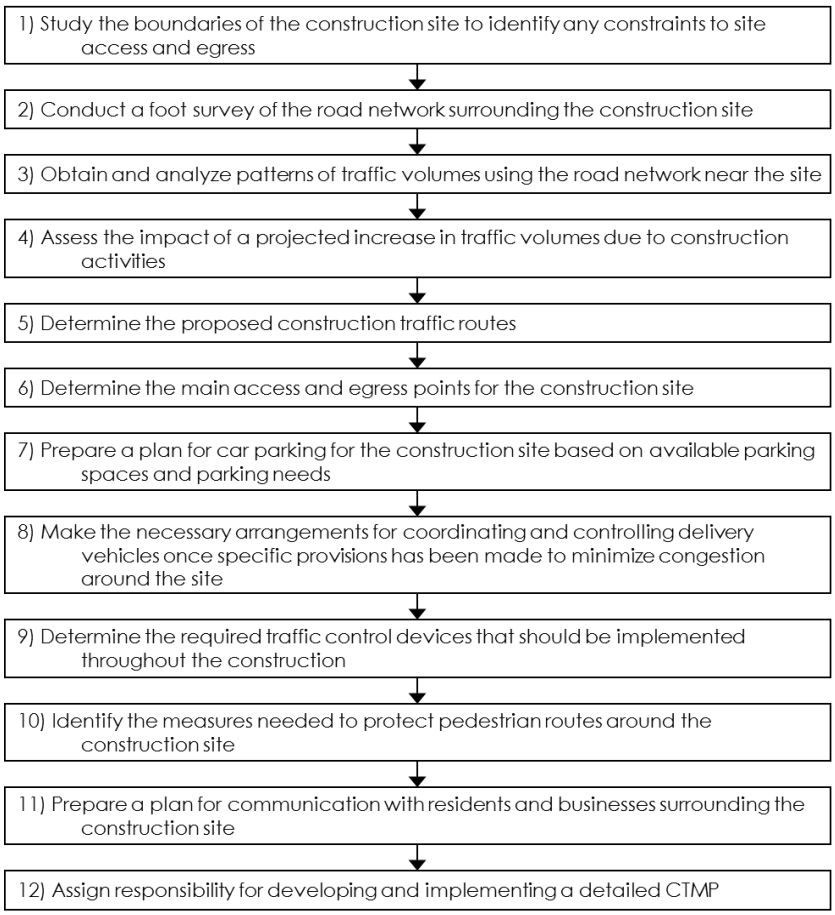

Figure 3. Developing a Traffic Impact Mitigation Plan

1. Study the boundaries of the construction site to identify any constraints to site access and egress. The study should include adjacent properties, gates, and restricted adjacent roads.
2. Conduct a survey of the road network surrounding the construction site on foot. The purpose of this survey is to obtain sufficient detail on the network, including load restrictions, height restrictions, road widths, parking availability, and their effects on current traffic flows, to make an informed decision on the selection of appropriate routes for construction traffic associated with the project.
3. Obtain and analyse patterns of traffic volumes using the road network near the site. The data needed should be available from municipal traffic departments, as traffic counts are conducted periodically to manage traffic. Traffic counts should include (i) traffic volumes and classification counts on major streets and (ii) peak hour counts at intersections.
4. Evaluate the impact of any projected increase in traffic volume due to construction activities in terms of congestion and change in circulation patterns based on the identified logistical construction requirements and the existing traffic patterns.
5. Determine the proposed construction traffic routes. This step involves (i) proposing routes for the transport of materials and equipment to and from the construction site, (ii) identifying the necessary modifications to the traffic regulations on these routes and (iii) determining alternative routes for the special case of high or oversized loads. The selected route should be suitable for the size and number of construction vehicles, in terms of their capacity, geometry, and height. The selected routes should also avoid residential side streets. Typical modifications to traffic regulations on the proposed traffic routes may include revoking some restrictions currently in place on these routes for the duration of the project or repealing metered parking along some road sections for the duration of the construction work (in this case, double yellow lines are needed on both sides of the road). For selected routes, planners should consider whether there are other ongoing developments in the local area or along the route. The approved construction traffic routes should be communicated to subcontractors, delivery companies, and suppliers through written briefings and site plans highlighting those routes.
6. Determine the main access and egress points for the construction site throughout the project duration, along with scheduled changes in these access and egress points, if applicable. These points need to be shown on the construction site layout (i.e., site setup) drawings. This step should minimise the points of conflict between construction traffic and existing traffic to limit the possibility of traffic accidents and disruptions to road users. Based on the traffic study, a gate may be chosen as a construction entrance and should therefore be used for construction site access only. A gate can be designated as an egress site only. The designated entrances and the roads around them need to be kept clear of dirt and debris from site operations by a wheel wash unit and road sweeper. Site layout plans should show all points of access, where materials, skips, and equipment will be stored and how vehicles will access the site. Pedestrian access to the site should also be shown on the site layout, which should include the

properties surrounding the site. A construction egress point should be selected to enable construction vehicles to turn around on the site to exit in a forward direction. In the selection of access points, planners should designate a place where delivery vehicles can wait to load or unload if they cannot access the site.

7. Prepare a plan for car parking for the construction site based on the parking needs and parking spaces available. The plan should include strategies for dealing with a shortage of spaces and avoid the use of public parking spaces to minimise the impact on the areas surrounding the construction site, especially in commercial and residential areas. Parking and traffic controls around building sites must be respected. Adequate provisions need to be made for contractor/worker vehicles in a manner that minimises disruption to the surrounding area.
8. Make the necessary arrangements for coordinating and controlling delivery vehicles once specific provisions have been made to minimise congestion. Examples of these arrangements include (i) providing set times for the arrival of deliveries, (ii) sending delivery instructions to all the suppliers and contractors, (iii) assigning trained site staff to assist when delivery vehicles are accessing the site or parking on the highway adjacent to the site, (iv) assigning a flagman to ensure the safe passage of pedestrians and vehicular traffic in the street when vehicles are being unloaded and (v) providing practical measures to ensure that construction vehicles do not wait or stack up on public roads if a large number of delivery vehicles is expected. This requires that an appropriate location be assigned (i.e., vehicle holding procedures) outside of the congested area for waiting, providing for suppliers to call the site manager before their vehicle arrives at the site and to wait outside of the congested area if the loading area is unavailable. Restrictions applying to suppliers should be communicated to them before they undertake the journey to the site.
9. Select the required traffic control devices that should be installed and used throughout the construction period. These include (i) road signage to be erected in the vicinity of all the entrances and junctions to satisfy the requirements of the regulatory authority (i.e., departments of transportation or municipalities) specifications and (ii) traffic monitoring and guiding of motorists outside of the site boundaries. This step involves deciding what signs will be required and where they should be placed before work begins on the project as well as before work begins for each stage of the project, e.g., warning signs on and around the site. Full-time traffic control (a flag person) may be needed, along with the required signage, on the main egress point of the construction site to direct construction traffic off of the site and onto the road and to prevent the development of a traffic jam on the road.
10. Identify the measures needed to protect pedestrian routes around the construction site from the construction work. If it is anticipated that this work will involve disruption or use of a public highway during the construction period, protective measures should be taken for those using walkways, especially vulnerable users, such as wheelchair users, the elderly, people with walking difficulties, young children, people with prams

or strollers, the blind and partially sighted, etc. A secure hoarding will generally be required at the site entrance with a lockable access. Any work above the ground floor level may require a covered walkway adjacent to the site. Appropriate ramping must be used if cables, hoses, etc. are run across the walkway. The adjoining public highway must be kept clear and free of obstructions. Lighting and signage should be used on temporary structures and hoardings.

11. Prepare a plan for communication with local residents and businesses surrounding the construction site. Effective communication with local stakeholders is essential to minimise the inconvenience to the surrounding community caused by the construction as well as to ensure the safety of drivers and pedestrians in the vicinity of the site. The plan should include measures to (i) advise those affected well in advance of any special transport issues, such as wide loads, that will affect traffic flows in the area, (ii) respond to the inputs and reservations of local community members regarding construction traffic and (iii) disseminate information regarding the construction schedule. The plan should specify methods for advising the general public of the impending changes, such as fixed signage; radio, newspaper, and leaflet announcements, and community liaison meetings, and the ways in which information will be communicated in a timely fashion. The communication plan should also assign responsibility for addressing any concerns, comments, and complaints from local residents and businesses to an appropriate representative. Generally, this will be the project manager, site manager, owner or the owner's agent.
12. Assign responsibility for developing and implementing a detailed CTMP. The contractor is generally required to develop a detailed plan for the construction work and to designate an individual to supervise and manage the implementation of this plan. The consultant should, in conjunction with the contractor, review the implementation and effectiveness of the plan on a regular basis. Any changes, modifications or adjustments deemed necessary as a result of these reviews should be implemented.

DISCUSSION

The proposed framework is intended to provide guidance for construction planners in the essential management of the traffic impacts of building construction projects. Construction planners need to understand the challenges involved in managing traffic impacts caused by the dynamic nature of both the construction site and the traffic conditions in the surrounding road network. Unforeseen circumstances, such as accidents, weather conditions or events in the neighbourhood, could affect the expected traffic conditions. These uncertainties need to be considered in the plan. Alternative traffic routes for deliveries need to be identified in case unexpected changes in the planned traffic routes require changing the delivery route. The recent development in mobile applications for real-time traffic information is expected to provide valuable information about traffic conditions before making delivery trips. These challenges suggest that the developed traffic mitigation plan should be a live document that should be

frequently updated to reflect the dynamics of the construction site as well as the road network surrounding the site.

Further research is required to quantify the trade-off between planning an efficient construction activity schedule and the need to mitigate construction impacts on the traffic conditions around the construction site. Allowing construction traffic movements to and from a construction site considering only the needs of the construction can cause severe traffic snarls and even create safety risks to road users when deliveries of construction materials and equipment are allowed during normal business hours, especially at peak periods when traffic densities are high. However, restricting construction traffic movements to out-of-hours deliveries may adversely affect the project schedule and cause noise pollution from trucks moving past nearby residential areas. Applying the proposed framework to several case studies in future studies is also needed to evaluate its effectiveness in mitigating the traffic impacts of building projects.

CONCLUSION

The negative impacts of major building construction projects on traffic conditions are frequently the centre of controversy and can lead to unnecessary delays, lost productivity, added project costs, and bad public relations with the surrounding communities. The general disturbance and annoyance associated with construction projects need to be mitigated by construction planners and site managers. This paper has presented a framework for managing the traffic impacts of building construction projects in urban areas. The framework consists of two phases: identifying the logistical traffic requirements and developing an impact mitigation plan to control potentially negative impacts on the surrounding community and road users. The proposed framework was developed based on (1) a review of existing construction traffic management plans for twenty large building projects worldwide, (2) site visits to seven large building construction projects in urban areas and (3) multidisciplinary focus group sessions held to extract knowledge from professionals associated with managing the traffic impacts of building construction projects. This framework contains practical strategies for managing traffic impacts and should be useful to construction planners and site managers in satisfying contractual and regulatory requirements for traffic impact mitigation and in preventing unnecessary delays due to construction activities.

Proper planning for mitigating the traffic impacts of construction operations is a proactive approach, which is better than the existing reactive approach in many construction sites where spontaneous measures are taken to mitigate traffic impacts in response to community complaints or traffic congestion. The absence of reported research on the traffic impacts of building construction operations has led to a lack of awareness of these impacts among construction planners. The proposed framework is expected to encourage the development of CTMPs even if they are not enforced by municipal jurisdictions. The framework is also expected to improve the current practice in which a CTMP is required and enforced by authorities. The development of systematic guidelines for preparing the CTMP provides a checklist to ensure the inclusion of all the elements that should be considered in developing the plan.

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