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UNIQUE DETERMINANTS OF CRANE SELECTION FOR MULTICRANE BUILDING CONSTRUCTION SITES

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Mega building projects typically employ numerous tower cranes covering the entire area of the building footprint and staging areas with multiple overlapping work envelopes. This paper aims to answer the following question: Are the determinants of crane selection for mega building projects similar to projects serviced by a small number of cranes? On-site interviews found: (1) the visibility of the crane forest in the surroundings of the project affects the approach to crane selection; (2) various modes of action are taken by project management to share information with the neighboring residents and business and to ease the hardships of living and working near a busy construction site; and (3) cranes are often selected and located such that they could dismantle other cranes, due to difficulties of using a dismantling mobile crane in the depth of the crane array.

Keywords: Equipment planning, Mega building projects, Tower cranes.

1 INTRODUCTION

Mega building projects typically employ numerous tower cranes covering the entire area of the sizable building footprint and staging areas with multiple overlapping work envelopes. This paper aims to answer the following question: Are the determinants of crane selection for mega building projects similar to projects serviced by a small number of cranes? Several measures were investigated based on ten case studies of multicrane projects located in urban European surroundings. The paper first presents a concise review of the relevant literature, then the data collection and analysis method, then the presentation and discussion of the findings, followed by concluding remarks.

2 BACKGROUND

Mega building projects, as multicrane projects are often referred to, differ greatly from what are commonly termed as just "megaprojects", i.e., *infrastructure* projects. Likewise, most of the published literature on construction mega projects focuses on large-scale national and international development plans (e.g., Fiori and Kovaka 2005, Oliomogbe and Smith 2012, van Marrewijk 2013). Major issues that appear to be of interest to the research community with regard to megaprojects (e.g., political, social, ecological, cultural, statutory) are typically associated with large-scale infrastructure projects (e.g., Flyvbjerg *et al*. 2003, Sanderson 2012). Thus, research that exclusively addresses mega building projects in the context of the present study—a *single* large-scale building project serviced by multiple cranes—was unavailable. Similarly, the literature review revealed neither characteristics *specific* to mega *building* projects nor quantitative measures by which to define them.

In the current context, crane selection—hereinafter also equipment planning—refers to the selection, location, and operation management of cranes, whose specific models and layouts are the primary products of that process (the selection of other major equipment, such as concrete pumps and forming systems, is intertwined with that of the cranes). The professional literature rarely addresses multicrane sites. This may stem from a notion that such sites differ from smaller sites only in magnitude and not necessarily in complexity, and that no different approach to crane selection and location should therefore be developed for such sites. With the ever-increasing industrialization of construction and the acceleration of construction schedules, multicrane sites appear to be steadily growing in number. Nevertheless, their relative scarcity may be another reason for their absence from the body of published research. Another reason may be the recent focus on crane-related construction planning research, i.e., on high-rise construction in which the advantages offered by tower cranes are fully realized, whereas multicrane sites in the current sense are typically spread out and low-to-medium rise.

Research on crane locations driven by productivity and safety algorithms that use various advanced information technology tools to obtain optimal solutions has been offered (e.g., Tam *et al*. 2001, Kang and Miranda 2008, Lien and Cheng 2014). These, however, commonly address only three cranes at the most, which touches on the fundamental question of how many is actually “multi” with reference to the number of cranes on site. Wang *et al*. (2014) exemplify their optimization model on a 12-crane site. However, theirs is not a single-building project serviced by numerous cranes, as is studied here, but rather a cluster of six buildings, each serviced by two cranes. Furthermore, the aforementioned efforts tackle the problem from a computational perspective with a focus on the product (e.g., crane locations, collision-free paths, and motion planning), whereas the planning *process* is of no less interest. Indeed, a qualitative perspective that gives room to often-governing soft factors may yield important aspects of crane selection that the use of hard factors alone may not reveal.

3 RESEARCH METHOD

3.1 Case Studies and Interviews

Data were collected through case studies of ten multicrane building construction projects in Germany, the UK, and France. Each case study consisted of one-to-three in-depth structured interviews with the contractor's project manager (and often with other personnel in charge of crane selection), site visits, and inspection of exclusive project materials. The interviews contained both open-ended and structured questions; they addressed a broad range of topics to characterize the process of crane selection, of which a selected few are reported on here. All principal interviewees were senior practitioners with dozens of years of experience. Additional interviews were conducted with senior representatives of several independent equipment- and logistics-planning firms, mainly to gain a deeper understanding of the issues treated in the current study.

Selection criteria of the case study projects included: (1) gross built area ≥ 50,000 m^2 (mean value was 115,300 m^2); (2) construction budget ≥ €100M (€233M); (3) number of tower cranes ≥ five (6.9 and max of 12); (4) a distinct horizontal dimension; (5) a single building; and (6) busy urban location. All 69 cranes used on the projects were of the top-slewing type; 40 were company-owned and 29 were rented. The ten projects were executed by eight different construction companies known as leading contractors, and included various uses such as shopping centers, office buildings, and a variety of mixed uses. The number of workers per project at peak time ranged between 400 and 1,200, and the site's administration staff numbered between 40 and 80.

3.2 Measures

A list of factors potentially affecting crane selection was established based on previous studies (Shapira and Glascock 1996, Shapira and Goldenberg 2007, Yona 2011). Given the omnipresence of hard factors (e.g., quantities and weights of materials, building and site coverage, construction schedule) as major determinants in the decision about crane type, configuration, and size, emphasis was placed on soft selection factors. The factors were grouped under three headings: (1) project/site conditions—physical factors such as crane overlapping and obstruction of operator view; (2) project/company conditions—organizational factors such as the tendency to use company-owned equipment and company reputation; and (3) environmental conditions—infrastructure, regulatory, market, and weather conditions. Interviewees were requested to evaluate the influence of these factors on the selection of cranes for their projects. The influence was rated on a three-level scale: "high to very high" (indicates factors of a dictating nature), "low to moderate" (indicates factors of a supportive nature), and "not applicable or not at all".

Collected data included the number of cranes, jib lengths, heights, and location, as well as crane configuration, make, color, and procurement method (i.e., company-owned or rented). This measure examined the cranes and their layouts on the sites, mainly through investigation of various geometric features and their implications for crane work. Three other measures addressed within the current study were the multiplicity of parties involved in the equipment planning process, the uniqueness of involved parties, and the multiplicity of plan formats; see Shapira *et al*. (2015) for the report on the findings regarding these measures.

4 FINDING: UNIQUE DETERMINANTS OF CRANE SELECTION

4.1 Soft Selection Factors

Notably, only two soft factors of the physical site conditions group were rated by most interviewees as having high to very high influence on crane selection for their sites: site congestion, and on-site or adjacent obstacles. Crane overlapping was a dictating factor on four of the ten projects and a supportive factor on two more. Of the company-level conditions, only company tradition played a somewhat significant role. Typically, factors common in high-rise construction such as obstruction of operator view, repetitiveness of concrete elements, and winds (Yona 2011) scored a zero influence on most to all projects, given the low-rise and spread-out nature of most projects investigated. Crane dismantling was a problem on six of the investigated projects in the current study, which was solved by taking crane dismantling into consideration in the crane selection stage. Of the group of market conditions factors, most notable is the zero influence that the availability of skilled labor had on crane selection on all projects investigated, reflecting a relative low-activity construction market and unlimited supply of (often foreign) labor.

4.2 Company Reputation and Visibility

The importance accorded by the construction company to its reputation and visibility as factors considered in the course of crane selection was one of the unique characteristics of multicrane sites identified in the current study. The most noticeable and immediate indication was the uniform appearance of the tower cranes on the site, an initial impression substantiated later in the open discussion. When contractors use their own cranes, they have better control over visual maintenance (e.g., periodical paintwork) and over the types used on any given project, compared with rented cranes. But even then, the cranes might not always be in best of shape and exhibit uniform appearance, as this has much to do with company tradition and culture. When cranes are rented, control over visual maintenance is obviously low to begin with. Yet, on all ten sites investigated, including the five with exclusively- or partly-rented cranes, the sight of the crane forest was unique in terms of uniformity of crane color and visual care. The following examples demonstrate how the project—not the manufacturer, rental company, or construction company—was the governing factor in determining crane color: (1) the nine cranes on one of the projects, five of which were rented (four Liebherr and one Wolffkran) and four company-owned (three Liebherr and one Potain), were all painted yellow; and (2) of the two projects constructed by the same construction company, the five rented Wolffkran cranes on one project were painted red, whereas the 12 company-owned cranes on the other project—nine Wolffkran and three Liebherr—were all painted yellow. The participation of an assigned PR person in the equipment planning team also attests to the importance attributed by the company to visibility and reputation, far beyond what is common in smaller projects.

4.3 Public Sensitivity

To check the sensitivity to the needs of the public near the mega sites during construction and its influence on crane selection, the interviewees were asked to address a list of actions potentially taken by the project's management; this list was compiled from the literature (e.g., Glass and Simmonds 2007) and after the preliminary site visits and interviews was conducted as part of the current study.

On all but two projects, sharing information with the public in the immediate vicinity of the site and accommodating their needs to the greatest extent possible were considered a crucial element of equipment and logistics planning. This action took various forms, such as weekly newsletters distributed to the neighbors, periodical meetings with neighborhood representatives, visits to the site, and advance notification regarding certain specific operations (e.g., exceptionally late night work hours). Issues of mutual concern related to equipment were, for example, occasional oversailing of crane jibs outside the site's boundaries and above public areas, and noise from machines operating at late hours. These issues were particularly pronounced in the investigated sites, given their size and work intensity, combined with central locations in busy urban settings. This attention paid by the construction company to the needs of the public around the mega site partially contradicts findings reported by Close and Loosemore (2014), whose study did not focus on mega projects. Based mainly on responses to questionnaires received from 150 construction professionals in the UK, Australia and New Zealand, Close and Loosemore found that community concerns were perceived to be the responsibility of town planners before work starts; once work started, interaction with the community was viewed as a nuisance and community consultation was considered a burdensome, costly, and time-consuming exercise.

4.4 Crane Overlapping

Crane work in shared zones created by overlapping crane envelopes requires more caution and is therefore slower; productivity is affected and safety becomes a matter of greater concern. While this is true on any site employing at least two overlapping cranes, it is particularly an issue on multicrane sites. The main findings produced by investigation of crane layouts in the current study are summarized as follows:

- Almost the entire footprint of the building is covered by *overlapping* work envelopes. There is a substantial number of locations where three and even four cranes overlap, creating a particular challenge to safe work. For example, the crane layout in one of the projects revealed three locations in which four cranes overlap and 16 locations with three intersecting cranes.
- While the work envelope of each individual crane on a regular site is commonly characterized by four different zones at the most, crane envelopes on multicrane sites are characterized by multiple different zones. For example, the work envelope of a typical crane in one of the projects contained as many as 12 different zones; the envelope of another crane on the same project contained 15 zones, and those of a third and fourth cranes contained “only” nine zones each. On the average, each of the 12 crane envelopes on that project contained nine different work zones. With the great extent of coordination and communication needed between operators, the most competent and skilled crane operators available are required.
- As is common on multicrane sites, some of the cranes are located in the depth of the site, and thus their dismantling after construction finishes may pose problems. This is true even if the large dismantling mobile crane has access from all sides of the completed project; if access from some sides is limited or impossible, not only is the challenge even greater, but it concerns more cranes on the site. For example, on one of the investigated projects, four of the nine cranes were selected such that they could dismantle the other five cranes before being themselves dismantled.

- Materials delivered to the site are sometimes needed in parts of the building where the crane is too busy to unload the truck, or has a load capacity lower than required to handle the lift. In such cases, another crane is assigned to the task and crane overlapping is used to transport the materials to their final destination (i.e., "double handling"). Similarly, crane overlapping is used when access restrictions prevent trucks from unloading materials where they are needed.

5 CONCLUSION

This study discussed several crane selection determinants unique to multicrane sites. The case-study research method with face-to-face interviews of senior experienced professionals gained insights unobtainable using a research method like questionnaires. To accord statistical significance to the findings, a larger population of multicrane projects will be used in the next phase of the study, alongside a population of smaller sites, with two to three cranes only, which will serve as a control group.

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