Involved Parties and Plan Formats in Equipment Planning for Mega Building Projects

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Abstract
Mega building projects are distinguished by the use of multiple tower cranes that oversail numerous shared work zones at graded heights. This paper aims to provide an answer to the following question: is the process of equipment planning for such projects similar to that of smaller projects? The answer was sought through the investigation of two measures, involvement in planning and issuance of plans, based on case studies of mega building construction sites in Europe. On-site interviews focused on three research variables: project planning stages, planning parties, and plan formats. Main findings were: (1) the number of participating parties was about twice as high as the respective numbers of involved parties identified in previous studies of regular sites; (2) various functionaries other than the "classic" parties were important players in equipment planning for mega building projects; and (3) the number of different format types used to document the outcome of equipment planning was about six times the respective number found in previous studies for regular projects. These findings indicate that the equipment planning process for mega building projects differs significantly from that conducted for regular projects.

Keywords
Construction, Equipment planning, Mega building projects, Tower cranes

1. Introduction

Mega building projects are distinguished by the use of a great number of tower cranes that work in harmony while oversailing numerous shared work zones at graded heights. This paper aims to provide an answer to the following question: is the process of equipment planning for such projects similar to that of smaller projects? The answer was sought through the investigation of two measures, based on case studies of mega building construction sites in Europe. The paper first presents a concise review of the relevant literature. Then the data collection method and the variables and measures used for analysis are presented. Next come the presentation and discussion of the findings, followed by concluding remarks.

2. Background

2.1 Mega Building Projects

The wide body of published research on construction megaprojects focuses almost exclusively on *infrastructure* rather than on building projects. This is likely because mega infrastructure projects have a larger physical, environmental and economic footprint; they affect a larger segment of the public; and are typically affiliated with national or international development plans (e.g., Brockmann, 2002; Kim, 2010), whereas mega building projects are often perceived merely as larger "regular" projects. One noticeable indication of the exclusive focus of megaproject studies on civil and infrastructure works rather than on building construction is the fact that the debate on the definition of megaprojects essentially addresses infrastructure construction and discusses parameters and magnitudes of parameters (mainly cost and physical size) that are either irrelevant to building construction or far exceed values extant in building construction (e.g., Fiori and Kovaka, 2005; Oliomogbe and Smith, 2012; Hu *et al.*, 2013). Thus, in addition to the lack of a uniform definition of megaprojects and of a characterization that distinguishes them from smaller projects, major issues that appear to be of interest to the research community with regard to megaprojects (political, social, ecological, cultural, statutory, and more) are typically associated with large-scale infrastructure and development projects (see Flyvbjerg *et al.*, 2003; Fainstein, 2008; Sanderson, 2012). Nevertheless, although building projects differ in many respects from infrastructure projects, the review of the literature on mega infrastructure projects can still shed light on several characteristics that may also be shared by mega building projects. Of the five characteristics proposed by Fiori and Kovaka (2005), only one—lofty ideals—appears to be exclusive to mega infrastructure projects and irrelevant to mega building projects of the type studied here; the other four characteristics listed are magnified cost, extreme complexity, increased risk, and high visibility—all of which are relevant also to building projects. Among megaproject characteristics listed by Oliomogbe and Smith (2012) in a summary of a literature review, most of which are typically relevant to infrastructure projects, several features may also apply to building construction of the kind addressed by the current study: the main contractor is privately owned (Sanderson, 2012); the project/structure is captivating because of its size, engineering achievements, or aesthetic design (Frick, 2008); and the project may arouse public opposition to the likely social, economic, and environmental impacts (Sykes, 1998). Nonetheless, the literature review conducted within the current study revealed neither characteristics *specific* to mega *building* projects nor quantitative measures by which to define them.

2.2 Equipment Planning for Mega Building Projects

The term "equipment planning" in the current context refers to the selection, location, and operation management of equipment for building construction; some related aspects of logistics planning are, necessarily, included as well. Tower cranes are the main piece of equipment addressed by the planning process, and their specific models and layout are the primary products of that process. The professional literature hardly ever addresses sites with multiple cranes, to say nothing of focusing on equipment planning for such 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; yet, their relative scarcity may be another reason for their absence from the body of published research. Another reason for the relative disregard of multicrane sites by the literature may be the natural focus placed in recent years, in crane-related construction planning research, on high-rise construction in which the advantages offered by tower cranes are fully realized, whereas mega building sites in the current sense are typically spread out and low-to-medium rise. Focusing on crane locations that are driven by productivity and safety, algorithms have been offered that use various advanced information technology tools to obtain optimal solutions (Zhang *et al.*, 1999; Kang and Miranda, 2008; Zavichi *et al.*, 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, all of the aforementioned research efforts address the problem from a quantitative perspective with a focus on the product (e.g., crane locations, collision-free paths, motion planning, lift scheduling), whereas the planning *process* and its parameters are of no less interest. Indeed, a qualitative perspective that gives room to often-governing soft factors may yield important aspects of equipment planning and management that the use of hard factors alone may not reveal.

3. Research Method

3.1 Case Studies

Projects

Data were gathered through case studies of ten multicrane building construction projects in Europe (Germany, the UK, and France). Selection criteria were: (1) gross built area ≥ 50,000 m^2; (2) construction budget ≥ €100M; (3) number of tower cranes ≥ 5; (4) a distinct horizontal dimension; (5) under construction at the time of the study; (6) a single building; (7) busy urban location; and (8) willingness of the project's management to cooperate with the research team. Mean values of the first three criteria for the ten projects were: gross built area 115,300 m^2, construction budget €233M, and number of tower cranes 6.9 (with max. of 12 cranes). Of the 69 cranes used on the ten projects, 40 were company-owned and 29 were rented. As is expected from projects of such magnitude, they were all executed by (eight different) leading construction companies known for their highly developed planning culture. While homogeneity was maintained in terms of project type (i.e., exclusively buildings), project designation included various uses (e.g., commercial, residential, offices). The number of workers per project at peak time ranged between 400 and 1,200 and the site's management, engineering and technical staff numbered between 40 and 80 persons. Thus, by any standard, these were mega building projects.

Interviews

Each case study included several phases and consisted of personal interviews, site visits, and inspection of various exclusive project materials provided by the site. The core of the study comprised in-depth structured interviews—one to three per project—with the contractor's project manager and often with the participation of other personnel in charge of equipment planning. The interviews, which were conducted on the construction sites, were based on an interview guide that contained both open-ended and structured questions and typically lasted three hours each; the mean cumulative duration of interviews for each project was about six hours. The interviews addressed a broad range of measures by which to characterize the process of equipment planning for multicrane sites, of which two are reported on here. All principal interviewees were senior practitioners with dozens of years of experience, and with 11 to 28 years of specific experience in the managing of mega building projects. Additional interviews were conducted with senior representatives of four independent firms who provided equipment and logistics planning services to several of the projects studied. These interviews served both to complete project-specific information and to gain a deeper understanding of the issues treated in the current study.

3.2 Variables

The on-site interviews focused on multiple research variables, three of which are reported on here: (1) project planning stages, (2) planning parties, and (3) plan formats.

Project planning stages

Three project planning stages were distinguished between as follows (Shapira and Laufer, 1993):

- Prebid planning (PBP): takes place prior to the submission of the bid. Its duration varies widely, from a few weeks to several months, depending mainly on the type of contract and the owner's timetable.
- Preconstruction planning (PCP): starts immediately upon the award of the contract and continues up to a certain point in the construction, typically not more than two months beyond mobilization.
- During-construction planning (DCP): starts one to two months after mobilization and lasts with varying intensities throughout the life of the project, following a repetitive pattern.

Planning parties

The initial list of parties participating in equipment planning (hereby also termed "involved parties") was based on lists offered by Laufer *et al.* (1993), who did not focus on equipment but rather addressed a whole range of construction plans, and by Shapira and Schexnayder (1999), who focused on equipment planning in a mobile-crane culture. The list was then expanded and refined during the preliminary interviews conducted in the current study, to include a higher-resolution composition of participants as follows: (1) owner; (2) company management (e.g., general director, chief engineer); (3) company office (i.e., technical staff at the company's home office); (4) project manager; (5) general superintendent (also termed "construction manager" or "site manager"); (6) project engineer; (7) company equipment manager; (8) company safety manager; (9) other clients of crane time (typically various subcontractors); (10) crane supplier; (11) structural engineer; (12) geotechnical engineer; (13) external logistics planner; (14) public relations; and (15) authorities.

Plan formats

As with the planning parties, the initial list of formats used for the issuance of equipment plans followed the list used by Laufer *et al.* (1993). That basic list was then expanded, in the course of the preliminary interviews, to appropriately address the expected nature of equipment planning on sites employing multiple tower cranes.

3.3 Measures

Two measures were used to identify and analyze the parameters of equipment planning in the projects investigated in the current study: (1) involvement in planning—the interviewees were requested to evaluate the degree of involvement of each party in the preparation of the equipment plan; the involvement was rated three times, once in each project planning stage, on a four-level scale, from "high" to "not at all"; and (2) issuance of plans—the interviewees were requested to check the various formats used for plans issued as the documented outcome of equipment planning, in each of the three project planning stages; the interviewees received a list of suggested formats, but they were not restricted to it.

4. Findings

4.1 Multiplicity of Involved Parties

Considerably more functional parties were involved in the equipment planning of the studied projects than are typically involved in the equipment planning of regular projects. This increase appears to be the result of project scale, complexity, and unique needs associated only with building projects of the magnitude examined here. Mean numbers of all participating parties were computed for the PBP, PCP, and DCP stages across all projects, and were found to be 7.1, 8.7, and 7.8, respectively. To filter for considerable involvement only and to compare results with two previous studies, mean numbers of participating parties were also calculated separately for the two upper levels on the four-level scale, namely high and moderate degrees of involvement; results for PBP, PCP, and DCP were 4.4, 6.8, and 4.2, respectively, with an overall mean number of participating parties across all planning stages of 5.1.

Table 1 presents the profiles of the current study and the two previous studies whose findings are examined here vis-à-vis those of the current study. Shapira and Schexnayder (1999) studied equipment planning using variables and measures similar to those used in the current study, though the projects in their study were regular building projects. The respective numbers of participating parties they found (Table 2) were considerably lower than those found in the current study: the overall mean number for megaprojects is 70% higher than for regular projects, and in PCP the increase—of 94%—is the highest. Indeed, previous studies defied the conventional notion that planning is done only before construction starts and showed how it is conducted—with changing focuses and patterns—continually throughout project life (Laufer *et al.*, 1993, 1994; Shapira and Laufer, 1993). Nevertheless, pre-construction is still the project stage during which most planning takes place. The current results further accentuate this conclusion with respect to megaprojects, given the complexity and wide span of interrelated planning issues involved, which appear to surface and demand detailed attention mainly during PCP.

Table 1: Compared Studies

Study	Number of projects	Project cost (million $)		Project duration (month)	
		Range	Median	Range	Median
Current	10	130–650	260	23–48	33
Shapira and Schexnayder 1999	36	1–200	5.5	3–28	8
Laufer et al. 1993, 1994	18	10–195	58	7–50	23

Table 2: Participating Parties

Study	Mean number of considerably involved parties				Key involved parties[a]			
	PBP	PCP	DCP	Overall	PBP	PCP	DCP	Overall
Current	4.4	6.8	4.2	5.1	HO, PM	PM, PE, HO, GS, EM, SE	GS, PE, PM	PM, GS, PE, HO
Shapira and Schexnayder 1999	2.4	3.5	3.0	3.0	HO, PM	SC, PM, GS	GS, SC, PM	PM, GS, SC
Laufer et al. 1993, 1994	2.0	1.0	3.0	2.0	PM, HO	GS	GS, PM, PE	PM, GS

PBP: prebid planning; PCP: preconstruction planning; DCP: during-construction planning

PM: project manager; HO: home/company office; PE: project engineer; GS: general superintendent; SC: subcontractors; EM: equipment manager; SE: structural engineer

[a] Parties are listed in descending order of their degree of involvement

In an earlier construction planning study, Laufer *et al.* (1993, 1994) examined the degree of involvement of various parties in nine functional plans. Their analysis was based on data collected through interviews from 18 projects executed by eight leading construction companies in the US. One of the nine functional plans, termed "major equipment," was equivalent to equipment planning in the current study. Laufer *et al.* found that the number of participating parties with considerable involvement in major equipment in more than 50% of their sample projects was 2, 1, and 3 in PBP, PCP, and DCP, respectively (mean of 2). Major equipment was only one of nine plans examined in that study and therefore the depth of its investigation was probably lesser than in the current study. But even when this variance is taken into account, the difference between the results—2 involved parties compared with 5, on average—is rather telling, and the difference in PCP is even more striking. Here, again, the projects were not what we termed megaprojects in the current study, although they were larger than the 36 projects addressed in the 1999 study.

4.2 Uniqueness of Involved Parties

Previous studies showed that the very same "classic" parties—the home office, project manager, general superintendent, project engineer, and often subcontractors— were repeatedly involved in equipment planning for regular sites throughout project life, albeit with changing roles and intensities. The current study, however, brings to the focus various other functionaries as important players in equipment planning for multicrane sites. Overall, in nine of the ten projects studied, at least one functionary other than those listed above was involved to a high or moderate degree in equipment planning in at least one of the three planning stages. At least two such functionaries were highly or moderately involved in at least two of the planning stages in six of the projects, and at least three were involved in all PBP, PCP and DCP in five of the projects. PCP is the planning stage at which the participation of such parties was the highest in seven of the ten investigated projects.

The additional parties with the highest frequency of high or moderate involvement were the company's safety manager and equipment manager, and the crane supplier. The former two were highly or moderately involved in seven and six of the ten projects, respectively; the crane supplier was highly or moderately involved in a smaller number of projects—four—but in three of these four projects that involvement was high in either two or three of the planning stages. The involvement of the crane supplier is, understandably, correlated with the mode of crane procurement: it is expected to be high in projects whose cranes—all or part of them—are rented and to be much lower or non-existent in projects where the cranes are owned by the construction company. In the current study, the cranes were all rented on four projects, of which the crane supplier was highly involved on three; the crane supplier was also involved, albeit to a lesser degree, on the sole project of the ten-project sample in which five of the nine cranes were rented and the others were owned by the contractor. The company's equipment manager plays a similar role, but not as distinctly and with an inverse mode. The equipment manager's involvement is expected to be higher when the contractor uses the company's own cranes and lower when the cranes are rented. Of the six projects in which the equipment manager was highly or moderately involved, four used contractor-owned cranes and one was the project with the partially-owned partially-rented cranes. Only one project in which all (nine) cranes were rented exhibited moderate involvement of the equipment manager (and only in PCP); the involvement of the crane supplier in that project was high and in both PBP and PCP.

Two other parties, associated with crane-related issues, that showed high or moderate degrees of involvement on some of the projects—always in PBP or PCP—were the structural engineer (who was consulted on issues such as temporary shoring of slabs in case of an internally-climbing crane or anchoring of an externally-climbing crane to the façade) and geotechnical engineer (who was consulted mainly on issues concerning crane foundations). Perhaps the two most unique parties involved in equipment planning that were identified in the current study are a public relations (PR) functionary and the local authorities. These two parties, who represent the interface between the site and its surroundings, were kept in the picture of equipment planning on all of the examined projects, although for the most part they did not actively participate in the planning process itself. However, in some of the projects, the active involvement of the authorities and PR was recognized by the interviewees, and was even rated as high or moderate, always in PCP and/or DCP. The PR functionary typically addressed the concerns of neighboring residents and near-by facilities regarding traffic, noise, and nighttime lighting. Examples of issues on which the authorities were brought into the equipment planning process are the need for temporary road closing during construction, off-limit zones for oversailing of crane jibs outside the site boundaries, and securing helicopter routes of to and from the roof of an adjacent hospital.

Finally, two additional parties, external to the site or the construction company, whose involvement emerged from the current study, should be mentioned as unique participants in the equipment planning process for mega building projects. The first of these is the owner, who although not new as a party participating in construction planning at large, is commonly not involved in equipment planning per se. In the current study, however, owners were found to be involved in five projects to various degrees. The owner's involvement was found to be highly correlated to the project's delivery method in which the owner joined forces with the construction company to execute the project as a joint venture. The second external party worth mentioning here is the construction company's management, which is normally not expected to take part in equipment planning for common-size projects, particularly not in companies the size of those that built the projects examined here. Yet company top management was identified as a highly involved party in two projects (in PCP).

4.3 Multiplicity of Plan Formats

Laufer *et al.* (1993, 1994) recognized that the mere issuing of a documented plan and, even more so, the multiplicity and variety of formats used for plans, is an indication of both the rigor of planning and the progressiveness of the construction company's planning culture. In light of this, and given both the nature of the examined projects and the reputation of the contractors executing them, similar findings were expected in the current study.

The most noteworthy of the findings, summarized in Table 3, is that, on average, eight different format types were used to document the outcome of equipment planning on each project. The respective number found by Laufer *et al.* (1993) was 1.2. This striking difference may be explained in part by slight differences between the two study methods, e.g., the current study used 13 formats whereas Laufer *et al.* used 11 formats. Furthermore, since Laufer *et al.* investigated nine functional plans and did not focus only on equipment planning, four of these 11 formats were a priori irrelevant to equipment planning. On the other hand, the one format type that Laufer *et al.* called "drawings" was addressed here as three different types (layout, elevations, and detailing), given the requirements of equipment planning. And yet, the over-500% increase in the mean number of format types stems primarily from the size and complexity of the sample projects in the current study; the planning rigor that these size and complexity necessitate; and the apparent centrality of equipment planning in construction planning for multicrane building projects.

Table 3: Formats of Plans

	Number of projects per format type													
Planning stage	Notes taken after phone call	Meeting minutes	Checklist	Table	Calculation	Standard form	Graph	Sketch	Flowchart	Gantt chart	Drawing: layout	Drawing: elevation	Drawing: detailing	All format types	**Mean number of format types per project**
PBP*	5	10	5	6	10	6	6	6	2	9	9	9	0	83	8.3
PCP	7	9	7	6	9	5	5	6	3	9	10	10	8	94	9.4
DCP	5	10	5	5	3	7	2	4	3	6	5	5	4	64	6.4
[Mean]	5.7	9.7	5.7	5.7	7.3	6.0	4.3	5.3	2.7	8.0	8.0	8.0	4.0	80.3	8.0

* Numbers normalized for ten projects (original entries were for eight projects, as two projects did not have PBP due to their delivery method)

The multiplicity of format types was most noticeable in PCP, while in DCP the rate of multiple format utilization was the lowest. Drawings of layouts and elevations were the most frequently used formats in PCP, followed closely by meeting protocols, calculations, and Gantt charts. Overall, these five formats, led by meeting protocols, were also those most used in all projects. Analysis in terms of format *families* show that drawings of various types emerge as the most frequently used medium. This result is quite understandable given the geometrical complexity associated with crane planning.

It is noted that, while in the current study the variety of format types exhibited in PCP is 13% higher than in PBP, Laufer *et al.* (1993) found the opposite: variety in PBP was 4% higher than in PCP for major equipment. Thus, the dominance of PCP in the current study, identified already in terms of the multiplicity of involved parties, is further substantiated. Finally, it should be noted that, although the aforementioned Laufer *et al.* studies took place some two decades ago, plan formats fundamentally have not changed since then; the interviewees in the current study did not add formats to the list presented to them although they were encouraged to do so. Naturally, what did change are the production means of plans, which are nowadays produced digitally.

5. Conclusion

With respect to the question posed at the beginning of the paper, this study found that equipment planning for mega building projects differs significantly from that conducted for regular projects. The suitable methodology to gain this insight appeared to be one of depth rather than breadth; hence, this paper is based only on ten case studies. Long face-to-face interviews of senior experienced professionals helped expose findings that would not have been obtainable using a research method such as the distribution of questionnaires to a larger project population. It is now possible to expand the current study with a similar one, in which (1) a larger population of mega building projects will be used to accord statistical significance to the observations found here; and (2) a population of regular projects will be studied in a comparative manner.

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