

## **Schedules and Schedulers: A Study in the U.S. Construction Industry**

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## **Schedules and Schedulers: A Study in the U.S. Construction Industry**

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## **ABSTRACT**

This research examines how the construction industry addresses the roles of schedulers and schedules, with the goal of improving current practices. We use a mixed-mode approach of qualitative and quantitative data regarding the use of schedules and role of schedulers in construction. Through influence diagrams and statistical analyses, we discover seven themes in the data and identify corresponding industry challenges related to each theme. Themes include the dynamic nature of schedules, changes in schedule level of detail throughout the life cycle, differences between planning and scheduling, and the evolving roles of schedulers. Based on in-depth discussions with a focus group and examining a large cross section of professionals in a nationwide survey, we propose recommendations to increase collaboration when developing schedules and to improve the roles of schedulers.

**Keywords:** scheduling; construction; planning; schedulers; U.S. Construction Industry

## **INTRODUCTION AND LITERATURE REVIEW**

This research examines the relationship between schedulers and schedules and the corresponding implications for engineering practice, especially in the construction industry. Specifically, we examine the differences between planning and scheduling, the roles schedulers play in project success, the effects of the baseline schedule, and the evolving role of the schedule throughout the project life cycle. Our research stems from open industry-based research questions posed by the Construction Industry Institute (CII) and refines into a nuanced understanding of the planning, scheduling, and scheduler roles throughout the life cycle. The insights gained in our analysis serve as inputs for the scope of a large scale study on collaborative scheduling practices and corresponding implications in the United States construction industry and beyond.

Schedules are part of the backbone that supports project management in construction, as well as in any other field of work. Despite its importance, planning and scheduling deficiencies are the most significant factors that influence cost performance in construction projects (Doloi, 2013). The scheduling of these projects rely heavily on the use of tools which employ the Critical Path Method (CPM), and the development and implementation of construction schedules are well documented in the literature (e.g., Antill & Woodhead, 1990; Ibbs & Nguyen, 2007; Lucko, et al. 2014). However, numerous studies discuss the limitations of CPM as a construction scheduling method and its shortcomings to manage construction projects, while proposing alternatives to schedule construction activities and manage production (Laufer & Tucker, 1987; Ballard & Howell, 1998ab; Koskela & Howell, 2002; Hamzeh, 2009; Kenley & Seppanen, 2010; Olivieri, Seppanen & Granja, 2018). Few of these studies have focused on perceptions about scheduling and how schedules are developed and used in practice, as well as the role of schedulers within the construction process. One notable exception is a series of articles published by a group of authors

in the 1980s and 1990s, which examined day to day tasks and roles of the staff developing schedules and managers planning field work (i.e., Laufer & Tucker, 1987, 1988; Laufer, 1990ab; Laufer, 1992; Laufer, Tucker, Shapira & Shenhar, 1994). Much focus has been placed on the tools used to develop schedules, especially the use of CPM, but little on understanding subtle differences between planning and scheduling and the role of planners and schedulers in the management of construction projects (Laufer & Tucker, 1987; Laufer, et al., 1994).

CPM scheduling in the construction industry is pervasive yet not properly understood in practice, as observed in a study regarding the use of CPM in construction projects developed by Galloway (2006, p.697); she affirms:“(w)hile critical-path method (CPM) scheduling has been around since the 1950s, its application in the construction industry has still not received 100% acceptance or consistency in how it is used.” In addition to the construction industry, this comment would be very much applicable to industries whose focus is not mainly on technological constraints, have high levels of variability in their tasks, and do not have unlimited amounts of resources to complete their projects, which represents the antithesis of the environment that originally developed CPM schedules.

To put this problem in context, a recent study conducted by some of the authors of this article surveyed practitioners in Brazil, China, Finland, and United States and found out that 71% (out of 532 responses) of the respondents used CPM (Olivieri, et al., 2019). Despite its shortcomings documented in the literature (Laufer & Tucker 1987; Koskela and Howell 2002), CPM is the tool of choice regardless of country, industry, type and size of organization, or job position (Olivieri, et al., 2019). Still, little is understood regarding the mechanics of who and how schedules are developed, the use of CPM or other techniques (e.g., location-based scheduling, takt

time, scrum), and how they are implemented to deliver value to the owner. This article aims to contribute to this discussion and works towards addressing this gap in the human elements.

Understanding construction industry practitioners' perspectives on these topics is critical for improving current scheduling practices; consequently, project performance, in terms of proper time and effort, needs to be allocated to scheduling and planning tasks (Laufer et al., 1994). In addition, clarifying misconceptions is also necessary for proper training of students and construction professionals to take into account not only what is really expected from them when they take the role of a scheduler but also what schedules entail (AlNasseri & Aulin, 2015).

This study started with an investigation of the limitations of current scheduling practices to support a broader investigation on the development and implementation of collaborative schedules and was broadly discussed with a group of practitioners from member companies of the Construction Industry Institute (CII), an organization based at The University of Texas at Austin. We use a set of initial research questions and statements provided by the CII and its advisory board as the departing point of this study; the questions were deemed worthy of investigation based on CII members' feedback at the time the study was conducted. The research questions are presented later in this article alongside the qualitative focus group and quantitative survey analyses. The objective of this research is to investigate both current construction practitioners' approaches to schedules and scheduling and their views on scheduling and planning, as well as suggest areas for improvement within both the construction industry and beyond. This article focuses on the investigation, including a relevant literature review on the definitions of planning and scheduling, as an input to a broader study. We also focus on the roles of schedules and schedulers in the United States construction industry. A total of 168 usable responses to the survey were obtained from four professional events in four different states. The results shed light into current practices in

U.S. construction, identify perceptions held by industry leaders, and suggest areas for future research as well as industry best practices. The results extend to other industries and may also be used as inputs to a broader study on collaborative scheduling practices in both the United States and abroad.

### **Commonly Accepted Planning and Scheduling Definitions**

The PMI (2017) defines five categories of Project Management Processes (Process Groups) that support different managerial functions and tasks in an organization, namely: Initiating, Planning, Executing, Monitoring and Controlling, and Closing. In this categorization, the planning of schedule management, the definition of activities and their sequencing, the estimation of activity resources and durations, and the development and control of schedules are located at the intersection of the Planning Process Group and the area of knowledge titled Project Schedule Management. Thus, we relate our discussion to this intersection, as defined by the PMI.

The literature on scheduling practices in the construction industry is broad and well documented. However, much of the discussion about schedules has centered on techniques and algorithms (e.g., Kenley & Seppänen, 2010; Kim, Anderson, Lee, & Hildreth, 2013; Lucko, Said, & Bouferguene, 2014; Li & Lu, 2017) as well as construction claims and disputes (e.g., Ibbs & Nguyen, 2007; Braimah, 2013), with little on the roles schedules play in the construction process, how they are developed, and for what they are used. More recently, schedules have been integrated with virtual tools supporting Building Information Modeling (BIM) and resulting in 4D-BIM schedules to support construction activities (Dave, Boddy, & Koskela, 2011; Harris & Alves, 2013; Kim, et al., 2013). However, despite advances in planning and scheduling alternatives, practitioners might still feel comfortable with using more traditional tools of which they are familiar, even if the use of some of these alternatives in dynamic construction projects do not allow them to foresee problems (Harris & Alves, 2013; AlNasseri & Aulin, 2015).

Considering that most research on planning has focused on specific tools and techniques and little on actual planning and control processes and the tasks and roles associated with them, great potential exists to advance theory and practice (Laufer, Shapira, Cohenca-Zall, & Howell, 1993; Laufer et al., 1994; Ackoff, 1999; Koskela and Howell, 2002). This was the case in the 1980s when the problem was discussed by Laufer & Tucker (1987) and continues to be a relevant issue to this date 30 years later. The Architecture Engineering and Construction (AEC) industry and Construction Engineering and Management (CEM) researchers have addressed this problem by offering new algorithms and tools to project managers (e.g., Karin & Adeli, 1999; Herroelen & Leus, 2004; Kim et al., 2013; Lucko et al., 2014), even though the managers lack quality time to plan (Telem & Laufer, 2006). Moreover, the separation between those developing the schedules and those implementing them has been discussed as unproductive in the literature (Appelbaum, 1982; Laufer, 1992). Consequently, the construction planning task has also been the subject of much discussion spearheaded by the Last Planner System of Production Control summarized by Ballard & Howell (1998) and related research aiming to involve those closer to construction/production tasks in both planning the execution of these tasks (Laufer & Tucker, 1987; Laufer, 1992; Abou-Ibrahim, et al., 2019) and monitoring their outcomes (Hamzeh 2009).

In conclusion, while planning and scheduling has received a lot of attention from the CEM community, the same cannot be said about the actual roles of schedules and schedulers in construction. Schedules might be created by those close to action, where projects are built, but might also be developed by those at company headquarters.

This review discusses how planning and scheduling have been addressed and defined in the literature. Note that treating planning and scheduling as synonyms has been reinforced in



practice. In reality, schedules are the main focus and end result of the planning process and are mostly used as contractual documents.

### *Planning*

Neale & Neale (1989, p.5) stated that planning is “*the creative and demanding mental activity of working out what has to be done, how, and when, by whom, and with what, i.e. doing the job in the mind*”. Similarly, Ackoff (1970) defined planning as “*a decision-making process performed in advance of action which endeavors to design a desired future and effective ways of bringing it about*”. These definitions emphasize that planning involves answering multiple questions involving a detailed method describing what (activities), how (methods), when (sequence and timing), and by whom (resources, competence) a desired future is to be accomplished (Laufer, Tucker, Shapira, & Shenhar, 1994). Plans are the output of the planning process and should also address constraints that need to be observed during implementation (Ballard & Howell, 1998). They are developed in multiple formats and points in time, involving and addressing different users (Laufer et al., 1994).

Preparing plans is one of the five stages of the planning process, namely: (1) planning the planning process; (2) information gathering; (3) preparation of plans; (4) information diffusion; and (5) planning process evaluation (Laufer & Tucker, 1987). However, preparing plans is the stage that usually receives a disproportional amount of attention (Laufer & Tucker, 1987), when the efforts should be better balanced throughout the process. Because of this dysfunction in the planning process, as far as allocation of efforts, plans are produced but the other activities are not properly dealt with, rendering plans ineffective (Laufer & Tucker, 1987).

In current practice, the way planning is practiced versus the way it should be might ultimately impact how the role of schedulers is perceived and how schedules ultimately get used

to manage projects. Schedulers might be viewed merely as those who crunch numbers and generate contractual documents, when they actually could be doing much more to generate plans that drive execution of projects. The planning effort and the planning skills of project team leaders are important factors affecting project success (Chan, Scott, & Chan, 2004); however, little is said about the work of schedulers and their role in schedule development, performance, and ultimately project success.

### *Scheduling*

As noted, although the terms planning and scheduling are often used synonymously, they are separate activities. More specifically, Antill & Woodhead (1990, p.9) stated that scheduling *“is the determination of the timing of the operations comprising the project and their assembling to give the overall completion time”*. The scheduling activity produces schedules, which are part of the planning process when different types of plans are generated. The Project Management Institute (2013, p.561) defines the schedule model as *“(a) representation of the plan for executing the project’s activities including durations, dependencies, and other planning information, used to produce a project schedule along with other scheduling artifacts.”*

Others define schedules as tools, which are designed, developed, and maintained with the goal of supporting the coordination of activities (Carson, Oakander, & Relyea, 2014). Schedule design refers to defining a structure for the schedule before the scheduling task starts. This includes the definition of a work breakdown structure to support the next phase, as well as the development of the schedule with its activities, durations, and relationships. Finally, schedule maintenance refers to the constant maintenance of the schedule to reflect changes in the project, its stakeholders, and resources.

Schedules are vital parts of projects and often used as a benchmark to collect schedule-related performance metrics, which are important indicators of project success (Hughes, Tippett, & Thomas, 2004; PMI, 2017). Different issues -- including the time project managers devote to specific projects, experience in similar projects, frequency of meetings with project personnel, constructability programs, and monetary incentives -- affect construction schedule performance (Kog, Chua, Loh, & Jaselskis, 1999). However, schedules are subject to manipulation and gaming of software used for their development (Glenwright & Mattos, 2008; D'Onofrio, 2017). Schedules might also be produced by staff who have little to no direct contact or experience with construction means and methods used on the field. This distance between planning and making also affects plan implementation (Laufer & Tucker, 1988). For these reasons, schedules should be validated before they become an official project document, reasonable in terms of the assumptions used, rational by incorporating proper construction methods, and achievable within the project constraints (Glenwright & Mattos, 2008).

## **Summary**

Exhibit 1 compares and contrasts the difference between planning and scheduling for construction projects, as outlined in the literature. Definitions for planning and scheduling are repetitive; thus, the focus of Exhibit 1 is to highlight general differences and commonalities between the terms, considering recurring themes in the literature regarding their definition (what), objectives (why), phases or levels (when), types (how). This categorization is broadly based on Laufer, Tucker, Shapira & Shenhar's (1994, p. 55) discussion of the 'multiplicity concept in planning', which states that effective construction planning: "*1. addresses numerous purposes and various users [Why/Who]; 2. requires numerous plans and various formats [What/How]; 3.*

*requires numerous timings and various time horizons [When]; 4. requires numerous participants and various modes of preparation [Who/How].”*

The common characteristics of planning and scheduling are that they are both dynamic and iterative processes, which need to involve multiple participants’ input and support. Scheduling is viewed in the context of this study as a dynamic activity that produces an evolving document that is constantly reviewed to address and reflect project constraints while focusing on accomplishing the goal of successfully delivering the project. However, this is an ideal definition, which was put to the test during this study, in order to facilitate the understanding of current industry perceptions about planning, schedules, and schedulers.

*Insert Exhibit 1 here.*

## **STUDY DESIGN**

This research examines how the construction industry addresses the roles of schedules and schedulers. Because a disconnect exists within the phases of construction as well as between owners and contractors, as shown in the literature, one of the goals of our study is to index current practices and limitations, which will then serve as an input to a larger study on collaborative scheduling in the construction industry. We also aim to understand roles and effects, especially between baseline schedules and the project life cycle. The motivation for this work was the Construction Industry Institute’s request to investigate collaborative scheduling and actions that are needed to break away from traditional scheduling practices currently used in the industry (Construction Industry Institute, 2016).

CII provided an initial set of research questions that were derived by its member companies. Established in 1983, CII is the premier Research and Development center in the capital projects industry in the United States. It has numerous owner, engineering-contractors, and

supplier firms from both the public and private arenas (CII, 2019). The CII is based at the University of Texas at Austin and performs many professional roles for the construction industry. One of those roles is to establish research teams to examine needs of its member companies. Therefore, the questions provided by CII reflect immediate industry growth opportunities, and research into solutions will have immediate impact in practice. The questions posed by CII (2016) are listed below:

- A. Has the schedule become a deliverable for contracting and litigation rather than a tool for collaboration (among owners, designers, contractors, and trade partners), commitment, and accountability?
- B. Is the scheduling effort focused on justifying the baseline schedule because of contract requirements, or is it put towards better solutions?
- C. Are schedulers now merely computer technicians, or do they facilitate team planning and subsequent re-scheduling?
- D. Is it understood that planning and scheduling are two different skill sets?
- E. How significant are the differences between level of detail during CPM development and during execution?
- F. Do project teams perform life cycle planning and scheduling from the owner's perspective, integrating and aligning schedules with important owner milestones?

Given the existing literature on planning, scheduling, and schedulers, there is a clear tie of these questions to existing research gaps, including Galloway (2006) to support questions A and B; Laufer & Tucker (1987) and Laufer, Tucker, Shapira & Shenhar (1994) to support question C; Laufer, Tucker, Shapira & Shenhar (1994) and Ponce de Leon (2008) to support question D; Laufer & Tucker (1988) and Hamzeh (2009) to support question E; and CII (2006) and Griego &

Leite (2016) to support question F. These connections are summarized in the first two columns of Exhibit 2. The questions are also generally validated by published literature as points of concern that have not been clearly addressed in the construction management (e.g., Galloway, 2006) and, in some cases, the project management literature (e.g., Koskela and Howell, 2002). For instance, the mechanical approach applied to scheduling is also linked to many failed projects. Today's technology has made it increasingly simple to create a schedule that completely ignores the planning process as well as the thought process that should come behind schedule creation (Ponce de Leon, 2008, p.1). Furthermore, CII singled out the critical path method (CPM) as the ubiquitous scheduling technique used across the construction industry and called for ways to identify and implement other scheduling techniques that might promote collaborative scheduling practices in addition to these specific questions.

To address these research questions and collect data, we convened a focus group and then executed an industry wide survey. We use a focus group to examine each question posed by CII and understand the current state of practice. Results of that analysis allowed for themes to emerge that were examined in a large-scale survey. Therefore, we built from overarching questions that drove our research, which were then refined, through the focus group, into more focused questions for quantitative analysis via the survey. This approach scaled the research questions posed by CII into a process that defined scope for a larger study on collaborative scheduling while also contributing immediate impacts to industry practice.

Generally speaking, focus groups can be used with quantitative or qualitative research. A key advantage of focus groups is that researchers interact directly with participants and can discover more about individuals' perceptions and views (Langford & McDonagh, 2003). A focus group was especially relevant for this study, as we had access to subject matter experts (SMEs)

geographically located together at a workshop meeting. This enabled in-person discussion as well as collection of non-attributable data, which could then be grouped into patterns or themes.

A survey “*provides a quantitative or numeric description of trends, attitudes, or opinions of a population by studying a sample of that population*” (Creswell, 2013). From sample results, researchers can make claims about the population using appropriate statistical methods. Surveys are among highly reliable scientific research methods because they provide participants with standardized stimuli; therefore, researchers’ own biases are eliminated (Sincero, 2012).

The survey was constructed to validate or dispute themes that emerged during the focus group and was an appropriate means to collect data also from a targeted expert group. Having both qualitative and quantitative data then allowed for a mixed-methods approach with triangulation in order to reach our conclusions. Scheduling can be a unique process, and the complexity of the task depends on many factors, including the size of the project. As a result, those with experience in this area have a wealth of knowledge that may or may not be quantitative in nature. A focus group allows for collection of data and relevant experience, which served as the basis for analysis. A follow-on survey then allows for a quantitative data collection and analysis to support or challenge the qualitative themes that emerged from the focus group.

Thus, the results of the focus group informed the generation of the survey. Data obtained from the focus group and the survey were cross-analyzed for response differences and similarities and to support and validate research findings. We discuss each method and the cross analysis in detail below.

## **FOCUS GROUP**

### **Protocol**

The focus group was the first step in examining the research questions as well as perceptions and trends. CII provided access to a team of construction industry professionals that represented companies from multiple sectors (e.g., oil and gas, pharmaceutical, energy, commercial, etc.) and multiple roles (e.g., owners, contractors, and designers). Specifically, the team comprised of six owners, six contractors, and one designer. They had on average 17 years of experience in construction planning and scheduling. Their positions/duties included but were not limited to Construction Resident Engineer, Director of Project Controls, Project Control Manager, Project Controls Analyst, Project Manager, Project Director on EPC Projects, Schedule Advisor, and Master Scheduler. The most experienced participant in the group had over 30 years of experience in planning and scheduling, and the least experienced participant had 4 years, with most of the group having between 10 and 24 years of experience each. The total years of experience in construction planning and scheduling was over 189 years. Size of projects on which they typically worked ranged from USD \$20 thousand to USD \$ 2 billion. This team became our main SMEs.

The focus group met in person at the University of Texas at Austin in June 2016. During this day and half workshop, the group was prompted with the six CII research questions. Our goals were to examine traditional scheduling methods and propose new, potentially more collaborative solutions.

To assess group member responses without attribution, each SME was given a notepad of pages with removable adhesive (e.g., Post-it™ notes). Researchers moderated the session, and asked one research question at a time, giving the group time to reflect on the question and formulate individual responses. Each comment or response to each research question was to be written by an SME on a separate page. Responses were gathered, read aloud without attribution, and grouped into an affinity diagram of clusters based on emerging themes within the responses. For example,



contractual requirements, tools, processes, and management are four separate themes, so individual responses that supported each of those themes were arranged into four separate groups.

Very early in the discussion it became clear that the SMEs had different views on how schedules are developed and implemented, as well as the roles schedulers play in this process. Because the comments were read without attribution and SMEs did not offer verbal explanation as the comments were read, it was difficult to discern if those views were driven by industry sector and/or role. For example, views on the roles of the scheduler varied and ranged from a technician who manages software to an integrated part of the project team. SMEs also were split almost equally on their views of planning and scheduling as the same or different skill sets. Because of these dichotomies, and even though the SMEs were accomplished professionals in the construction industry, this small group of thirteen respondents may not generalize to the industry at large. However, the focus group expertise enabled understanding of the complexity of the research problems at hand and enabled an understanding of potential themes in the industry at large, which could then be validated by the survey.

## **Results**

As questions A through F were individually discussed and affinity diagrams created, major themes surfaced, which are shown in Exhibit 2. For instance: question A addresses schedules as contractual instruments and/or tools for collaboration. Accordingly, the major themes associated with answers to this question were related to schedules being viewed as: (1) historical records, (2) tools to keep project participants accountable, (3) commercial/contractual tools, and (4) other. Comments in the Other group were made only once and therefore did not constitute unique themes. Questions B through F were analyzed in a similar fashion. Additionally, the theme-based sample statements in Exhibit 2 are direct comments provided during the discussion, except for the Other

theme, as those are inventories of the ideas mentioned only once and therefore are not direct comments.

*Insert Exhibit 2 here.*

Furthermore, because the responses to each research question were open-ended, SMEs did not always provide the exact same wording on their pages, even though their comments aligned with a theme. For example, within question A, those who commented on the topic of a schedule being a historical record also used key words such as minimum effort, reporting tool, and documentation. Appendix A arranges all key words provided by SMEs into an influence diagram. Note the range of responses for question A, especially those with a negative connotation such as punitive, protecting parties, and minimum effort.

Question B has a similar range of responses over the themes of accuracy, baseline, and strategic dynamic tool. Appendix A also presents all key words provided for question B in an influence diagram. Here the focus group perceptions varied from positive to negative, as schedules were proposed to be positive (strategic and dynamic) and also possibly negative (unrealistic deliverable, aggressive push).

Influence diagrams were built in a similar fashion for questions C-F. Perspectives of the roles of schedulers in question C were across a wide range. Key words for planning were more collaborative and leadership/experience driven, while keywords to support scheduling were more tactical and standardized. Key words that support the level of detail as well as planning and scheduling across the life cycle are shown in Appendix A.

SMEs were allowed to provide multiple comments to each of the questions, as long as each comment was included on a separate non-attributed page. Some SMEs did not provide comments for every question; others provided multiple comments. Hence the total number of comments for

each focus group question does not always add up to the total (13) SMEs. Exhibit 3 presents each focus group question along with the count and relative frequency of SME responses to each question. From these results and the influence diagrams, multiple conclusions can be drawn.

*Insert Exhibit 3 here.*

First, it became clear that even the SMEs participating in this exercise had different views about each question and how they perceived the role of schedules and schedulers in the construction industry. This reaffirms that general industry conclusions based on this small sample may not be reliable without additional quantitative analysis. The summaries presented in Exhibits 2 and 3 and Appendix A reveal that the SMEs viewed schedules very much as contractual instruments to hold people accountable (question A), tools to define and keep track of the project baseline (question B), and a document with varying levels of detail depending on projects' phases, life cycle, and owners' needs (questions E and F). Schedulers were viewed mostly as computer technicians who are often very skilled in scheduling software but not necessarily in intricacies of construction operations (question C). However, some participants emphasized that schedulers' roles might vary in projects depending on project size and how their roles are defined from the start of the project. Finally, from this discussion, different opinions emerged regarding the understanding that planning and scheduling are different skill sets (question D).

These results set the stage and provided more context to the initial six CII research questions. By understanding the perceptions of SMEs, we are able to propose trends that may hold across the industry. Furthermore, the contextual milieu that emerged via the influence diagrams show the CII research questions, as originally worded, may not be specific enough to be quantitatively tested. Thus, we use the trends and keywords identified via the focus group to create specific sub-questions to further investigate and validate to the industry at large, via a survey. The

survey also was able to support an additional goal of identifying potential practices to improve in order to support developing more collaborative schedules, which was necessary to understand for the larger research project.

## **SURVEY**

### **Protocol**

The influence diagrams demonstrate that the focus group SMEs have varying views of planning, scheduling, roles of schedulers, the baseline schedule, and the life cycle. This may indicate that a standard does not exist in current practice, with roles and views evolving. However, thirteen SMEs is a small sample size and a large-scale survey would provide more insight into broader industry trends. Because the original six CII research questions instigated such broad responses, we use the themes that emerged in the influence diagrams to formulate more focused sub-questions that can be quantitatively measured via a survey.

Thus, the survey focused on five main areas: (1) respondent demographics; (2) scheduling and planning methods used with degree of involvement; (3) selection and timing of methods in both preconstruction and construction; (4) types of planning meetings held; and (5) level of agreement with statements regarding planning and scheduling practices. Survey section 5 comprised of the research sub-questions primarily based from the CII research questions. Survey section 1 is essential to understanding the background, industry, and other characteristics of a survey respondent. Survey sections 2, 3, and 4 are mostly relevant to our broader research on collaborative scheduling and are not the focus of this study. Therefore, the discussion in this article is limited to sections 1 and 5.

Survey section 5 is comprised of eight questions that were assessed on a five point Likert scale. These questions are

1. Schedule is a historical, static document instead of a collaborative, ongoing tool.
2. Baseline schedule is a form of reporting and/or planning instead of a dynamic tool.
3. The level of detail required for scheduling significantly varies throughout the life cycle of the project.
4. A project team performs life cycle planning and scheduling from the owner's perspective, integrating and aligning schedules with important owner milestones.
5. Planning and scheduling involve different skill sets.
6. Schedulers are just computer technicians who know how to use scheduling software.
7. The scheduler role evolves based on the size of project.
8. Schedulers take on wider roles in smaller projects.

Observe how these questions are directly linked to themes in Exhibit 2, which emerged in the focus group and are tied to the original CII research questions. Thus, survey section 5 essentially queried respondents' level of agreement on the statements listed in Exhibit 2. For example, one question is *"Please check your level of agreement with the following statements. Schedule is a historical, static document instead of a collaborative, ongoing tool."* This question is question A from Exhibit 2 and is an adaptation of the original CII research question. A full listing of the section 1 demographics questions, as well as the section 5 questions and Likert scale are found in Appendix B.

Survey distribution was targeted at four construction industry events across the United States during 2016. In sum, 179 total responses were obtained, of which 168 were usable. Selection of events for survey distribution was based on access but also the ability to reach out to a broad cross-section of the construction industry in the United States. To increase participation, paper copies of the survey were included with event registration packets or passed out randomly

to participants. The four events were (1) the 24<sup>th</sup> International Group for Lean Construction (IGLC) Industry Day in Boston, Massachusetts (31 responses); (2) BIM training in Raleigh, North Carolina (10 responses); (3) CII Annual Conference in National Harbor, Maryland (98 responses); (4) Lean Industry Day in San Diego, California (40 responses). The CII Annual Conference and the IGLC are both major conferences for the professional and academic construction industry. Specifically, the IGLC is an international conference for professionals and researchers in architecture, engineering, and construction. The BIM training and Lean Industry Day were smaller, regional events.

The survey responses collected from the four events are valuable and beneficial to understand the current practice and experts' opinions about schedules and schedulers in the U.S. construction industry on a broad scale. In the events in Boston and San Diego, participants were given a chance to anonymously enter a drawing for a \$25 gift card from Starbucks. The surveys had raffle tickets attached to them, which were collected by the events' organizers and separated from the survey before the researchers received the completed surveys. At all four events, participants returned the survey at the event; responses were not mailed or submitted online. The use of paper allowed for broad distribution at the events without requiring respondents to complete extra steps (log on, find a mailbox, etc.) to participate. The survey allowed for large scale, quantitative validation of the themes that emerged from the focus group.

### **Demographics**

In summary, survey respondents across all events comprised four main groups: contractors (58%), owners (27%), designers/engineers/consultant/supplier (13%), and academics (2%). The project sizes indicated by respondents were distributed in the following range in USD: \$500 million and above (8%), \$100-\$500 million (19%), \$50-\$100 million (16%), \$10-\$50 million

(27%), \$10 million or less (26%), and no answer (4%). Regarding project duration, respondents indicated the following: more than 4 years (7%), 3-4 years (7%), 2-3 years (16%), 1-2 years (36%), one year or less (25%), and no answer (9%). From the demographics reported, the data is skewed towards contractors, as they were the largest group responding to the survey.

Respondents were fairly distributed over five project types (sectors) on which they usually work; these sectors align with the classification used by the CII (CII, 2018). Participants were instructed to choose all options that applied and some respondents selected more than one option. Therefore, the numbers reported amount to more than 100%. Sector representation included: healthcare and facilities (43%), manufacturing and life science (26%), power, utilities, and infrastructure (35%), downstream and chemicals (30%), and upstream, midstream, and mining (18%). Job title was an open-ended response and included a variety of comments, such as Project Engineer, Project Manager, Superintendent, Director, Consultant, Engineer, and Vice President. Finally, experience in the industry included: 30 or more years (17%), 20-30 years (26%), 10-20 years (26%), 5-10 years (13%), 5 or less years (15%), and no answer (3%), reflecting a large range of respondents' experience in terms of construction planning and scheduling. The demographics questions provided a respondent profile which is comparable with the focus group SMEs. Furthermore, the demographics questions in this survey align with similar demographics questions in other surveys that focus on the construction industry and/or collaborative scheduling, such as Galloway (2006), Fernandez-Solis et al. (2013), and Olivieri, et al. (2019).

## **Results**

To validate and further investigate the focus group responses, we specifically examine the results for survey section 5. The statements from section 5 are repeated in Exhibit 4, along with the percentage of all 168 usable respondents who agreed to each extent with each statement on a

5-point Likert scale. Note that the survey statements are directly tied to the major themes that emerged from the focus group. Specifically, statements 1 and 2 in Exhibit 4 are related to focus group question A, addressing if the schedule is truly a historical document or a dynamic tool. Statement 3 maps to question E and addresses the level of detail throughout the life cycle of the project. Statement 4 is related to question F, addressing if life cycle planning is done from the owner's perspective. Finally, statements 5-8 relate to question C and examine the extent of the role of schedulers.

*Insert Exhibit 4 here.*

About 75% of respondents disagreed or strongly disagreed with the first statement *“Schedule is a historical, static document instead of a collaborative, ongoing tool.”* This was in sharp contrast to most of the statements made by participants in the focus group. Similar numbers were found when the responses of the two largest groups of participants, contractors and owners, were analyzed. The majority of owners (71%) disagreed or strongly disagreed with this statement, and 79% of contractors had the same opinion.

For statement 2, *“Baseline schedule is a form of reporting and/or planning instead of a dynamic tool,”* participant responses did not reveal much agreement (34% disagreed or strongly disagreed, 18% neutral, and 48% agreed or strongly agreed). However, when responses were broken down by owners and contractors, owners mostly agreed or strongly agreed (65%) with this statement, whereas contractors' opinions were inconclusive (40% disagreed or strongly disagreed, 18% neutral, and 42% agreed or strongly agreed).

Respondents were in strong agreement regarding the statement *“The level of detail required for scheduling significantly varies throughout the life cycle of the project.”* About 83% indicated they either agreed or strongly agreed with this statement. Similar numbers were found for owners



(84%) and contractors (82%), showing strong support to the fact that the level of detail in schedules varies throughout the project life cycle. Similar support was communicated during the discussions in the focus group.

Most participants also agreed or strongly agreed (71%) with the statement “*A project team performs life cycle planning and scheduling from the owner’s perspective, integrating and aligning schedules with important owner milestones.*” Owners and contractors agreed to this statement in similar numbers, 68% and 72% respectively. The focus group results were in agreement with this statement as SMEs had indicated they perform this analysis to comply with owner stated milestones and requests.

The majority of respondents indicated that they agreed or strongly agreed (80%) with the statement “*Planning and scheduling involve different skill sets.*” Similar support was found when owners’ and contractors’ responses were analyzed: 84% and 79% respectively. The focus group discussion showed a wide range of responses to the question regarding the different planning and scheduling skill sets. Most focus group SMEs indicated these require two different skill sets; however, SMEs did not have a common industry understanding about how different they are.

Survey respondents rejected the statement “*Schedulers are just computer technicians who know how to use scheduling software,*” as 81% disagreed or strongly disagreed with it. Contractors were more emphatic in their disagreement, as 86% of them either disagreed or strongly disagreed with the statement versus 66% of owners. The results from the focus group were more scattered. Some SMEs supported this statement. Others indicated the role of schedulers varied according to not only the types and sizes of projects on which they worked, but also how their roles were defined by the organizations for which they work. This discussion during the focus group motivated the next two questions related to the roles of schedulers in different projects.

About 74% of respondents either agreed or strongly agreed with the statement “*The scheduler role evolves based on the size of project,*” with similar numbers observed for owners (72%) and contractors (77%). However, responses centered on neutral (33%) and agree (42%) regarding the level of agreement with “*Schedulers take on wider roles in smaller projects.*” A similar pattern was found for owners (34% neutral, 41% agree) and contractors (32% neutral, 42% agree). Focus group SMEs indicated that large projects usually have budgets that can absorb the costs of a dedicated person for scheduling in contrast to smaller projects that might include the scheduling task as part of a project manager’s or superintendent’s duties. In that case, small projects might not have the budget to hire a scheduler, and this job duty would fall on some other management position.

### **Statistical Analysis and Discussion**

To investigate themes beyond responses to the survey statements, we conduct correlation analyses and construct 3D charts to visualize the data. Our goal in this analysis is to understand any connections and relations between multiple survey statements and to identify any underlying patterns that may be in the survey responses. This analysis directly leads to identification of industry challenges and proposal of improvement recommendations.

We first investigate correlations. For this analysis, note that respondent agreement levels were measured on a 5-point Likert scale. As a result, the levels are non-parametric, violating the parametric assumption of the Pearson correlation (Field, 2009). Therefore, in this research, the Spearman’s rank-order correlation was used to measure the strength and direction of association between respondents’ level of agreement on the statements regarding schedules and schedulers. There are two reasons for choosing the Spearman rank correlation method. First, the level of agreement is in the form of rank: ranging from strongly disagree (rank 1), to disagree, neutral,

agree, and strongly agree (rank 5). The Spearman rank correlation coefficient is the usual correlation coefficient used to measure ranks (Aczel & Sounderpandian, 2008). Second, the Spearman rank correlation analysis assumes that participants were randomly selected, selection of rank is independent, and the relationship of one rank with another is monotonic (Kraska-Miller, 2013). In this research, participation in the survey is volunteer-based. Respondents are from four professional events in four states within the United States. Although they are all associated with the construction industry, they are from different industry sectors, work for different organizations, and did not share answers before turning in the survey forms. Therefore, it is reasonable to assume that both the respondents were randomly selected and the selection of rank is independent. In a monotonic relationship, as the value of one variable increases, so tends the value of the other variable, or as the value of one variable increases, the value of the other variable tends to decrease. Non-monotonic patterns were not found after plotting the rank for each pair of statements.

We conduct two-tailed tests because no directional hypothesis on the relationship was made. In other words, we did not make assumptions on the direction of the correlation before running the tests. The results of the Spearman correlation coefficient test are summarized in Exhibit 5. Please note that the statement numbers correspond to the numbered questions in survey section 5, which are also included in Appendix B. The values marked with double asterisks (\*\*) indicate that the correlation is significant at 0.01 level. The values marked with a single asterisk (\*) indicate that the correlation is significant at 0.05 level. The positive sign of the Spearman correlation indicates that as values of one variable increases, the value of another variable tends to also increase. If the correlation coefficient is negative, it means that another variable tends to decrease as one variable increases. A Spearman correlation of zero indicates no tendency for another variable to either increase or decrease when one increases. The closer the coefficient  $r$  is

to +/- 1, the stronger the relationship (Kraska-Miller, 2013). The correlation coefficient between the rank for statements 1 and 2 has the highest absolute value of 0.398. The absolute correlation coefficients for the other significant pairs are between 0.162 and 0.262.

*Insert Exhibit 5 here.*

To further investigate how the responses were distributed, 3D graphs show the count of respondents who selected the same combination of level of agreements on a pair of statements. For example, as shown in Exhibit 6, 17 survey respondents selected “Strongly disagree” for statement 1 and “Disagree” for statement 2. This analysis provides additional verification for the level of agreement between the survey respondents. In some cases, despite the existing correlation between pairs of statements, respondents’ answers are clustered around neutral responses or spread out between disagree, neutral, and agree (see Exhibit 6). Conversely, some other pairs of statements correlated at the 0.01 or 0.05 levels have responses that are tightly grouped around a specific area of the 3D graph (i.e., Exhibit 7). The 3D graphs provide additional insights into how the survey responses drove any correlation relationship.

*Insert Exhibit 6 here.*

*Insert Exhibit 7 here.*

To translate Exhibit 6, observe Exhibit 5, which shows two pairs of statements correlated at  $\alpha = 0.01$  level of confidence. The first one is between statements 1 and 2 with a correlation coefficient of 0.398. This means that respondents who selected a higher rank for the statement “*Schedule is a static document instead of a collaborative tool*” are also likely to select a higher rank for “*Baseline schedule is a form of reporting and/or planning instead of a dynamic tool.*” Even though the analysis of this pair of statements showed positive correlation at 0.01 confidence, an additional analysis of 3D plots revealed that answers converged around strongly disagree and

disagree for statement 1 and disagree, neutral, and agree for statement 2 (see Exhibit 6). Accordingly, a conclusive statement about the relationship between this pair of statements could not be made, as responses are not clustered around the same ranks. Respondents seemed to contradict themselves in the survey regarding the statements related to focus group question A. They also contradicted the themes that emerged from the focus group for that question. If schedules in practice were truly collaborative, respondents in both the focus group and the survey would disagree profoundly with the historical, static, reporting characteristics of a schedule.

To translate Exhibit 7, the second highest confidence correlation in Exhibit 5 is between statements 4 and 5 with a correlation coefficient of 0.262. It can be interpreted that the respondents who chose a higher rank for “*A project team performs life cycle planning and scheduling from the owner’s perspective, integrating and aligning schedules with important owner milestones*” (71% agreed/strongly agreed) also tended to select a higher rank for “*Planning and scheduling involve different skill sets*” (80% agreed/strongly agreed). The significant correlation between these two statements might suggest that respondents understand that schedules are needed to meet owners’ needs, but planning skills are needed to fully accomplish goals while integrating them with other important milestones.

There are also six pairs of statements that are correlated at  $\alpha = 0.05$  level of confidence (Exhibit 5). The correlation is negative between statements 1 and 4 and statements 3 and 6. The correlation is positive for the following four pairs of statements: 2 and 6, 3 and 4, 3 and 5, and 7 and 8.

Respondents went in opposite directions (correlation coefficient -0.177) regarding their level of agreement with statement 1 “*Schedule is a historical, static document instead of a collaborative, ongoing tool*” (75% disagreed/strongly disagreed) and statement 4 “*A project team*

*performs life cycle planning and scheduling from the owner's perspective, integrating and aligning schedules with important owner milestones*" (71% agreed/strongly agreed). This also appears to support the views discussed for the level of agreement between statements 4 and 5, indicating that to support owners' needs in terms of life cycle planning, schedules need to be viewed as dynamic tools and not as static documents.

The negative correlation of -0.196 between statement 3 "*The level of detail required for scheduling significantly varies throughout the life cycle of the project*" (83% agreed/strongly agreed) and statement 6 "*Schedulers are just computer technicians who know how to use scheduling software*" (81% disagreed/strongly disagreed) suggests that responders did not agree that schedulers are just computer technicians and might suggest that schedulers need to know more than just using software and punching numbers. Schedulers need to understand the different levels of detail required in a project throughout its life cycle and view scheduling as part of a much larger planning process.

Statement 2 "*Baseline schedule is a form of reporting and/or planning instead of a dynamic tool*" (48% agreed/strongly agreed) and statement 6 "*Schedulers are just computer technicians who know how to use scheduling software*" (81% strongly disagree/disagree) are positively correlated (0.187). However, the 3D graph for this pair of statements showed that most of the responses are grouped around disagree, neutral, and agree for Statement 2 and strongly disagree and disagree for Statement 6. Perhaps when schedules are viewed as dynamic tools, schedulers need to play larger roles than just computer technicians.

Not surprisingly, statement 3 "*The level of detail required for scheduling significantly varies throughout the life cycle of the project*" (83% agreed/strongly agreed) and statement 4 "*A project team performs life cycle planning and scheduling from the owner's perspective, integrating*

*and aligning schedules with important owner milestones*” (71% agreed/strongly agreed) are also positively correlated (0.195). An analysis of the percentage of respondents who agreed/strongly agreed with these statements and the correlation between them reflects an agreement between respondents that planning and scheduling activities over the life cycle require different levels of detail in order to address multiple objectives and stakeholders needs. This is also suggested by the literature.

Also positively correlated (0.162) are statement 3 *“The level of detail required for scheduling significantly varies throughout the life cycle of the project”* (83% agreed/strongly agreed) and statement 5 *“Planning and scheduling involve different skill sets”* (80% agreed/strongly agreed). Over 80% of respondents agreed or strongly agreed with these two statements. This suggests that respondents support the notion that planning and scheduling involve different skill sets while also recognizing that schedules need to be dynamic to accommodate varying needs throughout the project life cycle.

Finally, statement 7 *“The scheduler role evolves based on the size of project”* (74% agreed/strongly agreed) and statement 8 *“Schedulers take on wider roles in smaller projects”* (49% agreed/strongly agreed) are also positively correlated with a coefficient value of 0.192. About a third of the respondents (46 out of 147 responses for this pair of statements) agreed with both statements. An analysis of the 3D graph for this pair of statements showed additional pairs of agreement around disagree, neutral, and agree. There is an indication that respondents support the idea that schedulers’ roles vary based on the size of projects, aligning with discussion in the focus group.

## **IMPLICATIONS FOR ENGINEERING MANAGERS**

Schedulers and schedules are key components to project success. Engineering managers and the construction industry in particular can benefit from better understanding of how schedules are used and developed in practice as well as the role of schedulers in this process. Fully understanding the current practices of the industry enables identification of best practices and continuous improvement opportunities that truly will support positive change and growth through implementation. Industry professionals who understand the root cause analysis for implementing changes in practice will be more willing to accept change and work towards more collaborative and beneficial scheduling practices. This research provides analysis of the current state of collaborative scheduling in the construction industry and sets the stage for improving practices.

Therefore, we call on the construction industry to learn from this in-depth analysis and open their thinking to new innovative methods for planning and scheduling process improvement. Exhibit 8 summarizes our main findings and provides recommendations for improvement. We also call on engineering managers from other industries to consider how these recommendations can improve their practices. The first finding is that large scale survey respondents consider schedules to be collaborative and dynamic tools. Project participants' involvement is critical for developing reliable schedules, as those making commitments related to the schedule are those who are going to actually perform the tasks. Quality and on-time updates are also important. In order to develop collaborative schedules, leadership support, practical step-by-step training, and mindset change through education is needed. This is a crucial point for engineering managers in other industries; incorporating feedback from those who will perform project tasks is critical for project success. Leadership should support the team and foster a collaborative dynamic.

*Insert Exhibit 8 here.*



The second finding, especially for construction, is that owners consider baseline schedules to be a form of reporting. The baseline schedule will serve as a benchmark to compare and evaluate the actual project progress. However, accurately estimating potential risks facing a project during its early stages is not an easy task, especially if responsible parties did not have enough time to validate the schedule. Beyond owners, these recommendations can apply to any stakeholder who considers baseline schedules.

The third finding is that respondents agree that the level of detail of schedules varies throughout the project life cycle; levels of detail change as project progresses. In the early stage, when a lot of information is unknown, schedulers tend to start at the milestone level. During execution, multiple entities participate in both schedule review and audit; the level of detail increases as additional people bring in different perspectives and information. This applies to any industry in which the schedule detail changes over the project life cycle. The fourth finding, reflected in Exhibit 8, is that respondents believe it is important to have life cycle planning and scheduling from the owners' perspective. This requires using an integrated approach to cover all phases in the project life cycle and viewing the schedule as a much larger process. An integrated approach can be extended to consider stakeholders at large. Regarding the fifth finding, respondents agree that planning and scheduling are different skill sets. The challenge is that many professionals in the industry often treat planning and scheduling as the same concepts and function. Educating professionals to realize the forecasting and optimization aspects of planning will be helpful to address this issue. The sixth finding is that respondents agree that schedulers are more than computer technicians. Schedulers are also responsible to obtain updates on previous completion status, coordinate with various departments to get ready for new activities, assess the risk, and make decisions on time allowed in the next plan. Emphasizing the coordination aspect of

scheduling is key. Understanding these roles and skill sets can lead to improved schedule collaboration, regardless of industry. The seventh finding is that the scheduler role evolves as the size of project changes. Project size and duration can vary from a few thousand dollars in a few months to multi-billion dollars over a decade. As project size changes, the role of the scheduler will need to adjust accordingly. In a small project, a scheduler can also act as planner and coordinator. However, in a large project, schedulers need to focus on updating and managing the schedule. Evolving roles can occur in any industry.

In general, our findings can be extended to other industries, considering stakeholder dynamics instead of just the owner/contractor dynamic. This is especially true for stakeholders who have competing interests, which is a parallel to the owner/contractor dynamic. Many engineering managers are involved in projects that employ planners and schedulers and must balance competing interests. Collaboration leads to improved schedules which by default will positively affect cost and technical performance aspects of projects. Therefore, although this analysis was specifically done with the construction industry as a focus, our recommendations extend to other collaborative scheduling dynamics. Every engineering project has a schedule and a scheduler, or at least someone responsible for managing schedules. Understanding the roles of the schedule and scheduler is interesting and important for engineering managers, as this reflects how the schedule and schedulers are treated by the project team and stakeholders. Construction is just one example of engineering, and examining one industry in detail allows for understanding of patterns and trends that might not be visible in a cross-industry analysis. By looking at one case in particular, we determine recommendations applicable not only to that specific industry, but also extendable to engineering managers at large.

## **CONCLUSIONS**

Overall, this analysis sheds light on the role of schedulers and schedules in the construction industry. Such analysis is critical for understanding current practice, so that future research and best practices can be identified. The results include: (1) survey respondents consider schedules to be collaborative, ongoing tools; (2) owners consider baseline schedules to be a form of reporting; (3) the level of detail of schedules vary throughout the project life cycle; (4) life cycle planning and scheduling is from the owner's perspective; (5) planning and scheduling are different skill sets; (6) schedulers are more than computer technicians; and (7) the scheduler role evolves based on the size of project. To come to these conclusions, we employed a focus group of industry SMEs and a survey of construction industry professionals. The focus group was prompted by industry research questions posed by the CII; the survey sought to validate and/or challenge the themes raised in the focus group. By examining a large cross section of professionals in the survey, generalized conclusions can be drawn, extending beyond the small sample size of the focus group. These conclusions can aid practice and improve the current state of planning and scheduling in construction. Specifically, we provide seven industry challenges and recommendations for improvement. Engineering managers and project managers, regardless of industry but especially in the construction industry, can directly employ these recommendations to increase collaboration when developing schedules and to improve the roles of schedulers. Our future research includes identifying and developing best practice guidelines as well as a maturity model as part of a larger study on collaborative scheduling.

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**Dr. Ashtad Javanmardi** specializes in Construction Management and Lean Construction, including the use of predictive models and machine learning techniques to develop strategies for improving workflow reliability in construction projects. He is currently working as a Data Scientist

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**APPENDIX A**

Please insert Appendix A here.

**APPENDIX B**

This appendix includes the complete survey questions for survey sections 1 and 5.

Section 1					
1. What best describes the type of company you work for?					
Owner	Contractor	Other _____			
2. What would you estimate to be the average project size you typically work on?					
\$ _____		Duration _____			
3. What project type(s) do you usually work on? (circle all that apply)					
a) Healthcare and Facilities (Residential/Commercial)					
b) Manufacturing and Life Science					
c) Power, Utilities, and Infrastructure					
d) Downstream and Chemicals					
e) Upstream, Midstream, and Mining					
4. What is your job position/duty? _____					
5. How many years of experience do you have in Construction planning and scheduling?					
_____					
Section 5					
10. Please check your level of agreement with the following statements about <i>how schedules are used in your organization and what skills are required to develop/manage schedules</i> :					
<b>Statement</b>	<b>Strongly disagree</b>	<b>Disagree</b>	<b>Neutral</b>	<b>Agree</b>	<b>Strongly agree</b>

1. Schedule is a historical, static document instead of a collaborative, ongoing tool.					
2. Baseline schedule is a form of reporting and/or planning instead of a dynamic tool.					
3. The level of detail required for scheduling significantly varies throughout the life cycle of the project.					
4. A project team performs life cycle planning and scheduling from the owner's perspective, integrating and aligning schedules with important owner milestones.					
5. Planning and scheduling involve different skill sets.					
6. Schedulers are just computer technicians who know how to use scheduling software.					
7. The scheduler role evolves based on the size of project.					
8. Schedulers take on wider roles in smaller projects.					

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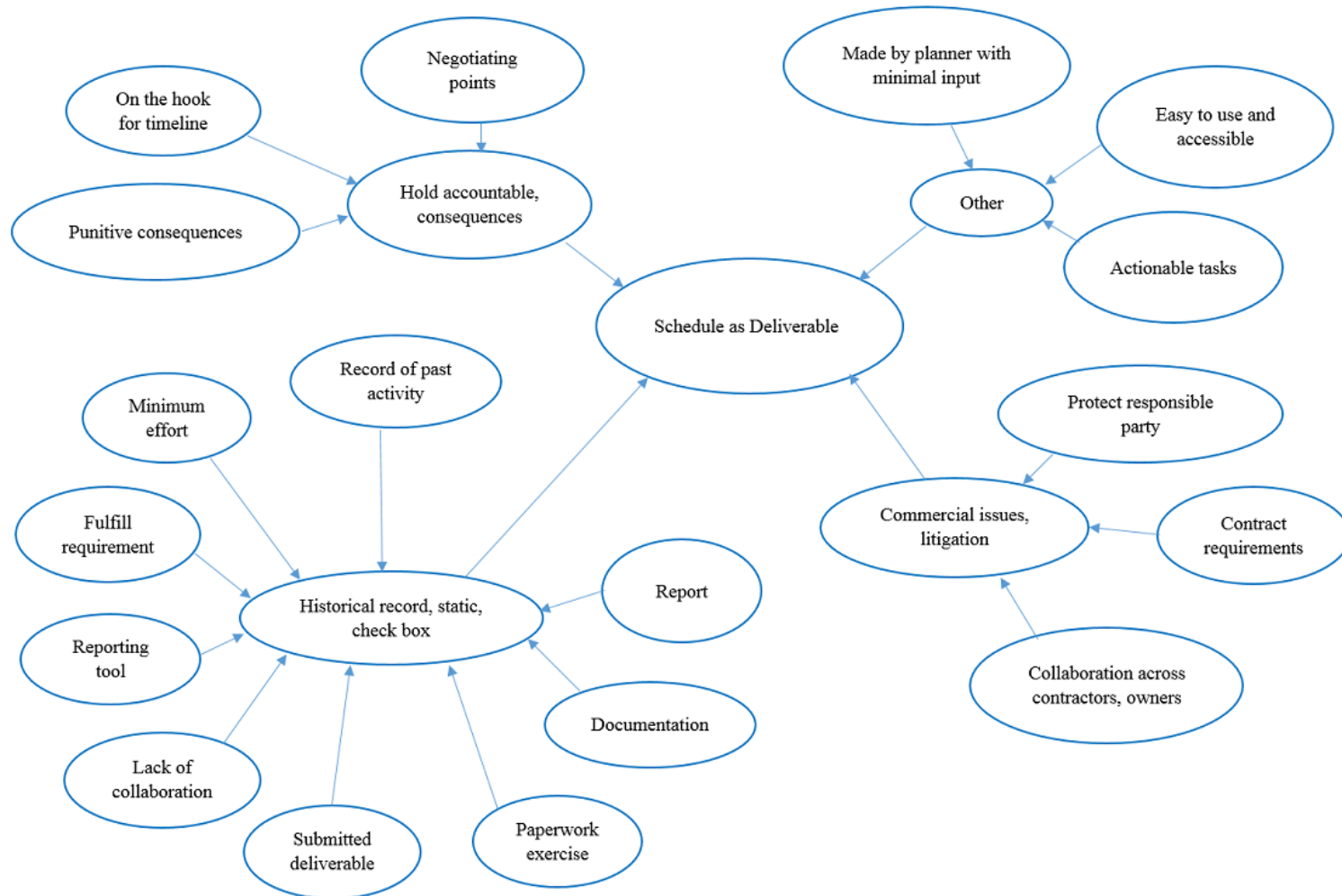
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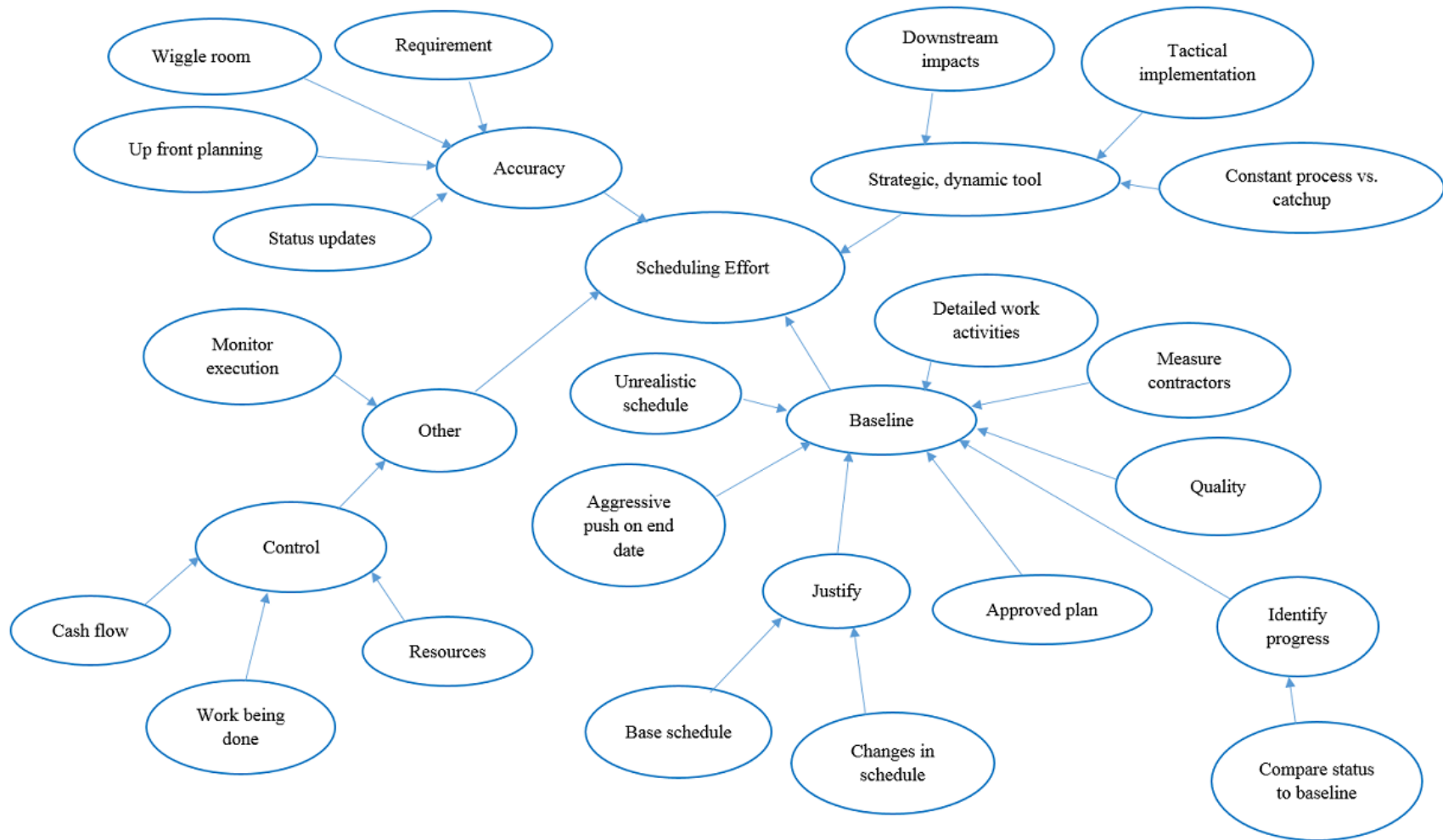
## APPENDIX A

This appendix presents the influence diagrams built from focus group responses to the CII research questions A-F.

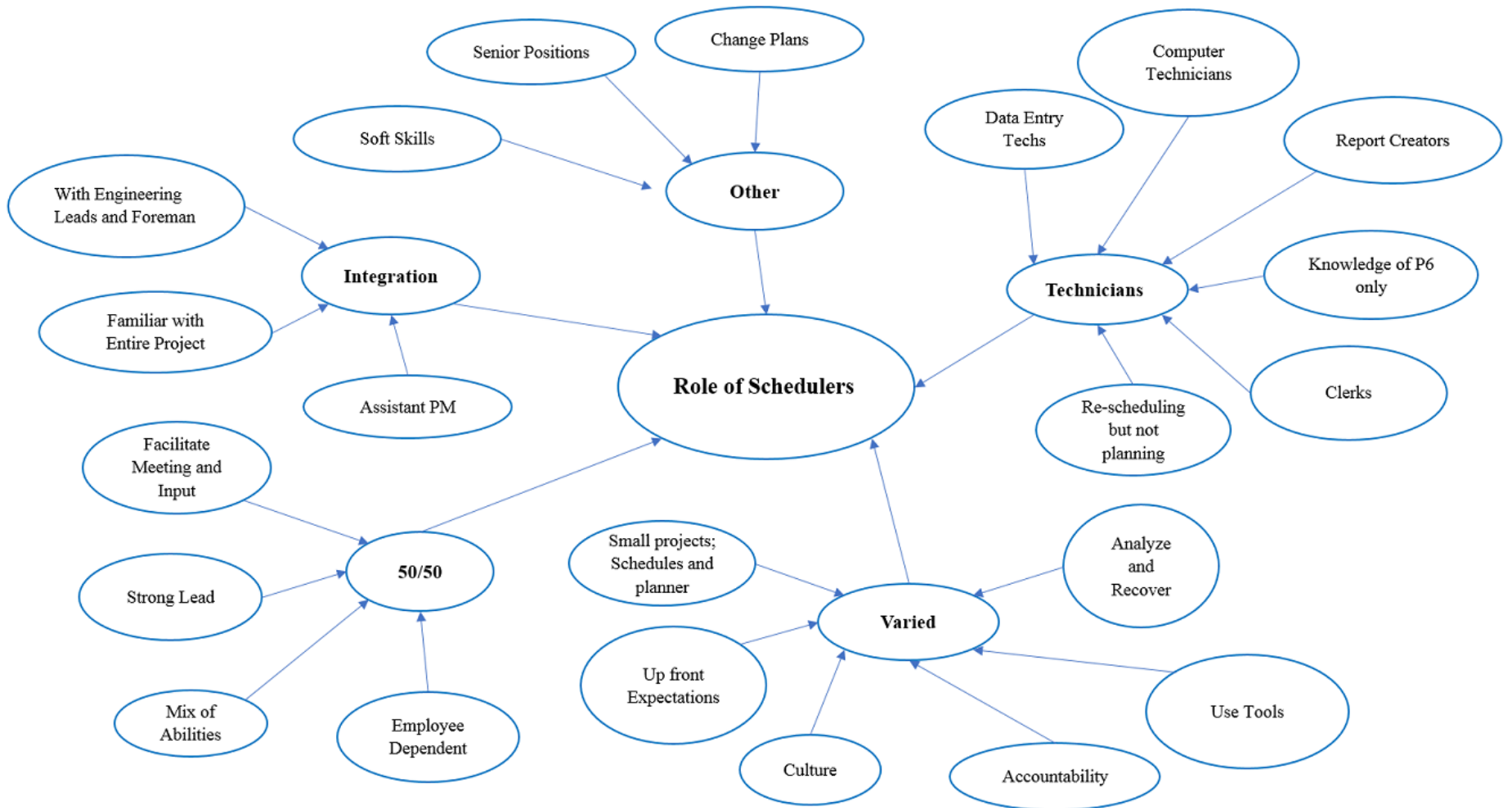
Influence diagram for question A:



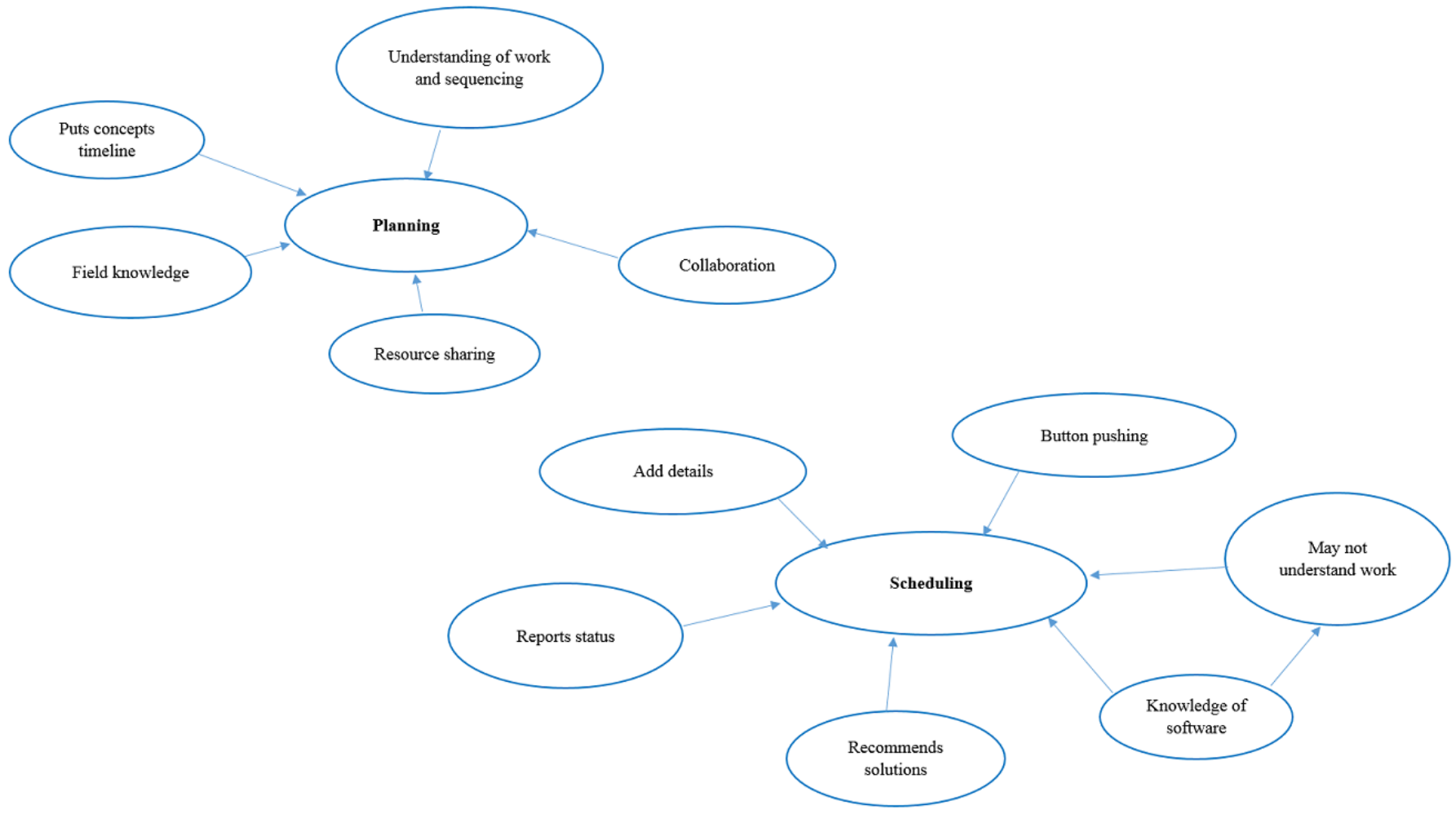
Influence diagram for question B:



Influence diagram for question C:

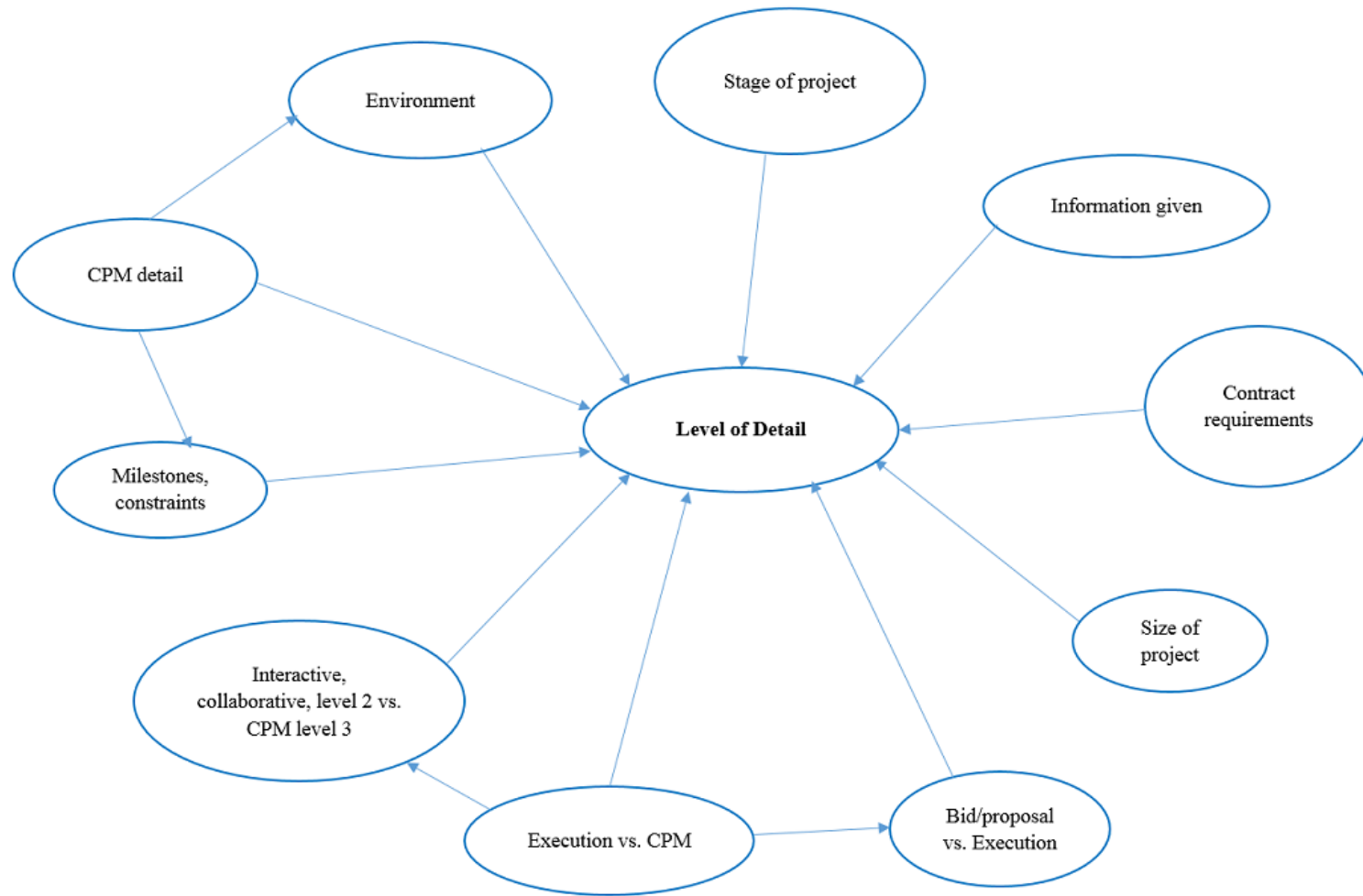


Influence diagram for question D:

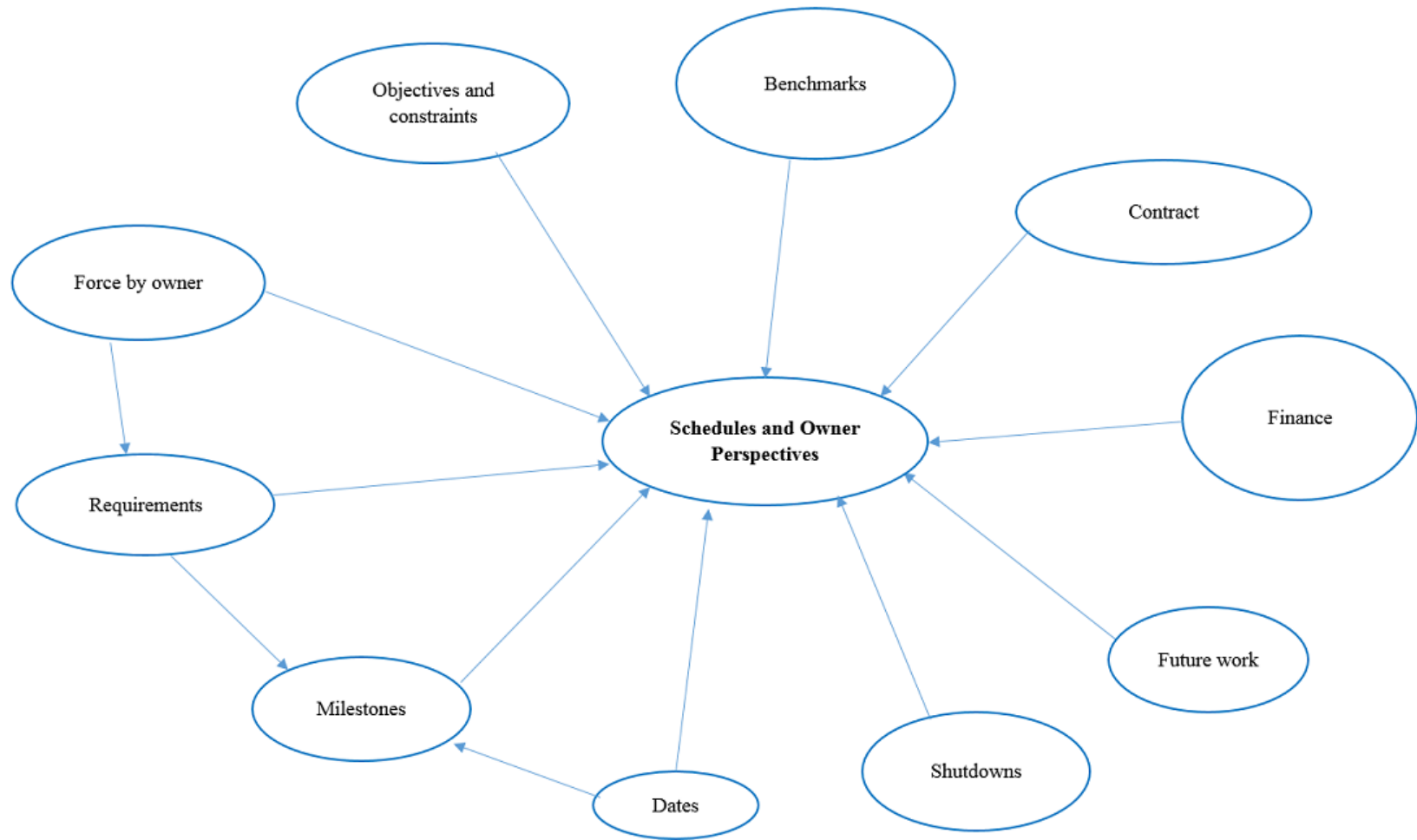




Influence diagram for question E:



Influence diagram for question F:



**Exhibit 1. Literature comparison between Construction Planning and Scheduling**

	<b>Planning</b>	<b>Scheduling</b>
<b>Definition (What)</b>	“The production of budgets, schedules, and other detailed specifications of the steps to be followed and the constraints to be obeyed in project execution” (Ballard & Howell, 1998, p.11).	The determination of the timing, resources, means, and methods of the operations comprising the project along with their assembling in order to give the overall completion time (Antill & Woodhead, 1990).
<b>Objectives (Why)</b>	(1) Direct and control project; (2) coordinate and communicate with various participants; (3) establish targets to facilitate project control; (4) forecasting; (5) optimization (Laufer & Tucker, 1987).	(1) Conform to contract and key milestones; (2) execute, monitor and control the work; (3) coordinate participants, especially trade/crew movement; (4) provide means and methods; (5) relate how a project was planned and how it was actually built (Mosaic, 2014).
<b>Phases/Levels (When)</b>	Five phases: (1) planning the planning process; (2) information gathering; (3) preparation of plans; (4) information diffusion; and (5) planning process evaluation (Laufer & Tucker, 1987).	Five levels: Level 1 - Project Master Schedule; Level 2 - Summary Master Schedule; Level 3 - Publication Schedule; Level 4 - Project Working Level Schedule; and Level 5 - Detailed Schedule (Mosaic, 2014).
<b>Types (How)</b>	Textual (lists and checklists, procedures); technical diagrams and drawings; organizational diagrams (e.g., work breakdown structure, organizational charts); time charts (schedules); tables (Laufer, et al., 1994).	Baseline schedule (long term schedule covering the entire timeframe of a project, contractual document attached to a project’s main agreement); pull planning schedule (developed collaboratively by those involved in a project/phase working backwards from a defined milestone (Ballard, 2000)); lookahead schedule (medium-term, tactical schedule with activities to be developed usually within a few weeks or months)
<b>Who</b>	Project manager; superintendent; project engineer; home office staff; subcontractors (Laufer, et al., 1994)	

**Exhibit 2.** Focus group questions, major themes, and sample statements.

Questions (CII 2016)	References	Major Themes	Sample Statements
<p>A. Has the schedule become a deliverable for contracting and litigation rather than a tool for collaboration (among owners, designers, contractors, and trade partners), commitment, and accountability?</p>	<p>Galloway (2006)</p>	<p>Historical record, static, check box</p>	<p><i>“Yes and no – yes because of lack of collaboration. No because it is more of a paperwork exercise vs. a useful tool in project management. It needs to be a tool that produces meaningful deliverables.”</i></p>
		<p>Hold accountable, consequences</p>	<p><i>“Often schedules are used as negotiating points rather than as a plan. Focus is on punitive with consequences rather than on optimizing path forward.”</i></p>
		<p>Commercial issues, litigation</p>	<p><i>“Individually, contractors, owners, designers do this well within their scope, but commercial issues keep us from really collaborating across those distinct, separate organizations.”</i></p>
		<p>Other</p>	<p>Made by planner with minimal input. Easy to use and accessible. Tool needs to be easy to use and accessible. Schedule as actionable tasks. Schedules should be a set of actionable tasks defining the project execution plan. Ineffective tool.</p>
<p>B. Is the scheduling effort focused on justifying the baseline schedule because of contract requirements, or is it put towards better solutions?</p>	<p>Galloway (2006)</p>	<p>Baseline</p>	<p><i>“I believe that most of our efforts are spent on justifying the baseline...time I would say doesn’t allow us to explore better options.”</i></p>
		<p>Accuracy</p>	<p><i>“Some project managers will not provide true updates. They prefer to keep wiggle room in the schedule.”</i></p>
		<p>Strategic, dynamic tool</p>	<p><i>“No – scheduling helps to flag downstream impacts of constraints, changes, etc. Use it as a strategic tool, not for tactical implementation.”</i></p>
		<p>Other themes</p>	<p>Control. Monitor execution. Schedule rarely met. Commercial issues in way of planning.</p>
<p>C. Are schedulers now merely computer technicians, or do they facilitate team planning and subsequent re-scheduling?</p>	<p>Laufer &amp; Tucker (1987); Laufer, Tucker, Shapira &amp; Shenhar (1994)</p>	<p>Technicians</p>	<p><i>“Yes, they are clerks or technicians, rarely understand the interaction between activities relationship or how work is actually executed.”</i></p>
		<p>Varied role, depending on project size and other factors</p>	<p><i>“A scheduler does not have a one size fits all description. A smaller project may call for the scheduler to also be the primary planner.”</i></p>
		<p>50/50 role, split</p>	<p><i>“50/50 we have schedulers to facilitate the meeting for every discipline to input. They know the schedule inside and out. Then we have ones who put activities and durations in and that seems to be the extent of it.”</i></p>
		<p>Integration</p>	<p><i>“To be effective, schedulers need to be closely integrated in the day-to-day work of engineering leads and construction foremen.”</i></p>

		Other themes	Senior positions, authority. Change plan outside of schedule. Static, isolated.
D. Is it understood that planning and scheduling are two different skill sets?	Laufer, Tucker, Shapira & Shenhar (1994); Ponce de Leon (2008)	Yes	<i>"Yes, planning puts the concepts together. Schedulers add the details, reports status, recommends solutions."</i>
		No	<i>"Planning and scheduling are often used inter-changeably."</i>
		Maybe, it depends	<i>"No, it is not widely understood. It should be established so the industry can establish a standard."</i>
E. How significant are the differences between level of detail during CPM development and during execution?	Laufer & Tucker (1988); Hamzeh (2009)	Significant	<i>"Depends on size of the project and contract requirements. On larger projects the differences can be significant."</i>
		Not significant	<i>"Most cases the same detail."</i>
F. Do project teams perform life cycle planning and scheduling from the owner's perspective, integrating and aligning schedules with important owner milestones?	CII (2006); Griego & Leite (2016)	Yes	<i>"The schedule is usually made to meet owner requirements and milestones."</i>
		No interface	<i>"We typically do not interface with the owner. (We are the contractor.)"</i>
		It depends	<i>"Typically project teams will plan and schedule in accordance with the contract. Will rarely go above and beyond to avoid any commercial implications."</i>

**Exhibit 3.** Number of responses and relative frequency for focus group questions and major themes.

<b>Questions (CII 2016)</b>	<b>Major Themes</b>	<b>Number of Responses</b>	<b>Relative Frequency</b>
A. Has the schedule become a deliverable for contracting and litigation rather than a tool for collaboration (among owners, designers, contractors, and trade partners), commitment, and accountability?	Historical record, static, check box	7	44%
	Hold accountable, consequences	2	13%
	Commercial issues, litigation	4	25%
	Other	3	19%
B. Is the scheduling effort focused on justifying the baseline schedule because of contract requirements, or is it put towards better solutions?	Baseline	9	56%
	Accuracy	3	19%
	Strategic, dynamic tool	2	13%
	Other themes	2	13%
C. Are schedulers now merely computer technicians, or do they facilitate team planning and subsequent re-scheduling?	Technicians	6	30%
	Varied role, depending on project size and other factors	5	25%
	50/50 role, split	4	20%
	Integration	2	10%
	Other themes	3	15%
D. Is it understood that planning and scheduling are two different skill sets?	Yes	4	33%
	No	4	33%
	Maybe, it depends	4	33%
E. How significant are the differences between level of detail during CPM development and during execution?	Significant	9	90%
	Not significant	1	10%
F. Do project teams perform life cycle planning and scheduling from the owner's perspective, integrating and aligning schedules with important owner milestones?	Yes	9	69%
	No interface	2	15%
	It depends	2	15%

**Exhibit 4. Percentage (%) of agreement with survey statements**

<b>Statement</b>	<b>Strongly disagree</b>	<b>Disagree</b>	<b>Neutral</b>	<b>Agree</b>	<b>Strongly agree</b>
1. Schedule is a historical, static document instead of a collaborative, ongoing tool.	42%	33%	9%	11%	5%
2. Baseline schedule is a form of reporting and/or planning instead of a dynamic tool.	9%	25%	18%	39%	9%
3. The level of detail required for scheduling significantly varies throughout the life cycle of the project.	1%	11%	5%	46%	37%
4. A project team performs life cycle planning and scheduling from the owner's perspective, integrating and aligning schedules with important owner milestones.	2%	12%	15%	52%	19%
5. Planning and scheduling involve different skill sets.	3%	7%	10%	48%	32%
6. Schedulers are just computer technicians who know how to use scheduling software.	46%	35%	8%	8%	3%
7. The scheduler role evolves based on the size of project.	1%	13%	12%	62%	12%
8. Schedulers take on wider roles in smaller projects.	3%	15%	33%	42%	7%

**Exhibit 5.** Correlation matrix for survey statements

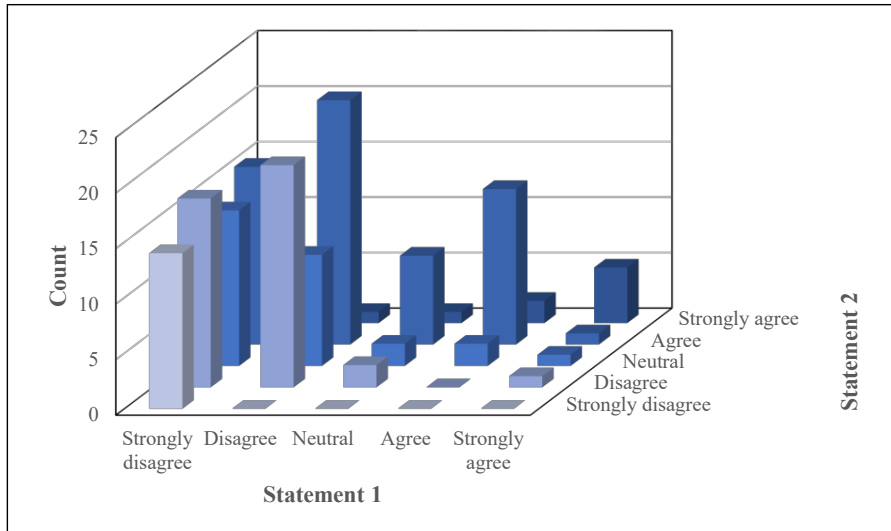
		Statement Numbers								
		1	2	3	4	5	6	7	8	
Statement Numbers	1	<i>r</i>	1.000	.398**	.039	-.177*	-.099	.121	.143	-.094
		<i>N</i>	159	158	159	158	158	155	157	149
	2	<i>r</i>	.398**	1.000	.016	-.104	-.034	.187*	.046	-.036
		<i>N</i>	158	158	158	157	157	154	156	148
	3	<i>r</i>	.039	.016	1.000	.195*	.162*	-.196*	.042	.077
		<i>N</i>	159	158	159	158	158	155	157	149
	4	<i>r</i>	-.177*	-.104	.195*	1.000	.262**	-.101	-.056	.002
		<i>N</i>	158	157	158	158	157	154	156	148
	5	<i>r</i>	-.099	-.034	.162*	.262**	1.000	-.138	.141	-.033
		<i>N</i>	158	157	158	157	158	154	156	148
	6	<i>r</i>	.121	.187*	-.196*	-.101	-.138	1.000	.042	-.114
		<i>N</i>	155	154	155	154	154	155	153	145
	7	<i>r</i>	.143	.046	.042	-.056	.141	.042	1.000	.192*
		<i>N</i>	157	156	157	156	156	153	157	147
	8	<i>r</i>	-.094	-.036	.077	.002	-.033	-.114	.192*	1.000
		<i>N</i>	149	148	149	148	148	145	147	149

\*\*Correlation is significant at the 0.01 level (2-tailed)

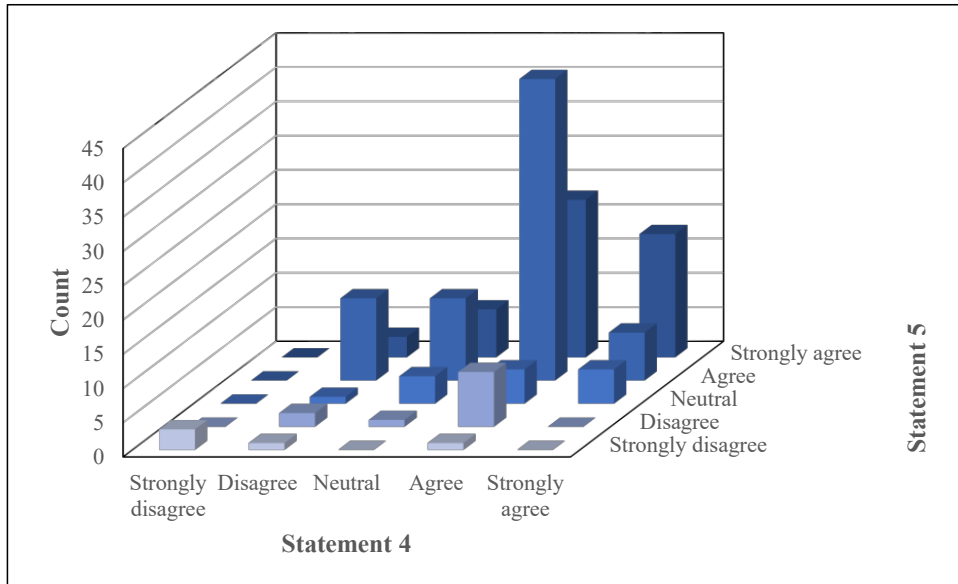
\*Correlation is significant at the 0.05 level (2-tailed)



**Exhibit 6. Relationship between responses for Statements 1 and 2**



**Exhibit 7. Relationship between responses for Statements 4 and 5**



**Exhibit 8. Main Findings and Recommendations**

<b>Findings</b>	<b>Challenges</b>	<b>Recommendations</b>
Survey respondents consider schedules to be collaborative, ongoing tools	Not aware of practical method to facilitate collaborative scheduling or means to measure effectiveness	Obtain leadership support, educate professionals to change mindset, use step-by-step guidance to train professionals
Owners consider baseline schedules to be a form of reporting	Estimate risks at early stage and communicate with owners	Cover various phases and entities, especially the handoffs
The level of detail of schedules vary throughout the project life cycle	Find balance between the detail level, develop practical ways to track, conflicting methods of developing details, lacks consistent methods to develop details, managing large volume of activities	Develop experience, from high level to detailed level
Life cycle planning and scheduling from the owner's perspective	Use integrated approach to cover front-end planning, design, procurement, construction/commissioning/start up	View schedule as a much larger process
Planning and scheduling are different skill sets	Treat planning and scheduling as the same concepts and function	Realize the forecasting and optimization aspects of planning
Schedulers are more than computer technicians	Regard scheduling as only determination of time for activities	Emphasize the coordination aspect of scheduling
The scheduler role evolves based on the size of project	Match experience and skill set to project size	Train and educate schedulers so that they are capable to adjust as project size varies