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Article

Construction Site Utilization Planning: A Process Based upon Industry Best Practices

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Abstract: Construction site utilization planning (CSUP), also known as jobsite layout planning, has implications on the safety, productivity, scheduling, and budgetary performance of a project. Past research efforts on CSUP have mainly focused on the development of optimization systems that delineate and allocate site space to predetermined temporary facilities based on time and/or cost constraints. Despite the significant body of knowledge on site optimization systems, the applicability of optimization algorithms remains limited due to the unique requirements and site constraints faced on each construction project. An important aspect not identified in past research efforts are the current practices for site utilization plan (SUP) development currently used by the construction industry. Therefore, the objectives of this research were to: (1) determine the state-of-the-practice regarding CSUP within the construction industry, (2) identify current SUP best practices, and (3) develop a procedure that outlines the CSUP process. An electronic survey was sent to 4021 industry professionals inquiring on current CSUP practices. A total of 240 responses were received, for a response rate of 6%. Thirteen best practices were identified from the survey, each focusing on an important aspect of the site planning process. These best practices were validated through a follow-up survey, as well as in-person interviews with experienced construction professionals. From the best practices, a procedure describing the development of a SUP was created. Key components identified were: (1) begin CSUP during budget development, (2) involve all stake holders associated with the project, and (3) remain flexible on space allocation throughout the construction life cycle.

Keywords: site layout; site logistics; temporary facility identification

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1. Introduction

Construction site utilization planning (CSUP) is a decision-making process for determining the location of temporary facilities (TFs) within the boundary of a construction site. CSUP identifies spatial relationships and develops alternative solutions so that construction efficiency is optimized over the construction life cycle. TFs are defined as those facilities and areas designated to specific tasks that support the construction process (e.g., project trailers, cranes, material lay down yards, etc.). The number, type, and size of TFs depends upon project type, scale, design, contractor philosophy, and construction execution strategy. Site utilization plans (SUPs), also known as jobsite layout plans, are documents that depict the locations of TFs within the construction site boundary. The development of these documents is critical for vertical construction projects due to space limitation but is often overlooked on horizonal construction projects due to space abundancy. Over the past three decades, many research studies have focused on developing static and dynamic mathematical models that optimize TF placement within the site boundaries using computer-based algorithms [1]. While these efforts have made revolutionary advancements in site optimization modeling, there remains a lack of practical step-by-step knowledge that outlines the CSUP process employed by project management professionals on today's jobsites (i.e., how are SUPs currently developed by project managers). The goal of this study was to identify CSUP best practices applied within the construction industry and develop a CSUP procedure that can be referenced by entry level project management professionals during the planning process.

2. Literature Review

Construction site utilization planning is a process for determining what TF will be needed during construction, where each TF will be placed on site and how long each TF will occupy a finite area on site [2]. The goal of site utilization planning is to predict the activities associated with a construction project and plan accordingly so that the project duration and project cost can be minimized [3]. Due to time and budget constraints, subcontractors are more involved in the construction of large projects now than ever before. Each subcontractor working on a project has a specific task to complete; however, in order to complete the task, the subcontractors need a specific amount of work space, equipment space, material storage, travel paths, etc. Traditionally, site superintendents have delineated workspace daily for scheduled activities. This method of space allocation often results in space conflicts between subcontractors, which result in decreased productivity, schedule delays, and lower employee morale [4].

To improve the SUP development process, numerous studies have been conducted to develop complex algorithms and models that optimize the placement of TF within the limits of a construction site based on various optimization strategies such as improvement method [5], trajectory method [6,7], population-based method [8–15], and geospatial method [16–18]. More recently, researchers have developed whole site dynamic planning models [19,20]. Several recent articles have also aimed to provide readers with a comprehensive review of the published literature pertaining to CSUP model development [21–23]. While these articles provide valuable insight into the site layout planning problem and the strides taken to improve mathematical solutions, they fail to identify fundamental procedures utilized by construction professionals that ultimately lead to the develop of a basic SUP on which optimization analyses can be conducted. Zolfagharina and Irizarry [24] recognized this shortfall and developed a rule-based site layout checking system that was founded on the existing literature. While this system provides insight into the variables associated with site layout planning, it lacks the rigor of incorporating best practices, as identified by industry professionals, as validation.

3. Materials and Methods

The primary instrument used for data collection in this study was a questionnaire survey. Questions were developed through a process that started with the review of published literature on CSUP. During the literature review, limited to no information was discovered regarding the site planning process. To assist with questionnaire development, several in-person interviews were held with professionals from various construction firms. The interviews were semi-structured in that each interviewee was asked a logical sequence of open-ended questions regarding information on CSUP. From these discussions, a qualitative list of relevant questions was established and used to create a questionnaire that sought information on the practical aspects of CSUP.

The questionnaire was organized so that questions pertaining to the same topic would be displayed sequentially and skip logics were incorporated into follow-up questions. The questionnaire was published online and distributed to construction professionals for participation. The electronic survey (e-survey) was sent to a broad audience of construction professionals (i.e., Presidents, Chief Executive Officers, Vice Presidents, Engineers, Project Managers, Construction Managers, Estimators, Schedulers, Superintendents, etc.). Contact information for construction professionals was obtained from the Auburn University

Alumni Association (2100) and the Certified Construction Managers website directory (1921). In total, 4021 survey requests were distributed.

The survey was open for a period of three months; thereafter, results were compiled and the best practices of CSUP were identified. To validate the best practices identified, a second survey was distributed to respondents, asking them to indicate their opinion (i.e., agree/disagree) on each best practice. The best practices were then used to develop a guideline that summarizes practical aspects of CSUP recognized by the construction industry. The developed guideline, provided in Appendix A, was distributed to industry professionals for reference on future construction projects. Figure 1 illustrates the sequence of events for the study.

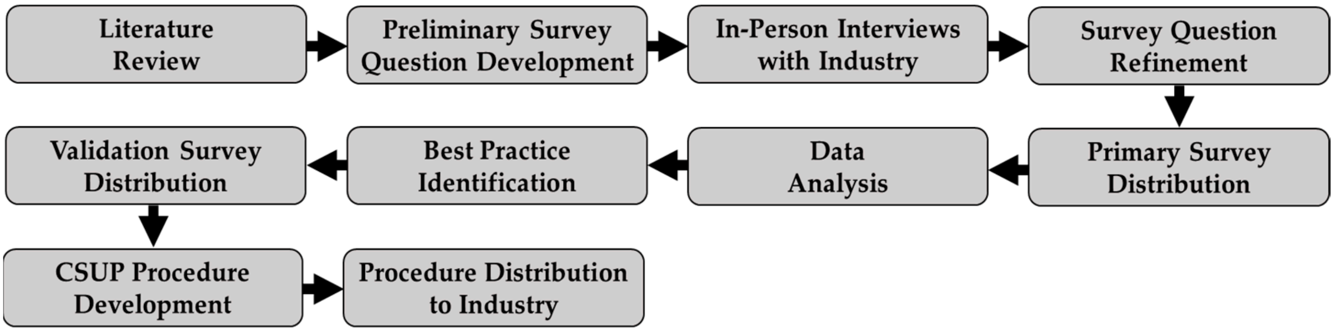

Figure 1. Research organizational flowchart.

4. Results

Two hundred and forty (240) survey responses were received. Construction professionals represented in the survey were employed at large multi-national companies with over 100,000 employees, as well as small local construction companies. Table 1 provides a summary of respondent diversity. The average experience by job title was quite substantial in that only one job title category was less than 15 years. Thus, the results of the survey provide valuable insight and information based upon the experiences of seasoned construction professionals.

Table 1. Survey Respondents Summary.

Respondent Job Title	No. of Respondents	Avg. Experience (Years)
President/CEO/Owner	20	32
Vice President	33	27
Engineer	21	11
Project/Construction Manager	93	24
Estimator	14	15
Superintendent	11	15
Project Executive/Director	18	28
Miscellaneous	22	29
Total	232	24

Note: Eight respondents did not indicate job title nor experience.

4.1. Construction Site Utilization Planning within the Industry

Proper project planning is critical to deliver a construction project on time and within budget. Many practitioners and researchers have recognized CSUP as a critical step in the construction process, and if an effective and systematic approach to site planning is not achieved, extensive time losses and cost overruns may result [2,25]. Of the survey responses, 74% (178 respondents) indicated that their companies develop SUPs for construction projects, while 26% (63 respondents) did not develop any type of SUP. A follow-up correspondence was sent to respondents that indicated SUPs where not developed, inquiring why they choose not to do so. Responses included that space was not an issue on projects or that their job was to represent the owner and oversee the project, thus developing SUPs was not their responsibility.

Of the 74% of respondents that develop SUPs, 60% stated that they create SUPs for every project; 22% only develop SUPs when site space is limited; and 19% indicated that project characteristics dictate site plan development.

4.2. Design Aspects of Construction Site Utilization Plans

Many aspects must be considered when designing the layout of a construction site. It is important to recognize that comprehensive SUPs cannot be developed before other planning tasks are completed. Conversely, some planning tasks are affected by the site layout [4]. To successfully develop a SUP, a practitioner must know: (1) personnel involved with CSUP, (2) time frame for developing the plan, and (3) factors affecting the layout.

4.2.1. Personnel Involved with Construction Site Utilization Planning

Typically, the project manager is responsible for developing SUPs [12]. As shown in Figure 2, this trend was observed in 46% of the respondents, while 29% reported that the site superintendent is responsible for developing the plan. Interestingly, only 17% reported that this process is a collaborative decision-making process where the project manager, site superintendent, and other management personnel are all involved.

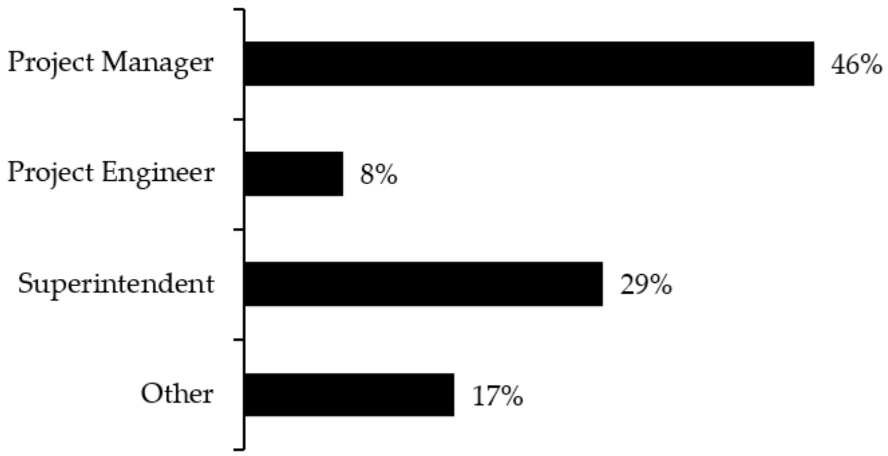

Figure 2. Typical site utilization plan developer.

Depending on project size and space availability, the number of subcontractors working on a project can be an important factor during the planning process. Respondents (61%) indicated that the number of subcontractors involved in a project does not influence the decision to develop a SUP. This suggests that many construction companies focus on the overall scope of the project versus the number of people carrying out construction-related tasks when deciding whether to develop SUPs.

When determining which subcontractors should be involved in the planning process, the planner must consider the project type, as well as specific tasks associated with the project. Based on survey responses, subcontractors that typically contribute information to the development of SUP include: structural (80%), foundation (72%), electrical (72%), plumbing (62%), and heating, ventilation, and air conditioning (HVAC) (54%). Respondents also noted that the civil/site work contractor should be consulted to determine whether site space will be needed for pipe storage, soil and aggregate stockpiling, or clearing and grubbing activities. To promote safe equipment operations, space requirements for excavation, grading, and earth moving activities should also be considered. By contacting all major subcontractors potentially requiring significant area for storage and/or equipment operations, a planner is more likely to perform a comprehensive assessment of the site when delineating space.

Before contacting subcontractors, a planner must know what to ask in order to obtain the information needed to prepare an accurate SUP. Although a variety of questions can be asked, the most common questions were (percentages indicate how often questions are asked): (1) what type of equipment will be on-site (80%); (2) how much on-site space is needed for storage (80%); (3) what tools sheds/job trailers will be on-site (78%); and (4) how many employees will be on-site (62%). A minority of respondents (4%) reported that they do not seek subcontractor input, but instead dictate the work conditions to the subcontractors. Utilizing subcontractor input certainly assists in SUP development; however, their request is not always achievable. To provide each subcontractor with sufficient site space, the planner should analyze all information gathered and allocate space based on scope of work and precedence. Once construction is underway, space adjustments can be made to compensate for the dynamic nature of the construction process.

Subcontractors are not the only individuals who can contribute useful information to SUPs. Owners, including individuals and organizations (e.g., universities, businesses, municipalities), can provide critical information that can directly affect the success of a project. Typically, 70% of project owners are involved with the SUP. Communication between project managers and owner/owner's representative should be established prior to mobilization and maintained throughout the construction life cycle.

Information owners contribute can range immensely, depending on scope of work. In many cases, information needed to develop SUPs can be found within the contract documents. However, such documents may not always contain the information needed to properly locate TFs. As shown in Figure 3, the following information was considered important when consulting the owner about SUP development: (1) preferred ingress and egress points (89%), (2) existing site conditions (75%), (3) construction traffic routes (73%), and (4) environmental concerns (52%). Owners may also indicate space limitations, preferred pedestrian routes, restricted areas, construction personnel parking, and major utility locations. Determining these parameters early in a project's life cycle can help planners develop SUPs that satisfy the needs of subcontractors and owners. Maintaining a good relationship with the owner is critical, thus contractors should keep owners informed on site operations throughout a project.

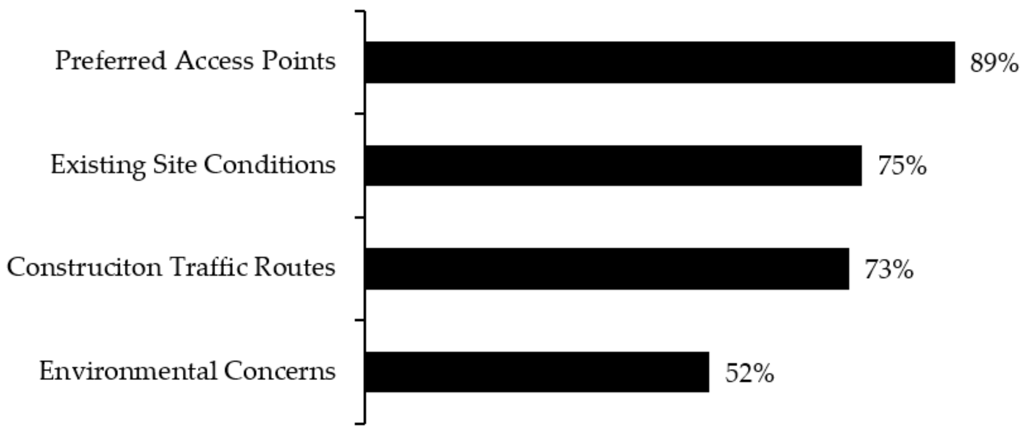

Figure 3. Typical information provided by project owner.

4.2.2. Planning Time Frame

SUPs are as important as other planning tasks that have to be accomplished. Before mobilizing on-site, detailed SUPs need to be prepared showing the positions of all TFs within the site boundaries [25]. The majority of respondents (69%) stated that SUP development begins in the pre-bid stage of a project, while the remaining respondents (31%) stated that SUP development begins after the project is awarded. There are advantages and disadvantages to each of these approaches. By starting SUP development prior to bidding, the SUP can be used in several ways. For instance, 30% reported that SUPs are used for budget development and proposal presentation. However, planning this early requires a capital investment upfront, which may not be recouped if the project is awarded to a competitor. Conversely, preparing a SUP after a project is awarded can also result in monetary losses. Issues easily identifiable on SUPs, but were overlooked during bidding, can result in extensive capital losses to contractors. In either case, it seems that most companies consider the development of a SUP to be part of the estimation process. This allows the firm to establish a more accurate budget, which increases their chance of winning the award while maximizing their profit margin.

Although the initiation of a SUP typically occurs either before or after bidding, the conclusion of the SUP can vary greatly. Respondents (49%) indicated that SUP is a continuous process over the duration of a project, while 38% indicated that site plans were completely developed prior to arriving on-site. Only 5% alleged that SUPs are completed prior to arriving on-site and altered as the needs of site change. The remaining 8% indicated that they finished developing the SUP once on-site.

4.2.3. Factors Affecting Site Utilization Plans

Space management involves three primary elements: site layout planning, path planning, and space scheduling [4]. When beginning the CSUP process, the site layout planning team must determine the basic site space requirements based on the project scope, schedule, and construction method. The following discussion provides insight into these factors based on survey responses.

Temporary Facilities (TFs) play an important role in supporting construction activities over the duration of a project. The planner must understand the characteristics of each temporary facility before planning the site layout, as unsystematically placed TFs can significantly affect productivity [25]. Many types of TFs varying in shape, size, and functionality can exist on a construction site. Respondents were asked to identify TFs considered during SUP development. Figure 4 illustrates common TFs considered during the development process.

In addition to the TFs shown in Figure 1, several respondents identified additional TFs, which include: crane locations and swing radii, concrete washout stations, emergency access points, first aid stations, construction fencing, toilet facilities, existing buildings, erosion and sediment control practices, and above ground utilities. Respondents also indicated that most TFs listed in the survey were applicable but not always used. Thus, one could conclude that TFs required for construction are based on project type, project location, and schedule complexity.

Site route planning is the process of delineating on-site space based on the transitional needs of equipment, material, and personnel from point A to point B. Respondents were asked to identify movement planning operations that are typically considered during site plan development. The two main operations considered were material movement (95%) and equipment movement (89%). On-site personnel movement (64%) was also considered but to a lesser extent. Based on these responses, it is apparent that most respondents understand the impacts that can arise from neglecting movement planning operations. Most likely, these elements are considered separately based upon project-specific characteristics.

Once TFs required for a project are selected, the construction team must determine the space requirements for each, as well as their locations within the construction boundary. This part of the planning process is intended to decrease congested work areas that result from trade stacking, mismanagement of material deliveries/storage, and poor waste management on-site [26]. When asked about site space priority, 77% of the respondents stated that some subcontractors/trades do receive priority in site space allocation at some point during construction. This is particularly important when the amount of available site space is limited. In such instances, the construction team must give thorough consideration when determining which subcontractors/trades receive on-site space priority. This is often done based on project-specific characteristics such as manpower requirements, estimated quantity of work, production rate, site space availability, and cost considerations [25]. Respondents indicated that structural contractors (61%) are the most frequent subcontractor/trade that falls within the space priority group, followed by electrical (48%); foundation (41%); plumbing (37%); and heating, ventilation, and air conditioning (HVAC) (37%).

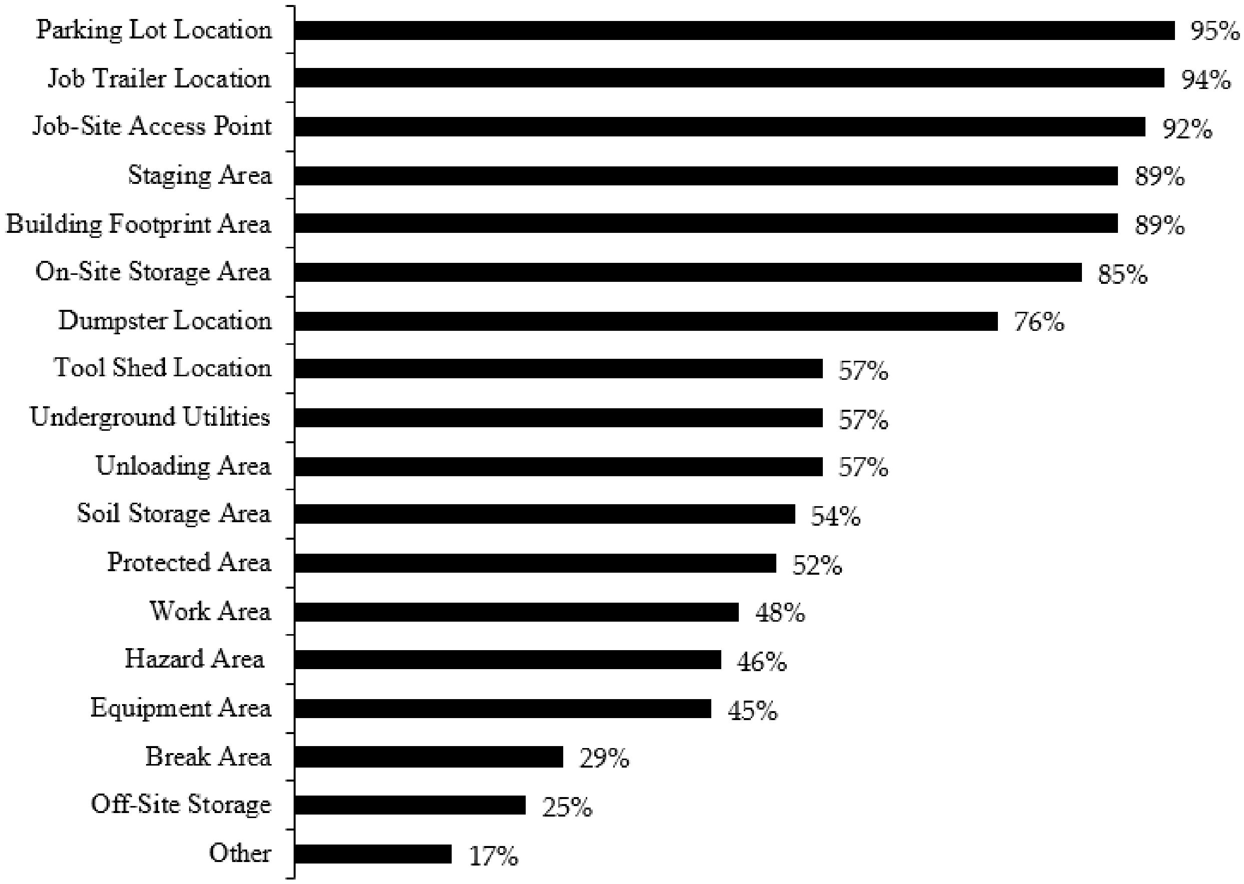

Figure 4. Typical temporary facilities shown on a site utilization plan.

It is imperative to realize that even though the subcontractors/trades listed above are recognized as priority groups over the course of a project, on-site space priority can vary between subcontractors/trades over time. For instance, the foundation and structural subcontractors may receive space priority early in the project; however, as the project progresses, space priority may shift to the mechanical, electrical, and plumbing (MEP) subcontractors to keep the project on schedule. Respondents pointed out that space priority is a function of critical path activities and any subcontractors/trades preforming critical tasks will likely receive space priority. Thus, it could be debated that subcontractor/trade space priority assessment is directly related to the project's schedule, which in turn dictates critical activities.

The physical characteristics of each TF should be well understood before selecting its location on-site. The positioning of on-site TFs is directly linked to the site conditions and special relationships between construction activities, equipment, and material. In some situations, local by-laws, such as emergency access routes, may be controlling factors during the locating process [25]. Project owners can also influence the location of TFs by providing specific site layout instructions within the contract documents to ensure their operational needs are met. Respondents were asked to identify the methods most commonly used to determine the locations of TFs within the construction site boundary. Experience obtained from previous projects, as indicated by 89% of respondents, was the primary method used for creating SUPs.

When designers are creating construction drawings, it is critical to include a high level of detail on the drawings so pertinent information can be clearly transferred between all stakeholders. Depending on the project size, the amount of detail needed cannot be effectively illustrated on a single drawing. Thus, construction drawings are usually categorized into phases (e.g., site, structural, MEP, etc.). This also holds true for SUPs. Respondents (71%) indicated they create multiple SUPs for different phases of construction as opposed to a single master site plan. This is necessary due to the ever-changing space requirements on-site. Surprisingly, 69% of the respondents develop SUPs for the entire project duration, not just the critical phases. This suggests that construction management teams have recognized the benefits of having a well-organized job site throughout the construction life cycle. While construction drawings are usually very detailed, SUPs are typically the opposite. A medium level of detail, indicated by 72% of respondents, is incorporated into SUPs with only essential TFs and storage locations shown on the plans.

The time it takes to develop a SUP is a function of the project scope and complexity. The majority of respondents (53%) indicated that time allocated to developing SUPs for most projects is between eight and forty hours. Knowing the typical amount of time spent on SUP development is important during project cost estimation. A project planner's time is valuable and should be accounted for and effectively utilized. Understanding the time allotted for creating SUPs is important because it provides project estimators an avenue to quantify additional development cost.

4.3. Implementation and Monitoring

A well-developed SUP can greatly enhance construction operations. However, if not properly implemented at project start-up and monitored over the entire project duration, costly non-value adding activities may occur. To properly implement a SUP, all tradesmen involved with the project need to be well informed of site space allocation. This can be accomplished by posting signage throughout the site indicating the location of TFs and/or displaying the SUP on an information board that can be viewed by all involved parties. SUPs can also be distributed to all stakeholders via e-mail. Signage and posted SUPs should be updated over the course of the project and verbal announcements updating workers, should be made at toolbox/safety meetings. To ensure that each subcontractor abides by the site plan, specific terms need to be included in contractual documents specifying reprimands for non-compliance. When asked about punitive actions imposed on subcontractors for non-compliances, 95% of the respondents indicated actions would be taken to persuade the subcontractors to follow SUPs. Common actions identified were verbal warnings, written warnings, monetary penalties, and disposal of improperly stored items.

Respondents also indicated that insubordinate subcontractors are typically not an issue on most projects as companies try to avoid hiring subcontractors with a history of not collaborating well within a team environment. When issues do arise, a simple discussion to educate subcontractors on the importance of SUPs is usually the only action needed. If discussions and punitive actions do not correct the non-compliance issues, additional actions must be taken to keep the project running efficiently and safe. In extreme cases of repeated non-compliance, removal of insubordinate subcontractor staff or subcontractor termination may be necessary.

Monitoring and managing SUPs usually falls under the responsibility of the site superintendent. Site superintendents oversee day-to-day operations on construction sites and control short-term scheduling. Site logistics should be second nature to site superintendents and they should always know the locations of material, equipment, and personnel. Knowing the jobsite layout has as much to do with jobsite safety as it does productivity and other aspects of a project. When monitoring construction operations, site superintendents need the ability to identify problems quickly and provide solutions that minimize disruption to other construction activities. Surprisingly, when respondents were asked about monitoring site plan efficiency, only 15% indicated they had methods in place to do so. As shown in

Figure 5, the common methods for monitoring, as identified by 15% of respondents, were: flow of construction activities (100%), ability to access and move material (78%), and time spent managing subcontractors (41%).

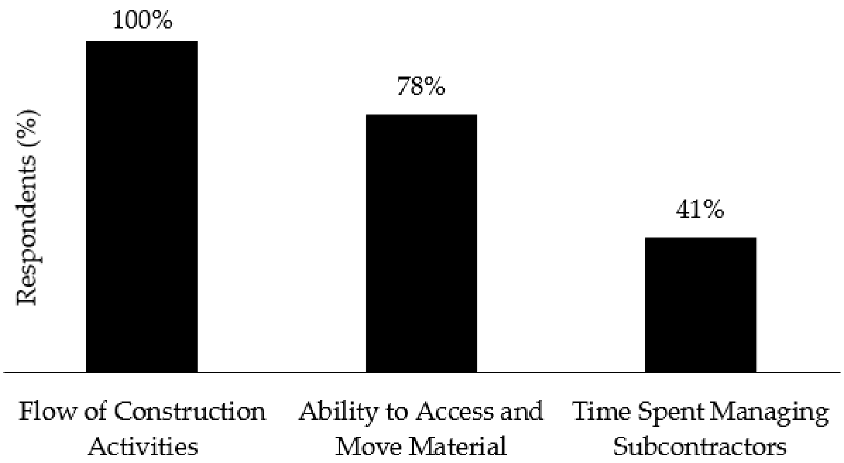

Figure 5. Methods for monitoring SUP effectiveness.

The effectiveness of SUPs can be monitored in many ways. For example, on vertical construction, the number of crane picks and buck hoist over the course of a day can give the site superintendent an idea of how well the site is operating. Site superintendents can quickly determine whether the SUP is working properly by monitoring installed work and/or tasks not performed due to a lack of materials or slow material delivery. Site superintendents are typically the first to notice contingencies on-site; therefore, it is critical for them to have authority to make decisions on site operations and space allocation. Caution should be taken not to micromanage superintendents, which could paralyze their ability to make critical decisions.

4.4. Training and Documentation

One of the key elements associated with developing an effective SUP is employing a construction management team containing individuals with several years of experience in site planning. In many cases, companies cannot afford to assign all of their experienced employees to a single project. This results in companies assigning less experienced management personnel to a construction management team. Less experienced management personnel tend to have little to no experience developing and implementing SUPs. When asked about SUP development training, only 22% of responding companies provided training in this area. This training void may result from a lack of effective methods available to teach skills needed to design SUPs. Training methods used by companies were in-house training (63%), on the job training (15%), or a combination of the two.

Remarkably, none of the respondents indicated that training was conducted by external experts. This suggests that there are very few individuals with expert knowledge of SUP development capable of formally teaching others. The need for effective training and expertise will most likely increase as site planning becomes more prevalent within the construction industry.

Final project reports have become a standard practice among many construction companies. These reports contain a vast amount of information pertaining to problems encountered during a project and sometimes include lessons learned. These documents are ideal sources of information that can assist less experienced employees in learning about CSUPs and strategies used to overcome problems encountered during construction. Respondents (58%) stated that they document knowledge acquired on SUPs over the course of a project. The most common method for storing information was in a company database (47%) accessible by management personnel throughout their organization.

4.5. Software

Technology plays a major role in the construction industry as it provides a communication platform that enhances the delivery and exchange of information among various parties involved in a construction project. Unfortunately, a software system specifically designed to create SUPs has yet to emerge within the construction industry. When asked about software systems, 69% of the respondents indicated that a software system was used to create SUPs. The common software systems identified were PDF Overlay (80%), Building Information Modeling (BIM) (60%), and Computer Aided Design (CAD) (49%). Additional site planning systems identified were Google SketchUp, On Screen Takeoff, Visio, and Bluebeam. It is apparent that PDF Overlay is the predominant method for creating SUPs. When comparing PDF Overlay to BIM and CAD, PDF Overlay is substantially easier to operate, and requires little training to use. BIM is becoming one of the most beneficial tools within the construction industry due to the wide range of capabilities it offers each stakeholder. Respondents (71%) indicated that their company had implemented BIM on recent construction projects for clash detection (96%), communication (77%), schedule visualization (61%), SUP (57%), and/or documenting claims and change orders (36%).

4.6. Cost

Past research has acknowledged transportation costs between TFs as a major factor in determining the efficiency of a particular site layout [27]. However, the indirect cost associated with establishing and eliminating TFs has yet to be documented. Although this cost can vary greatly depending on the project scope and size, an average cost associated with TFs needs to be established to provide inexperienced site planners with a perspective on capital invested in TFs. For this reason, the respondents were asked what percentage of the total project cost is allocated to TFs. The majority of the respondents (56%) indicated that between 0% and 2% of the total project cost is allocated to TFs.

Costs associated with TFs can become significant on multi-million-dollar projects. This cost can impact the general contractor's profit margin considerably if not accurately integrated into the bid. Site planners not only need the skills to accurately develop a site plan, but also need the ability to estimate the implementation cost of their SUP.

5. Discussion

The first step in identifying best practices and developing a process for site planning was to acquire industry information on current methods used for site planning via an on-line survey. Using this data, trends were identified based on response similarities. From the identified trends, current best practices were itemized. Using these best practices, a procedure for developing SUPs was created.

To date, no research supporting the site planning process exists that outlines current methods used by industry for SUP development. The SUP procedure presented herein is based on data collected through a questionnaire survey, interviews, and site visits. The SUP procedure identifies important aspects that should be considered during the site planning phase of construction. The procedure was developed to serve as a reference document for site planners designing and implementing individualized site planning strategies, which allows companies to customize the process to suit individual needs. Overtime, the identified best practices will likely evolve to reflect new and innovative industry operations.

The best practices presented in this section are general and applicable to CSUP. The thirteen best practices identified from the survey, in no particular order, are as follows:

1. Conduct an in-person investigation of the site prior to SUP development.
2. Start SUP development as early as possible in the construction life cycle.
3. Involve stakeholders (e.g., owner, subcontractors, project managers, superintendents, management personnel, CM) throughout SUP development.
4. Consider impacts of inclement weather and safety regulations during SUP development.
5. Communicate and distribute the SUP to all stakeholders.

6. Ensure that all stakeholders buy in to the SUP.
7. Clearly communicate SUP enforcement polices to each subcontractor.
8. Implement and enforce the SUP from day one of construction.
9. Monitor SUP effectiveness regularly.
10. Remain flexible on-site space allocation throughout the project.
11. Update/modify the SUP as needed, communicating the updates to all stakeholders.
12. Document and share lessons learned with others in the organization.
13. If available, use BIM technology for SUP development. It should be noted that BIM is a relatively new technology that is rapidly being adopted by stakeholders within industry.

To provide validation for the best practices identified, a follow-up survey was sent to 133 respondents that indicated they were available for follow-up questions (i.e., 133 of the original 240 respondents). Responses were received from 58 industry professionals. The survey asked the respondents to indicate their opinion on each best practice in the form of strongly agree, agree, neutral, disagree, or strongly disagree. To determine a weighted average opinion for each best practice, weighting factors ranging from 5 (strongly agree) to 1 (strongly disagree) were applied. The weighted average opinions are shown in Figure 6.

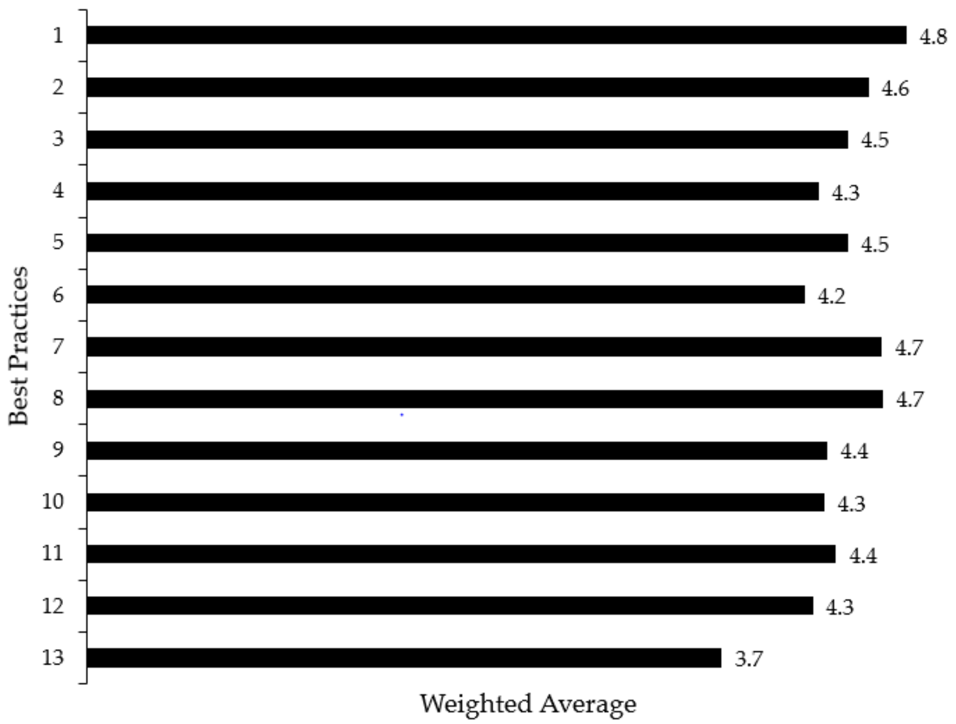

Figure 6. Best practices (weighted opinions).

The majority of the best practices had a weighted average above 4.0, indicating that most respondents agreed or strongly agreed with the list of best practices. Only one best practice had a weighted average below 4.0. This best practice indicated that BIM technology should be utilized for SUP development if available. Reasons for this practice not being strongly supported may be due to the cost associated with hiring/training individuals to use BIM, as well as a lack of understanding of the capabilities of BIM technology. Many professionals still rely on traditional 2D drawings and are reluctant to change; however, this will likely change as construction technology improves and young professionals emerge within the industry.

Based upon the evaluation of published literature, in-person interviews with industry professionals, and best practices identified from the survey, a comprehensive procedure for CSUP was developed. The procedure contains eight major steps, each outlining important aspects that need to be considered during SUP development. The procedure was developed in a manner that allows easy modification, facilitating individual preferences to be incorporated into the procedure. The basic purpose of the procedure is to provide inexperienced site planners with a guideline on site plan development and management. The developed procedure is outlined in Appendix A.

6. Conclusions

The formation of an easily understood process for developing SUPs gives practitioners a mechanism for developing site plans that is strongly supported by industry professionals. The process developed from this research will allow site planners to develop comprehensive SUPs that decrease the number of non-value-adding activity occurrences on construction sites. By eliminating the additional costs and time associated with non-value adding activities, project overhead can be reduced considerably. This research fills a general knowledge gap that exists between past research efforts and current industry practices regarding CSUP. The results of the survey and this research can serve as a vital resource to many construction and project management companies in the development of more robust policies and processes.

The procedure developed is generic in that it summaries important aspects of the CSUP process, leaving specific space delineation methods up to the planners. It is recommended that site planners continuously develop the procedure and make necessary modifications so their individual planning techniques are reflected in the procedure. By doing so, their standards of planning will emerge in the means and methods used for SUP development. Over time, the individualized SUP procedure will gain incredible value as a document of reference.

Companies are encouraged to develop a standardized method for collecting information on lessons learned at the end of each project. Information pertaining to unexpected site events can be gathered from management personnel in each of the eight steps outlined in the procedure. This can be achieved by developing a document that asks questions about each aspect of the site planning process. The information gathered can be organized and uploaded to a company database and made available to construction management/planning personnel. By developing a method for gathering and distributing lessons learned, non-value-adding events that occurred in past projects can be anticipated and prevented in future projects.

A limitation of the developed procedure is that of technology advancement. As software platforms become more readily available and user friendly within the construction industry, the steps outlined within the procedure may become obsolete. Future research efforts should focus on incorporating the practical steps identified in this study into a software interface that utilizes a state-of-the-art mathematical model. Once this merger is accomplished, a statistical analysis can be conducted to identify the significant impacts of TF placement with regard to construction productivity.

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Appendix A. Construction Site Utilization Planning (CSUP) Development Procedure

Step 1: Pre-Planning

- Conduct an in-person investigation of the site and surrounding areas;
- Identify local regulatory and safety requirements;
- Develop an understanding of the project scope and complexity;
- Analyze the potential impacts of inclement weather on site operations;
- Develop the Master Construction Schedule.

Step 2: Determine if a Plan is Necessary for the Project

- Determine if a site utilization plan is required for the project considering the following factors:

➢ Project Complexity	➢ Regulatory Requirements
➢ Scope of Work	➢ Project Safety Requirements
➢ Site Investigation	

Note: The development of a SUP should be a team effort that includes input from the site superintendent, project engineer, estimator(s), owner, subcontractors, and management team under the leadership of the project manager.

Step 3: Data Collection

- Identify all clauses set forth in the contract documents that may influence the site layout;
- Involve the owner in the site utilization plan development. Information from the owner that may affect site layout includes:

➢ Site Ingress / Egress	➢ Safety Requirements
➢ Traffic Routes	➢ Parking Area Availability
➢ Allotted Area for Construction	➢ Environmental Concerns
➢ Existing Facility Operations	➢ Utility Connections
➢ As-Built Drawings of Existing Facilities	➢ Local Regulatory Requirements
➢ Availability of Offsite Storage Space	

- Involve subcontractors in the site utilization plan development. The subcontractor may provide the following information that could affect the site layout:

➢ Office Trailer(s)	➢ Material Supply/Delivery
➢ Toolsheds (Type/Size/Quantity)	➢ Type of Storage (Outdoor/Indoor)
➢ Parking Requirements	➢ Storage Requirements
➢ Material Security Requirements	➢ Number of Site Workers
➢ Equipment Space and Access	

- It is important to distinguish between the "wants" and "needs" of the subcontractor.

Step 4: Plan Development

- Decide which information should be included in the site utilization plan based on project requirements;
- Determine whether multiple site plans are required (for a project with multiple phases) or if a single plan will suffice;
- Identify existing site conditions on the site plan. These may include:

➢ Site Topography	➢ Buried/Overhead Utilities
➢ Parking Lot	➢ Fire Hydrants
➢ Protected Areas	➢ Existing Facilities/Buildings
➢ Roadways & Sidewalks	➢ Undisturbed Areas
➢ Erosion & Sediment Controls ➢ Drainage Areas	➢ Leadership in Energy and Environmental Design (LEED) Requirements

- Determine the location of each temporary facility. This is typically achieved by applying construction knowledge that has accumulated over many years of experience.
- Temporary facilities that may be included on a site plan include:

➢ Worker Parking Locations	➢ Crane Loactions and Swing Radii
➢ Job Trailer Locations	➢ Buck Hoist Locations
➢ Job Site Access Points	➢ Concrete Washout Locations
➢ Tool Shed Locations	➢ Emergency Access Points
➢ Dumpster Locations	➢ First Aid Stations
➢ Building Footprint	➢ Construction Fencing/Gates
➢ On-Site Storage	➢ Off-Site Storage
➢ Toiler Facilities	➢ Break Area/Shelters
➢ Utilities	➢ Equipment Areas
➢ Unloading Areas	➢ Staging Areas
➢ Soil Storage Areas	➢ Work Areas
➢ Informative Signage	➢ Occupational Safety and Health Administration (OSHA) Safety Areas

- Consider the following logistics when selecting temporary facility locations:

➢ Public and Worker Safety	➢ Material Movement
➢ Crane Lift Radii	➢ Equipment Movement
➢ Temporary Facility Interrelationships	➢ Subcontractor Interrelationships

- Identify construction routes on and off site. These may include:

➢ Material Delivery Routes	➢ Traffic Flow
➢ Traffic Detour Routes	➢ Equipment Paths
➢ Material Paths (Vertical & Horizontal)	➢ Personnel Paths/Haul Routes

- When available, use BIM technology when developing site plans. BIM provides a data-rich environment in which site utilization plans can be created. It also offers graphical relationship information that can be beneficial during collaborative meetings.

Step 5: Communicate

- Allow all stakeholders to review and provide feedback in the site plan;
- Ensure that all stakeholders buy-in to the site plan before construction initiation;
- Maintain communication with all stakeholders throughout the construction process;
- Establish and clearly communicate the consequences of non-adherence to all subcontractors.

Step 6: Implement and Enforce Plan

- Distribute the finalized site plan to all stakeholders. Effective methods for informing subcontractors and workers on space allocation include: (1) displaying a large-scale site plan on-site that can be easily seen; (2) posting signage throughout the site identifying temporary facility areas; and (3) distributing an electronic copy of the site plan to all subcontractors.

- Enforce effective housekeeping rules at all times so that laydown areas and roads are maintained and kept free of trash and debris that would otherwise hinder the movement of material and equipment.

Step 7: Monitor and Evaluate Plan

- The site superintendent should monitor and evaluate the plan on a day-to-day basis;
- If the plan works effectively, continue using it. If problems arise, determine whether the problems are related to noncompliant subcontractors or unforeseen conditions;
- In noncompliant subcontractors are an issue, discuss the purpose of the site utilization plan with the subcontractor. If problems continue, punitive actions may need to be taken;
- Typical punitive actions include:

➢ Verbal Warnings	➢ Subcontractor Back-Charges
➢ Written Warnings	➢ Removal of Insubordinate Staff
➢ Monetary Warnings	➢ Contract Termination

- If unforeseen conditions are an issue, revise the plan and correct the issues;
- Update the plan on a regular basis and communicate updates to all stakeholders.

Step 8: Document Lessons Learned

- Document lessons learned at the end of each project;
- Develop a system for distributing documented information throughout the organization. A method commonly used for information distribution is a company database that can be accessed on-line by all management staff.

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