Construction Site Utilization Planning Best Practices

by

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Abstract

Construction site utilization planning has implications for project safety, construction efficiency, scheduling, and budgetary performance of a project. An important aspect not identified in past research efforts are the current practices for site utilization plan development currently used by the construction industry. Therefore, the objectives of this research were to: 1) determine the best practices for site utilization planning; 2) develop a procedure that outlines the site utilization planning process; and 3) show how current Building Information Modeling (BIM) technology can be harnessed for site utilization plan development. The main method for data collection was a survey. A total of 241 responses were received. From the survey, 13 best practices were identified with each focusing on an important aspect of the site planning process. From the best practices, a procedure describing the site utilization process was developed. The procedure incorporates important aspects associated with project constraint identification, plan necessity, data acquisition, plan development, communication, implementation and enforcement, monitoring and evaluating, and documentation. Finally, an elusive three dimensional site utilization plan was created using BIM.

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List of Abbreviation

ACO	Ant Colony Optimization
ANN	Annealed Neural Network
BIM	Building Information Modeling
CSUP	Construction Site Utilization Planning
GA	Genetic Algorithm
GIS	Geographical Information System
PSO	Particle Swarm Optimization
SUP	Site Utilization Plan
TF	Temporary Facility
TS	Tabu Search

Chapter 1 : Introduction

1.1 Construction Site Utilization Planning

Construction Site Utilization Planning (CSUP) is a decision making process for determining the location of temporary facilities within the boundary of a construction site identifying spatial relationships and developing best alternative solutions so that the efficiency of the construction process is improved over the project life cycle. Temporary Facilities (TFs) are defined as those facilities and areas delineated to specific tasks that support the construction process. Temporary facilities are typically not part of the permanent structure and have relatively short life spans. Examples of temporary facilities associated with construction projects include: laydown areas, unloading areas, material paths, staging areas, personnel paths, storage areas, prefabrication areas, work areas, tool and equipment areas, debris paths, hazard areas, and protected areas (Riley and Sanvido 1995). The number, type, and size of temporary facilities depends upon the project type, scale, design philosophy, and construction execution strategy. Basically, CSUP is a trade-off problem in which decisions must be made based on project attributes (e.g., cost and safety) without sacrificing site plan quality (Ning et al. 2010). CSUP is a critical part of the project planning process due to its impact on construction activities, project duration, safety, and cost.

Site Utilization Plans (SUP), also known as Jobsite Layout/Logistics Plans, are documents that depict the locations of temporary facilities within the construction site boundary. SUP are similar to the construction plan and schedule in that they are long-term and consider all aspects of the construction process (Mincks and Johnston 2010). Optimum SUP minimize the labor involved with movement of materials so that workers can spend the majority of their time performing productive construction tasks. Jobsites that are clean and well-organized provide a working environment that has a positive impact on work morale and in turn results in higher production during the work shift. A site utilization plan should include the following aspects:

- Jobsite space allocation – areas on the jobsite for material delivery, material storage, temporary offices, and facilities
- Jobsite access – access to and from the jobsite and to work areas within the jobsite, including haul roads
- Material handling – including material movement on the jobsite, both horizontally and vertically; lifting equipment, including forklifts and cranes
- Worker transportation – personnel movement and access to the jobsite
- Temporary facilities – temporary offices, storage facilities, dry shacks, sanitary facilities, temporary water, power, heat, telephone, and internet connections
- Jobsite security – temporary fencing, guard dogs, security patrols, electronic alarm systems, and watchmen
- Signage and barricades – protection of the public from construction hazards on the jobsite (Mincks and Johnston 2010)

1.1.1 Importance of Site Utilization Plans

Many tasks are involved in managing a construction site, one of which is site utilization planning. Typically, a project manager is responsible for developing a site utilization plan based on past experience, knowledge, intuition, and imagination (Osman et al. 2003). In the absence of a well-developed site utilization plan, many problems can occur resulting in time delays and cost overruns. Site utilization planning overlaps with other planning tasks such as scheduling, selection of construction method, procurement and material planning, manpower and equipment planning, and financial planning (Elbeltagi 2008). These interactions exist due to the fact that the timing for each plan must coincide at a precise moment so that the correct material, equipment, manpower, and finances are available to complete a planned task. Therefore, CSUP is an essential task for successful management of a construction project.

Despite the importance of CSUP, it is often done in a speedy manner or overlooked completely (Mawdesley et al. 2002). The results of such acts reflect in the day to day operations of the project, making it difficult to manage site operations. Despite the significant body of research on optimization methods, no well-defined optimization method can guarantee a solution that takes all possible elements into account (Chau and Anson 2002). The decision to develop good SUP early on in a project can have a significant impact on later site operations.

Temporary facility and equipment placement is directly related to the construction sequencing and performance of a project. Poor site planning and management can lead to work delays, misplacement of materials, double handling of materials, schedule delays, capital loss, and unsafe working conditions (Mincks and Johnston 2010). For construction to flow seamlessly, many projects specific factors must be considered during the space delineation process. Site space delineation should involve: i) site boundary identification, ii) temporary facility identification, iii) identification of temporary facility constraints, and iv) determining the relative position of each temporary facility so that the functionality and efficiency of temporary facility operations are maximized (Zouein et al. 2002). In addition, the scheduled timing of establishment and removal of each temporary facility should be determined (Mawdesley et al. 2002).

To allocate space effectively, the planner must have a clear understanding of the construction execution plan. It is imperative to realize the significance of site space constraints during the planning process due to the fact that site plans dictate the working conditions of site personnel for the duration of the project (Elbeltagi 2008). Depending on the location of a construction project, site space may or may not be limited. Typically, urban areas (e.g., downtown/metro areas) have less space available for construction activities due to the structure/building encompassing the majority of the site. Therefore, space planning is critical and should be delicately handled so that construction activities can be executed efficiently. On the other hand, space planning for large construction sites tends to be pushed aside during project startup due to space abundance. In such a case, project managers tend to place facilities randomly within the site boundaries, creating an environment that becomes increasingly inefficient (Mawdesley et al. 2002). No matter the scenario, jobsite planning and organization is essential for construction projects to be productive and profitable.

1.1.2 Dynamics of Site Utilization Planning

The difficulty associated with CSUP is that the construction process is inherently dynamic in nature. This time-space relationship means that TFs will not likely occupy the same space, quantity of space, and orientation within the site boundaries as a project progresses (Mahachi 2001). This consequently means that the SUP must constantly evolve over the duration of the project, thus making the problem challenging (Mawdesley et al. 2002). During construction, space availability is governed by the construction schedule, construction methods, and the contractor's mobilization and demobilization of materials, equipment, and personnel on-site. As a construction project reaches its peak, the site can become overly congested and the corresponding layout can become confined. No matter the space scenario, there will always be a high demand for prime space (i.e., space typically immediately surrounding the facility under construction) as travel distances increase for accessing the facility from more remote locations (Tommelein et al. 1992).

1.1.3 Construction Site Safety Planning

With safety being the number one priority on most construction sites, many contractors are focusing on developing methods for improving worker safety. Common methods that are employed by contractors include: morning tool box safety meetings, 10 hour Occupational Safety and Health Administration (OSHA) training for all workers on-site, and 30 hour OSHA training for supervisors and managers (Maynor 2013). Construction workers are engaged in many activities that can expose them to dangerous conditions; however, with proper planning many potential dangerous situations can be avoided. OSHA has been in charge of developing and enforcing safety regulation since 1971 and since their establishment, workplace fatalities have been cut by 62 percent and occupational injury and illness rates have declined 40 percent (US Department of Labor 2013a). OSHA recognizes site layout as being an area that, if not properly planned, can cause serious safety issues or fatalities. For instance, OSHA requires that: i) access roads into and throughout the site must be adequate for safe delivery and movement of derricks, cranes, trucks, other necessary equipment, and material to be erected (29 CFR 1926.752(c)(1)) and ii) adequate space be provided for the safe storage of materials and the safe operation of the erector's equipment, such space shall be firm, properly graded, drained, and readily accessible to the work (29 CFR 1926.752(c)(2)) (US Department of Labor 2013b). OSHA also requires a minimum distance from overhead power lines as shown in Table 1.1. Factors such as these must be considered when developing SUP.

Table 1.1: Minimum Clearance Distances

Voltage (nominal, kV, alternating current)	Minimum clearance distance (feet)
up to 50	10
over 50 to 200	15
over 200 to 350	20
over 350 to 500	25
over 500 to 750	35
over 750 to 1,000	45
over 1,000	(as established by the utility owner/operator or registered professional engineer who is a qualified person with respect to electrical power transmission and distribution)

1926.1408(a)(2)(iii)(A) (US Department of Labor 2014)

Several studies have shown that the factors leading to accidents can be controlled by improving project design, site organization, and implementing safety factors (Palumbo 2010). The ability to influence site safety can be directly related to how the site is initially conceptualized. Research suggests that safety considerations in the conceptual stage of a project has greater potential of influencing safety at project startup as opposed to implementing safety aspects after the project has begun (Szymberski 1997). Therefore, safety factors should be incorporated into the design of site utilization plans so that unsafe working conditions can be eliminated.

1.2 Problem Statement

A substantial amount of research has been conducted on robust multi-objective optimization methods that consider the temporal nature of layout planning. The research has been predominantly focused on identifying optimization algorithms which could produce optimal site utilization plans. As shown in the literature review (Chapter 2), very limited research efforts have focused on identifying the best practices of site utilization planning from a practical perspective. It is important to identify the state of the practice and answer questions such as:

1. Stakeholders: Who gets involved in the site utilization plan development process?
2. Information: What information is required to develop an effective site utilization plan? Furthermore, where does this information come from?
3. Timing: When does the development of the site utilization plan begin? When does the plan need to be completely developed?
4. Content: What information should be included in the site utilization plan?
5. Technology: Is software used to develop site utilization plans? If so, what software is used?

These questions have not been adequately answered in the current research literature. To further compound the layout problem, several key considerations (i.e., offsite storage, safety margins, etc.) have to be taken into account in order to solve the problem. The basic principles of site utilization planning have not been identified in the extant research literature. The basic principles of site utilization planning can be characterized as the best practices that site planners base their decisions. This particular body of knowledge can vary greatly depending on one's experience within the construction industry. For inexperienced site utilization planners to create an effective site utilization plan, this basic knowledge needs to be identified and documented so that the "Wheel" of site utilization planning does not have to be reinvented. As in calculus, the boundary conditions of a problem must first be identified to determine a unique solution to that specific problem. In the case of site utilization planning, computer software has the ability to solve specific problems; however, the basic principles (e.g., boundary conditions) must first be identified so that a unique solution can be obtained.

Construction site utilization planning is a unique skill that a construction professional acquires over a period of time in become proficient and competent in his/her work. Although the development of computer software for use in the construction industry is rapidly advancing, a gap still exists between site utilization designers and site utilization software implementation. Many of the design tools available require the user to be well versed on: i) site utilization planning, ii) challenges associated with site utilization planning, and iii) methods of overcoming unexpected obstacles prior to utilizing software capabilities, not to mention the learning curve associated with becoming familiar with new program operations. One must be knowledgeable on all aspects of site management and control to fully understand and resolve the site layout problem.

1.3 Research Objectives

The primary objective of this research is to review and evaluate the construction industry's current best practices and procedures on the site utilization planning process used to delineate construction site space for temporary facilities. Many construction professionals are unaware of the elements that need to be considered during the site planning phase. A need exists for the development of a means for creating an effective site utilization plan to help prevent future unjustified cost overrun and time delays. As a result, the primary goal of this research was to develop a procedure for creating site utilization plans that represent current industry standards which promote efficient, productive, and safe work flows.

The specific objectives of this research are as follows:

1. Identify the state-of-the-practice of site layout planning in the construction industry.
2. Identify the current best practices of site utilization planning.
3. Develop a procedure that practitioners can reference when developing site utilization plans.
4. Illustrate how Building Information Modeling (BIM) technology might be used for site utilization planning.

The specific tasks completed to satisfy these research objectives are as follows:

1. Identify, evaluate, and critically assess pertinent literature on current means and methods used in the development, implementation, and management of CSUP.
2. Conduct site visits and one-on-one interviews with industry professionals to develop a comprehensive understanding of current site utilization practices.
3. Develop and administer a survey of construction industry professionals to determine the predominant factors associated with the development and management of CSUP; as well as, determine the state-of-the-practice regarding CSUP.
4. Analyze the collected data and determine the best practices of CSUP, then use the data to develop a procedure that provide generic instruction on the development and management of CSUP.
5. Demonstrate how current BIM technology can be utilized in the development of highly accurate three dimensional CSUP.
6. Provide recommendations for future research efforts.

1.4 Research Methodology

The primary instrument used for data collection in this study was a questionnaire survey. The questions within the questionnaire were developed through a process that started with the review of published literature on site utilization planning. During the review, areas of the site planning process with limited or no information were identified. To assist with the questionnaire development, several in-person interviews were held with construction professionals from different companies. The interviews were semi-structured in that each interviewee was asked a logical sequence of open ended questions regarding information on site utilization planning that was unidentified in past publications. Comments on each question were logged by hand and additional questions were asked on interesting points that came up during the discussion. 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 site utilization planning.

To ensure an aesthetic design and an efficient distribution process, the questionnaire was created in the online survey software Qualtrics. The questionnaire was organized so that questions pertaining to the same topic would be displayed sequentially. This allowed skip logics to be incorporated into follow-up questions, thus minimizing the time required to complete the survey. The questionnaire was published to a web page and emails containing the web link were sent out to construction professionals explaining the reasoning behind the research effort and inviting them to participate. Construction research publications that used questionnaire surveys were reviewed to determine the typical number of responses required to validate research conducted via survey. Eleven similar publications were reviewed to provide detailed information on survey distribution methods, surveys distributed, and surveys received. The publications reviewed are shown in Table 1.2.

Table 1.2: Published Construction Industry Survey Results

Authors	Surveys Sent	Surveys Received	Response Rate
Ahmad and Minkarah (1988)	378	129	34%
Tavakoli et al. (1989)	400	122	30%
Riggs and Schenk (1990)	58	20	34%
George et al. (1994)	225	94	41%
Ramey and Wright (1997)	90	46	51%
Zeng et al. (2003)	200	60	30%
Arditi et al. (2008)	400	65	16%
Yang and Wei (2010)	120	100	83%
Hegab and Salem (2010)	82	27	33%
Lin et al. (2011)	285	89	31%
Tang et al. (2013)	295	78	26%

The survey was open from October 2013 to December 2013. Each response was individually reviewed and all incomplete responses were discarded. The results were compiled and the best practices of site utilization planning were identified. To validate the best practices identified, a second survey was sent to the respondents asking them to indicate their opinion (e.g., agree/disagree) on each best practices. The best practices were used to develop a guideline that summaries practical aspects of site utilization planning that are recognized by the construction industry. This guideline can be referenced by site planners during the planning process so that all major aspects of site utilization planning can be considered.

1.5 Organization of Thesis

This thesis is divided into seven chapters that organize, illustrate, and describe the steps taken to meet the defined research objectives. This thesis is organized as follows:

Chapter 1 – Introduction: Provides a detailed discussion on site utilization planning within the construction industry and the impact it has on construction projects. The research objectives are outlined along with the specific tasks to satisfy the research objectives.

Chapter 2 – Literature Review: Summarizes the body of knowledge pertaining to CSUP and provides a comprehensive, critical review of previous research efforts. The literature review focuses on two aspects of CSUP, the first being the practical aspects (e.g. development, management, etc.) of site utilization planning and the second being the optimization systems (e.g. algorithms) proposed in previous research.

Chapter 3 – Survey Development: Outlines the steps taken to develop and administer an online survey of construction professionals to determine the current state of CSUP.

Chapter 4 – Data Analysis: Discusses the effort in obtaining, organizing, and statistically analyzing the data collected from the survey. The information obtained from the survey is discussed and the best practices currently used among construction industry professionals are synthesized.

Chapter 5: CSUP Best Practices and Procedure: Discusses the best practices of site planning and outlines the procedure used by industry to develop site utilization plans.

Chapter 6: CSUP within the BIM Environment: Discusses how current BIM technology can be used to develop detailed CSUP within a virtual environment. Also, unique techniques for placing temporary facilities are discussed in detail with an example following.

Chapter 7: Conclusions and Recommendations: Provides input on the best practices and procedure of site utilization planning within the construction industry. Additionally, this chapter identifies the potential for further research that can be conducted to continue the research effort.

Chapter 2 : Literature Review of Site Utilization Planning

2.1 Introduction

To identify the best practices of CSUP, a comprehensive review of published research literature and books was performed. The databases searched for pertinent literature on CSUP were Academic Search Premier, ASCE Publications, EBSCO, Engineering Village, Google Scholar, and Science Direct. The key terms searched included construction site utilization planning, best practices of construction site layout planning, and construction site logistics planning. The objective of this research is to identify the best practices in Site Utilization Planning. Upon reviewing the literature, it was apparent that a significant amount of research focused on the development of algorithms that optimize the placement of temporary facilities and movement of equipment/material on a construction site. It was observed that limited consideration was given to the practical aspects of CSUP such as:

- The process of CSUP.
- When does the site planning process start?
- Who gets involved in the development?
- Do contractors typically develop one plan for the project or do they develop multiple plans?
- How do contractors ensure that the developed plans are implemented and enforced?
- What level of detail is incorporated in the plan

Limited information emphasizing these aspects was found within publications. Many articles did not address any of these aspects. Thus, the literature review is composed of two main sections. The first section discusses the practical aspects of site utilization planning while the second section discusses optimization systems developed for site utilization planning.

2.2 Construction Site Utilization Planning

Construction site utilization planning is the process of determining what temporary facilities (TF) will be needed during construction, where each TF will be placed on site and the duration each TF will occupy a finite area on site (Ning et al. 2011). The goal of site utilization planning is to predict the activities associated with a construction project and plan accordingly so that project duration and project cost can be minimized (Mawdesley et al. 2002). 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 results in decreased productivity, schedule delays, and lower employee morale (Guo 2002).

To create an effective and safe site utilization plan, health and safety factors must be incorporated into the plan. The storage locations of material and equipment have a significant impact on construction site safety. These locations need to be carefully selected so that the movement of material and equipment can be minimized (Elbeltagi et al. 2004). The successful implementation of an effective site utilization plan will be reflected in project cost, quality of work, operations safety, and the environmental aspects of the work (Mawdesley et al. 2002). The development of comprehensive site utilization plans may also decrease the amount of non-value adding work that is associated with poor site planning and coordination (Akinci et al. 1998).

During construction projects, many tasks are performed to produce a finished product within an allotted time frame. At any point during construction multiple tasks can be simultaneously underway and in many cases these task are in close proximity of one another so that production can be maximized (Thomas et al. 2006). To optimize the flow of resources for each task, comprehensive site utilization plans must be developed. The development of optimal utilization plans consists of developing layout alternatives that promote a smooth flow of construction resources (e.g. personal, equipment, materials) while also satisfying project constraints (e.g. construction boundary, safety zones, protected areas, etc.). In many projects the available area for TF placement changes as the project progresses, thus the locations of TFs may need to be altered over the duration of the project. The combination of these factors creates a multi-objective problem that requires substantial thought so that the optimal solution can be designed (Thomas et al. 2005).

Site utilization plans are typically secondary to project plans, schedules, resource allocation, and budgeting and in many cases they are neglected (Mawdesley et al. 2002). Often, after bidding and project startup, site layout decisions are left to the foremen and/or superintendent who normally handle day-to-day operations (Chau and Anson 2002). This leads to instantaneous decisions on area allocation when space is needed for delivered material and equipment storage. When this form of site utilization planning is used, job sites quickly become unorganized, cluttered, and difficult to manage. When site utilization plans are developed, they are typically based on rules of thumb, heuristics, expertise, judgment, code of practice, preference, and previous experience of the personnel involved with the construction effort (Chau and Anson 2002, Osman et al. 2003).

Therefore, when plans are developed prior to project start up, the foremen and/or the superintendent need to be involved due to their vast knowledge of material storage/handling and equipment operations. In addition, subcontractors also possess knowledge that may assist in the development of an effective site utilization plan; however, site utilization plan developers should be cautious about the information gathered from subcontractors as it may not always be in the best interest of the project (Thomas et al. 2011).

2.2.1 Construction Site Temporary Facilities

A temporary facility is a physical area within a construction site that has an associated time of establishment and removal during the project life cycle (Mawdesley et al. 2002). Many factors dictate what TFs are required on construction sites, some of which are: project type, scale, design, project location, and organization of construction work. The TFs included in a site utilization plan differ from project to project, as well as the duration of the TF in a specified area (e.g. TF may need to be relocated instead of eliminated). The location and size of a TF is directly related to the project for which the utilization plan is being developed. Many similarities can be found in site utilization plans for different project; however, each project has its own unique features (i.e., construction boundary, building orientation, site topology, etc.) that controls the space available for TF placement. In many cases, the locations and sizes of TFs interrelated with one another, thus adjusting one will effects the other. If construction site space is not abundant, which is the case in many scenarios, the size of TFs can sometimes be reduced while also keeping their functionality. On the other hand, projects that have an abundance of space also have unique challenges that must be anticipated. An abundance of space allows TFs to expand in size as a project progresses; however, the space preferred is usually the space immediately surround the building (e.g., prime space) (Tommelein et al. 1992). This preference of space can be of great value as the project reaches peak construction. During peak construction the prime space is heavily congested and if not controlled efficiently, productivity and construction flow can be significantly affected.

Riley and Sanvido (1995) suggest that construction space can be broken down into “Areas” and “Paths”. Each of these construction spaces can further be broken down into the following subareas: layout area, unloading area, staging area, storage area, prefabrication area, work area, tool and equipment area, hazard area, protected area, material path, personnel path, and debris path. Additional spaces that may be included are: site ingress/egress points, office trailers, welfare facilities and delivery areas (Elbeltagi et al. 2004). Before beginning the selection process, it is important to determine which TFs are required for a particular project. If all TF are not accounted for during the development of the site utilization plans, the plan selected and implemented will not yield optimal space allocations, thus not allowing for a smooth and seamless flow of materials and equipment on the construction site.

In past research, Mawdesley et al. (2002) interviewed practicing engineers and construction professionals to determine the importance of site utilization. From the interviews, several key factors were identified as being of importance during the development of site utilization plans. The key factors were: i) access and traffic routes, ii) material storage and handling, iii) administration building and welfare facilities, and iv) equipment, workshop, and services. Engineering and construction professionals also considered site utilization planning to be: i) difficult to specify (e.g., difficult to define the best layout plan), ii) interrelated with other management task, iii) highly dynamic (e.g. optimal site layout is changing through the project duration), and iv) under researched.

2.2.2 Construction Site Utilization Plan Development

The development of a site utilization plan consists of several factors. Before starting the development of a utilization plan the developer must be aware of three important elements: i) what is to be constructed, ii) what tasks are associated with construction, and iii) what method of construction will be used. With a comprehensive understanding of these elements the process of planning can begin; however, the development process is highly subjective and nontrivial and requires the developer to meet multiple prioritized objectives (Chau and Anson 2002). Currently, no specific agreed method exists for the development of site utilization plans (Tommelein et al. 1992). The nature of the utilization problem makes it extremely difficult to select a well-defined method that consistently yields a guaranteed solution. Researches have been able to identify key points to consider during the development phase. Mawdesley et al. (2002) recognized three key aspects that a complete site utilization plan should address. The aspects are: what are the TFs that need to be established, what is the geographical layout of the TF, and at what point during the project are the TFs going to be installed and removed. Although these aspects do provide some ideas of what is to be expected upon the completion of a site utilization plan, they do not provide a means on how to construct a utilization plan. To help fill this gap of uncertainty, Elbeltagi et al. (2004) suggested a five step approach for determining the TFs needed between any two dates. The steps as defined by Elbeltagi et al. are:

1) The necessary TFs must be identified and sized.
2) The project schedule must be developed.
3) The required activities of each TF must be defined.
4) The service times for each TF must be determined from the project schedule (e.g. TF start date and finish date).

5) The TFs that serve during a specific time interval can be defined and considered as the TFs needed on site in that interval.

Most research conducted on site utilization planning focuses on space allocation on the exterior of the structure being built. Very little research has been conducted on space allocation within the structure. Riley and Sanvido (1997) conducted research on space usage within multistory buildings and found that space usage was repeatable and predictable. By recognizing work flow patterns during construction, the area needed for a particular task could be predicted, as well as task duration, which could then help develop a utilization plan (Riley and Sanvido 1997). Thomas and Ralph (2007) proposed a microlevel planning process aimed at small contractors to describe effective prebid planning techniques. An element of the proposed planning strategy was to create a site layout plan.

2.2.3 Construction Site Utilization Plan Management

For a project manager to create an effective site utilization plan, he/she has to have ample knowledge of current construction practices. Normally, the scope of sequential construction projects a project manager would undertake varies considerably. Due to this variation, project managers must determine the elements (e.g., material, equipment, etc.) needed for construction, element schedule (e.g., arrival/departure times), and individuals (e.g., tradesmen, operators, etc.) associated with each element when starting a new project (Laufer et al. 1994). The ability to identify key elements of a project and choreograph an effective utilization plan strongly influences the constructability of a project (Tatum 1987).

Throughout the construction process, several tradesmen work concurrently at the site. With multiple tradesmen on site, congestion will occur in work and storage areas if a utilization plan is not implemented. By implementing a SUP that incorporates staggered work schedules, housekeeping, and organization; congestion can be minimized, thus allowing labor productivity and performance to remain optimal throughout the project duration (Thomas et al. 2006). When developing a SUP, it is critical to consider storage locations for certain materials so that workers are not constantly interfering with one another. To aid general contractors in the management of subcontractors, Thomas and Flynn (2011) developed a "to do" list that highlights principles that focus on the management of people and work. By implementing these principles, general contractors can have a positive impact on subcontractors, thus increasing the likelihood of the subcontractor following the site utilization plan (e.g., storing materials in the proper location, keep pathway clear of debris) selected for the project.

2.2.3.1 Material Management

Material management is an essential task that must be fulfilled to maximize worker efficiency and prevent project delays. The location of material storage areas on a site have to be incorporated into the SUP and these areas should be carefully selected. Ineffective site material management can contribute to waste in time and money. Thomas at el. (2005) developed a list of principles that deal with site material management that should be considered when selecting the location of material storage areas. Some principles listed that would affect site utilization planning are: i) locate parking lots, tool sheds, and spoil piles as far away from the building as possible, and ii) materials should be stored to allow easy access and retrieval (Thomas at el. 2005). It is extremely difficult to consider all the activities that could develop into a conflict when developing a site utilization plan. To assist the space conflict resolution process, Guo (2002) established criteria to resolve space conflicts between activities. The major criteria listed are: i) logical sequence of activities, ii) critical path, iii) space divisibility, iv) location change, v) space size modification, vi) start time of conflicting space occupation, and vii) length of occupancy time (Guo 2002). Using these criteria, a prototype decision support system was developed to solve the multi-objective problem. To identify dynamic conflict between activities, a CAD system was integrated with scheduling software (Guo 2002).

2.2.3.2 Equipment Management

The movement of equipment on a construction site requires knowledge of how the equipment functions as well as the space required so that the equipment can operate safely. Kim and Kim (2010) conducted a study to determine the effects of construction equipment on construction operations. This study applied a multiagent-based simulation model to a real word project and evaluated the efficiency of construction operations based on the equipment flow on-site. Several models were run, each having an increased volume of equipment on-site with hopes of increasing productivity. This volume increase resulted in traffic congestion and bottle necks, thus decreasing equipment speed by 48.8% and construction operation by 61.6% when compared to normal traffic operations (Kim and Kim 2010). This indicates that for a project to operate efficiently, the project manager or engineer must know what equipment is required to construct a project and monitor the equipment delivered to the site. The concept of equipment utilization planning can be of great concern when dealing with large construction operations (e.g. highway construction) that require a significant amount of earth moving equipment.

2.2.3.3 Site Plan Observation

Evaluating the effectiveness of a site utilization plan is an integral part of the site utilization planning process. To consistently improve future site utilization plans, the designer must be aware of on-site operations that are not able to transition to subsequent tasks due to ineffective temporary facility placement. An effective way to evaluate a site layout is by comparing the scheduled placement of temporary facilities with the actual placement of the facility (Menches and Hanna

2006). Site utilization planners must constantly be aware of unplanned events that occur on site that disrupt the site utilization plan. There are numerous ways a site utilization plan can become ineffective on-site. For instance, if materials are delivered earlier than planned available site area must be used to store the materials. This in turn starts a domino effect, which if not corrected, will continue to disrupt the construction process.

2.3 Dynamic Utilization Planning in Construction

Construction sites are areas that have constant movement in multiple directions over time. One way to manage the ever changing area is to develop a dynamic utilization plan (e.g. time dependent plan) that considers the area requirements of workers, equipment, and material. This type of plan takes into account the time that a particular object will occupy a finite area over a predetermined time frame. For many projects, a single site utilization plan would not suffice due to the complexity and restrictions associated with the site. Because of this, site utilization plans may need to be developed in phases (e.g. primary time dependent variable), each of which corresponding with the different phases associated with construction. Going a step further in the dynamics of site utilization planning, each of the utilization phases may be further broken down according to the duration of the construction phase. For example, depending on how the project is scheduled, one phase of a project may have a duration of one week and during that week no changes in TFs occur, thus a static (e.g. does not change with time) site utilization plan would be sufficient. Conversely, a phase of construction may last several months and during this time many TFs may be created, relocated, or terminated, thus adding a secondary time dependent variable to the site utilization planning process.

Many researchers have proposed approaches that optimize the placement of TFs based on predetermined constraints (e.g. available site area, access points, etc.). When developing dynamic site utilization plans using predetermined constraints, it is important to consider spatial interference between TFs. Akinci at el. define spatial interference as "the physical conflict of an activity's space requirement with another activity's space requirements or work-in-place" (Akinci at el. 1998). As a site utilization planner, it is critical to identify and correct spatial interferences prior to the execution of the schedule. It has been estimated that spatial interferences can increase the total project duration by 27%, which in turn increases the cost of the project (Akinci at el. 1998). Many additional aspects should also be considered in the development of dynamic site utilization plans, some of which are: worker health and safety, safety zones, closeness of TFs (Elbeltagi et al. 2004), TF lifespan, space demand over time, location constraints and relocation cost (Zouein and Tommelein 1999).

2.4 Site Layout Optimization

The development of a universal site layout optimization tool has long been the focus of many researchers. Within the last two decades, several researchers have developed software systems that allocate space based on a set of predetermined constraints and an optimization function. This method of optimization planning can also be found in many other areas of research such as: i) manufacturing (Singh 2006), ii) architecture (Liggett 2000), and iii) computer chip design (Kozminski and Kinnen 1984). Each of these areas has unique challenges that must be addressed so that a solution can be obtained; however, the optimization of construction site operations is significantly more complex due to the fact that construction is dynamic in nature.

2.4.1 Optimization Methods

Most of the facility layout optimization systems previously developed operate by allocating site space to predetermined TFs based on criteria (e.g., area requirements) that must be met and/or optimizing an objective function (e.g. cost of moving materials) (Liggett 2000). The categories in which site optimization solution techniques are typically classified are: i) constructive methods, ii) improvement methods, iii) trajectory methods (e.g., simulated annealing), iv) population based methods (e.g., genetic algorithms and swarm intelligence), and v) hybrid approach methods (Liggett 2000). The constructive method builds a layout solution in a step-by-step fashion, locating TFs one by one. This method is not suitable for complex projects but can be used to develop simple layouts. Improvement methods, trajectory methods, and population based methods generate solutions based on space availability. The performance of each generated solution is then evaluated against a predefined objective function. This optimization strategy is known as meta-heuristics.

2.4.1.1 Improvement Method

The improvement methods used for solving layout problems begins with an initial layout solution, which is provided by the user, and attempts to improve it incrementally. This method uses a pair-wise exchange which is a process of evaluating possible exchanges between any two activities until the initial criterion value is improved. The search for an improved criterion value is executed systematically and once an improved criterion value is found, the activities make an exchange. The main drawback to this hill climbing method is that it often gets trapped in local optima, which produces a sub-optimal solution (Liggett 2000).

2.4.1.2 Trajectory Methods

The two most commonly used trajectory methods for site optimization are Simulated Annealing and Tabu Search algorithms. Simulated annealing techniques have a significantly higher probability of converging on a good solution as compared to the improvement method. The reasoning behind this is that simulated annealing techniques allow activities to make an exchange even if the criterion value increases, thus decreasing the probability of getting trapped in local optima (Liggett 2000).Conversely, tabu searches incorporate a short term memory which prevents local optima entrapment. Yeh (1995) solved the site layout problem using an annealed neural network and Liang and Chao (2008) effectively placed TF using a tabu search algorithm.

2.4.1.3 Population Based Methods

Two distinct population based methods are found in the literature for generating an optimal site layout. The most common population based method is Genetic Algorithms (GAs), which are systems that allow survival of the fittest (e.g., survival of the optimal layout solution). Based on the theory of evolution, the weaker individuals (e.g., site layouts that have a high cost associated with material movement and long haul distances) within an environment (e.g., compute software) are over taken by the stronger individual (e.g., site layouts with low material movement cost and short travel distances), thus allowing the stronger individuals to prosper and reproduce. Over time, only the strongest survive and they become dominate (e.g., optimal site layout takes over) in their environment. Li and Love (1998) developed the first GAs for site-level layout based on this theory. Others researcher who have developed GAs for site optimization are Lam et al. (2009), Sanad et al. (2008), Elbeltagi et al. (2004), Osman et al. (2003), Mawdesley et al. (2002), Tam et al. (2002), Mahachi (2001), and Harmanani et al. (2000).

The second most popular technique is Swarm Intelligence (SI). This technique is a multi-agent system design based upon the social behavior of insects (e.g., ants, termites, bees, and wasp) and animals that group together (e.g., birds and fish) (Blum and Li 2008). Observations of these creatures have shown that they have a natural ability to find optimal paths; therefore, researchers have developed optimization algorithms that mimic this behavior (Kennedy and Eberhart 2001). Zang and Wang (2008) developed a particle swarm optimization (PSO) algorithm that could solve unequal-area layout planning problems. The PSO algorithm simulates the social behavior of birds flocking together. Lam et al. (2009) developed a hybrid system which incorporated both GAs and SI to solve the site layout planning problem.

2.5 Geospatial Site Utilization Planning

Over the past several years, several researchers have focused on developing modeling tools that can be used to design site layouts based on the geospatial relationship between activities. This method can be extremely effective due to the natural human ability of space conceptualization and space conflict identification. While no one platform has emerged that is ideal for developing dynamic site utilization plans, Building Information Modeling (BIM) and Geographical Information System (GIS) platforms can be used for site utilization planning. Each of the two platforms has the ability to create 4D simulations so that time variable planning can be performed. The key difference between the two platforms is that BIM focuses on detailed 3D geometry (e.g., buildings), while GIS focuses on geo-location of elements (e.g., city utilities, roads, etc.) (Liu 2012). Each platform has its own benefits in helping to solve the site layout problem. Some researchers have been able to integrate them together; however, to date, no tool exists that combines the two platforms seamlessly and efficiently (Bansal 2011).

Professionals in construction management have applied GIS to solve construction optimization problems such as 2D site layout planning (Cheng and O'Connor 1996), material site layout planning (Cheng and Yang 2001), and path planning of construction equipment (Varghese and O'Connor 1995). ArcSite, a GIS based system that integrates Database Management Systems (DBMS), was developed by Cheng and O'Connor (1996) to help solve the site layout problem. Based on knowledge acquired from site planning experts, the system models the decision making of humans and generates site layouts. A relationship objective function is then developed for each TF to determine if the layout is optimal.

Table 2.1: Algorithm Summary

Study	Algorithm	Objective
Yeh (1995)	ANN	Minimize layout cost
Li and Love (1998)	GA	Minimize travel distance
Cheng and O'Connor (1996)	GIS	Minimize travel distance
Harmanani et al. (2000)	GA	Minimize layout cost
Mahachi (2001)	GA	Minimize layout cost
Mawdesley et al. (2002)	GA	Minimize layout cost
Osman et al. (2003)	GA	Minimize layout cost
Elbeltagi et al. (2004)	GA	Minimize layout cost, Improve safety
Liang and Chao (2008)	TS	Minimize layout cost
Zhang and Wang (2008)	PSO	Minimize layout cost
Sanad et al. (2008)	GA	Minimize layout cost, Improve safety
Lam et al. (2009)	ACO, GA	Minimize transportation flow
Ning et al. (2011)	ACO	Minimize layout cost, Improve safety

Abbreviations:
ACO – Ant Colony Optimization
ANN – Annealed Neural Network
GA – Genetic Algorithm
GIS – Geographical Information System
PSO – Particles Swarm Optimization
TS – Tabu Search

2.6 Summary

It is clear that many factors affect the design of a robust CSUP capable of providing guidance in the optimal placement of TFs. From the research outline in this chapter, it is evident that a substantial amount of research has been conducted regarding CSUP development considerations, management issues, and optimization algorithms; however, there is a lack of published research on current CSUP best practices used by the construction industry and the methodologies followed for SUP development. Therefore, the objective of this research was to determine the current CSUP practices being used by the construction industry and develop a guideline for practitioners to reference when developing future SUP.

Chapter 3 : Data Collection and Analysis

3.1 Introduction

In the last two decades, the majority of researchers have focused on developing site layout optimization algorithms for minimizing travel cost and/or travel distance, with only a select few discussing the process of developing an effective site utilization plan. The design process of CSUP has not been discussed in great detail in research literature. The process aspects of CSUP includes:

1. Stakeholders: Who gets involved in the site utilization plan development process?
2. Information: What information is required to develop an effective site utilization plan? What are the sources of this information?
3. Timing: When does the development of the site utilization plan begin? When does the plan need to be completely developed?
4. Content: What information should be included in the site utilization plan?
5. Technology: Is software used to develop site utilization plans? If so, what software is used?

Since there is little to no information available in the literature pertaining to state-of-the-practice methods of CSUP, an Internet based electronic survey (e-survey) was conducted from October 2013 through December 2013 to collect relevant information.

The objectives of the survey were to:

1. Evaluate the current status of CSUP within the construction industry.
2. Identify design aspects of CSUP such as:
    - Personnel involved in the preparation of CSUP

    - Planning time frame
    - Elements affecting design
3. Determine implementation and monitoring methods.
4. Identify the current training and documentation practices.
5. Identify software used for CSUP.
6. Determine cost associated with CSUP.
7. Outline areas of improvement.

3.2 Survey Development

Several methods of survey circulation such as mail surveys, phone surveys, and electronic surveys were possible for this research project. After considering the advantages and disadvantages of each method, an electronic survey (e-survey) was chosen as the medium to launch the survey. An internet based survey is currently one of the most widely used methods for data collection. This method allows the survey to be launched in two ways: creating a website and providing the respondents with the website address (URL), where each response is stored within an online database and/or sending out the survey in the form of an email and asking the respondent to send their responses back as an attachment to the return email. For this research, the web-based survey software "Qualtrics" was used to create, launch, and collect the survey results.

Advantages of an online survey include:

1. *Geographical coverage*: online surveys offer wide geographical coverage, resulting in a wide range of respondents which correlates with high validity of results.
2. *Economical*: online surveys are a means of gathering a substantial amount of information at a minimum expense.

3. *Speed*: online surveys are the quickest method of gathering information. The responses can be received within minutes from the time of launch.
4. *Data Analysis*: web-based survey software allows for rapid data analysis. As the software gathers responses, percentages are calculated and displayed. The data can also be exported in digital format making additional analysis easier (Bailey 2007).

Disadvantages of an online survey include:

1. *Direct Responses*: online surveys do not give an opportunity for probing. If clarification is needed or a response is misleading, online surveys are unproductive.
2. *Respondent Control*: there is no guarantee that the intended respondent completes the survey.
3. *Fatigue*: numerous online surveys and questionnaires are constantly sent out to industry professionals and companies which may result in low priority responses (Bailey 2007).

3.2.1 Pilot Survey

Several in-person interviews were conducted to investigate the factors that affect CSUP. Six project managers/superintendents representing BL Harbert, Brasfield & Gorrie, Robins & Morton, and Turner Construction Company, each having more than 5 years in the area of CSUP, were asked a series of questions pertaining to the development and implementation of CSUP. The questions were general in that they queried each interviewee on the means and methods their company used for site utilization planning. The basic information sought was i) how are site utilization plans developed, ii) who is involved with plan development, and iii) what is indicated on the site plan. The interviewees mentioned a number of factors (e.g., locations of existing underground utilities, methods for insuring site plans are executed, jobsite access point considerations, etc.) that they consider important when developing a site utilization plan. These factors were taken into consideration as the online questionnaire survey was developed.

3.2.2 Best Practices of Site Utilization Planning Questionnaire Design

The survey consisted of 39 possible questions in eight categories: (1) *Respondent Information,* (2) *CSUP Usage*, (3) *Design Aspects*, (4) *Implementation and Monitoring*, (5) *Training and Documentation*, (6) *Software*, (7) *Cost Associated with CSUP*, and (8) *Best Practices*. A brief description of the information sought in each category is shown in Table 3.1.

Table 3.1: Summary of Survey Design

Category of Questions	Information Sought
Respondent Information	Job Title, Company Name, Business Category, Company Size (in terms of employees), Area of Operation, Years of experience in the construction industry, and Contact Information
CSUP within the Industry	Current status of CSUP within the construction industry
Design Aspects	Individuals involved with site planning, timing associated with site planning, temporary facility selection, route planning, sizing and locating temporary facilities, and site plan detail
Implementation and Monitoring	Site plan enforcement strategies, punitive actions for noncompliance, and site plan monitoring methods
Training and Documentation	Site planner training techniques and methods of documenting/storing information learned
Software	Software used during site planning and ways BIM is applied during construction
Cost Associated with CSUP	Temporary facility implementation cost and associated project cost
Best Practices	Open ended ideas that can improve the effectiveness of site utilization plans

The questions in the survey were formatted in three ways: i) multiple choice – single answer, ii) multiple choice – multiple answer, and iii) short written answer. The majority of questions were multiple choice. Only two questions were in the short answer category. Several multiple choice questions allowed respondents to check more than one answer if it applied; therefore, the sum of percentages may exceed 100%. Several of the multiple choice questions also allowed the respondent to answer “Other” and input a personal response in an answer box if the presented answers were not appropriate or sufficient. This method proved to be useful in that it allowed respondents to communicate their personal ideas and thoughts on a particular subject while answering the survey. For some multiple choice questions, skip logics were added so that follow-up questions pertaining to the same subject would be displayed based on the response of the preceding question. Because of this, some respondents were not asked all 39 questions. This method was used so that respondent response time could be minimized. The survey is in Appendix A.

3.3 Institutional Review of Survey

After the survey was developed, it was submitted to the Auburn University Institutional Review Board (IRB) for approval. The IRB#2 Chair declared the study not to be considered human subjects research and that a complete review of the survey was not required.

3.4 Distribution of Survey

To obtain a vast and diverse group of respondents, seven organizations associated with the construction industry (Construction Management Association of America (CMAA), American Society of Civil Engineers (ASCE), American General Contractors (AGC), Associated Builders and Contractors (ABC), Construction Industry Institute (CII), Construction Users Roundtable (CURT)) were contacted via phone and/or email in regards to circulating the survey to their members. Each organization was provided details about the research topic and the overall goal of conducting the survey. Additionally, the Auburn University Alumni Association (AUAA) was contacted to obtain contact information about Auburn Alumni working in the construction industry. AUAA provided the names and email addresses of 2,100 Auburn Building Construction Alumni, all of whom were invited via email to participate in the survey.

A directory of Certified Construction Managers (CCM) was found on the CMAA website which provided names, email addresses, employers, and geographical locations of all registered CCM. An email was sent to 1,921 CCM inviting them to participate in the survey. In total, 4021 emails were sent out inviting industry professionals to participate in the survey.

3.5 Survey Results

3.5.1 Respondents

Two hundred and forty one construction professionals from 154 companies, each having expertise in construction, engineering, and/or project management responded to the survey. The companies represented in this survey vary from large multi-national companies with over 100,000 employees to small, local construction companies. Table 3.2 shows the geographical distribution of company operations.

Table 3.2: Geographical Region of Operation

Location	Number of Responses
Southeastern US	107
Northeastern US	17
Western US	30
National	36
Global	37

These results represent more than 5,400 years of experience in construction. To show the diversity of the respondents, each respondent that provided job information was placed into a job category, and the average experience of each category was calculated. As shown in Table 3.3, the average experience of each category is quite significant in that only one category had an average construction experience of less than 15 years. Therefore, the results of the survey should provide valuable information that has taken several people many years to acquire.

Table 3.3: Survey Respondents by Job Title

Respondent Job Title	# 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

3.5.2 CSUP within the Construction Industry

Project planning is critical in order to deliver a construction project on time and within budget. Many practitioners and researchers have recognized CSUP as a critical step in construction planning, and if an effective and systematic approach to site planning is not used, extensive time losses and cost overruns may result (Elbeltagi 2008; Ning et al. 2011). Of all the survey respondents, 178 (74%) indicated that their companies develop site utilization plans for construction projects, while 63 (26%) respondent did not develop any type of construction site utilization plan. A follow up email was sent to the respondents that indicated they did not develop any type of site utilization plan asking them why they choose not to do so. Common responses were that space was not an issue on their projects or that their job was to represent the owner and oversee the project.

Of the 74% of respondents that develop site utilization plans, 106 (60%) stated that they create site utilization plans for every project; 39 (22%) only develop site utilization plans when site space is limited; and 33 (19%) indicated that project characteristics dictate site plan development.

3.5.3 Design Aspects of CSUP

Many aspects must be considered when designing the layout of a construction site. It is important to recognize that comprehensive site utilization plans cannot be developed before other planning task are completed. Conversely, some planning tasks (e.g., construction sequencing) are affected by the site layout (Mawdesley et al. 2002). In order to successfully develop a site utilization plan, one must know the following: Personal Involved with CSUP, Time Frame for Developing the Plan, and Factors Affecting the Layout. These factors are discussed in the following sections.

3.5.3.1 Personnel

3.5.3.1.1 Site Utilization Plan Developer

Typically, the project manager is responsible for developing the site utilization plan (Osman et al. 2003). This trend was observed in forty six percent (46%) of the respondents; while twenty nine (29%) of the respondents reported that the site superintendent is responsible for the development of the plan. Interestingly, only seventeen percent (17%) of the respondents reported that this process is a collaborative decision making process where the project manager, site superintendent and other management personal are involved, as shown in Figure 3.1.

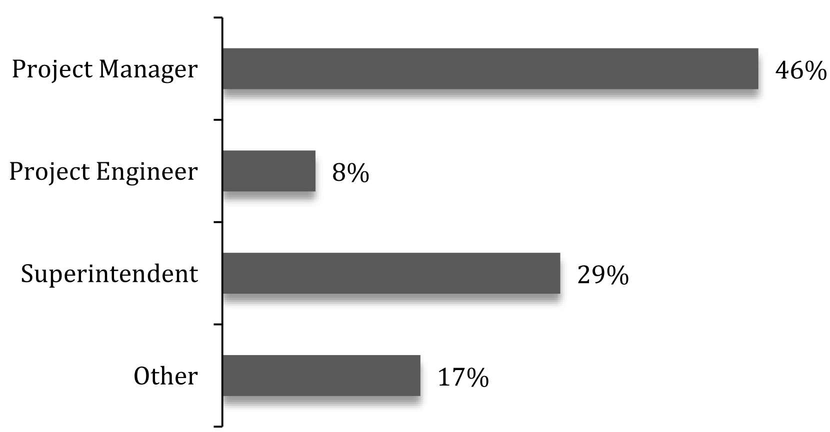


Figure 3.1: Typical Site Utilization Plan Developer

3.5.3.1.2 Subcontractors Information

Depending on project size and space availability, the number of subcontractors working on a project can be an important factor during the site utilization planning process. Sixty one percent (61%) of the respondents indicated that the number of subcontractors involved in a project does not influence the decision to develop a site utilization plan. This means that many construction companies focus on the overall scope of the project versus the number of people carrying out construction related task when deciding whether or not to develop a site utilization plan.

Before beginning the site utilization planning process, the planner must ask: 1) what temporary facilities will be needed during construction; 2) how much site space needs to be set aside for material storage; and 3) how much site space needs to be left open for material and equipment movement. To determine these parameters, planners typically rely on past experience and knowledge acquired during the years in the field (Osman et al. 2003; Elbeltagi 2008). Even with many years of experience, establishing early communication with each subcontractor and determining their material and equipment requirements can benefit the planning process. Involving subcontractors early in the planning process enables the planner to determine if the subcontractor's material and equipment will fit within their assigned area. If a subcontractor's allotted site area is not sufficient for the material and equipment which they plan to bring on site, special arrangements may need to be made prior to delivery or the quantity/size of the shipment can be altered so that site congestion can be avoided. Fifty one percent (51%) of the respondents said that they included subcontractors in the site planning phase, confirming that most companies see the value of early subcontractor involvement.

When determining which subcontractors should be involved in the site utilization planning process, the planner must consider the project type and specific requirements. Based on the survey responses, it was determined that the following subcontractors typically contribute information to the development of site utilization plan: structural (80%), foundation (72%), electrical (72%), plumbing (62%), and HVAC (54%). This is shown graphically in Figure 3.2. Respondents also noted that the civil/sitework contractor should be consulted to determine if site space will be needed for pipe storage, soil storage, or clearing and grubbing activities. It is important to consider this potential space as excavation, grading, and earth moving activities also require adequate space for safe equipment operations. 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 area when delineating site space.

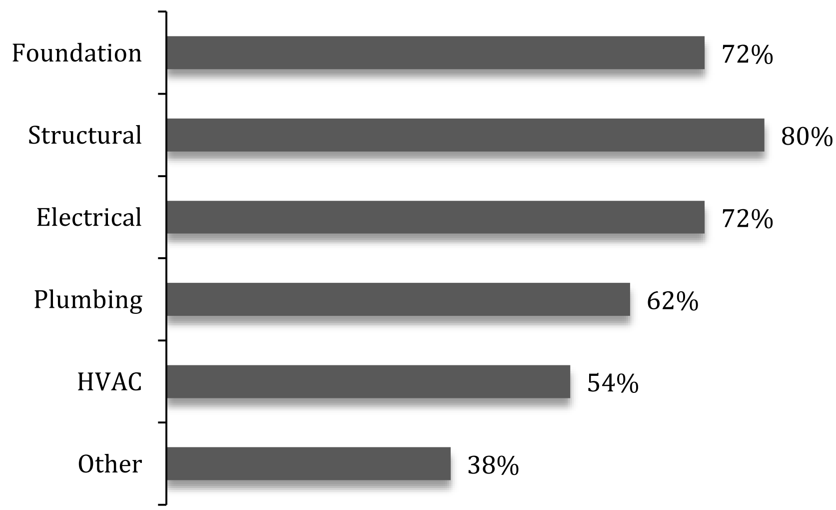


Figure 3.2: Subcontractors that Contribute Information

Before contacting subcontractors, a planner must know what to ask to obtain information needed to prepare an accurate site layout plan. Although there are a variety of questions a planner can ask a subcontractor, the most common questions asked by survey respondents were: i) what type of equipment will be on-site (80%); ii) how much on-site space is needed for storage (80%); iii) what tools sheds/job trailers will be on-site (78%); and iv) how many employees will be on-site (62%).

A minority of respondents reported that they do not seek subcontractor input, but instead dictate the work conditions to the subcontractors. It is important to utilize subcontractor input as much as possible, but it is not always possible to meet all subcontractor requests. To provide each subcontractor with sufficient site space, the planner should analyze all the information gathered and allocate site space based on each subcontractor's scope of work. Once construction is underway, space adjustments can be made as needed to compensate for the dynamic nature of the construction site.

3.5.3.1.3 Project Owner Information

Subcontractors are not the only project participants who can contribute helpful information in regards to the development of site utilization plans. Owners, including individuals and organizations (e.g., university, business, municipality), can provide information that can be critical to the success of a project. Seventy percent (70%) of the respondents indicated that project owners typically get involved in the development of site utilization plans. Communication between the project manager and owner/owner's representative needs to be established and maintained throughout the project lifecycle so that construction related events effecting the owner can be minimized.

The information an owner contributes can range immensely, depending on the scope of the project. In many cases, owner information needed to develop site utilization plans can be found within the contract documents. However, contract documents may not always contain the information needed to properly locate temporary facilities. Respondents indicated the following topics were important when consulting the owner about site utilization plan development: i) preferred ingress and egress points (89%), ii) existing site conditions (75%), iii) construction traffic routes (73%), and iv) environmental concerns (52%), as shown in Figure 3.3.

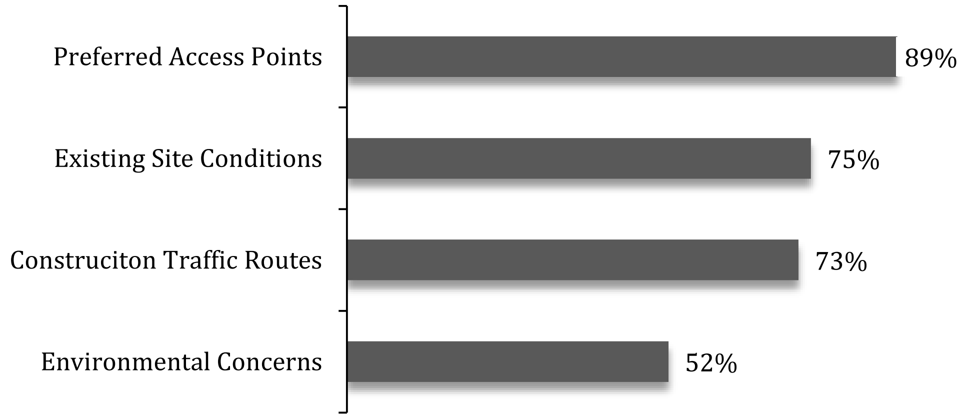


Figure 3.3: Project Owner Information

In addition to the above information, owners may also indicate space limitations, preferred pedestrian routes, restricted areas, construction personnel parking, and major utility locations. By determining these parameters early in a project's lifecycle, a planner can develop a site utilization plan that satisfies the needs of the subcontractors and the owner. To maintain a good relationship with the owner, the contractor should keep the owner informed about site utilization and operation plans throughout the course of the project.

3.5.3.2 Time Frame for Planning

Site utilization plans are as important as other planning tasks that have to be accomplished. Before moving on-site, detailed site plans need to be prepared showing the positions of all temporary facilities within the site boundaries (Elbeltagi 2008). Unfortunately, the greatest failure of contractors in the construction industry is the lack of preconstruction planning. However, preconstruction planning can provide significant benefits including project control and organization which leads to increased productivity, fewer accidents, and increased profitability (Plumbing-Heating-Cooling Contractors (PHCC) National Association 2002).

The majority of the respondents stated that site utilization planning begins in the pre-bid stage of a project, while the remaining respondents stated that site utilization planning begins after the project is awarded. There are advantages and disadvantages to each of these approaches. By starting the site plan development prior to bidding, the site utilization plan can be used in several ways. For instance, many respondents reported that the site utilization plan is used for project budget development and the proposal presentation. The negative impact of planning this early is that the capital investment in developing the site plan cannot be recouped if the project is awarded to another company. Conversely, preparing a site utilization plan after a project is awarded can also result in monetary losses when issues that would easily be identified on a site utilization plan were not accounted for in the bid proposal. In either case, it seems that most companies consider the development of a site utilization plan to be a part of the estimation process. This allows the company to establish a more accurate budget which increases their chance of winning the award while maximizing their profit margin.

Although the initiation of the site planning typically occurs either just before or after the bid, the conclusion of the site planning process can vary greatly. As shown in Figure 3.4, forty nine percent (49%) of respondents indicated that site utilization planning is a continuous process over the duration of a project while thirty eight percent (38%) indicated that site plans were completely developed prior to arriving on-site. Five percent (5%) said that site utilization plans are completed prior to arriving on-site and altered as the needs of site space change. The remaining respondents (8%) indicated that they finished developing the site utilization plan once on-site. Considering the dynamic nature of a construction site, it is clear that a fixed site plan established early in a project lifecycle will not work with site conditions through project maturity. Therefore, site utilization planning needs to be an ongoing process.

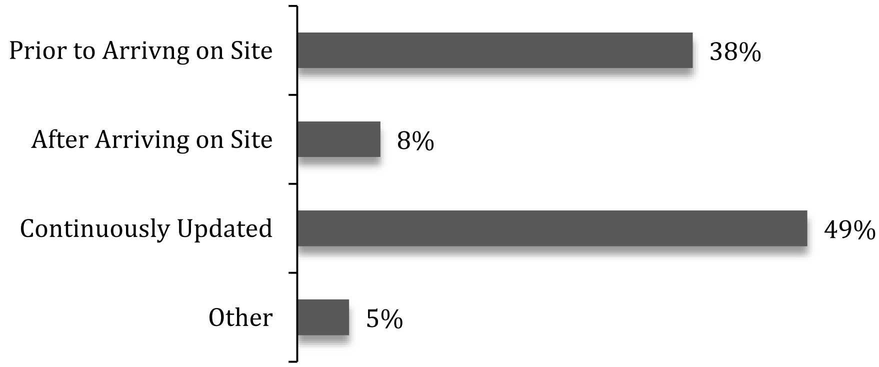


Figure 3.4: Time at which Site Utilization Plans are Fully Developed

3.5.3.3 Elements of Planning

Space management involves three primary elements: site layout planning, path planning, and space scheduling (Guo 2002). When beginning the site utilization planning process, the site layout planning team must determine the basic site space requirements based on the project scope, schedule, and construction method. The following sections provide insight into these factors based on participant responses.

3.5.3.3.1Temporary Facilities

Temporary facilities play an important role in supporting construction activities over a projects duration. The planner must understand the characteristics of each temporary facility before planning the site layout, as unsystematically placed temporary facilities can significantly affect productivity (Elbeltagi 2008). Many types of temporary facilities varying in shape, size, and functionality can exist on a construction site. A generic list of 17 temporary construction site facilities was developed based on past research and in-person interviews. The respondents were asked to identify the temporary facilities they considered when developing site utilization plans. As shown in Figure 3.5, facilities that were included in site utilization plans by more than 75% of the respondents were: parking lot location, job trailer location, job-site access point, staging area, building footprint, on-site storage, and dumpster location.

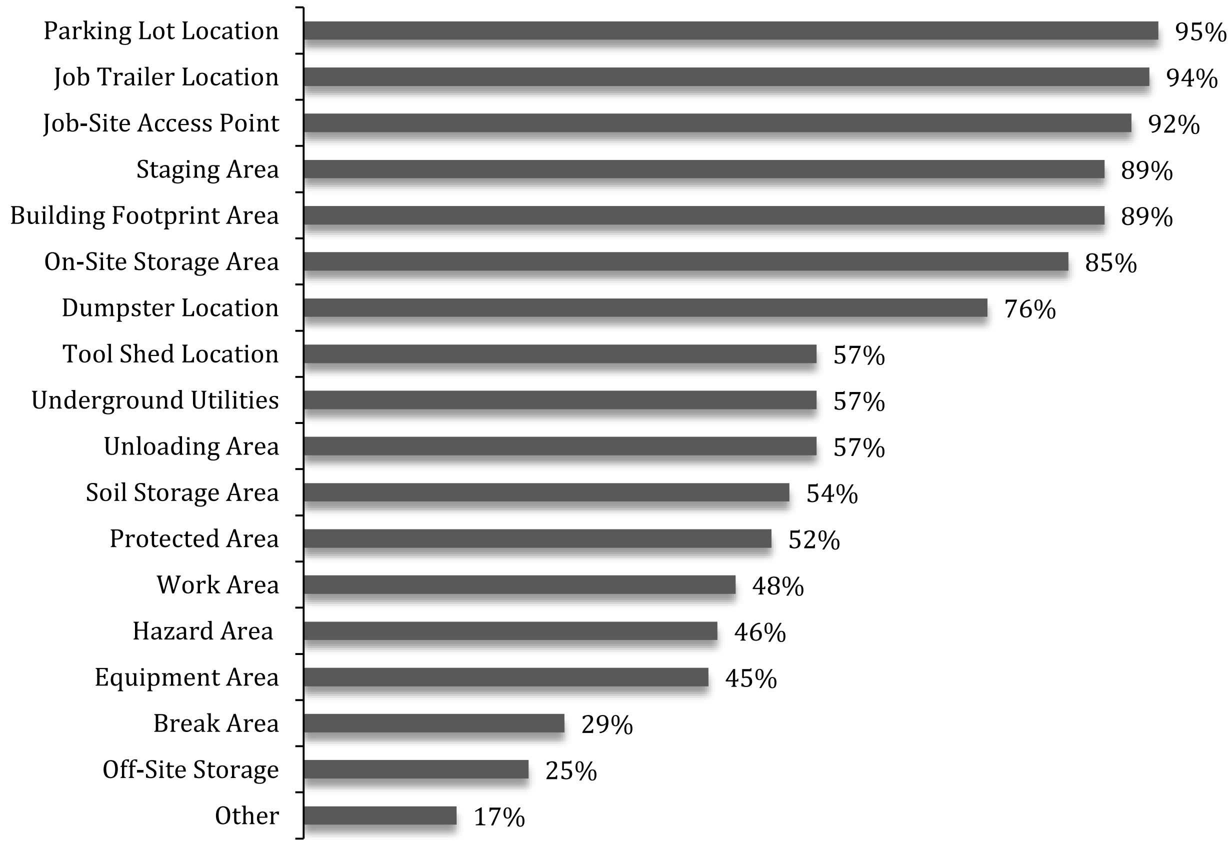


Figure 3.5: Typical Temporary Facilities Included in Site Utilization Plans

In addition to the temporary facilities shown in Figure 3.5, several respondents pointed out additional temporary facilities that are often included on site utilization plans. These additional temporary facilities are: crane locations and radii , concrete washout stations, emergency access points, first aid stations, construction fencing locations, toilet facilities, existing buildings, best management practices, and above ground utilities. Many respondents also indicated that most of the temporary facilities listed in the survey where applicable to site utilization planning but not always used. Thus, one could argue that the temporary facilities required for construction are based on project type, project location, and schedule complexity. To decide which temporary facilities to utilize on a project, the construction management team needs to take the project's unique characteristics into consideration.

3.5.3.3.2 Site Route Planning

Site route planning is a process for determining the shortest, collision-free path within the construction boundary for construction equipment and operations. Equipment and material flows can have a significant effect on the efficiency of construction operations (Kim and Kim 2010). Any interruption to normal equipment/material flows can result in serious degradation of performance and labor productivity (Thomas et al. 2002). Typical applications of route planning on construction sites include large vehicles routing, heavy-lift operations, and cut/fill operations (Guo 2002).

The respondents were asked to identify which movement planning operations are typically considered during site plan development. An overwhelming majority indicated that the two main movement operations to consider during site planning were material movement (95%) and equipment movement (89%). Sixty four percent (64%) of the respondent indicated that they also considered on-site personnel movement during the planning phase, as shown in Figure 3.6.

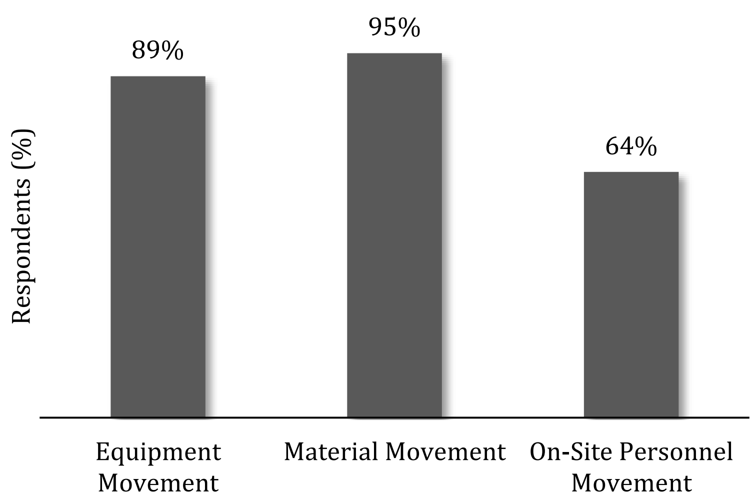


Figure 3.6: Construction Site Route Planning

Based on these responses, it is apparent that most respondents understand the impacts that can arise from neglecting movement planning. Most likely these elements of the site plan are considered separately based upon project specific characteristics when developing site utilization plans.

3.5.3.3.3 Space Priority and Temporary Facility Locating

Once the temporary facilities required for a project are selected, the construction team must determining the geographical space requirements for the temporary facilities, as well as their locations within the construction boundary. This part of the planning process is intended to decrease congested work areas that can result from stacking trades, mismanagement of material deliveries and storage, and poor waste management on site (Thomas et al. 2006). When asked about site space priority, seventy seven percent (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 of resources, availability of site space, and cost considerations (Elbeltagi 2008). The respondents indicated that the structural contractor (61%) is the most frequent subcontractor/trade that falls within the space priority group, as shown in Figure 3.7.

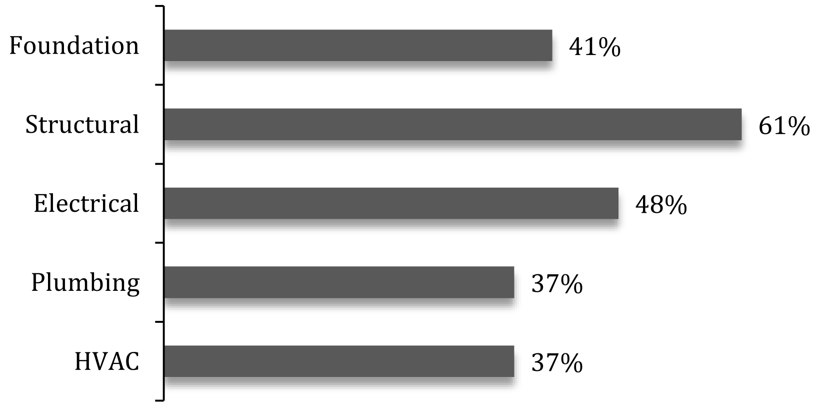


Figure 3.7: On-Site Space Priority Group

It is imperative to realize that even though the subcontractors/trades listed in Figure 3.7 are recognized as priority groups over the course of a project, the on-site space priority can vary between subcontractors/trades over time. For instance, the foundation and structural subcontractors may get space priority early on 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. Many respondents pointed out that space priority is a function of critical path activities and that any subcontractors/trades preforming critical tasks will most likely receive priority for on-site space, as indicated in Figure 3.8. Thus, it could be debated that the subcontractor/trade space priority assessment is directly related to the project's schedule, which in turn dictates the critical activities.

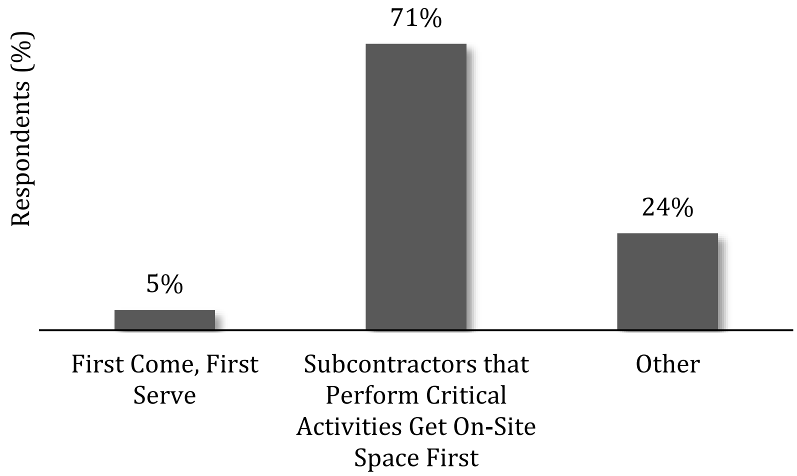


Figure 3.8: Methods for Allocating Priority Space

The physical characteristics of each temporary facility should be well understood before selecting its location on-site. The positioning of on-site temporary facilities is directly linked to the site conditions and special relationships between construction activities, equipment, and material. In some situations, local by-laws, such as required emergency access routes, may be a controlling factor during the locating process (Elbeltagi 2008). Project owners can also influence the location of temporary facilities 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 temporary facilities within the construction site boundary. Eight nine percent (89%) of the respondents indicated that they developed site utilization plans primarily based on past experience obtained from previous projects, as shown in Figure 3.9.

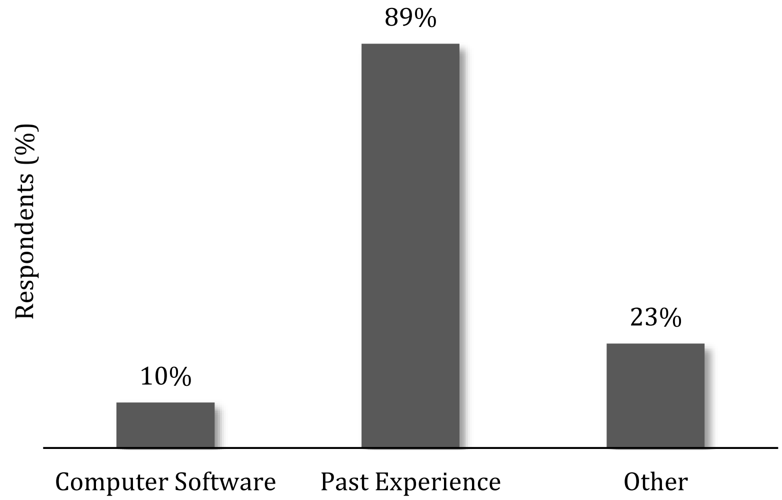


Figure 3.9: Methods for Locating On-Site Temporary Facilities

While some respondents (23%) stated that site conditions, contract documents, and utilities influence the locations of temporary facilities, the main method used for locating temporary facilities was experience. As shown above, only 10% of respondents used computer software for site utilization planning. The lack of site utilization planning software usage within the construction industry suggests that either a software capable of making complex decisions based on project specific constraints is not readily available to the industry or the software(s) available do not currently meet construction industry standards for site planning. None the less, the main focus of several past research efforts has been to develop site utilization planning software systems that make complex decision based on many constraints (Chau and Anson 2002, Mawdesley et al. 2002, Ning et al. 2011, Osman et al. 2003). The construction industry is historically slow to adopt new technologies (McGraw-Hill Construction 2012). However, as younger professionals emerge within the construction industry, software system implementation will most likely increase.

3.5.3.3.4 Planning Detail

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 broken down into phases (e.g., site, structural, MEP, etc.). This also holds true for site utilization plans. Seventy one percent (71%) of the respondents create multiple site utilization plans 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, sixty nine percent (69%) of the respondents develop site utilization plans 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 project life cycle. While construction drawings are usually very detailed, site utilization plans are typically the opposite. Seventy two present (72%) of the respondents specified that a medium level of detail is incorporated into most site plans with only essential temporary facilities and storage locations shown on the plans, as Figure 3.10 indicates.

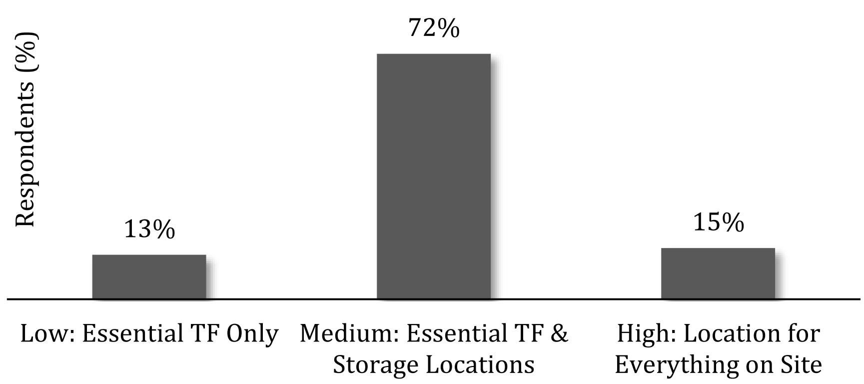


Figure 3.10: Site Utilization Planning Detail

The time it takes to develop a site utilization plan is a function of the project scope and complexity. The majority of respondents indicated that time allocated to developing site utilization plans for most projects falls between eight and forty hours, as shown in Figure 3.11.

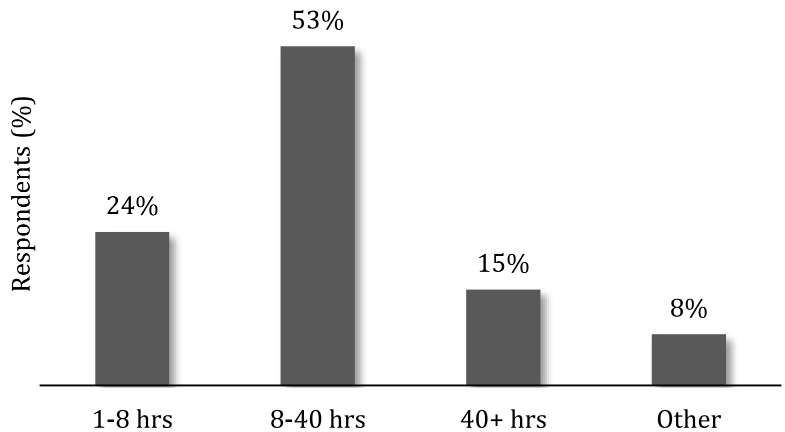


Figure 3.11: Site Utilization Planning Time Investment

Intuitively, people want to know how long it takes to complete a certain task. This applies to many aspects of construction. Knowing the typical amount of time spent on site utilization plan development is important during project cost estimation. A project planner's time is valuable and should be effectively utilized. Understanding that a typical site utilization plan takes between eight and forty hours to develop, project estimators can quantify the additional cost associated with site plan development.

3.5.4 Implementation and Monitoring

A well-developed site utilization plan 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 can occur. In order to properly implement a site utilization plan, 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 locations of temporary facilities and/or displaying the site utilization plan on an information board that can be viewed by all. Site utilization plans can also be distributed to all stakeholders via the internet. Signage and/or posted site utilization plans should be updated over the course of the project and verbal announcements of updates 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 the punitive actions for non-compliance. When asked about punitive actions imposed on subcontractors for non-compliances, ninety five percent (95%) of the respondents indicated that actions would be taken to sway the subcontractors to follow the site utilization plan. Common punitive actions identified were verbal warnings, written warnings, monetary penalties, and disposal of incorrectly stored items, as shown in Figure 3.12.

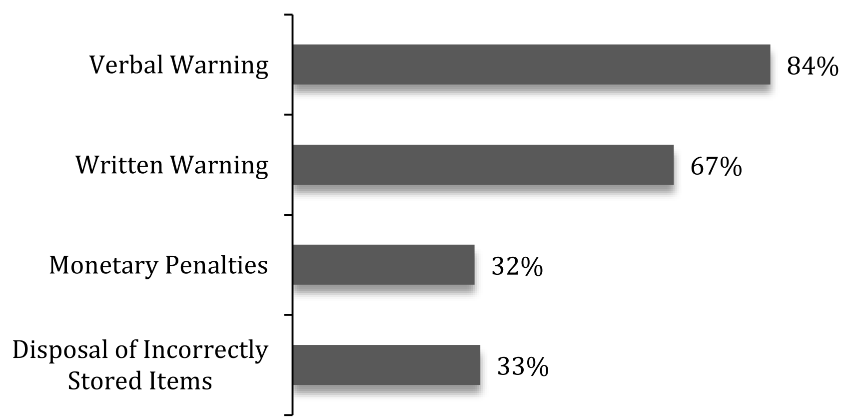


Figure 3.12: Common Non-Compliance Actions

Respondents also pointed out 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 on why site utilization plans are used and their effect on construction operations is usually the only action needed to adjust subcontractor behavior. If discussions and punitive actions do not correct the non-compliance issues, additional actions must be taken to keep the project on schedule. In extreme cases of repeated non-compliance, removal of insubordinate subcontractor staff or subcontractor termination may result.

Monitoring and managing implemented site utilization plans usually falls under the responsibility of the site superintendent. Site superintendents run the 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 on their jobsite. 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 the respondents were asked about methods for monitoring site plan efficiency, only fifteen percent (15%) indicated they used a method to monitor efficiency. Figure 3.13 shows the common methods for monitoring site utilization plans as identified by the fifteen percent of respondents. The respondents who utilized a method to monitor site plan efficiency indicated they used flow of construction activities in their monitoring, which had a 100% response rate.

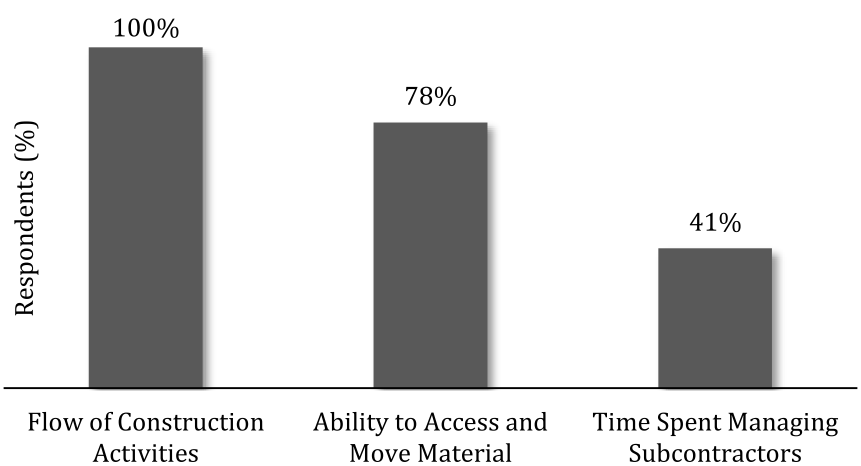


Figure 3.13: Metrics for Monitoring the Effectiveness of Site Utilization Plans

The effectiveness of site utilization plans can be monitored in many ways. For example, on vertical construction, the number of crane picks and buck hoist loads 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 if the site utilization plan is working properly by monitoring installed work and/or work 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 the authority to make decisions on site operations and space allocation. Caution should be taken not to over control the actions of the superintendents, making them paralyzed and unable to make decisions.

3.5.5 Training and Documenting

One of the key elements associated with developing an effective site utilization plan 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 are typically from a younger generation and have little to no experience developing site utilization plans. When asked about site utilization plan development training, only forty (22%) respondent companies provided training in this area. This lack of training offered by companies may be explained by a lack of effective methods to teach the skills needed to design site utilization plans. Some teaching methods used by companies were in-house training, on the job training, or a combination of the two, as shown in Figure 3.14.

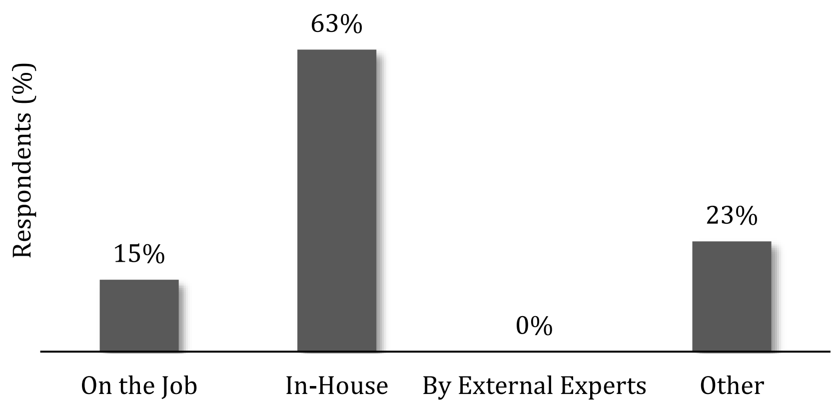


Figure 3.14: Site Utilization Planning Training Techniques

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 site utilization planning capable of formally teaching others. The need for individuals that are capable of effectively teaching site planning techniques 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 on the project. These documents are ideal sources of information that can help less experienced employees learn about site utilization planning and strategies used to overcome problems encountered during construction. Fifty eight percent (58%) of the respondents stated that they document knowledge acquired on site utilization planning over the course of a project. Documenting this information and making it available to all management personnel is one method of distributing knowledge to prevent similar mistakes on future projects. As shown in Figure 3.15, forty seven percent (47%) of the respondents store documentation in a company database accessible by management personnel throughout their organization.

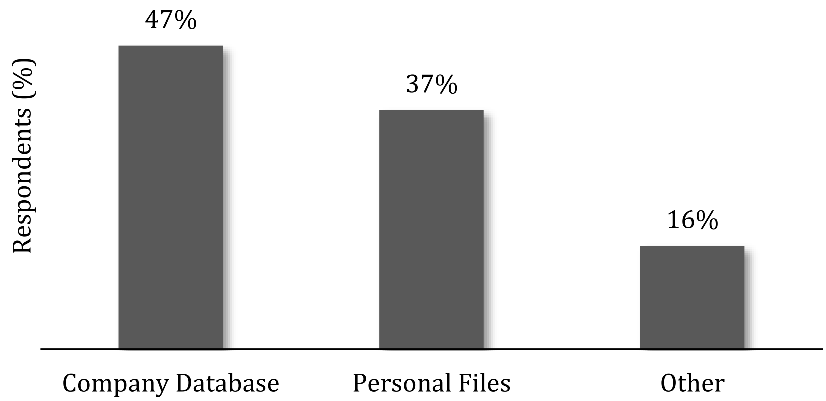


Figure 3.15: Methods for Documenting Acquired Knowledge

By storing information systematically within an online database, employees are able to quickly locate information and determine if their current situation has occurred on past projects. If similar documented situations are found, the information may provide guidance on how to handle the current problem or author contact information may be listed to enable collaboration and assistance in solving the current problem.

3.5.6 Software

Technology plays a big role in the construction industry as it provides a communication tool that enhances the delivery and exchange of information among different parties involved in a construction project. Unfortunately, a software system specifically designed to create site utilization plans has yet to emerge within the construction industry. When asked about software systems, sixty nine percent (69%) of the respondents indicated that a software system was used to create site utilization plans. The common software systems identified were PDF Overlay, BIM, and CAD, as shown in Figure 3.16. Additional site planning systems identified were Google SketchUp, On Screen Takeoff, Visio, and Bluebeam.

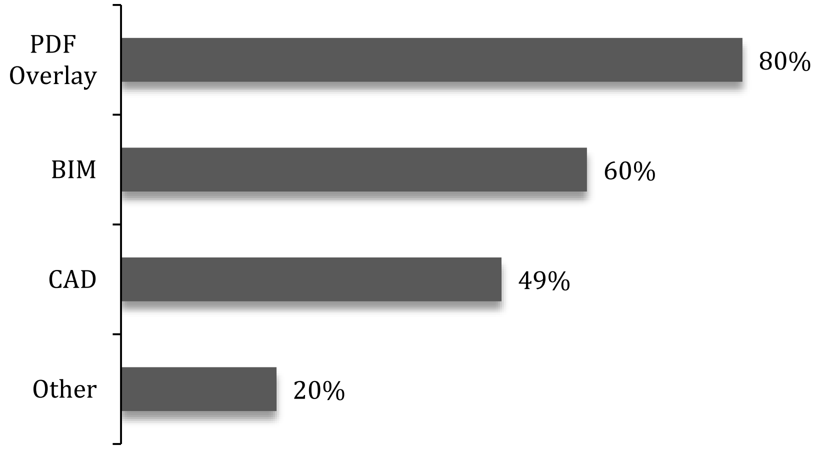


Figure 3.16: Software Used for Site Utilization Planning

It is apparent that PDF Overlay is the predominant method for creating site utilization plans. When comparing PDF Overlay to BIM and CAD, PDF Overlay is substantially easier to operate. BIM and CAD systems were initially developed for the architecture and engineering (A/E) industry and require the user to be well versed with the software. It typically takes several months of continuous use for someone to become proficient in BIM and CAD, while users of PDF Overlay can become competent in a few days. Another reason PDF Overlay is predominately used is that BIM and CAD systems are significantly more expensive than PDF Overlay and require more computing power and storage. However, 3D site utilization plans provide significant benefits. As these benefits become more apparent within the industry, fewer construction planners will use PDF Overlay.

BIM is becoming one of the most beneficial tools within the construction industry due to the wide range of capabilities it offers each stakeholder. Seventy one percent (71%) of the respondents said that their company had implemented BIM on recent construction projects for clash detection, communication, schedule visualization, site utilization planning, and/or documenting claims and change orders, as shown in Figure 3.17.

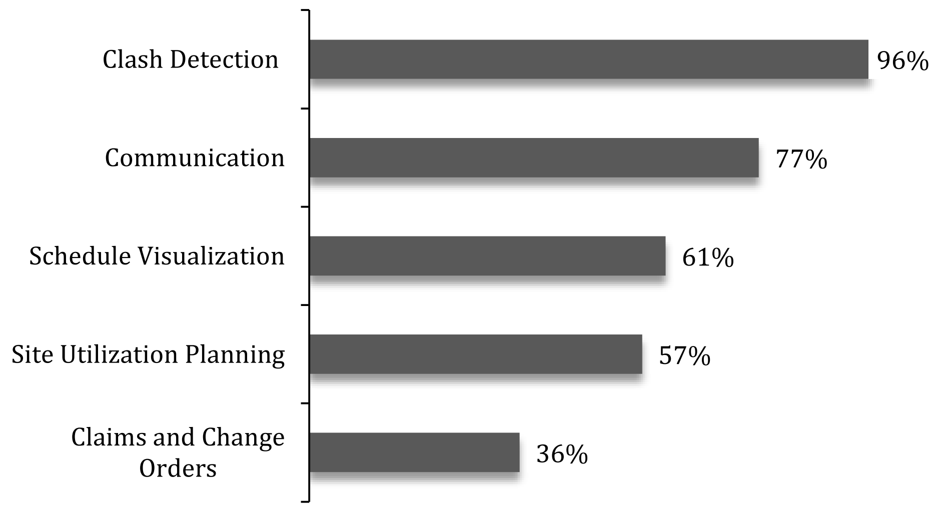


Figure 3.17: BIM Implementation within the Construction Industry

The primary benefit BIM offers the construction industry is the capability of determining clashes between objects. This can significantly reduce a project's budget by avoiding costly change orders. Currently, BIM is not significantly used for site utilization planning because current software systems offer very limited tools for modeling site operations. However, BIM technology for site utilization planning will likely see advances as the industry continues to demand time and cost savings without sacrificing development simplicity.

3.5.7 Cost Associated With Site Utilization Plans

Past research has acknowledged travel costs between temporary facilities as a major factor in determining the efficiency of a particular site layout. However, the indirect cost associated with establishing and eliminating temporary facilities has yet to be documented. Although this cost can vary greatly depending on the project scope and size, an average cost associated with temporary facilities needs to be established to provide inexperienced site planners with a perspective on the capital invested in temporary facilities. For this reason, the respondents were asked what percentage of the total project cost is allocated to temporary facilities. The majority of the respondents (56%) indicated that between 0% and 2% of the total project cost is allocated to temporary facilities, as shown in Figure 3.18.

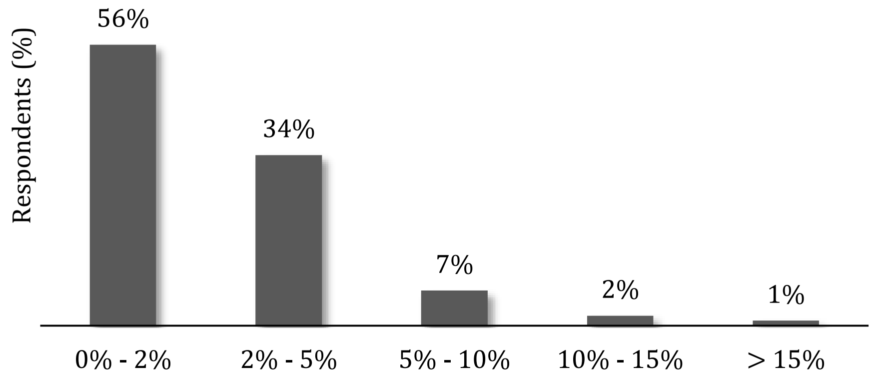


Figure 3.18: Percent of Total Project Cost Allocated to Temporary Facilities

Costs associated with temporary facilities can become significant on multi-million dollar project. 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 they also need the ability to estimate the implementation cost of their site plan. Seventy percent (70%) of the respondents stated that the monetary size of a project does not influence the decision to develop site utilization plans.

3.5.8 Best Practices

To provide the respondents with an opportunity to openly make suggestions for improving site utilization planning, a question was included in the survey that simply asked the respondents to identify three things that could be done to improve the effectiveness of a site utilization plan. Many recommendations were provided on ways to improve the site utilization planning process. Recommendations that were listed frequently by the respondents are outlined below.

1. Early Planning: The site utilization planning process should begin early in the project lifecycle, typically during project estimating.
2. Site Investigations: An in-person investigation of the site should be conducted to gain knowledge on existing conditions. Planners should not rely solely on Google® Earth imagery when planning the site layout as realistic site conditions and topography can vary considerably. Areas surrounding the site should also be investigated and documented in case of future litigation issues concerning property damage.
3. Stakeholder Involvement: All parties (e.g., owner, subcontractors, management, etc.) associated with the project should be involved during site plan development. Each party should be afforded the opportunity to provide input on site logistics and provide feedback on the finalized layout. It is critical to have buy-in from each party to ensure the plan works effectively over the course of the project. The site plan should also be thoroughly reviewed by senior management team members before implementation to validate the plan's feasibility.
4. Safety Planning: When developing the site utilization plan, all safety requirements enforced by OSHA and local government agencies need to be planned and properly implemented.
5. Plan Development Practices: During plan development, consider local weather patterns as some areas may experience frequent rain events or extremely hot/cold temperatures. Display Best Management Practices on the site plan so they can be avoided during space delineation, lessening the chance of damage. Temporary facility installation and removal methods also need to be considered during development to ensure decommissioning procedures flow smoothly. Finally, the General Contractor's (GC) job trailer location

should be placed in an area that allows a clear view to subcontractors and materials at all times. This allows the GC to quickly identify and correct inconsistencies that may occur on-site.

6. Communication: At the beginning of a project, an effective method for communicating between all stakeholders should be established and maintained until project completion. The site utilization plan should be distributed to all stakeholders so that everyone understands selected area allocation. Displaying easily seen large scale site utilization plans near the site entrance and defining areas within the site using signage can support the site plan information exchange process.
7. Implementation & Enforcement: Site utilization plans should be implemented at the start of a construction project so that everyone becomes accustom to working within their assigned space. The plan needs to be continuously enforced until project completion. If insubordination occurs, corrective actions should be taken.
8. Updating & Modifying: Over the course of a project, site utilization plan updates and modifications should be made on a regular basis to accommodate changing site conditions. Site plans need to be revised as needed for each phase of construction but certainly do not need to be abandoned. If unexpected scenarios arise during construction, make modifications to correct the issues.
9. Monitoring: The site utilization plan needs to be monitored on a day-to-day basis. Everyone involved with construction should be held accountable for housekeeping practices in their assigned area.
10. Flexibility: Remain flexible throughout the project on site space allocation and be able to adapt to unexpected circumstances.

These recommendations represent many site planning lessons learned within the construction industry.

3.6 Summary

The findings reported here are from a comprehensive survey of construction industry professionals from around the world. This survey queried individuals on CSUP practice within the industry, design aspects of site planning, implementation and monitoring practices, training and documentation methods, site planning software, implementation cost, and areas within the site utilization process that needed to be improved. A summary of the results from this survey is in Appendix B.

Roughly three fourths of the respondents develop site utilization plans for their project. Many key aspects of site planning, overlooked in published literature, were identified through the survey. These aspects include: 1) base the site plan development decision on the project scope, as some project may not require site utilization plans; 2) start the site planning process early, preferably during the pre-bid phase and have the initial site plan completed prior to arriving on site; 3) involve all stakeholders during the site planning process and allow each the opportunity to contribute information towards the plan and review the developed plan prior to implementation; 4) priority site space should be assigned to subcontractors/trades that perform tasks that fall on the critical path; 5) site planning detail is a function of project control requirements, more detail is associated with increased project control; 6) implement, enforce, and monitor the site plan from the initial day construction starts, execute punitive actions if non-compliances occur; 7) document lessons learned on each project and distribute the knowledge within the organization, as to reduce the risk of reoccurrence; and 8) utilize architecture and structural BIM models when developing site utilization plans.

Using these findings, the formation of a standard process for site plan development was initiated and site planning best practices established. The following chapter describes the best practices of site planning and outlines the procedure of site utilization planning

Chapter 4 : CSUP Procedure and Best-Practices

4.1 Introduction

The primary goals of this research were to: 1) identify the best practices associated with the construction site planning process; and 2) develop a comprehensive procedure that can provide guidance during the site utilization plan development phase of a construction project. The first step in identifying the 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 site utilization plans was created.

To date, no research supported site planning process exists that outlines the current methods used by the construction industry for site utilization planning. The site utilization planning procedure presented in this chapter is based on data collected through a questionnaire survey, interviews, and site visits. The procedure identifies important aspects that need to be considered during the site planning phase of construction. The procedure was developed to serve as a reference document that can be used to create individualized site planning strategies. This will allow companies to customize the process to suit their individual needs. The following sections outline the best practices within the industry and the site planning procedure.

4.2 Best Practices of CSUP

The Best Practices presented in this section are general and applicable to construction site utilization planning (CSUP). The thirteen Best Practices identified from the survey are:

1. Conduct an in-person investigation of the site prior to Site Utilization Plan (SUP) development.
2. Start SUP development as early as possible.
3. Involve stakeholders (e.g., owner, subcontractor, project manager, superintendent, 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 all subcontractors at the site.
8. Implement and enforce the SUP from day one of construction.
9. Monitor the 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. Utilize BIM technology for SUP development if available.

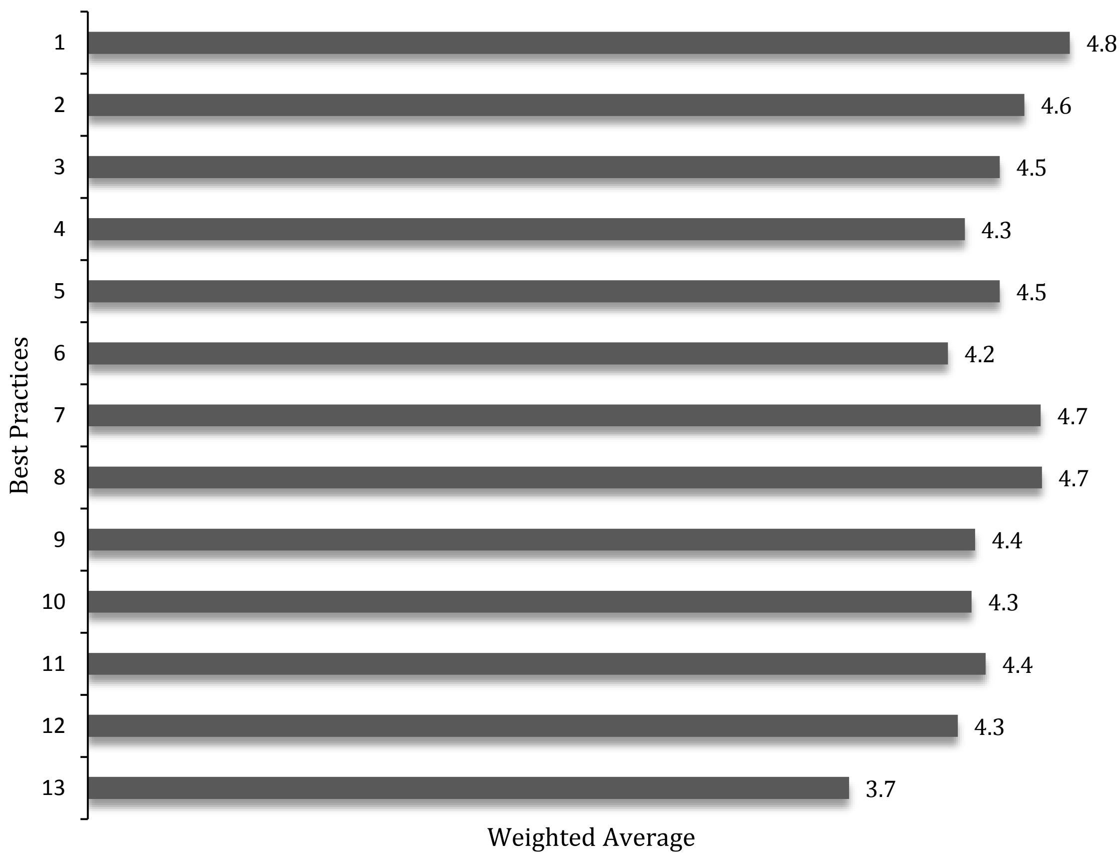
To provide validation for the best practices identified, a second survey was sent out in February 2014. This survey is available in Appendix C. The survey was sent to respondents that indicated they did not mind follow-up questions. The survey asked the respondents to indicate their opinion on each best practice in the form of strongly agree, agree, neutral, disagree, or strongly disagree.

In order to determine a weighted average opinion for each best practice, weight factors were applied. The weights of each opinion are shown in Table 4.1.

Table 4.1: Weight Factors

Respondent Opinion	Weight
Strongly Agree	5
Agree	4
Neutral	3
Disagree	2
Strongly Disagree	1

One hundred and thirty three emails were sent to respondents asking them to provide their opinion on each best practice. The survey was open for approximately three weeks. Within this time, 58 responses were received. The results of the survey are in Appendix D and the weighted average opinions are shown in Figure 4.1.



The individual responses are shown in Appendix E.

Figure 4.1: Best Practice Weighted Opinions

The majority of the best practices had a weighted average above 4.0. This indicates that most respondents agreed or strongly agreed with the practices. Only one best practices had a weighted average below 4.0. This best practice indicated that BIM technology should be utilized for SUP development if available. The primary reason behind this practice not being strongly supported is that many construction professionals have yet to recognize all the capabilities of BIM modeling. Seventy six percent (76%) of the respondents had more than 15 years' experience within the construction industry. Typically, professionals with this many years' experience rely on traditional 2-D drawings and are reluctant to change; however, this will more than likely change as construction technology improves and young professionals emerge within the industry.

4.3 Procedure for Site Utilization Planning

Based upon the evaluation of published literature, in-person interviews with industry professionals, and the best practices identified from the survey; a comprehensive procedure for site utilization planning was developed. The procedure contains eight steps. Each step outlines important aspects that need to be considered during site plan development. The procedure was developed in a manner that allows easy modification. This allows individual preferences to be incorporated into the procedure. The basic purpose of the procedure is to provide inexperienced site planners with a generic guideline on site plan development and management. The procedure is outlined below.

Construction Site Utilization Planning Procedure

Step One: Pre-planning

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

Step Two: Determine if Site Utilization Plan Development is Necessary

a. 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	

The development of the 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 Three: Data Collection for Site Utilization Plan Development

- 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 Areas	

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

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

- It is very important to distinguish between "Wants" and "Needs" of subcontractors.

Step Four: Site Utilization Plan Development

- Decide what information should be included in the plan based on project requirements.
- Determine if 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	☐ Drainage Areas
☐ Parking Lots	☐ Buried / Overhead Utilities
☐ Protected Areas	☐ Fire Hydrants
☐ Roadways, Sidewalks	☐ Existing Facilities/Buildings
☐ Best Management Practices for Erosion and Sediment Control	☐ Undisturbed Areas
	☐ LEED Requirements

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

☐ Worker Parking Locations	☐ Crane Locations and Swing Radii
☐ Job Trailer Locations	☐ Buck Hoist Locations
☐ Job Site Access Points	☐ Concrete Washout Stations
☐ Tool Shed Locations	☐ Emergency Access Points
☐ Dumpster Locations	☐ First Aid Stations
☐ Building Footprint	☐ Construction Fencing/Gates
☐ On-Site Storage	☐ Off-Site Storage
☐ Toilet Facilities	☐ Break Area/Shelters
☐ Utilities	☐ Equipment Areas
☐ Unloading Areas	☐ Staging Areas
☐ Soil Storage Areas	☐ Work Areas
☐ Informative Signage	☐ 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

> The level of detail identified on a Site Layout Plan will depend on the operational control requirements. It is important to keep the plan flexible in order to cope with the uncertainties associated with the construction process.

- Utilize 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 Five: Communicate

- Allow all stakeholders to review and provide feedback on 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 the subcontractors.

Step Six: Implement and Enforce

- Distribute the finalized site plan to all stakeholders. Effective methods for informing subcontractors and workers on space allocation are: 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 movement of material and equipment.

Step Seven: Monitor and Evaluate

- The site superintendent should monitor and evaluate the plan on a day-to-day basis.
- If the plan works properly, continue using it. If problems arises determine if the problems are related to noncompliant subcontractors or unforeseen conditions.
- If non-compliant 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	□ Subcontractors Back-Charges
□ Written Warnings	□ Removal of Insubordinate Staff
□ Monetary Penalties	□ Contract Termination

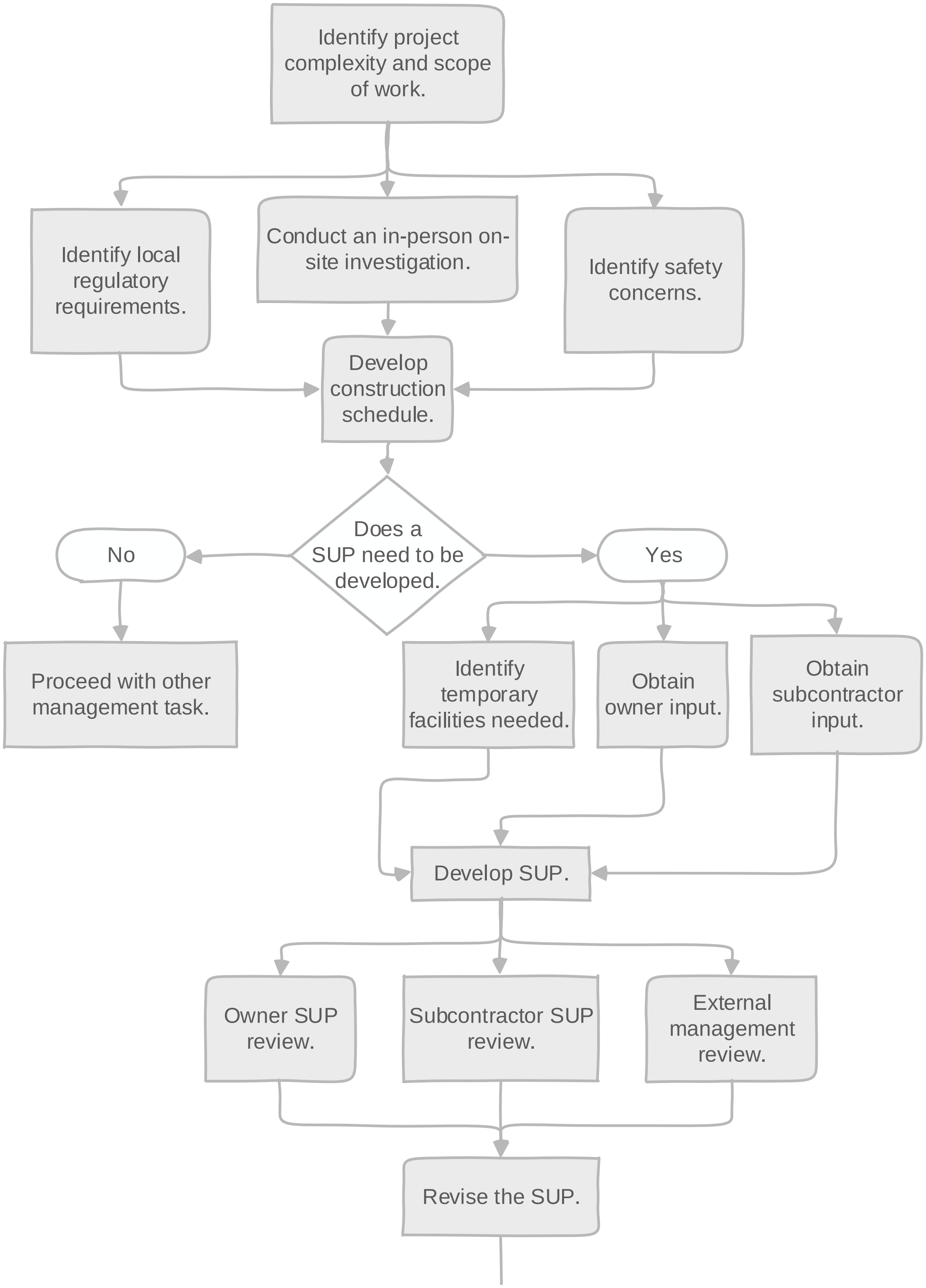
- If unforeseen conditions are an issue, revise the plan and correct the issues.
- Update the plan on a regular basis, communicating the updates to all stakeholders.

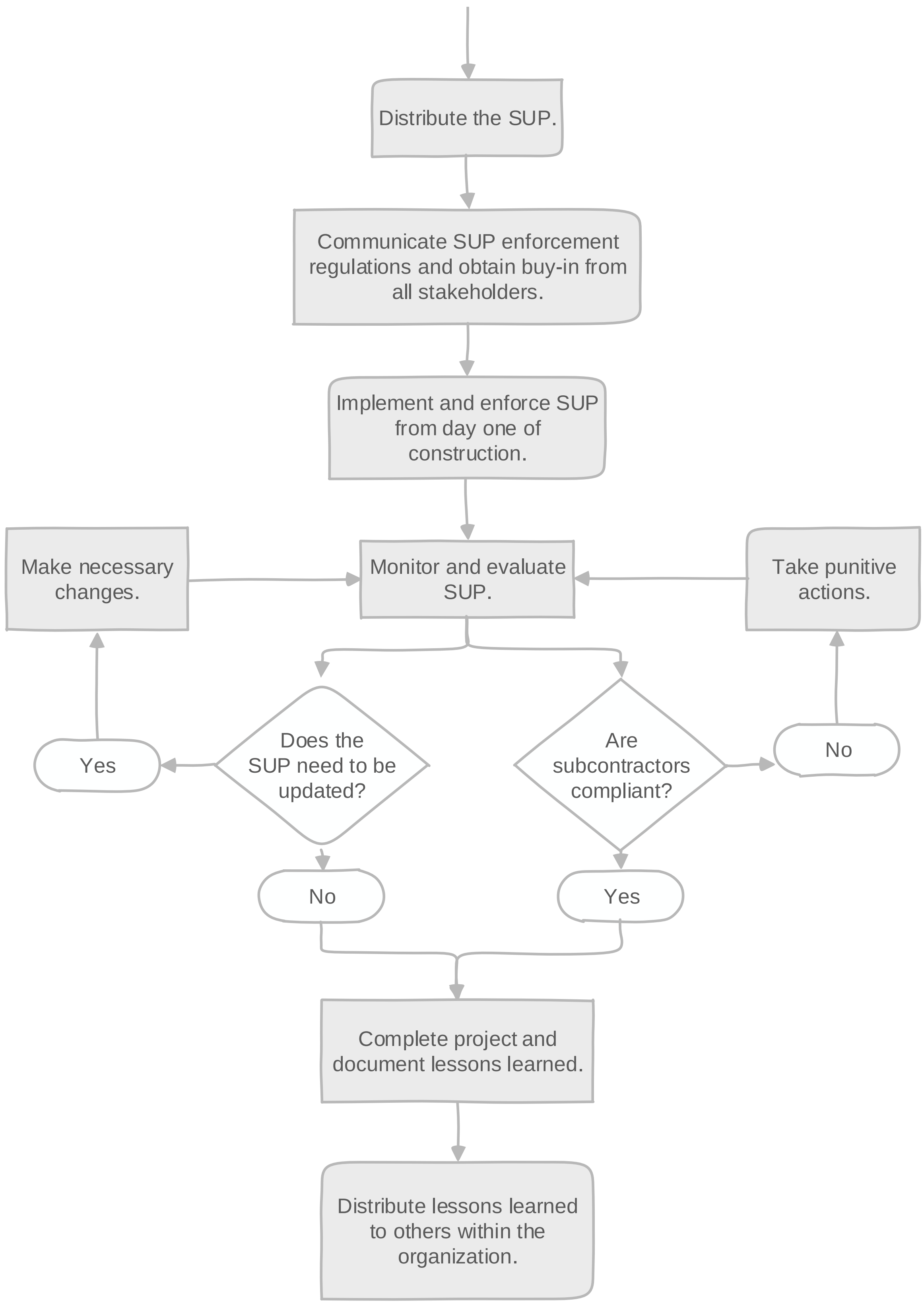
Step Eight: Document Lessons Learned

- 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 access on-line by all management staff.

A flow chart is provided below that outline the site utilization planning process.

CSUP Process Flow Chart




Distribute the SUP.
Communicate SUP enforcement regulations and obtain buy-in from all stakeholders.
Implement and enforce SUP from day one of construction.
Make necessary changes.
Monitor and evaluate SUP.
Take punitive actions.
Yes
Does the SUP need to be updated?
Are subcontractors compliant?
No
No
Yes
Complete project and document lessons learned.
Distribute lessons learned to others within the organization.

4.3.1 Procedure Validation

The validation of this procedure was achieved by conducting one-on-one interviews with construction industry professionals. Three interviews were held with employees from BL Harbert, Brasfield & Gorrie, and Robins & Morton. Questions were asked in regards to ways the procedure could be improved. Each professional stated that the procedure incorporated all major aspects associated with site utilization planning and that the procedure provided a good "checklist" of items that are sometimes overlooked during the planning process. In order to determine the practicality of the procedure, the professionals were asked to distribute the procedure to unexperienced site planners and allow them to develop a site utilization plan using the procedure. Once developed, the site plans will be emailed to the researchers for evaluation. The professionals stated that it could take up to three months before a site utilization plan can be provided.

A copy of the site utilization planning procedure was included in the emails inviting respondents to provide their opinion on the best practices. The procedure was included so that it could be referenced by respondents on future projects. A project engineer from Choate Construction Company indicated that his company did not currently have specific policies on site utilization planning. He stated that he wanted to implement site utilization planning into the company's means and methods of construction and would like to use the procedure as a starting point. With no foreseen issues, permission was granted. Therefore, the results of this research effort are already being implemented within the construction industry.

Chapter 5 : CSUP within the BIM Environment

5.1 Introduction to BIM

Building Information Modeling (BIM) has become one of the most influential tools used by architecture, engineering, and construction professionals. BIM technology provides a common interface in which multiple users/designers can create, store, and retrieve information pertaining to a construction project. One of the most noted benefits of using BIM is that an accurate virtual model of the structure to be built can be digitally constructed in three-dimensions, thus providing all stakeholders the ability to visualize the scope of the project (Azhar 2011). This significantly decreases misunderstandings associated with the more traditional two-dimensional drawings. In the past, construction managers have been given blueprints (e.g., scaled 2-D drawings printed on paper) of the structure to be built. This form of information exchange can be effective, but has limitations. It is quite challenging to ensure that all interrelated 2D design drawings are consistent and portray information correctly. Today, 2D drawings are still heavily used in the construction industry; however, 3D models are becoming more predominant because of the many benefits they offer during project design, planning, and construction.

Currently, the construction industry primarily uses BIM as a tool to visualize the construction process and to detect flaws in the design of a building and/or components within the building. Within the BIM environment, time lapsed simulations (e.g., 4-D simulations) can be performed over the project life cycle. As defined by Dodds and Johnson (2012), a 4-D model is a model that "represents the various activities of a construction project constrained to a project schedule".

Information obtained from a 4D simulation may include potential clashes between objects, crane lifting limitations, and improved construction strategies. This information can potentially save a significant amount of time and money due to the simple fact that components that interfere with one another can be relocated before construction commences.

As construction projects become more elaborate, the tasks associated with project management becomes more challenging. To assist management operations, several companies have developed software that can be used to develop 4D simulations so that building construction can be visualized prior to project startup. To date, 4D modeling has mainly focused on the construction of buildings; however, Retik and Shapira (1999) integrated site-related activities into the planning and scheduling of a modeled project. This virtual-reality-based model was developed so that site related activities could be simulated over the project duration (Retik and Shapira 1999). Site plan modeling such as this can have significant impacts on worker safety, material movement, and equipment operations. When asked about BIM usage on construction projects, seventy one percent (71%) of the respondents indicated that they had used it recently on a project. The main benefit BIM offered the respondents was its ability to identify clashes between objects. The remainder of this chapter presents a methodology which extends Building Information Modeling beyond the architect/engineering application and facilitates its implementation into site utilization planning.

5.2 Topographic Site Modeling within BIM

Many owners are beginning to require architects and engineers to develop BIM models for large projects because of the cost savings associated with detecting design flaws and redesigning prior to construction. Because of this, building models are usually available to the construction contractors for planning and scheduling. In order to plan the layout of a site, a virtual site has to be created. In some cases, the architect will incorporate the project site into the building model so that he/she can get a impression of how the building will fit in the surrounding area. If this is the case, creating the topography of the site surrounding the building is one less task that has to be done by the layout planner. However, if the topography is not included in the building model, the topography will need to be developed in order to have an accurate site layout model. The following discussion on site development using BIM is based on the capabilities of Autodesk® Revit®. This software was selected due to its wide acceptance and use in the architecture and engineering industry; however, other software can be used for site utilization planning. It should also be noted that Autodesk® Revit® was designed to model buildings and structures, and the site modeling tools within Revit® have very limited capabilities. Thus, site design and layout within Revit® should be conducted with caution.

There are several ways in which topographies can be developed for site layout planning purposes, each having its own advantages and disadvantages. The simplest way to create a topography site is to create a flat topography surface (e.g., no contours) surrounding the structure. A flat topography surface allows for easy placement of temporary facilities because modifications do not have to be made to temporary facilities (e.g., construction fencing) in order for them to follow the surrounding terrain. This method works well in geographical areas that do not have major changes in elevation such as costal and plain areas.

In many cases, the topography within and surrounding an urban area is available through local municipalities and/or independent companies. These topographies are usually developed from data collected using LIDAR or satellite sensing. Light Detection and Ranging (LIDAR) is a method of measuring the range between a remote platform (e.g., airplane or helicopter) and the Earth using pluses of laser light (NOAA 2013). Once terrain topography is generated, it is saved in a format which can be opened within modeling software. Most of the time topographies can to be purchased online in one square mile tiles. On the other hand, some companies offer software packages that allow a user to download topography from almost anywhere in the world. For example, Google® SketchUp Pro® is capable of retrieving topographic date from Google® Earth® and saving it in a modeling software file format, which can be easily imported into BIM software. If survey data is available, the survey points can be imported into modeling software and triangulations between the points can be conducted. From the triangulations, an accurate 3D topographic surface can be generated which can be used for site layout planning.

Topographic surfaces which contain elevation data can be of significant value when planning the layout of a site because it allows the designer to see areas within the site boundaries that have moderate to extreme elevation changes. Areas such as these may need grading so that the space can be used effectively throughout the project duration or the space may need to be discarded and not included in the layout. In any case, placing temporary facilities on a 3D surface can become time consuming and tedious. None the less, a site utilization plan developed using a 3D surface may identify unforeseen site limitations, which in turn can affect construction operations. Site planners should consider all options pertaining to site design in order to determine which type of topographic surface needs be used for a particular jobsite.

5.3 Site Layout Planning within BIM

Another benefit of using BIM for site layout planning is that it is the tool often used during the design phase of a project. This allows the site planner to spend less time on topography development and more time on analyzing and delineating available site space. To date, no known BIM technology can automatically calculate and delineate site space to predetermined temporary facilities; however, standalone systems have been developed that are capable of allocating site space to predetermined temporary facilities by means of artificial intelligence and knowledge databases. Although the focus here is not the implementation of complex algorithms in BIM software for site layout planning purposes, it does provide guidance on how current BIM software can be improved for site layout planning.

5.3.1 Existing Site Components

Depending on the method selected for topographic surface development, existing site components (e.g., roads, parking lots, water bodies etc.) may be difficult to model accurately within BIM. If survey points are gathered using a total station, identification (ID) points can distinguish the locations of existing site components. Gathering ID points requires little additional effort during the topographic point acquisition process because the equipment is already onsite. However, if a flat or imported topographic surface is used in the model, the task of identifying and marking the locations of existing site components is not as straight forward. A method for locating existing components in these scenarios is by importing an aerial image of the project site and scaling it to match the scale within the BIM model. This can be done by using the scale available on the image (e.g., Google® Earth® image) or by physically going to the site and measuring an existing site component. Once the image is properly scaled, it must be aligned with the model. Finally, the locations of existing site components can be marked and created within the BIM model.

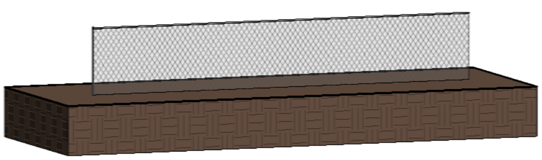
5.3.2 Site Barriers

To manage the location of temporary facilities, a clear and distinct site barrier (e.g., temporary site fencing) must be selected, installed and maintained over the life of the project. A site barrier not only provides a well-defined area in which site related activities can take place but it will also provide separation between site activities and the general public. Worker and public safety must always be considered when designing the layout of a site. One of the best ways to prevent accidents from occurring on or around a construction site is to analyze all possible accident scenarios and plan the construction activities so that the risk associated with the activity is minimized.

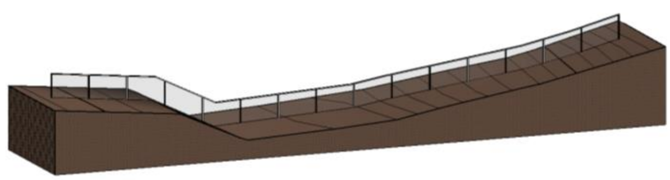
There are two distinct ways to create site barriers within a BIM model. The first and easiest way is to create or obtain a temporary construction fence family. A *family* is a group of elements that possess a shared set of properties (parameters), and a graphical representation. The various elements belonging to a family may have different values for some or all of their parameters, but the set of parameters (their names and meanings) is the same. These variations within the family are called *family types* or *types*. When a user adds an object of a family type in a model, a family type instance is created. Each element instance has a set of properties, in which the user can change element parameters independent of the family type parameters. These changes apply only to that specific instance of the element (AUTODESK® REVIT® 2014).

Temporary construction fence families can only be used effectively on a flat topographical surface due to the fact that the fence profile cannot be adjusted to follow terrain contours. In order to create a temporary construction fence that can be modified to follow the terrain contours, one must consider the available tools within the modeling software. Doing so, unique methods for placing temporary fencing can be developed. One method for placing temporary facilities is to place curtain walls along the site boundary. Normally, curtain walls consist of glass panels held in place with mullions. By editing the glass panel properties within the model, the glass panels can be replaced with chain-link fencing material and the mullions can be changed to steel fence post. Changing these two properties transforms a traditional glass wall, which is normal used for building modeling, into a site layout planning tool that can be used to model construction site barriers.

The issue of getting the temporary fencing to follow the site contour changes still needs to be addressed. In order to adjust the profile of the fence, a section view of the model needs to be opened. Within the section view, the profile of the temporary fencing (e.g., curtain wall) can be adjusted to follow the terrain and then offset upward to the desired height of the fencing, typical six to seven feet above the terrain. After this is complete, the resulting virtual fencing should resemble a real fence on a construction site. Figure 5.1 shows a fencing family and a fence created from a curtain wall. Notice that the fence family does not model the steel post supports; therefore it does not allow a user to specify the spacing between posts. On the other hand, the curtain wall fencing shows the location and spacing of the steel post and if needed the spacing can be modified.



a. Fencing Family



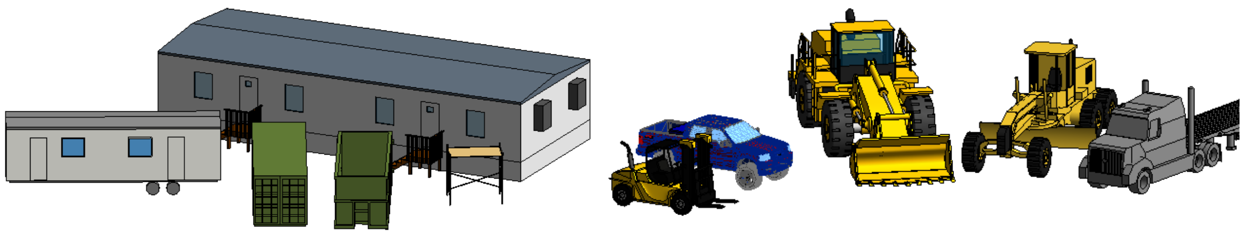
b. Curtain Wall Fencing

Figure 5.1: Construction Temporary Fencing

5.3.3 Site Layout Planning Components

Once the topography, existing site components, and site barriers are placed in the BIM model, the temporary facilities needed for construction and their locations can to be determined. Every construction project requires some type of temporary facility in order to produce a finished product. Fortunately, architectural BIM software provides means by which numerous types of temporary facilities can be model within a 3D environment. Within the virtual environment, site layout planning components can be placed on host elements (e.g., topographic surface, building floor, etc.) to simulate an object consuming space within the site boundary. This eliminates that particular space as long as the object remains in that space. As more and more objects are placed within the site boundary the reality of the layout problem becomes more evident to the planner.

Examples of site layout planning objects available are shown in Figure 5.2. Although many families are available for download, typically they can only be downloaded in one file format. Because of this, family libraries can only be used in software supporting the file format in which they were saved.



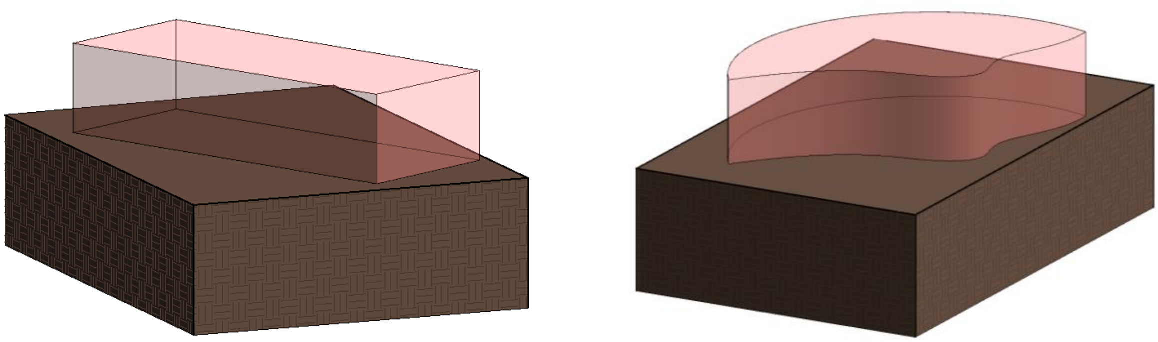
a. Site Services Facilities b. Site Equipment & Machinery

Figure 5.2: Site Planning Components

When it comes to specifying locations for material storage, equipment parking, and pathways; the planner must consider the objects available for modeling these areas. If a planner decides to model each of these areas as they appear in real life, a large amount of time will be consumed for very little reward. A more effective way of modeling these areas, while also retaining the integrity of the model, is to place finite 3D masses in areas used for such activities. A mass is a 3D object that can have material properties applied to its outer surfaces. The shape of a mass is unconfined, meaning that it can be as simple as a box or as complex as one can model. In the case of site layout planning, simple shapes such as rectangles can be used to identify areas that have been delineated for a particular task.

The most common way for modeling masses is to choose a mass from a mass library and place it within the model in the desired location or model the mass in-place. Selecting a mass and placing it is fairly straight forward and changing its dimensions and material properties is fairly simple. In certain instances, the masses available within the library are not suitable for areas that have complex constraints placed upon them. If this is the case, a mass will need to be modeled in-place so that an accurate site layout model can be created. This can be challenging at first, but over time in-place modeling can become second nature to the planner.

As masses are placed in a model, identity data should be assigned to each mass so that other users will be able to distinguish between masses. In order to make masses easier to identify within the model, material properties contrasting the surroundings (e.g. topography surface) need to be applied. Figure 5.3 shows examples of masses that can be used for site utilization planning. The surface material properties were set to "red" and the transparency of the mass was set to 65% so that objects within and/or behind the mass could still be seen.



a. Library Mass b. In-Place Mass

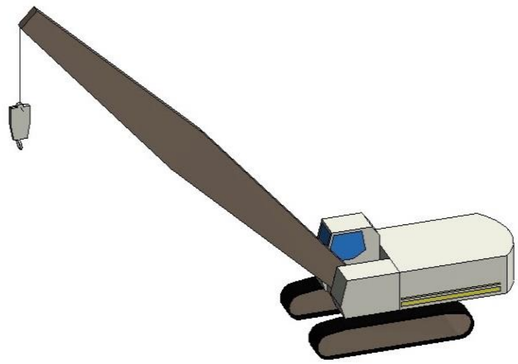
Figure 5.3: Mass Examples

5.3.4 Object Based Design Paradigm

Building information models are essentially object based parametric models. They are not composed of objects that are defined by just fixed geometry. The objects are represented in the model by parameters and rules that determine the geometry of the object as well as non-geometric properties and features. The parameters and rules can be expressions that relate to other objects, thus allowing objects to only exist in the context for which they were defined. The objects update dynamically with changes in design. In REVIT®, the object oriented design paradigm is implemented using families of objects.

REVIT® provides a very extensive set of system families to model architectural, structural and systems (HVAC, MEP) objects. For example, REVIT® Structure provides well-developed parametric families to model steel and concrete beams, columns and various types of concrete foundations. Additionally, software extensions can be used to model structural concrete reinforcement and connections between structural steel members. Each of these objects has an extensive set of parameters that accurately define its geometric characteristics, its use and its contextual relationships with other objects.

Unfortunately, the ability for creating objects for construction planning in most modeling software products, including REVIT®, is very limited. This is because software products are purposely built to meet the needs of the building design community. The families that can be practically used in site utilization planning include concrete truck, construction crane, construction trailer, porta-john, scaffolding, pick-up truck, and waste container. These families are very generic and have very limited parametric control over their behavior. For example, Figure 5.4 shows a 3D view of hydraulic crawler crane family currently available to modelers and Figure 5.5 shows the parametric properties of the crane.



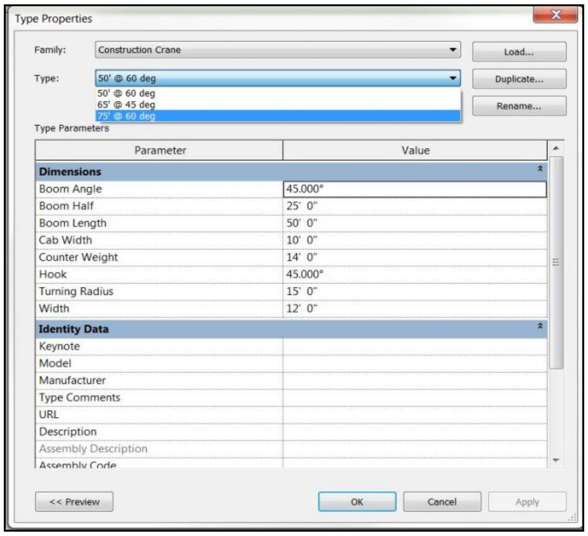


Figure 5.4: REVIT® Family: Construction Crane

Figure 5.5: Construction Crane: Type Properties

From Figure 5.5, one can see that the software offers very limited Types (50' @ 60 deg, 65' @ 45 deg, 75' @ 60 deg) in the Construction Crane family. More importantly, a very limited number of parameters are specified in this family. Crane boom angle can be changed in the model but swing angle about the center point cannot. The boom length adjustments are also very limited (i.e. full length and half length). The structure and dimensions (other than length) of the crane boom are not parameterized at all. Most imporantly, there are no parameters to represent the lifting capacity of the crane at various boom lengths and angles of lift. In its current design, the model can only be used to visualize a generic crawler crane at a construction site. It is of little use for actual planning of critical lifts during construction operations.

Construction crane manufacturers publish detailed specifications of each crane including detailed crane dimensions, lift rating for various boom lengths, radii, angle, working radius ranges, boom composition, etc. For the sake of comparison, an abbreviated version of the lift rating chart and the working radius chart of the TEREX® American Hydraulic Crane model HC 40 is shown in Figure 5.6 and Table 5.1.

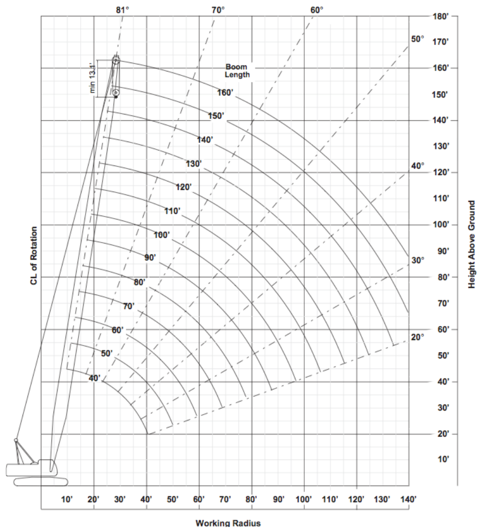


Figure 5.6: TEREX HC 40 Working Radius Chart

Table 5.1: TEREC HC40 Lifting Rating Chart

Boom Length	Radius (Feet)	Boom Angle (Degrees)	Side Frames Extended (Pounds)	From Boom Pt. to Ground (Feet)
40’	10	80.3	100,000*	45
(12.2M)	12	77.4	100,000*	44
	15	73.0	93,390	44
	20	65.3	59,020	42
	25	57.1	42,780	39
	30	48.1	33,370	35
	35	37.5	27,190	30
	40	23.4	22,840	21
50’	12	80.0	100,000*	55
(15.2M)	15	76.4	93,310	54
	20	70.5	58,910	53
	25	64.2	42,640	50
	30	57.7	33,230	48
	35	50.6	27,040	44
	40	52.7	22,670	39
	45	33.5	19,460	33
	50	20.9	16,960	23

It is evident that a construction manager planning a lift strategy for a project will need to use the data provided by the manufacturer to insure the lift is safe. Currently, this type of planning is done using two dimensional drawings. If the construction manager could use a current BIM model for planning a lift, he/she would benefit from the three dimensional environment of the BIM model. Additionally, the yet to be constructed elements of the structure can be hidden in the BIM model to accurately portray the current status of the project. This can provide an actual representation of the latest progress of the construction phase. The generic hydraulic crawler crane family provided by REVIT® is almost useless for such critical execution planning purposes. In order to make the families useful for lift planning, signficant modifications will need to be made to the generic construction crane family. This is most likely not worth the time and money spent on the process and may not produce desired accurate results for informed decision making. On the other hand, the power of a completely parametric hydraulic crane family can be harnessed by an experienced construction planner to effectively plan the lift using the BIM. In this case, the planner will be able to place the crane at various locations on site and evaluate the boom length/angle required for the lift and plan the lift effectively. Also, the most effective crane locations on site, over the life span of the project, can be determined. This can result in the development of usable site utilization plans that harness the power of BIM while also taking into account the intricacies of the construciton process.

5.3.5 Generic Objects Requiring Limited Parametric Definition and Control

The elements that fall into this category include temporary facilities such as office trailers, waste bins, storage containers, etc. These objects do not have a signficant impact on the construction execution process. A signficant modeling effort does not need to be expended in modeling these objects. These facilities can be modeled using very generic objects. Such objects do not need to be defined in great detail with many parameters. In order to model these low definition elements, one can use generic objects which have some graphical resemblance of the facility to be installed. These facilities can be modeled using the system families available in REVIT®. Many useful ready-modeled construction site temporary facility families are available online through websites such as AutodeskSeek and RevitCity. By downloading families, a designer can compile an object library that can be reused on multiple projects. The benefit of using ready-modeled families is that the designer does not have to spend a substantial amount of time creating the objects needed to develop a site layout plan; however, if a unique object is needed the object can be created and saved within the object library. Most of the object families look realistic and can be easily comprehended, thus allowing for timely plan interpretation when actual objects need to be placed on the jobsite.

5.3.6 Significance of Parametric Modeling

While the objects described in the section above do not require a signficant level of definition, some objects are mission critical for the execution of the construction process. Lifting equipment such as the crane described in the earlier section falls into this category. Very well defined hydraulic crawler construction crane models can be utilized to determine their optimal positions at the site for various lifts, as well as their capacity at various boom lengths and angles. Parametric models of telescoping mobile cranes can be utilized to evaluate the viability of using the cranes at various stages of the project based on the access routes available for crane movement. Based on the best location of the crane, its ability to lift various objects can then be determined.

Tower cranes remain stationary through the construction phase. A parametric model of a tower crane can be utilized to determine the capacity of the crane at certain values of lift radii. Admittedly, this can be done equally effectively in two-dimensional models. However, parametric three dimensional models may offer additional benefits. For example, when planning the use of tower cranes in the Audie L. Murphy Memorial Hospital Polytrauma Rehabilitation Center project in San Antonio, TX, Robins and Morton was required to obtain safety approval from the Federal Aviation Administration to prove that the location of the tower cranes would not hinder the movement of the helicopters carrying trauma victims to the top of the adjoining hospital. In this case, a three dimensional BIM model and animation showing the maximum radius of the cranes and the path of helicopters was used to expedite the approval of tower crane placement. Three dimensional BIM models are inherently easier to interpret, especially for non-technical users who may be involved in the decision making process. Cranes are not the only category of construction equipment that can benefit from extensive parametric 3D modeling. Concrete pump trucks are utilized in many projects involving signficant reinforced concrete construction of substructure and superstructure elements of buildings. Parametric BIM models can be effectively used in such cases to plan concrete placeworks.

While it is easy to recognize the benefits that can be obtained by creating well defined parameterized objects for site utilization planning, the effort and consequently the cost required for creating the object can be substantial. Software vendors such as AutoDesk cannot reasonably be expected to provide highly parameterized families for the wide variety of construction equipment available by all the manufacturers. As in the case of various building design products, the equiment manufacturers will eventually have to provide these models to the users of their equipment. Some crane manufacturers have already started providing AutoCAD 3D models of their cranes to construction contractors who request them. In the near future, this trend is likely to continue on account of increased use of BIM in the construction industry. In order to promote standardization, it may also help to create specifications of the parameters that should be provided by equipment manufacturers in their BIM models. The list of parameters will most likely vary signficantly across various categories of construction equipment. The availability of these models will more than likely accelerate the adoption of BIM site planning by construction planners.

5.3.7 Four Dimensional Site Utilization Planning

The temporary facilities, construction equipment, and processes over the life cycle of the construction project can vary signficantly. While some facilities such as site offices are long term static facilities, many temporary facilities exist at the construction sites only for a medium / short duration. The inherently ever changing nature of a construction site is very difficult to visualize and capture using two dimensional paper based processes. Many tools such as Navisworks® can integrate the three dimensional objects in a BIM model with the construction schedule to create 4D (temporal) simulations of the construction process. Traditionally, the 4D models are limited to the components of the building designed by various design professionals. With a little bit of creativity, a construction planner can add activities in a construction schedule which represent the mobilization and de-mobilization of various temporary facilities at construction sites. This combination can be used to produce very powerful simulations of the placement and removal of various temporary facilities. This concept has the potential to greatly improve the quality of a project execution plan.

5.4 Site Layout Case Example

A BIM based site utilization plan example was conducted on the Auburn University Wellness Center project which is located on Heisman Drive in Auburn, Alabama. The Wellness Center is a state-of-the-art fitness and recreation center that houses eight basketball courts, an elevated running track, a three story rock climbing wall and several other amenities. The BIM models for the Wellness Center, Student ACT, and Aquatics Center were provided by the general contractor. The Student ACT and Aquatics Center are existing buildings that are in close proximity to the Wellness Center. The Student ACT currently houses six basketball courts, a weight room, a cardio room, and other workout facilities used by students. The Aquatics Center contains an Olympic pool that is used for swimming and diving. The models of these two building were incorporated into the site utilization plan so that a visual relationship between the existing buildings and the new Wellness Center could be obtained. The Beard-Eaves Memorial Coliseum is also within close proximity to the Wellness Center; however, a BIM model of the Coliseum was unavailable. Due to this unavailability, only the foundation of the Coliseum was modeled. The purpose of this example was to demonstrate that BIM can be used to develop an accurate site utilization plan within a virtual environment.

Initially, the topographical surface model provided by the contractor was opened and the Wellness Center model was linked so that a base point could be established. Next, an aerial image of the project site (e.g., streets, parking lots, etc.) surrounding the Wellness Center was imported from

Google® Earth® and scaled so that the dimensions of the image matched that of the model. Using the image as a guide, the streets, parking lots, outdoor Olympic pool, and existing building pads were created on the topographical surface by modifying/splitting the topographic surface into multiple surfaces so that it would resemble the existing site. In order to determine the location of the site boundary, the approved site boundary on the original 2D site plan was used. Knowing the relationship between existing objects and the site boundary, temporary site fencing was modeled around the site so as to create a barrier between construction activities and the public. Figure 5.7 shows the existing components of the site, building pads, and the temporary construction fencing around the perimeter of the site.

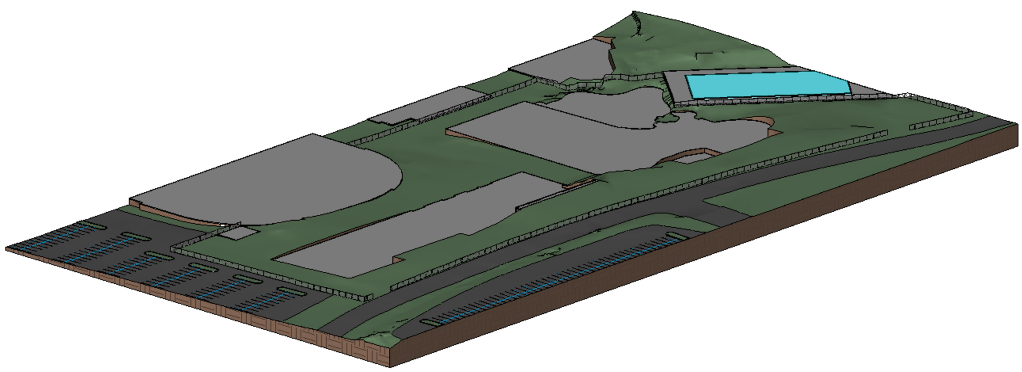


Figure 5.7: Existing Site and Construction Fencing

Next, the locations of the construction entrances and equipment/material pathways were determined and modeled on the topographic surface. The remaining site area was then delineated to temporary facilities that were needed to support construction activities. Figure 5.8, Figure 5.9, Figure 5.10, and Figure 5.11 show the finished site layout utilization plan developed for the Wellness Center. Notice that the office trailers were located near the construction entrances so that personnel visiting the site have direct access to the offices. This minimizes the amount of unauthorized personnel walking through the site. For this particular project, the building footprint and equipment/material paths encompass a large portion of the site. This limits the amount of material that can be stored on site. In order to maintain a smooth flow of material and support productivity, offsite storage (not shown) was used. Notice that the laydown areas are divided into sections. This allows different material properties and identity data to be applied to each section. The laydown areas are located along the perimeter of the site so that a clear path could be maintained around the building. A pathway could easily become congested with building material if the laydown areas are not maintained. Therefore, it is important to communicate the areas available for storing material to all personnel working on site. This can be done by posting the site layout plan on an information board and updating it as the project progresses.

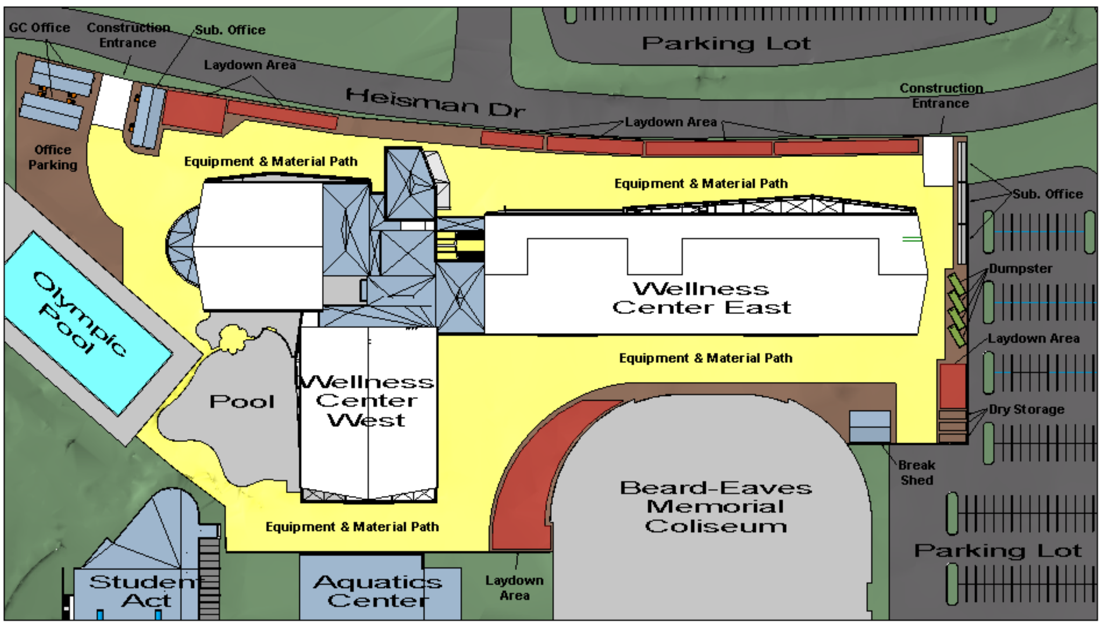


Figure 5.8: Wellness Center Site Layout (Plan View)

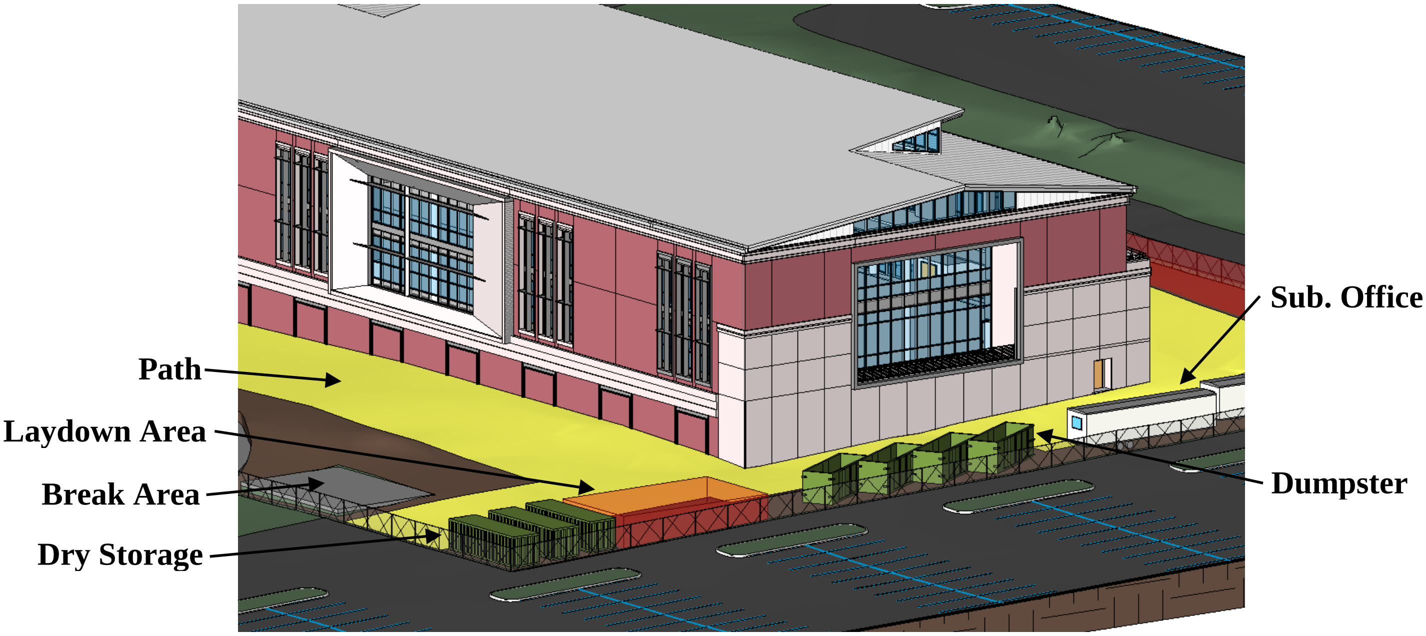


Figure 5.9: Wellness Center Site Layout East (3-D View)

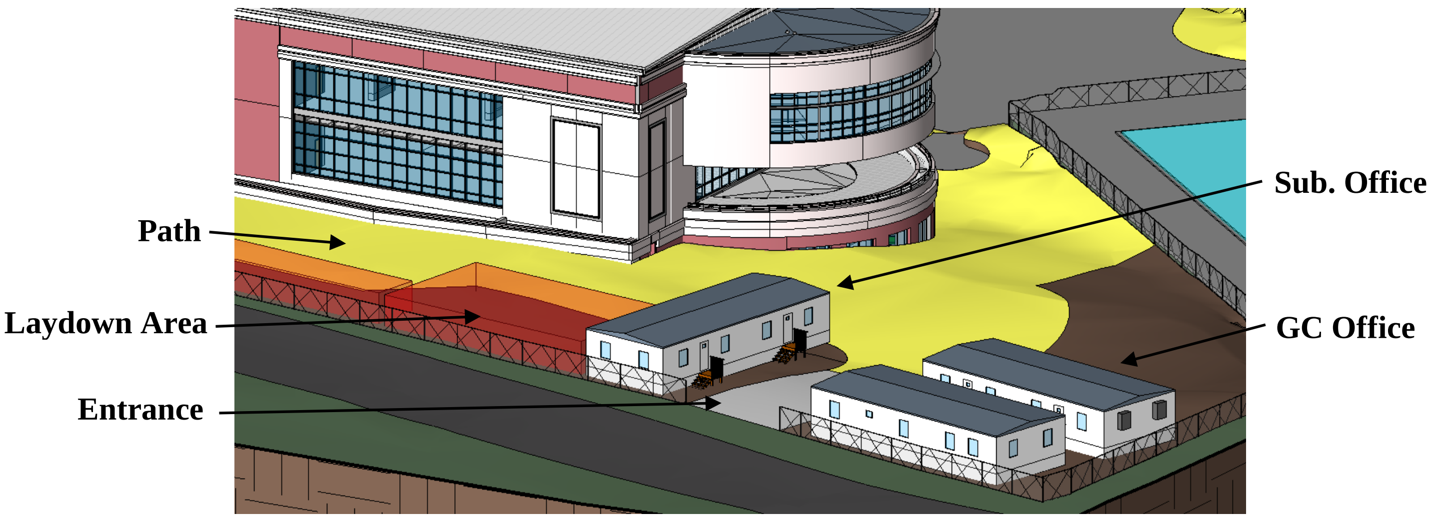


Figure 5.10: Wellness Center Site Layout West (3-D View)

Figure 5.11: Wellness Center 3-D View

5.5 Benefits, Challenges, and Risk Associated with BIM

5.5.1 BIM Benefits

Although many construction professionals agree that the use of BIM can ultimately reduce project cost, increase construction efficiency, and decrease finished product delivery time, there is little to no factual data available to confirm this notion. However, case studies have shown that the use of BIM is all phases of a project can have significant cost benefits, time savings, and help owners make definitive decisions (Azhar 2011). When using BIM for site utilization planning, project managers are able to communicate the locations of temporary facilities effectively due to the fact that a virtual 3D representation is available.

With the integration of 3D modeling and scheduling, project managers are now able to create detailed construction sequencing animation. The idea of construction sequencing can also be applied to site utilization planning. Typically, a single site utilization plan is not capable of delineating space effectively for projects that last prolonged periods of time. In such cases, site utilization plans can be developed in phases. By assigning start and finish time to each phase or each temporary facility, a site utilization animation can be developed for the project. This animation can then be used to determine if any temporary facilities conflict with one another during the project. This also helps maintain a safe working environment.

5.5.2 BIM Challenges

Although the monetary and productivity benefits associated with BIM technology is widely acknowledged across the construction industry, the adoption of BIM modeling has been slower than anticipated (Azhar et al. 2008). This could be due to the amount of time required to become proficient with new software or the lack of concise reference material that provides guidance on the application and use of BIM software in site utilization planning. This is not to say that educational material is not available, but instead implies that the material available is more in-depth and prolonged than one may be confident with when learning solely on their own. For instance, current BIM software has not been designed to assist in the design of a site utilization plan, thus unique methods for constructing site utilization plans have to be conceived by individuals that understand the capabilities of the software. From this observation it is clear that in order for more construction professionals to adopt BIM technology, advancements must be made within the software.

Another challenge associated with site utilization planning within BIM is the lack of ready-made temporary facility families. Although some construction site objects are available for download, many temporary facilities required to create an accurate site layout are not available. This can discourage construction planners from using BIM because of the added time it takes them to create the families needed. Lack of data interoperability also pose issues between design and construction professionals using multiple software systems. Interoperability as defined by Thompson and

Miner, is “the ability for different systems and models to interface without creating inaccuracies or requiring inefficient data re-entry that is prone to error and data aging.” The ability to transfer electronic data from one person to another is a key communication element in the construction industry.

5.6 Summary

Construction Site Utilization Planning has signficant implications for efficiency of construction operations, schedule and cost performance of the project, and safety at a construction site. Traditionally, this planning has been done in two dimensions using hand drawings or AutoCAD files. Use of Building Information Modeling can enhance this process by leveraging the various models made available to the construction planner by designers. The latest BIM SmartMarket report published in 2012 by McGraw-Hill states that construction contractors are adopting Building Information Modeling at a very fast rate. BIM models are increasingly being used for constructability analysis by the construction industry. BIM models have the potential to provide a data rich visual context for planning construction operations.

Chapter 6 : Summary and Recommendations

6.1 Introduction

Construction Site Utilization Planning (CSUP) is a decision making process for determining the locations of temporary facilities within the boundary of a construction site by identifying spatial relationships and developing best alternative solutions so that the efficiency of the construction process is improved over the project life cycle. CSUP is a trade-off problem in which decisions must be made based on project attributes without sacrificing site plan quality. The advantages associated with site planning is that it provides a means for operational control which directly affects construction activities, project duration, site safety, and project cost. A significant amount of research has focused on optimization algorithms and very limited research has been done on the practical aspects of CSUP.

This research project focused on four specific goals: i) determine the predominant factors associated with the development and management of CSUP, ii) determine the best practices of CSUP, iii) use the identified best practices to develop a process that provides clear instruction on the development and management of CSUP, and iv) demonstrate how current BIM technology can be utilized in the development of highly accurate three dimensional CSUP. The successes, shortcomings, and recommendations for future work are addressed in the following sections.

6.2 CSUP Survey

The first step in achieving the goal of this research was to obtain a better understanding of the current practices being implemented by industry professionals when developing site utilization plans. This was accomplished through the use of an online survey. A total of 241 responses were obtained from construction professionals worldwide. The survey first revealed that one fourth of the respondents do not develop any type of site utilization plans for their construction projects. This suggest that some respondents have yet to acknowledge the potential benefits of site utilization planning or that some construction projects do not require a site utilization plan to operate effectively. Secondly, effective site utilization planning requires exceptional decision making skills. There are many aspects that must be considered during the development of a site utilization plan. In order to make correct decisions, one must make a significant effort to collect the requisite data that affects the success of the site layout plan and one must be considerably knowledgeable on construction operations and methods. Finally, establish and maintain effective communication with all stakeholders involved with the project. This helps all stakeholders recognize the current status of the project and understand what needs to be accomplished in order for the project to remain on schedule and within budget.

6.3 Best Practice Identification

The second objective of this research was to analyze the results of the survey and identify the most predominant factors taken into consideration by industry professionals when developing site utilization plans. The predominant factors identified were considered the best practices of site utilization planning. A total of thirteen best practices were identified, each focusing on an important aspect of the site planning process. The best practices are as follows:

1. Conduct an in-person investigation of the site prior to Site Utilization Plan (SUP) development.
2. Start SUP development as early as possible.

3. Involve stakeholders (e.g., owner, subcontractor, project manager, superintendent, 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 all subcontractors at the site.
8. Implement and enforce the SUP from day one of construction.
9. Monitor the 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. Utilize BIM technology for SUP development if available.

In order to validate these best practices, a second survey was sent out asking the respondents to indicate their opinion on each practices. All of the best practices, except for one, had an average opinion within the range of agree to strongly agree. The one practices that did not fall within this opinion range was Best Practice 13: Utilize BIM technology for SUP development if available. It had an average opinion within the range of neutral to agree.

6.4 CSUP Procedure Development

The third objective of this research was to develop a procedure for developing site utilization plans. The procedure was meant to be generic so that it could be modified to suit the unique conditions experienced in each project. The purpose was to develop a procedure that bridged the knowledge gap between past research efforts and current industry practices while also providing practitioners with a basic outline that summarizes the site utilization planning process. The procedure developed accomplished these goals. The procedure clearly defines the steps that may be used by industry professionals when developing a site utilization plan. The procedure involves project constraint identification, data acquisition, plan development, communication, implementation and enforcement, monitoring and evaluating, and documenting. The procedure presents a robust set of policies and practices for developing site utilization plans.

6.5 CSUP within the BIM Environment

The final objective of this research was to illustrate how current BIM technology can be utilized during the development of site utilization plans. Current BIM technology is predominately designed around the needs of architecture, structural, MEP, and HVAC designers. Although there are BIM technologies available for scheduling and cost estimating, site utilization planning within the BIM environment remains to be a daunting task. To develop accurate site utilization plans within BIM, one must be knowledgeable on BIM capabilities and be capable of significant software manipulation to obtain the desired outcomes. By obtaining a comprehensive understanding of BIM capabilities and researching software operations, a BIM based site utilization plan example was developed. A major issue identified during site utilization plan development was the lack of readily-available parametric families for modeling purposes. Significant advancements in readily-available site utilization families will need to be made in order for BIM based site planning to become an industry standard.

6.6 Usefulness to the Industry

The formation of an easily understood process for developing site utilization plans 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 site utilization plans 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 exist between past research efforts and current industry practices in regards to site utilization planning. 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 on construction site utilization planning.

6.7 Recommendations

6.7.1 Further Industry Development

The site utilization planning procedure developed under this research outlines the process of site utilization planning as identified by industry professionals. The procedure is generic in that it summarizes important aspects of the site utilization planning process, leaving specific space delineation methods up to the planners. It is recommended that site planners continuously develop the procedure and make necessary modification 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 site plan development. Over time, the individualized site utilization planning procedure will gain significant value as a document of reference.

Companies are encouraged to develop a standardized method for collecting lessons learned information 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 ask 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 information, non-value adding events that occurred on past project can be anticipated and prevented on future projects.

Currently, a need exist for a method to teach basic site utilization principles to inexperienced site planners and managers. The results of this research provide a basis for developing a workshop that can provide training on the site utilization planning process. The workshop would need to be general enough to accommodate different company planning practices but, at the same time, remain detailed enough to provide sufficient guidance. Examples of past site layouts can be incorporated into the workshop illustrating effective and ineffective site operation as compared to the planning technique applied. Approaches for documenting lessons learned can be discussed, as well as potential benefits of sharing lessons learned within the company.

6.7.2 Further Research Development

The best practices identified from this research summarize the major components of site utilization planning. Past research efforts on site optimization systems have overlooked these best practices. In order to utilize these practices, future research efforts need to focus on the development of robust optimization systems which incorporate the findings of this research. This system would also need the capability of interacting with BIM technologies, such as Autodesk REVIT®. In such a system, part of the site utilization planning process will be achieved by expert planner knowledge, while the movement of equipment and materials can be optimized using the appropriate meta-heuristic. The optimized result can then be viewed in three dimensions allowing all stakeholders the opportunity to obtain an indepth understanding of site space delination. A system such as this could potentially counteract current views on optimization algorithms as essentially being black box type systems that have limited capabilities and flexibilities.

In order for BIM to become a widely accepted platform for site plan development, future research needs to be conducted on methods for developing high parametric site utilization families. Currently, no standardized method exist that outlines the process of site family development. Thus, design standards will need to be established so that site planning families will be developed systematically. The seamless intergration of the results of this research, optimization systems, BIM technology, and high parametric families into a centralized site planning system could provide the construction industry with an opportunity to redefine construction execution planning.

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Appendices

Appendix A

Copy of Electronic Survey

Best Practices for Site Utilization Planning

AUBURN
UNIVERSITY

Dear Survey Participant,

Thank you for your willingness to participate in this study to help identify the Best Practices of Site Utilization Planning (SUP). The objective of the study is to determine current practices, methods and techniques used by the construction industry in developing the layout of temporary facilities on job-sites that have limited space for construction activities.

This Questionnaire Survey is aimed at General Contractors / Construction Managers. Please answer the questions in this survey based on your experience. Your participation in this Survey is voluntary.

We will only share / publish the data collected in this survey in an aggregated format. Mr. Blake Whitman and Dr. Abhijeet S. Deshpande will be the only individuals with access to individual survey results.We will not share your personal information with anyone.

The data collected in this on-line survey in transmitted using Secure Sockets Layer (SSL) protocol to ensure confidentiality of the information being transmitted.

The survey should take approximately 20 - 25 minutes.

Please contact Mr. Blake Whitman (jbw0012@tigermail.auburn.edu) or Dr. Abhijeet S. Deshpande (adeshpande@auburn.edu) if you have any questions or comments about the survey.

We appreciate your help.

Thank you,

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Department of Civil Engineering
Samuel Ginn College of Engineering
Auburn University

Next

Survey Completion

0% 100%

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

Please fill in as much of the following information as possible:

Name of Respondent:	
Job Title:	
Company Name:	
Business Category (e.g., Building Construction, Industrial Construction, Heavy Civil, etc.):	
Company Size (e.g., Number of employees):	
Region of Operation (e.g., Southeastern U.S., Central U.S., etc.)	
Telephone Number:	
Email:	
Years of experience in the construction industry:	

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Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

May we contact you with follow-up questions?

- Yes
- No

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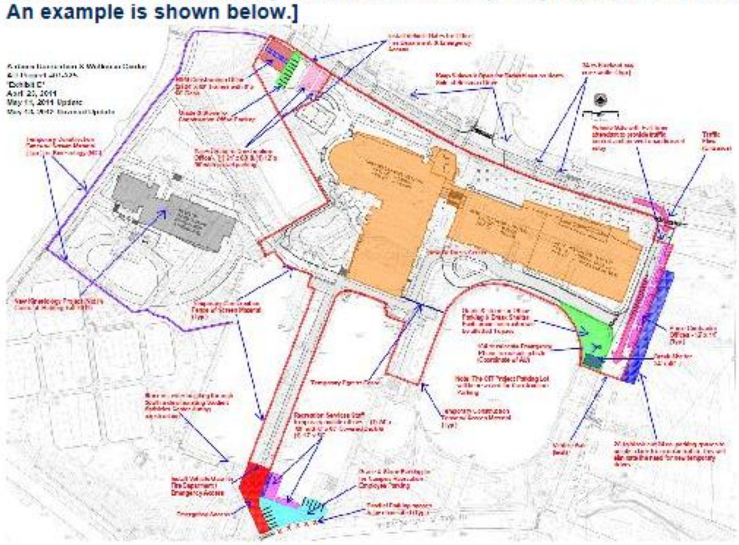
Best Practices for Site Utilization Planning

Does your company develop site utilization plans for construction projects? [Note: Site utilization plans are documents that identify the locations of temporary facilities within the construction site boundaries. An example is shown below.]



- Yes
- No (Note: Your Survey will end here)

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Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

Please choose the statement that accurately reflects your philosophy in the creation of site utilization plans:

- ○ We create a site utilization plan for every project we construct
- ○ We create site utilization plans only for projects where space available is very limited
- ○ Other

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Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

Does the number of subcontractors participating in a project influence the decision to develop site utilization plans? (For Example, Site Utilization plans are typically only created in projects where large number of subcontractors are likely to participate, creating a competition for space at the job site.)

- ○ Yes
- ○ No

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Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

Does the monetary size of a project influence the decision to develop site utilization plans?

- Yes
- No

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Survey Completion

0% 100%

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

At what project value are site utilization plans developed?

- $0 - $100,000
- $100,000 - $500,000
- $500,000 - $1,000,000
- $1,000,000 - $10,000,000
- > $10,000,000

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Survey Completion

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Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

Does your company use software to develop site utilization plans?

- Yes
- No

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Survey Completion

0% 100%

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

What software is used to develop site utilization plans? [Select all that apply.]

- CAD
- BIM (Building Information Modeling)
- PDF Overlay
- Other

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Survey Completion

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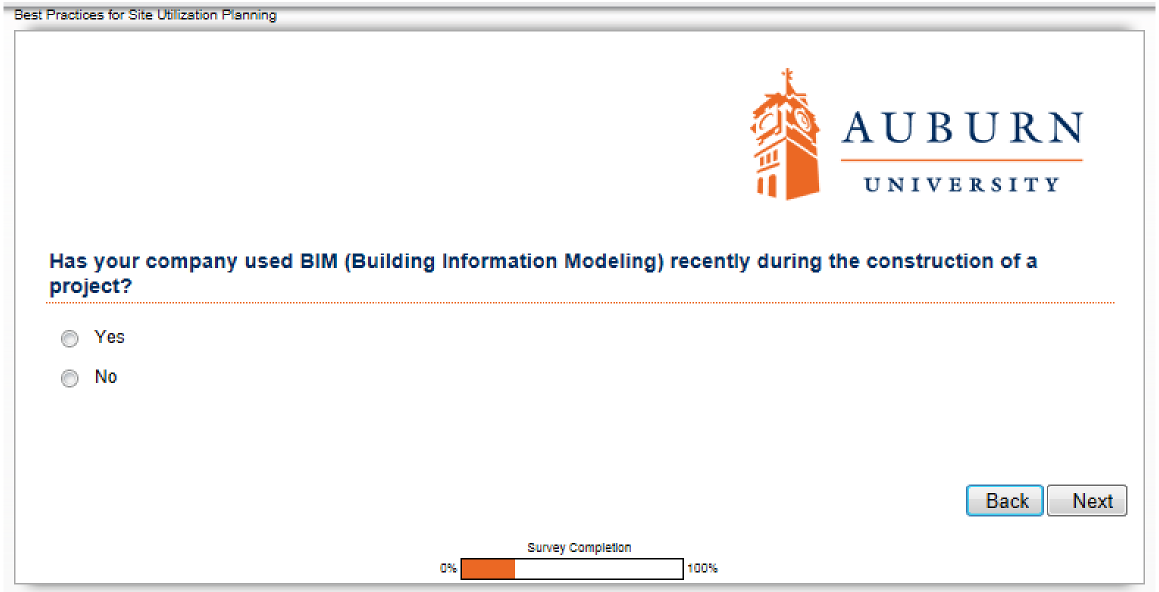

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

Has your company used BIM (Building Information Modeling) recently during the construction of a project?

- Yes
- No

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Survey Completion

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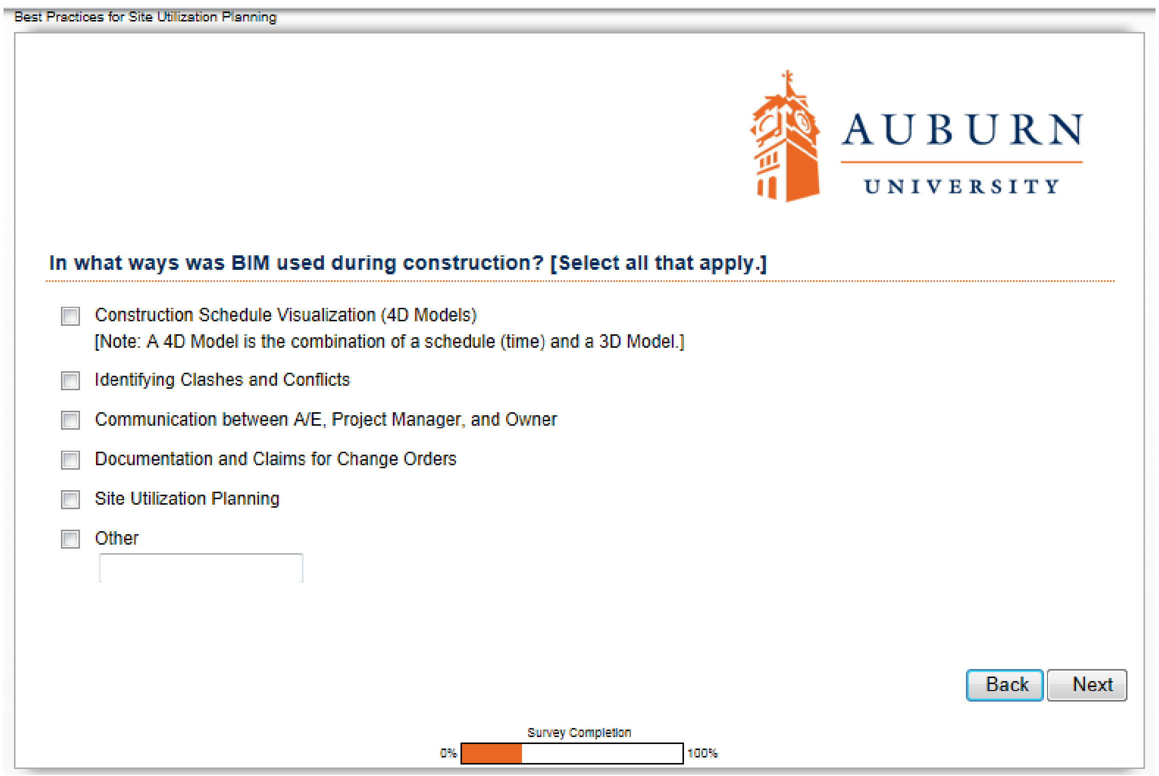

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

In what ways was BIM used during construction? [Select all that apply.]

- Construction Schedule Visualization (4D Models)
  [Note: A 4D Model is the combination of a schedule (time) and a 3D Model.]
- Identifying Clashes and Conflicts
- Communication between A/E, Project Manager, and Owner
- Documentation and Claims for Change Orders
- Site Utilization Planning
- Other

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Survey Completion

0% 100%

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

Who is typically in charge of the development of site utilization plans?

- Project Manager
- Project Engineer
- Site Superintendent
- Other

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Survey Completion

0% 100%

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

Are subcontractors involved with the design of site utilization plan(s)?

- Yes
- No

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Survey Completion

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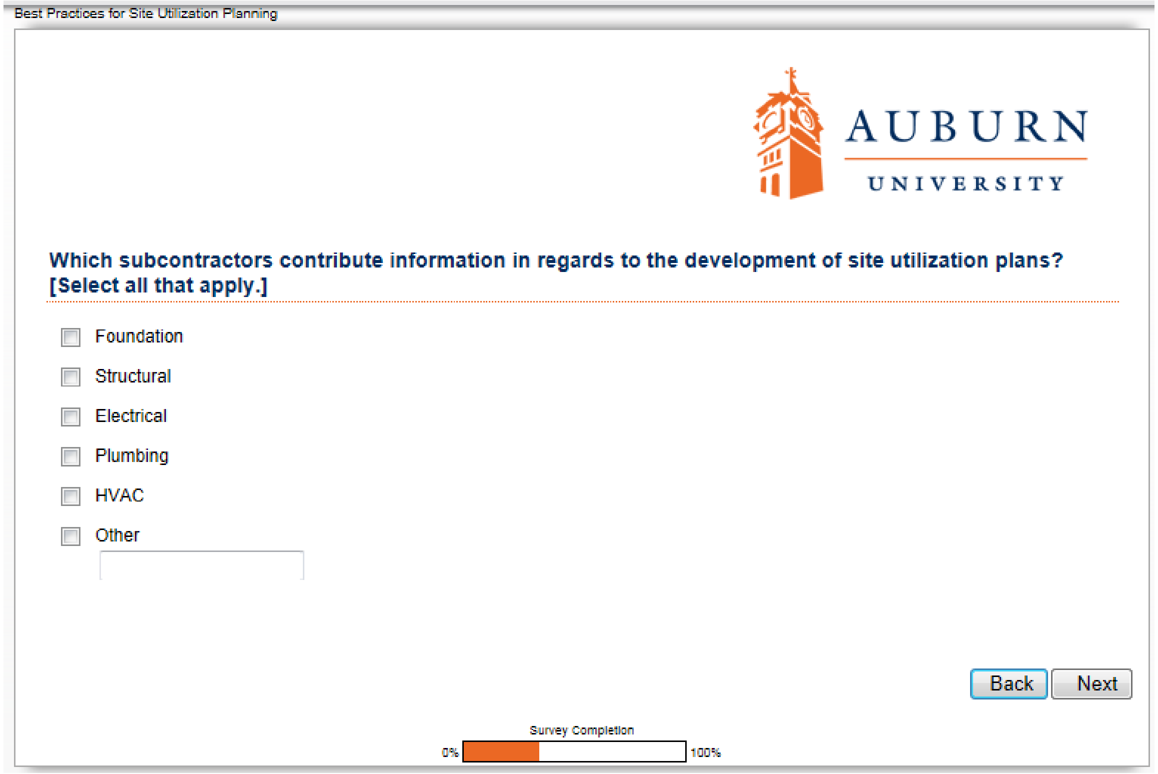

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

Which subcontractors contribute information in regards to the development of site utilization plans? [Select all that apply.]

- [ ] Foundation
- [ ] Structural
- [ ] Electrical
- [ ] Plumbing
- [ ] HVAC
- [ ] Other

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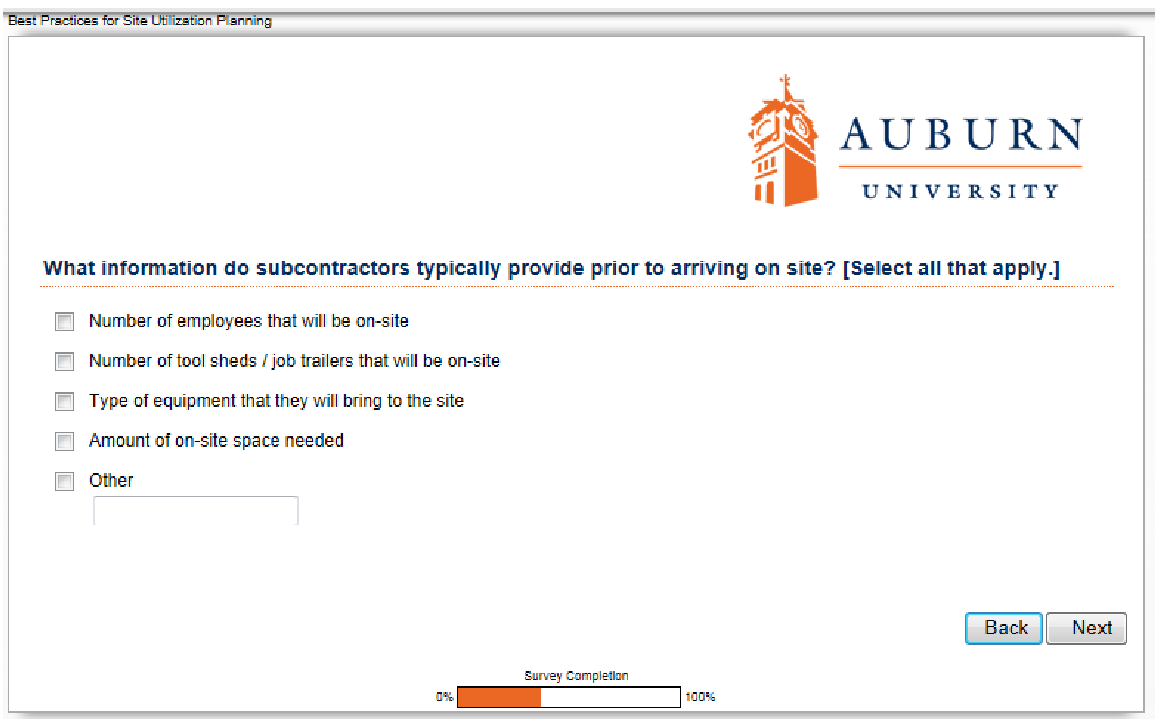
Survey Completion

0% 100%



Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

What information do subcontractors typically provide prior to arriving on site? [Select all that apply.]

- [ ] Number of employees that will be on-site
- [ ] Number of tool sheds / job trailers that will be on-site
- [ ] Type of equipment that they will bring to the site
- [ ] Amount of on-site space needed
- [ ] Other

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Survey Completion

0% 100%

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

Do any subcontractors / trades get priority in site space allocation?

- Yes
- No

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Survey Completion

0% 100%

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

Which subcontractors / trades get priority in space allocation? [Select all that apply.]

- Foundation
- Structural
- Electrical
- Plumbing
- HVAC
- Other

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Survey Completion

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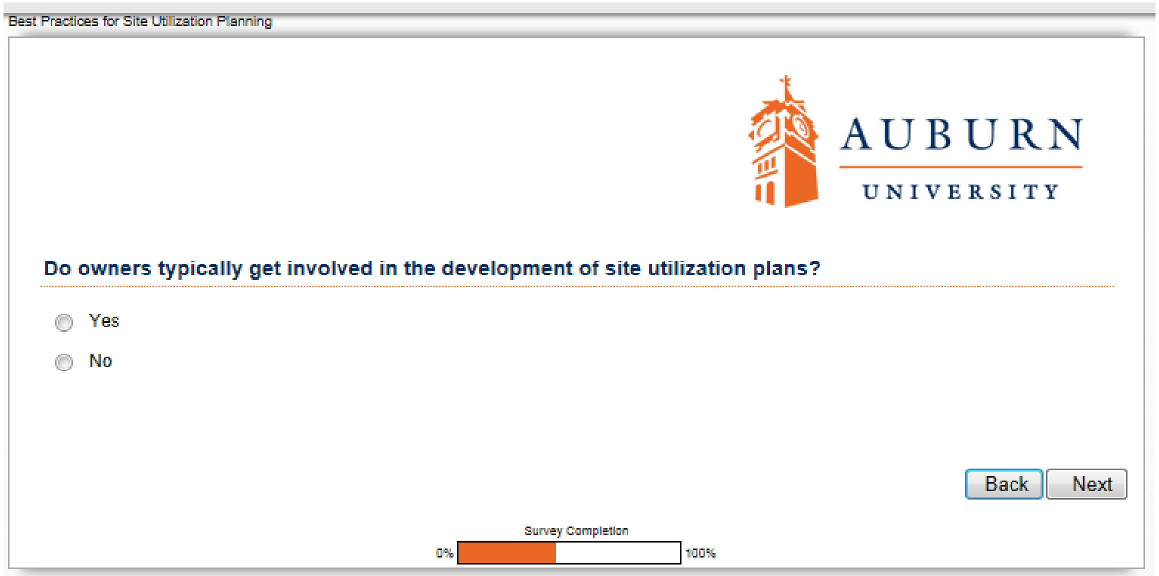

Best Practices for Site Utilization Planning

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Do owners typically get involved in the development of site utilization plans?

- Yes
- No

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Survey Completion

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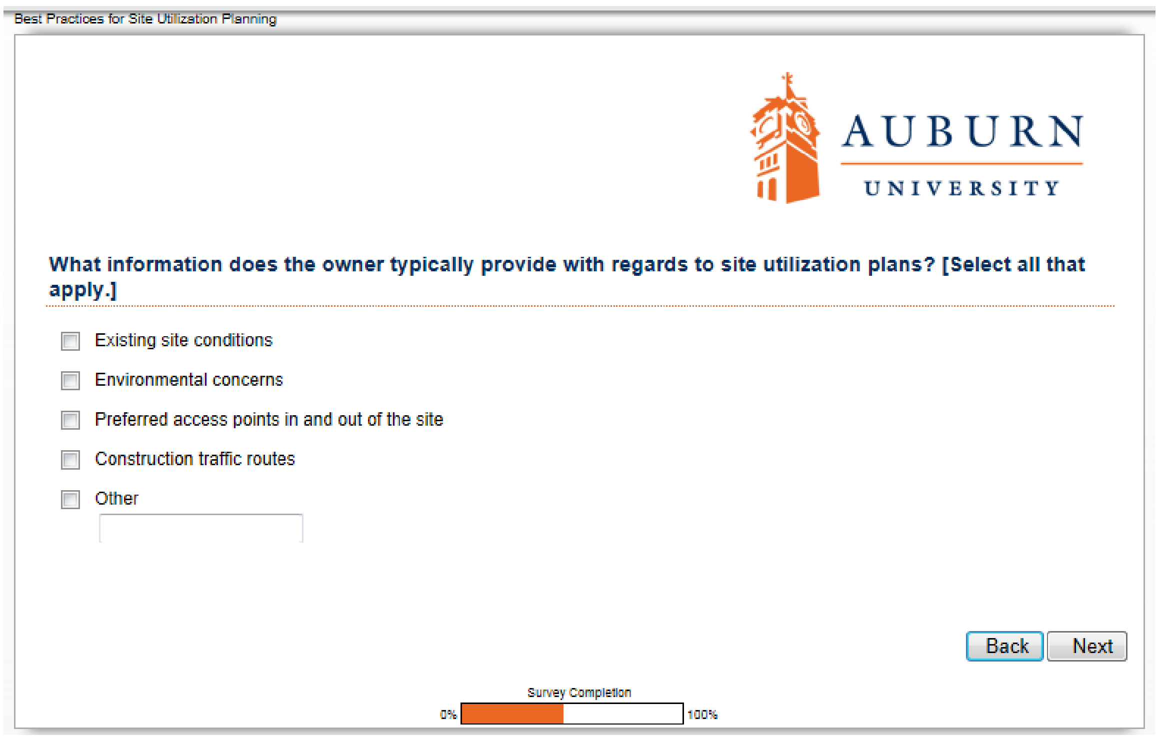

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

What information does the owner typically provide with regards to site utilization plans? [Select all that apply.]

- Existing site conditions
- Environmental concerns
- Preferred access points in and out of the site
- Construction traffic routes
- Other

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Survey Completion

0% 100%

Best Practices for Site Utilization Planning

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Which of the following temporary facilities are typically included in your site utilization plans? [Select all that apply.]

- ☐ Job Trailer Location
- ☐ Tool Shed Location
- ☐ Parking Lot Location
- ☐ Dumpster Location
- ☐ Break Area
- ☐ Underground Utilities
- ☐ Building Footprint Area
- ☐ Job-site Access Point
- ☐ Off-Site Storage
- ☐ On-Site Storage
- ☐ Unloading Area
- ☐ Work Areas
- ☐ Staging Area
- ☐ Equipment Area
- ☐ Hazard Area
- ☐ Protected Area
- ☐ Soil Storage Area
- ☐ Other

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0% 100%

Best Practices for Site Utilization Planning

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On an average, what percent of the total project cost is allocated to temporary facilities?

- ○ 0% - 2%
- ○ 2% - 5%
- ○ 5% - 10%
- ○ 10% - 15%
- ○ > 15%

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Survey Completion

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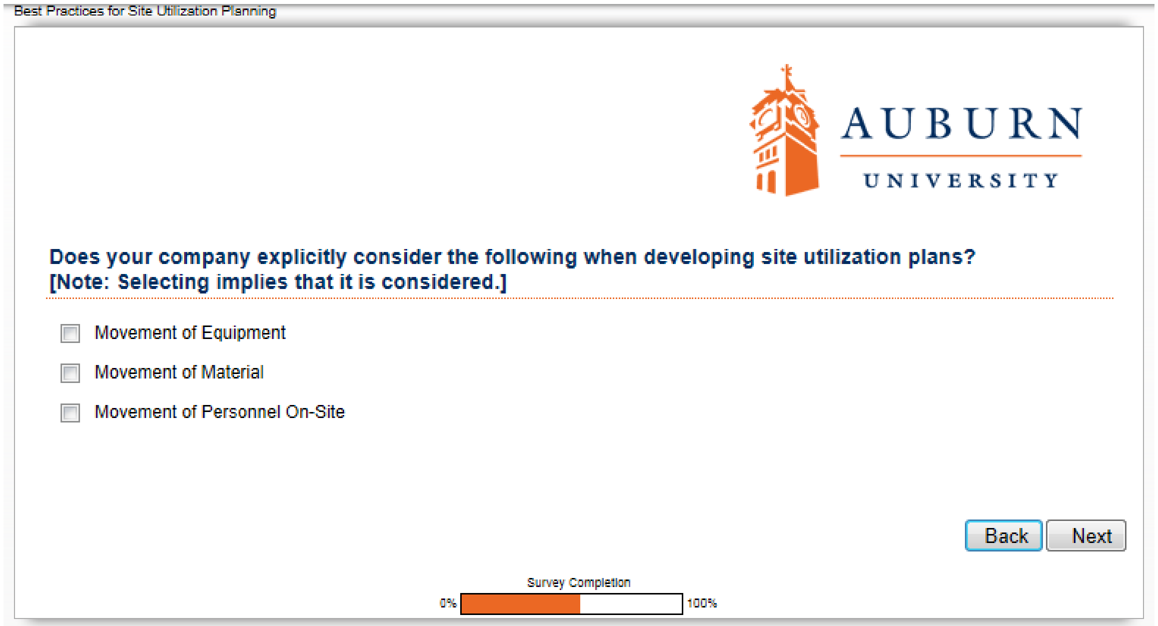

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

Does your company explicitly consider the following when developing site utilization plans? [Note: Selecting implies that it is considered.]

- [ ] Movement of Equipment
- [ ] Movement of Material
- [ ] Movement of Personnel On-Site

Back Next

Survey Completion

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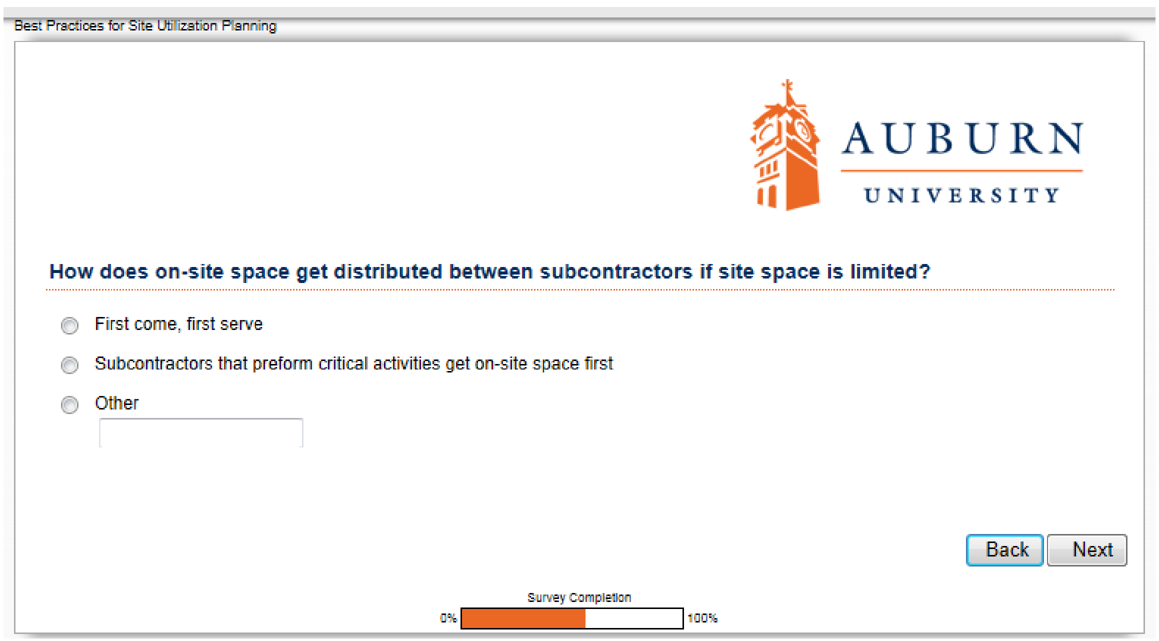

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

How does on-site space get distributed between subcontractors if site space is limited?

- First come, first serve
- Subcontractors that preform critical activities get on-site space first
- Other

Back Next

Survey Completion

0% 100%

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

How is the location of each on-site temporary facility determined? [Select all that apply.]

- [ ] Computer software
- [ ] Past experience of the site utilization plan developers
- [ ] Other

Back Next

Survey Completion

0% 100%

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

Does your company create multiple site utilization plans for different phases of construction? For instance, developing site utilization plans for substructure phase, superstructure phase etc.

- Yes
- No

Back Next

Survey Completion

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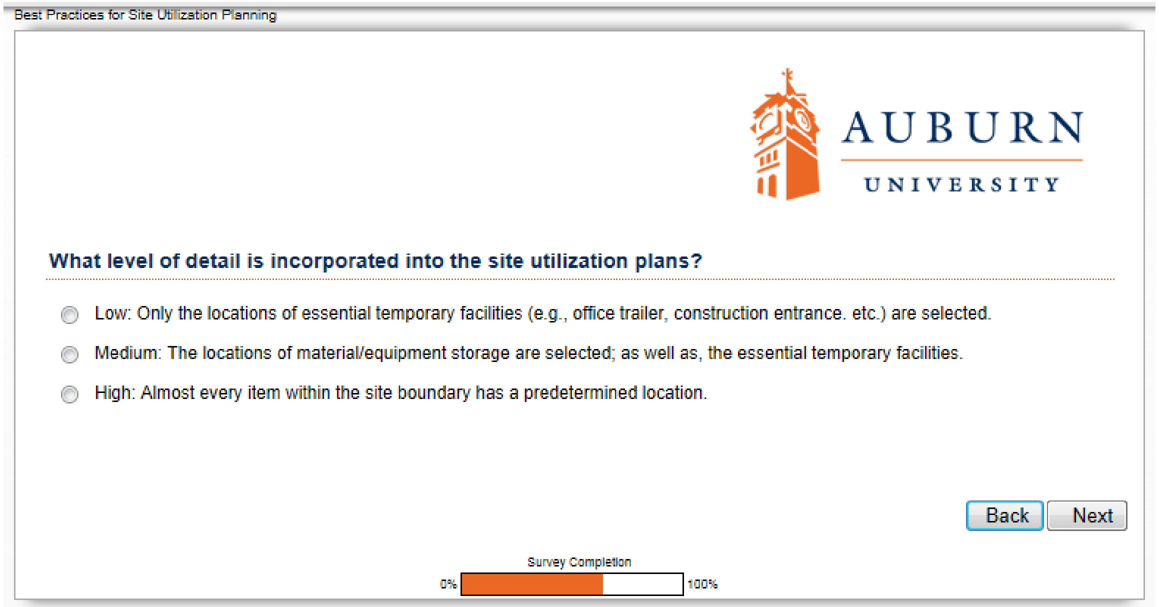

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

What level of detail is incorporated into the site utilization plans?

- Low: Only the locations of essential temporary facilities (e.g., office trailer, construction entrance. etc.) are selected.
- Medium: The locations of material/equipment storage are selected; as well as, the essential temporary facilities.
- High: Almost every item within the site boundary has a predetermined location.

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Survey Completion

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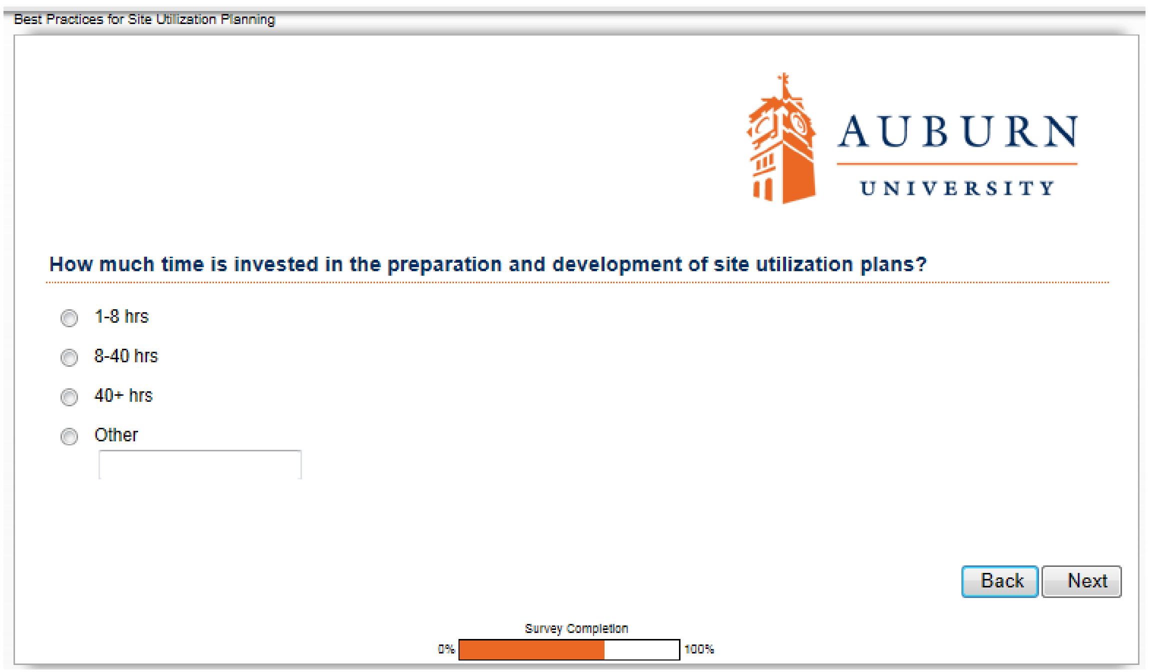

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

How much time is invested in the preparation and development of site utilization plans?

- 1-8 hrs
- 8-40 hrs
- 40+ hrs
- Other

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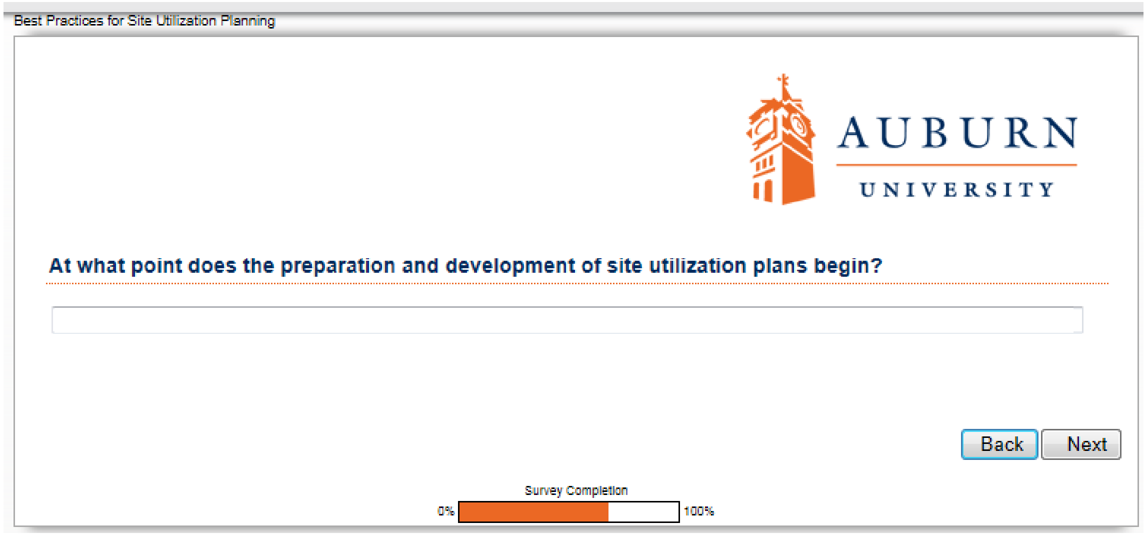
Best Practices for Site Utilization Planning

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At what point does the preparation and development of site utilization plans begin?

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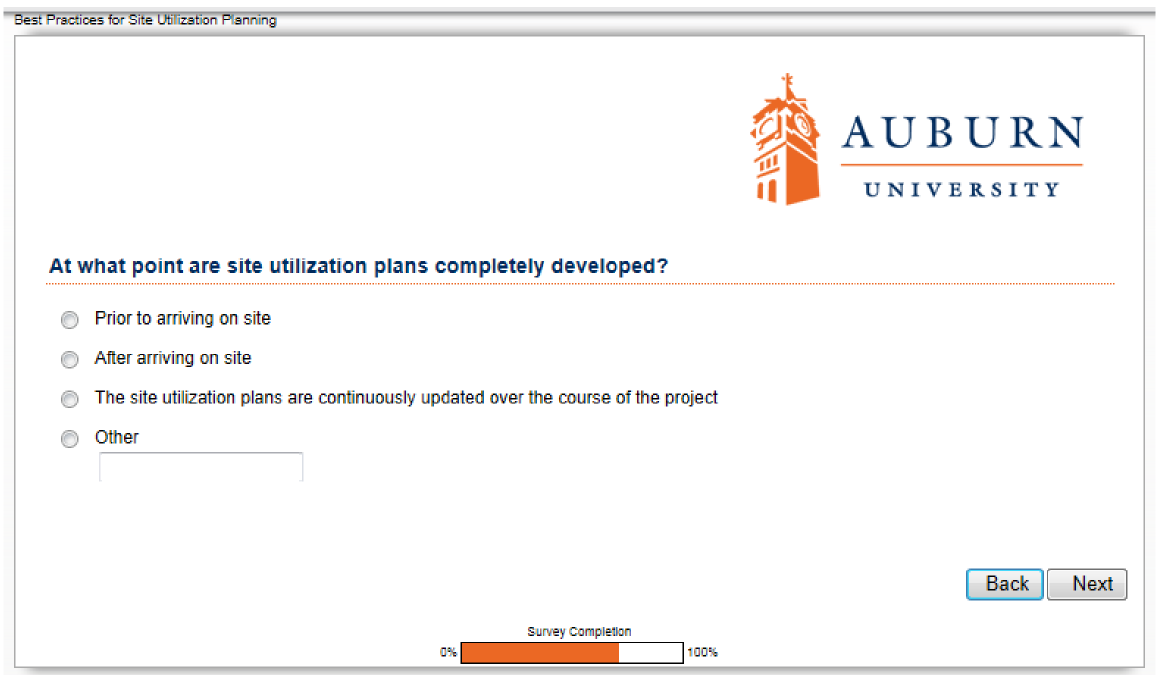
Best Practices for Site Utilization Planning

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UNIVERSITY

At what point are site utilization plans completely developed?

- Prior to arriving on site
- After arriving on site
- The site utilization plans are continuously updated over the course of the project
- Other

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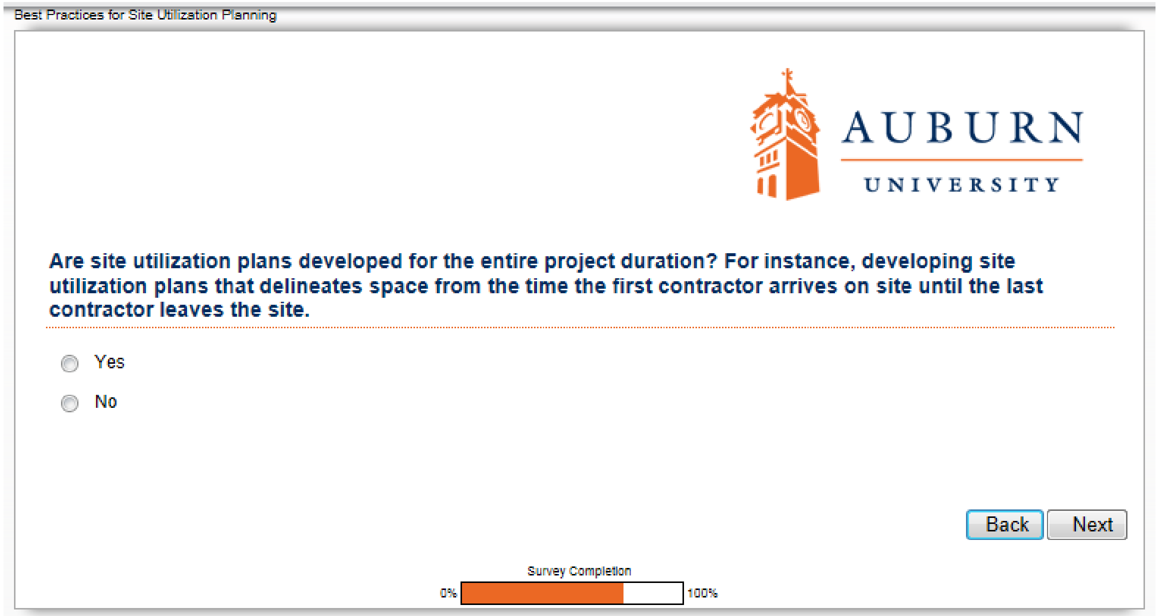
Best Practices for Site Utilization Planning
AUBURN
UNIVERSITY
Are site utilization plans developed for the entire project duration? For instance, developing site utilization plans that delineates space from the time the first contractor arrives on site until the last contractor leaves the site.
Yes
No
Back
Next
Survey Completion
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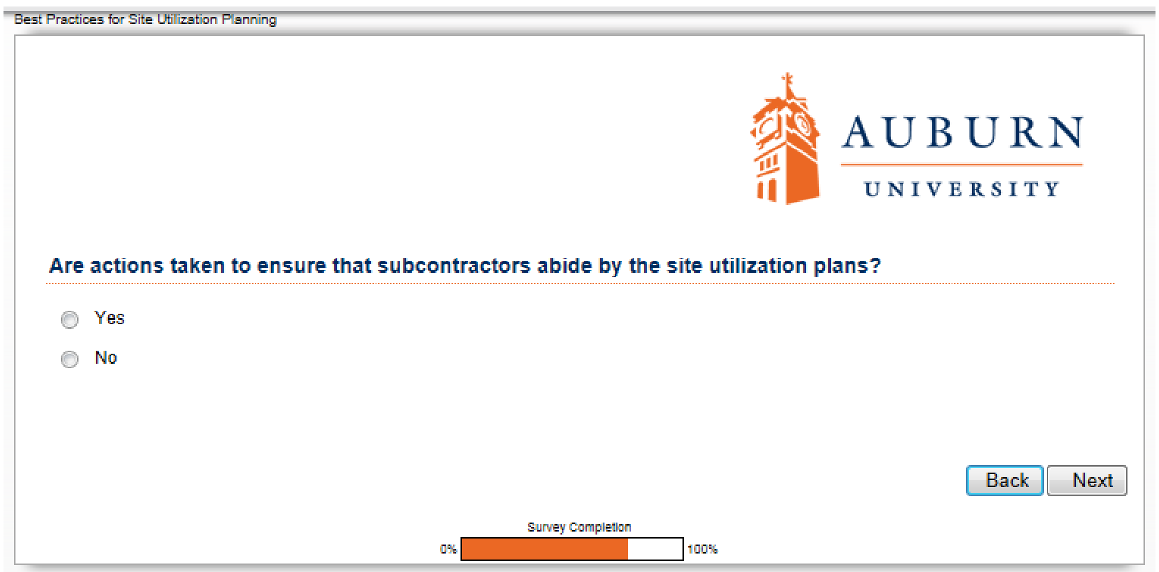
Best Practices for Site Utilization Planning
AUBURN
UNIVERSITY
Are actions taken to ensure that subcontractors abide by the site utilization plans?
Yes
No
Back
Next
Survey Completion
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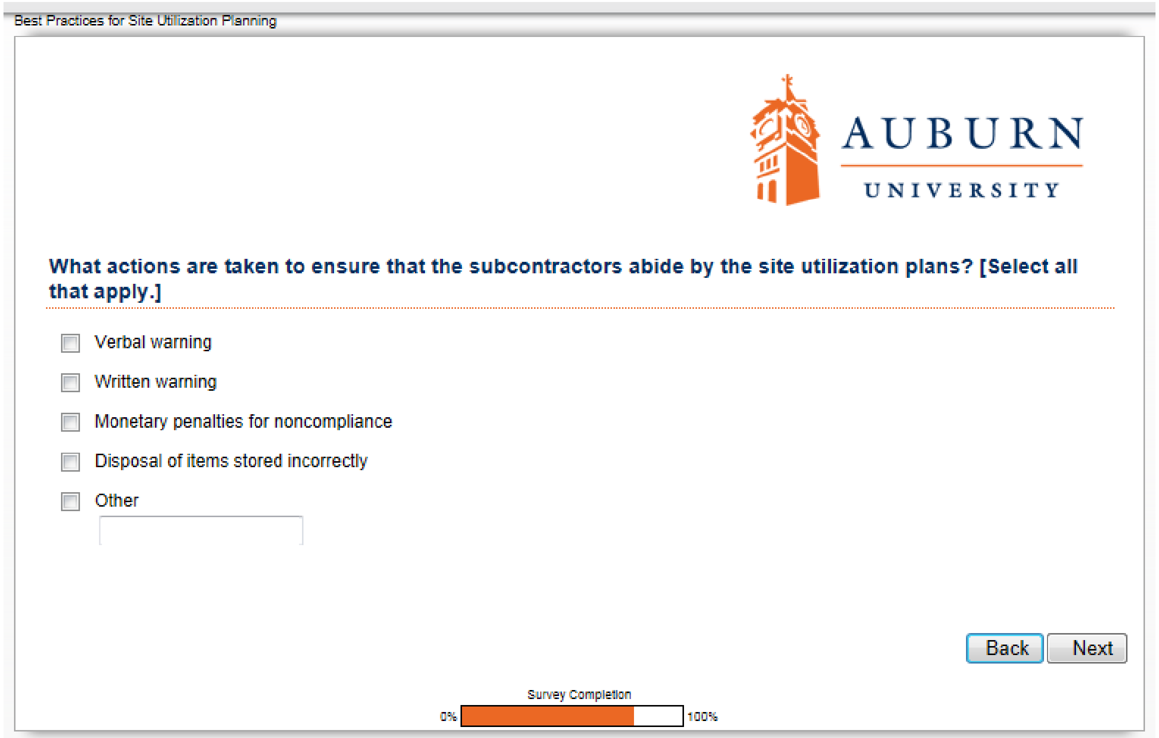

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

What actions are taken to ensure that the subcontractors abide by the site utilization plans? [Select all that apply.]

- [ ] Verbal warning
- [ ] Written warning
- [ ] Monetary penalties for noncompliance
- [ ] Disposal of items stored incorrectly
- [ ] Other

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Survey Completion

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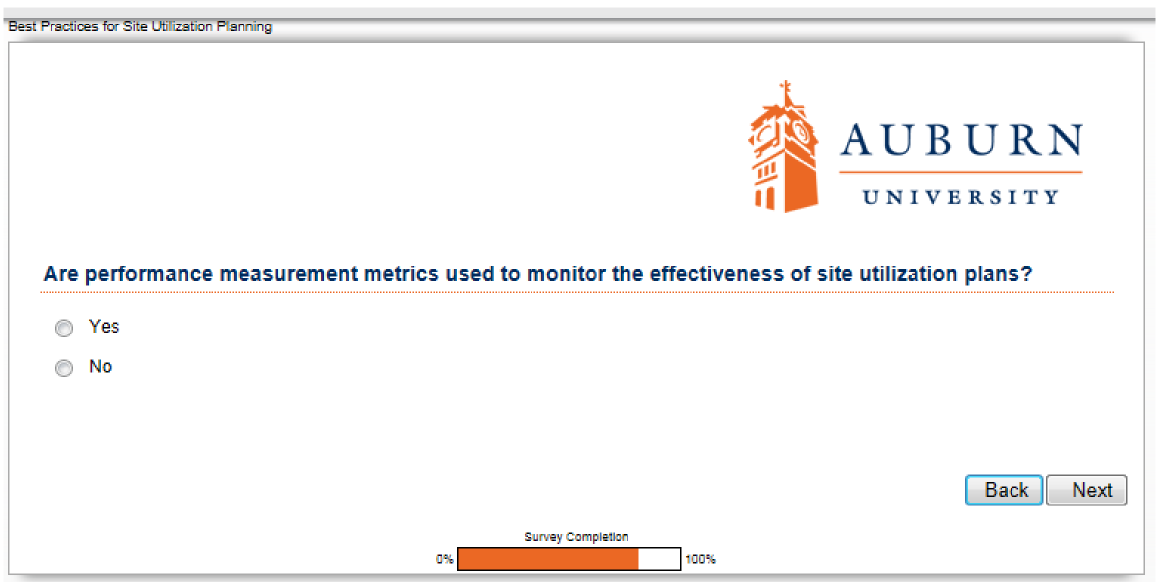

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

Are performance measurement metrics used to monitor the effectiveness of site utilization plans?

- Yes
- No

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Survey Completion

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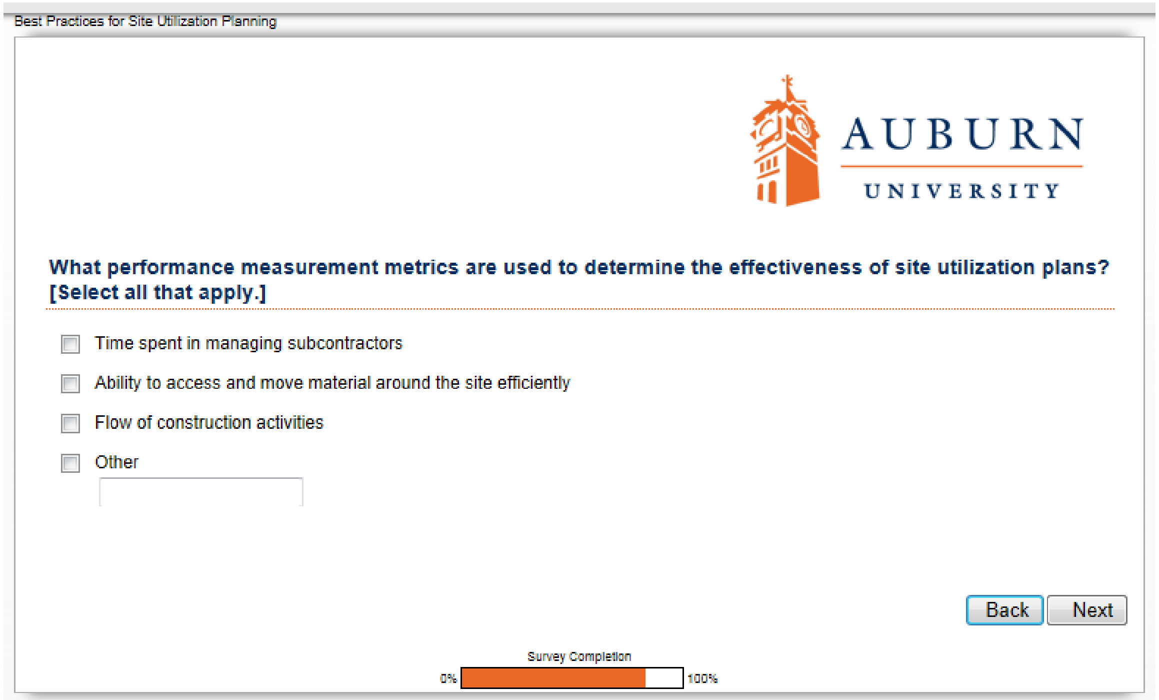

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

What performance measurement metrics are used to determine the effectiveness of site utilization plans? [Select all that apply.]

- [ ] Time spent in managing subcontractors
- [ ] Ability to access and move material around the site efficiently
- [ ] Flow of construction activities
- [ ] Other

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Survey Completion

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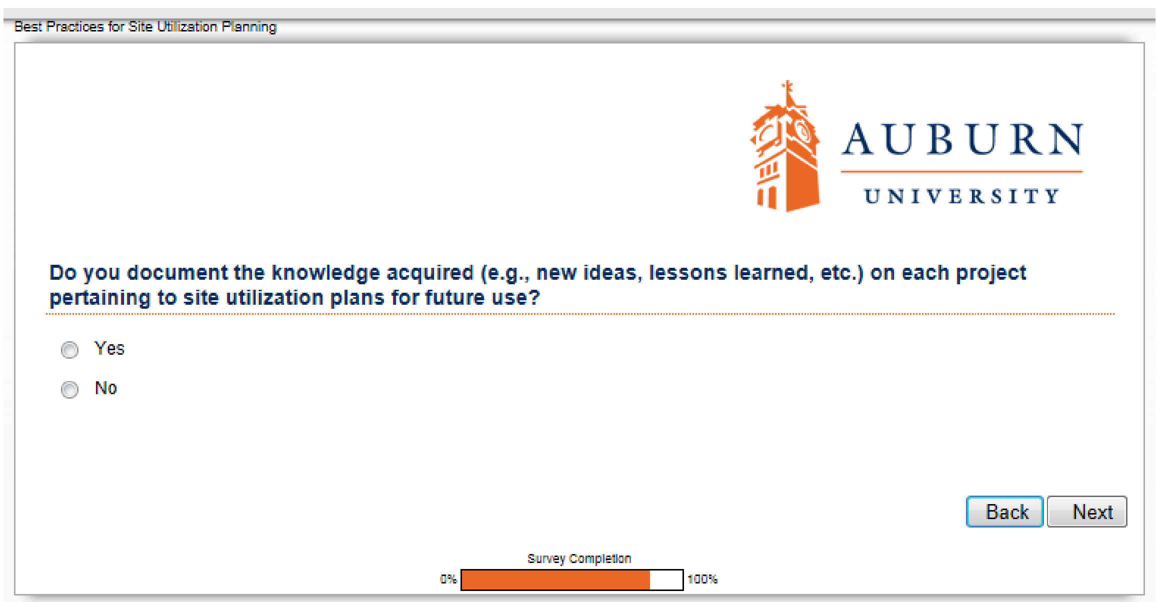

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

Do you document the knowledge acquired (e.g., new ideas, lessons learned, etc.) on each project pertaining to site utilization plans for future use?

- Yes
- No

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Survey Completion

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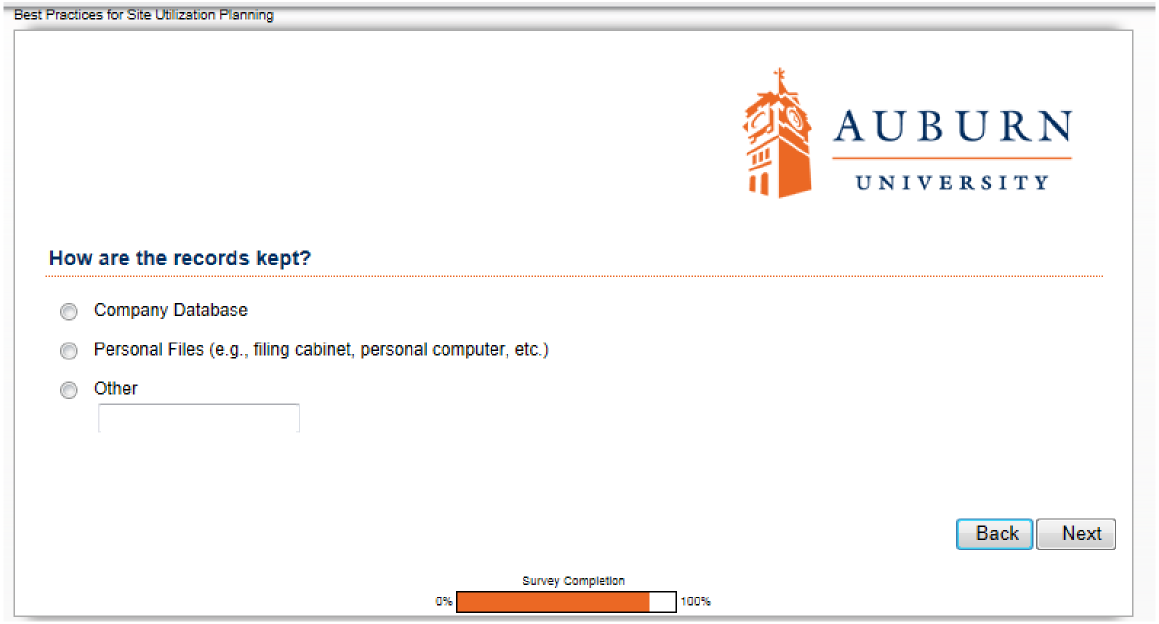

Best Practices for Site Utilization Planning

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How are the records kept?

- Company Database
- Personal Files (e.g., filing cabinet, personal computer, etc.)
- Other

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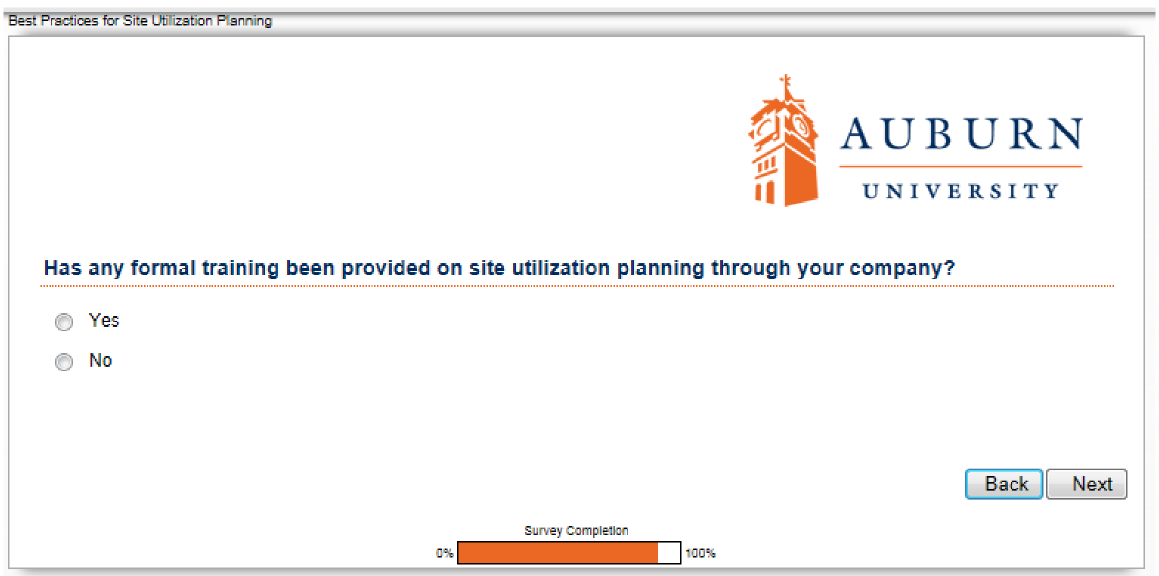

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

Has any formal training been provided on site utilization planning through your company?

- Yes
- No

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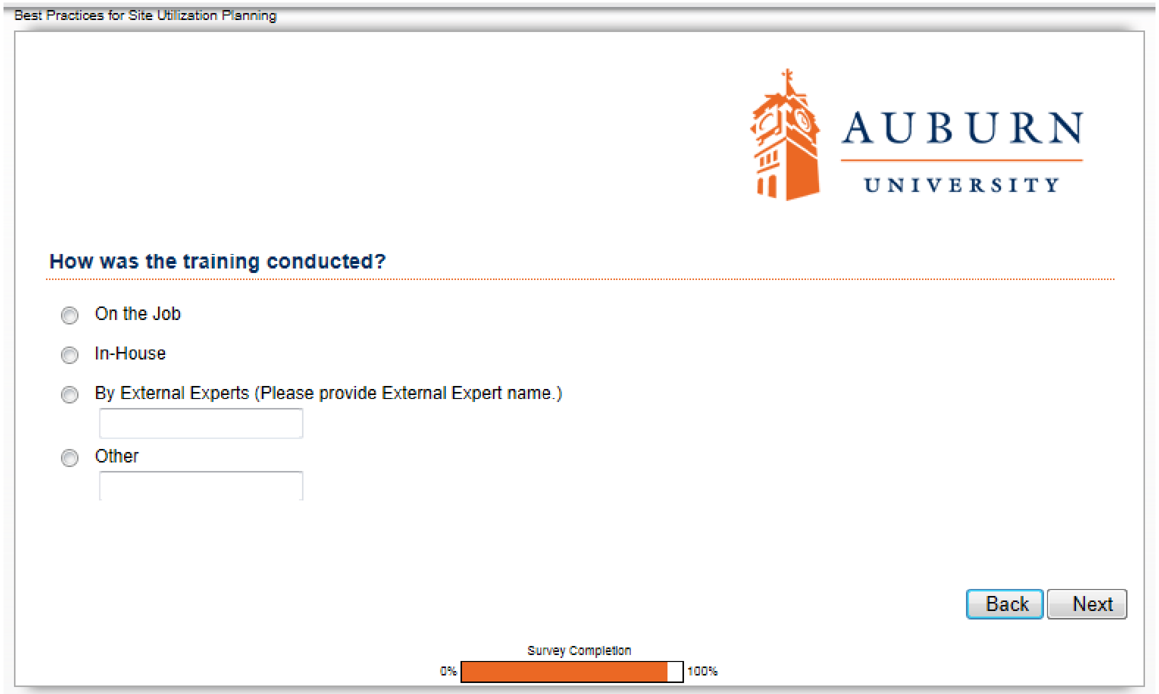

Best Practices for Site Utilization Planning

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How was the training conducted?

- On the Job
- In-House
- By External Experts (Please provide External Expert name.)
- Other

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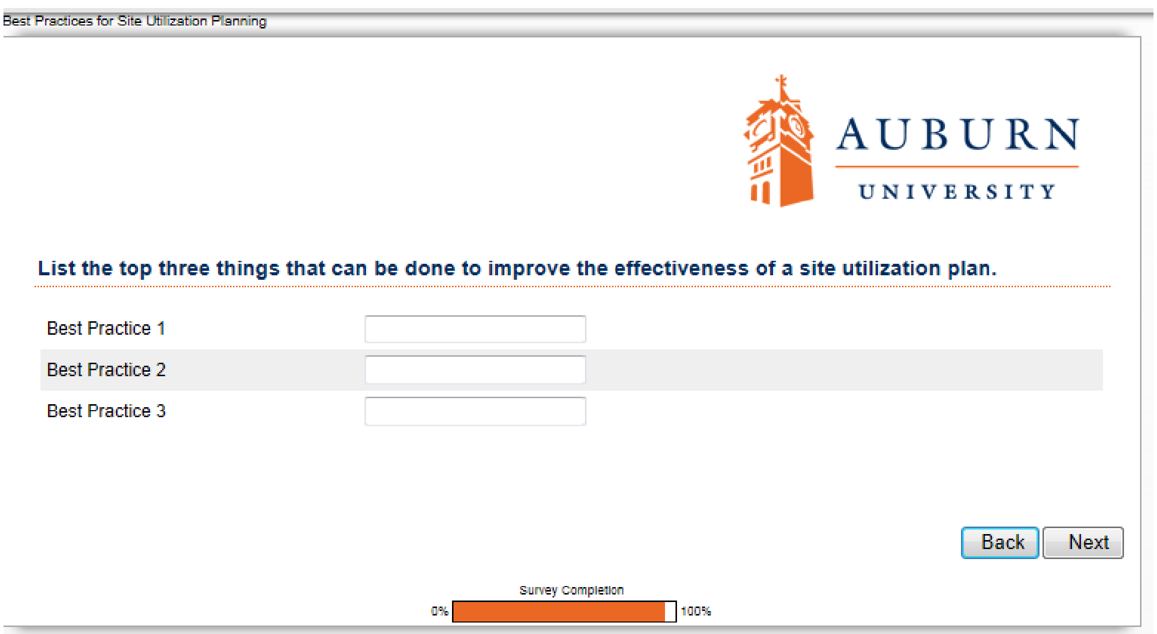

Best Practices for Site Utilization Planning

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List the top three things that can be done to improve the effectiveness of a site utilization plan.

Best Practice 1

Best Practice 2

Best Practice 3

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Survey Completion

0% 100%

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

It would be very helpful in my research to review site utilization plans in recent projects. I will be grateful to you if you could share site utilization plans from your recent project. If possible, please email me a copy at jbw0012@tigermail.auburn.edu. I will not share this plan with anyone. It will be viewed only by me and my thesis advisor, Dr. Abhijeet Deshpande.

Thank you for completing the survey. I appreciate it. I will share the results of my research with you next spring.

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Survey Completion

0% 100%

Best Practices for Site Utilization Planning

AUBURN UNIVERSITY

We thank you for your time spent taking this survey.
Your response has been recorded.

Survey Completion

0% 100%

Appendix B

Summary of Survey Results

Construction Site Utilization Planning Report

1. Please fill in as much of the following information as possible:

Name of Respondent:	Job Title:	Company Name:	Business Category (e.g., Building Construction, Industrial Construction, Heavy Civil, etc.):	Company Size (e.g., Number of employees):	Region of Operation (e.g., Southeast U.S., Central U.S., etc.)	Phone Number:	Email:	Years of experience in the construction industry:

Statistic	Value
Total Responses	221

2. May we contact you with follow-up questions?

#	Answer		Response	%
1	Yes		200	85%
2	No		36	15%
	Total		**236**	**100%**

3. Does your company develop site utilization plans for construction projects? [Note: Site utilization plans are documents that identify the locations of temporary facilities within the construction site boundaries. An example is shown below.]

#	Answer		Response	%
1	Yes		177	74%
2	No (Note: Your Survey will end here)		63	26%
	Total		**240**	**100%**

4. Please choose the statement that accurately reflects your philosophy in the creation of site utilization plans:

#	Answer		Response	%
1	We create a site utilization plan for every project we construct		106	59%
2	We create site utilization plans only for projects where space available is very limited		39	22%
3	Other		33	19%
	Total		**178**	**100%**

5. Does the number of subcontractors participating in a project influence the decision to develop site utilization plans? (For Example, Site Utilization plans are typically only created in projects where large number of subcontractors are likely to participate, creating a competition for space at the job site.)

#	Answer		Response	%
1	Yes		69	39%
2	No		109	61%
	Total		**178**	**100%**

6. Does the monetary size of a project influence the decision to develop site utilization plans?

#	Answer		Response	%
1	Yes		53	30%
2	No		125	70%
	Total		**178**	**100%**

7. Does your company use software to develop site utilization plans?

#	Answer		Response	%
1	Yes		123	69%
2	No		54	31%
	Total		**177**	**100%**

8. What software is used to develop site utilization plans? [Select all that apply.]

#	Answer		Response	%
1	CAD		60	49%
2	BIM (Building Information Modeling)		74	60%
3	PDF Overlay		98	80%
4	Other		24	20%

Other
Google Sketchup
Sketch-Up
Bluebeam
MS visio
SketchUp
OST
Sketch up
MS Office (Excel, Word and Powerpoint)
Powerpoint
On Screen Takeoff
Bluebeam
On Screen Takeoff
on screen
google earth
Aerial Photos (Google Earth), Sketch-up
Drafting
Hand sketches
sketch up, visio
Visio
Bluebeam

9. Has your company used BIM (Building Information Modeling) recently during the construction of a project?

#	Answer		Response	%
1	Yes		127	71%
2	No		51	29%
	Total		**178**	**100%**

10. In what ways was BIM used during construction? [Select all that apply.]

#	Answer		Response	%
1	Construction Schedule Visualization (4D Models) [Note: A 4D Model is the combination of a schedule (time) and a 3D Model.]		77	61%
2	Identifying Clashes and Conflicts		122	96%
3	Communication between A/E, Project Manager, and Owner		98	77%
4	Documentation and Claims for Change Orders		46	36%
5	Site Utilization Planning		72	57%
6	Other		17	13%

Other
All of the Above
Prefabrication
Point Cloud
Estimating, Quantity Take-Off
5D Model Based Preconstruction
Planning for job site safety risk
Renderings
Quantity Takeoff
5D quantity export
Limited marketing
Phasing Plans
Coordinations with Trades & to build the project
Subcontractor coordination
not involved. can't say

11. Who is typically in charge of the development of site utilization plans?

#	Answer		Response	%
1	Project Manager		81	46%
2	Project Engineer		15	8%
3	Site Superintendent		51	29%
4	Other		30	17%
	Total		**177**	**100%**

Other
General Field Coordinator
PM & Superintendent together
Both Super and PM
Project Executive and/or PM depending on the size of the job
and PM
Collaborative effort betweek Project Engineer & Project Superintendent
PM & Supt
Project Superintendent and Project Manager
BIM Manager
Project Team does it collabortivly
PM, PE and Superintendent all build one together
Project Team with the superintendent as the lead
Shared responsibility between PM & Supt
Pm and super
PM and Site Manager
Estimating w/ Help from Project Management & Supervision team
All above
Superintendent/PM
Project Manager and Estimating Team
PM & Estimator with Input from General Superintendent
Typically it is a collaborative effort between the Project Manager and the Site Superintendent
Combination of CM, Project Controls Planner
PM (for the “picture”) with the Superintendent for most of the technical input
A/E
Depends on the make up of the team and our role.
Design/civil engineer
PM and BIM Integrator
Construcion Manager
designer

12. Are subcontractors involved with the design of site utilization plan(s)?

#	Answer		Response	%
1	Yes		91	51%
2	No		87	49%
	Total		**178**	**100%**

13. Which subcontractors contribute information in regards to the development of site utilization plans? [Select all that apply.]

#	Answer		Response	%
1	Foundation		64	72%
2	Structural		71	80%
3	Electrical		64	72%
4	Plumbing		55	62%
5	HVAC		48	54%
6	Other		34	38%

Other
civil
Sitework/Erosion Control Subcontractor
any with large storage requirements
depends on the project specifics
Site Subcontractors
Site contractor
Sitework and Utility
typically all major subs
process piping and instrumentation
all
Earthwork/Utilities
Civil
Site contractors
Sitework
depends on the project. I'd also like to add that it is not always that a sub is involved. The previous question did not allow for an "other" answer.
All trades that have major material deliveries, are involved with civil and or temp utilities, and that need onsite storage / offices are involved.
All
Pool, Grading/Utilities
sitework
Civil
All (anyone that needs laydown, trailers, etc.)
Site
Sitework, Mason
All of the Above
Utilities and skin
MEP trades
utilities
Large subs needed laydown areas + all utility subs
"major" subs with significant access, laydown, staging, equipment requirements....varys from job to job
all
General Contractor
Predicated on site size, site complexity, project size and inter-trade complexity

14. What information do subcontractors typically provide prior to arriving on site? [Select all that apply.]

#	Answer		Response	%
1	Number of employees that will be on-site		110	62%
2	Number of tool sheds / job trailers that will be on-site		139	78%
3	Type of equipment that they will bring to the site		143	80%
4	Amount of on-site space needed		142	80%
5	Other		23	14%

Other
USACE doesn't have access to subs when preparing site utilization plans
depends on the project conditions
Subs are expected to work within the site space available due to schedule constraints factored into the space provided by GC. Allowances are made as needed.
Materials, Sequencing, Coordination Requirements
Delivery/laydown area/staging
Access to work, loading of materials, traffic control
again, this all depends on the size of the project, the size of the subcontractor scope and the complexity of the subcontractor. We try to utilize subcontractor input as much as necessary but they do not always get what they want.
Access/hoisting reqts/preferences for major deliveries
Delivery sequences
None
Crane reach, delivery frequency, etc
In most cases you can not allow the subs to tell you how much space they think they need because one or two subs will want all of your avalible space, you tell the subs what space they can have for trailers and laydown and have them work out the logistics of properly utilizing the area they have to work in.
In most cases as the Prime EPC Contractor we define the site office area space then subs provide space they require for material lay down needs
subs are not consulted - preparation of plans is largely based upon our experience
Typically we coordinate with them and limit what the site allows for
Sub provide information to our prime contractors, not to us.
typically the plan is developed before subs are involved. Often they are told how much space they can use, not how much they want.
all of the above
we do not normally deal with the subcontractors
to the prime
n.a. to me
Any special security considerations

15. Do any subcontractors / trades get priority in site space allocation?

#	Answer		Response	%
1	Yes		134	77%
2	No		41	23%
	Total		**175**	**100%**

16. Which subcontractors / trades get priority in space allocation? [Select all that apply.]

#	Answer		Response	%
1	Foundation		56	41%
2	Structural		83	61%
3	Electrical		65	48%
4	Plumbing		50	37%
5	HVAC		50	37%
6	Other		50	37%

Other
CIVIL
timing based
It depends on size and project type. Early one, the foundation and 144riority144l guys get allocation as needed. Later in the game, MEP trades tend to get the most attention.
Masonry, others as required by specific project needs
Depends on who has the most "stuff" (materials, on site staff, equipment, etc)
Depends on who has most scope and amount of space needed also.
Depends on where you are in the schedule
Site
the subs related to critical path items will typically get 144riority.
Depends on Timing
Depends on the complexity of the subcontractors scope if they get priority space allocated to them.
We fab all rebar, structural steel and process piping onsite,
Any trades that have Critical Path Activites to maintaining the schedule
Civil/Utilities, Exterior Skin
Scope defined
Any trades with large material deliveries that require sequencing, identification can get priority. Each project is different
Precast
Usually job dependent
All subs – depends on activity being performed
Precast, Steel
Most critical contractor for that period of time
any sub with critical work
Drywall, Skin trades
Varies per project.
Drywall
Critical Path Subs
At some point, they all get priority
It is based on schedule and critical path. Priorities are assigned and change based on the schedule.
Determination of this is very project specific. Also the "site" and priorities change over the coarse of a project
utility
Varies, foundation, then structural, then skin, etc.
Depends on the job and relationships with the general contractor
Varies through different phases of the project
Mechanical
Site
Depending on the specific project, those that need it most
GC (PA is a multi-prime state – our company works primarily for the public sector)
again…can vary based on size / scope of different packages
Site Grading/ utilities

Primary work sub
Depends on logistics and site
Unknown to us as the Owner. This is between our Prime contractor and the sub.
Earthwork equipment mandates space allocation more than other trades.
Those who require it once their need has been vetted and confirmed
depends on the specifc needs of the sub and the project
the schedule dictates the priority – earlier subs get priority but then must yield when the bulk of their work is completed
Predicated on phasing and scheduling
depends on the project

17. Do owners typically get involved in the development of site utilization plans?

#	Answer		Response	%
1	Yes		124	70%
2	No		54	30%
	Total		**178**	**100%**

18. What information does the owner typically provide with regards to site utilization plans? [Select all that apply.]

#	Answer		Response	%
2	Existing site conditions		132	75%
3	Environmental concerns		91	52%
4	Preferred access points in and out of the site		156	89%
5	Construction traffic routes		128	73%
6	Other		35	20%

Other
Fence Details
space limitations
Only contractually required information
Pedestrian Routes, Available Delivery Times, Restricted Work Hours, many others
Sales/Leasing Office
Public and Staff Safety
Hours in operation. Major utility locations if buried
The owner should be well aware of how the site will be operating in term of entry points, laydown, protection, etc...
This is where it gets a little tricky, as ExxonMobil Development is the owner (we manage site construction based on our expectations/priorities)
Ongoing campus operation information. We construct in "active" sites all the time and this is valuable info
Lay Down, Parking, Fence
Areas to stay away from
Safety/Security
the owner's typically don't get involved but they typically do provide restrictions that will impact certain aspects of the site utilization plan. Many times, these restrictions are stated in the RFP.
Temp Utility connection points
Any coronation if they have facilities or operations on site
Campus/ Area logistics & challenges, lane closures
Normally the only owner in put is where to put the construction entranc, unless you are at an univerity or a plant like Mercedes were the owner gets very involed to the point of already having most of your site plan done before you even get on site.
sometimes approvals, otherwise it is means and methods
An operating facility can affect site utilization plan
Interface with existing operations
operational impact feedback
As EPC contractor we work with owner to provide space required and since they often review submittal
as-constructed drawings
safety
owners we represent are not typically involved
Occupied areas
What they will allow for us to use and what concerns they will have relative to the construction...
Site evacuation routes, parking, sanitary facilities
Parking for their people
Timeframes, notifications, coordination requirements with property owners, permit conditions, etc.
approval

Predicated on whether project is rural, urban, or in the CBD; the unique characteristics of the project will place special demands on project participants; I.e. a rural gas plant may required a camp; an urban WWTP could require noisy pile driving and a tunnel under the CBD could require in street top down construction
Operational constraints for their access to critcal portions of their plant site

19. Which of the following temporary facilities are typically included in your site utilization plans? [Select all that apply.]

#	Answer		Response	%
1	Job Trailer Location		168	94%
2	Tool Shed Location		101	57%
3	Parking Lot Location		169	95%
4	Dumpster Location		136	76%
5	Break Area		51	29%
6	Underground Utilities		102	57%
7	Building Footprint Area		158	89%
8	Job-site Access Point		164	92%
9	Off-Site Storage		44	25%
10	On-Site Storage		151	85%
11	Unloading Area		102	57%
12	Work Areas		85	48%
13	Staging Area		158	89%
14	Equipment Area		80	45%
15	Hazard Area		81	46%
16	Protected Area		92	52%
17	Soil Storage Area		96	54%
18	Other		31	17%

Other
Conc washout, toilets
Construction Limits
Tire wash, Construction Fence, Temp Utilities Connections, Easements, Emergency Access, Media Staging, Wayfinding
Emergency staging areas
it varies depending on t he job, but I've chosen the ones I've most often been asked ot model
Crane Area
First Aid
Crane pads, temp roads
Currently work in a fabrication yard, and not in a stick built green/brownfield environment.
Temp roads and utilities
Restricted Areas
Tower Crane locations as well as pedestrian access when it needs to be re-routed.
Crane paths, toilets, etc.
Emergency routes
Fencing, Crane location
boundaries, existing buildings, tower crane, buckhoist/ material lift location, toilet facilities
Crane and Hoisting locations
all of these
Muster Area
concrete wash out, SWPPP
Note that subs are provided material Layton area by square feet/ acre requirements in which they are to confirm is acceptable during negotiation. This info is also base on delivery schedule as well. Additionally, our site utilization plans also include a crane plan for major rigging and heavy load picks.
Areas requiring BMP
Most of these apply and not all of these are used all the time.
Temporary power
Specifics dependent on project
Environmental considerations
Haul routes, all hoisting equipment and swing radii
All predicated on the type of project, project location, and schedule complexity
tracking pads

20. Does your company explicitly consider the following when developing site utilization plans? [Note: Selecting implies that it is considered.]

#	Answer		Response	%
1	Movement of Equipment		148	89%
2	Movement of Material		159	95%
3	Movement of Personnel On-Site		107	64%

21. How does on-site space get distributed between subcontractors if site space is limited?

#	Answer		Response	%
1	First come, first serve		8	5%
2	Subcontractors that preform critical activities get on-site space first		125	71%
3	Other		42	24%
	Total		**175**	**100%**

Other
not considered
Critical Path 1st
most productive use of limited space, subs rotate in and out
Just In Time Delivery
Coordination based on schedule sequence, amount of material, alternate storage locations, contractor performance, other factors
Depends on when sub is needed on site along with amount of scope and number of people managing the scope of work.
Critical items usually get priority
Longest duration on site gets first priority. Typically these same firm have most work.
Depends on Timing
largest amount of materials get priority
Depends on manpower and indirect staffing requirements
Superintendent's discretion
On-site space provided when needed according to schedule and phasing
Case by Case Basis
staging and sequencing of work depends on different phases of construction and different materials implemented along with the method of installation
LEAN considerations – what is most effective use with least wasted motion
Again job dependent on which subs will get what amount of space and its location.
Job specific – can't answer without understanding the project first.
The on-site space isneed based when considering the projects best interest.
Plan work for on time deliveries and flow of manpower.
Depends on project.
If done correctly, the general contractor should gather input from all vested parties and work collaboratively to determine the proper allocation of on-site space, taking into account the fact that the site itself will change and well as the demands for space will change on a daily, weekly, monthly basis. Site utilization, if done properly, is not a one time exercise, but should be addressed in project progress meetings.
We utilize "pull" scheduling, so we coordinate activities in collaboration
This is a contractor question.
CPM Schedule
Work needs that require subcontractor presence on site
by need
Coordinated by GC
Depends on the project, subs whos work requires most space, gets most space
Phase gets priority, those working demo/site clearing get first shot, then those working at/below surface level, etc.
Based on the sequence of work
Our prime contractor negotiates or directs this to his subs
Every trade is important, but time critical activities are often a priority.
Actual need vs want
Staged by schedule sequence
Prime contractor makes this determination

Prime is in charge
schedule and importance
Predicated on scope criticality, progress, or struggles, phasing out one scope and phasing in another. Also can vertical space be utilized as in high rise construction
determined by GC on a project by project basis

22. How is the location of each on-site temporary facility determined? [Select all that apply.]

#	Answer		Response	%
1	Computer software		18	10%
2	Past experience of the site utilization plan developers		155	89%
3	Other		40	23%

Other
coordination with existing/new utilities
DPW
discussion with subs
Knowledge of the areas least likely to need disturbance
interview with users
It is reviewed by the team to see what is logistically the best location. Each job is different.
Evaluating Jobsite
Hoar's experience
General site layout reviews
Existing conditions
Taking into account Owner instruction or contract document requirements
What works best for the current project.
Job dependent
location of temporary power, roads, etc.
Construction sites are not standardized. You could be on a high rise on job and at an airport the next.
Past experience and unique job layout considerations
least interference with the completed structures
specifics to each site determine what makes sense on that project. Use understanding of construction activities, equipment, and material to determine spatial relationships
Based on specific site conditions for serviceability, access, and to ensure Superintendent has 152ontrol of deliveries and all access to the site.
A combination of past experience and a fresh look at current project needs. I don't know how a software program could be utilized to determine this.
Site specific
Staging, phasing and schedule
Preconstruction Director input
Detailed Owner interview to understand operational needs
coordination with Owner – most times the Owner will provide direction with their preferred location(s)
GPR / As-builts
Community outreach and input
feedback from appropriate parties
Coordination between contractors
sub input
Prime is in charge
Site Observation
Construction staging needs of unique project being planned
It may be driven by owners documents. It may be that GC dictates site temp facilities to subs and drives them to drive their scope, or predicated on GC/Sub past working relationships it could be performed in a collaborative workshop
Available spaces at the operating plants
Specifically laid out based on exact site conditions and constraints

Project particulars usually dictate the terms of the plan. Very few plans are considered "boiler plate."

23. Does your company create multiple site utilization plans for different phases of construction? For instance, developing site utilization plans for substructure phase, superstructure phase etc.

#	Answer		Response	%
1	Yes		126	71%
2	No		52	29%
	Total		**178**	**100%**

24. What level of detail is incorporated into the site utilization plans?

#	Answer		Response	%
1	Low: Only the locations of essential temporary facilities (e.g., office trailer, construction entrance. etc.) are selected.		23	13%
2	Medium: The locations of material/equipment storage are selected; as well as, the essential temporary facilities.		127	72%
3	High: Almost every item within the site boundary has a predetermined location.		27	15%
	Total		**177**	**100%**

25. How much time is invested in the preparation and development of site utilization plans?

#	Answer		Response	%
1	1-8 hrs		42	24%
2	8-40 hrs		94	53%
3	40+ hrs		26	15%
5	Other		15	8%
	Total		**177**	**100%**

Other
Varies depending on project size and complexity
Depends on the job , size and logistics. Some jobs have unlimited space with less planning time needed while others may need many hours of research and development and planning by all team members.
Varies based on the complexity of the project
contingent on job size and scope. Jobs that we build can span over multiple years and construction is phased so the plan is constantly evolving.
Depends on size and complexity of the project
Depends on project type.
Depends on the project, but most plans can be created in less than 1 day, more than likely.
Depend of the site and complexity of the project
40+ depending on project size
Dependent on project size and complexity.
The more complex the project the more time is spent.
Developed by engineer
Predicated on project scope, location, complexity and schedule demands, site utilization plans may take a 100 hrs or more
Depends on the individual project. Varies by the size of the site, where the project is located, phasing requirements, etc. Could range from a couple of hours to a couple of weeks
Time invested is completely dependent on the project particulars and Owner requirements.

26. At what point does the preparation and development of site utilization plans begin?

Text Response
During project planning phase
After award and before mobilization onsite
Shortly after Notice of Award.
Design of the Project or Beginning of the Request for Construction Proposals
After contract award and prior to mobilization.

pre-bid. We need the information to do a good estimate of GCs
Pre construction
Fisrt thing
Prior to groundbreaking
Depends on scope of project. Sometimes during estimating, other times upon GC mobilization.
Once plans are received from the architect for construction.
Estmating/preconstruction
proposal
Preconstruction
At the start of the scope and estimate.
Preconstruction
pre-construciton. Usually with DD drawings
Either before award of the job if in a negotiated setting so that the owner can see this during the interview or soon after award.
Initially for bidding to determine if off-site storage and personnel/office allowances need to be budgeted into bid
Typically we put the preliminary plan together prior to a proposal.
At dirtwork
as soon as the bid is won
During site Schematic Design Phase
Estimating
In the bid process
During the initial design phase around 65% developement.
Notice to proceed from Owner
Usually well before the job is awarded, as this needs to be completed in order to price, schedule and plan.
After DD's are complete and when we know the project is going forward
Immediately with mobilization
business development, we create them for proposals all the time then if we when the job they develop the logistic as the project moves through precon and into construction
First week
Usually during Design Development Phase
After award, prior to mobilization and construction where possible.
Prior to construction start and erection of BMP's
Estimate/Bid
Early Programming Stage
Usually during the bidding process, site utilization is considered.
Award of contract
Discussed during pricing. Fully implemented upon contract award.
During bidding or negotiation to determine cost of temp facilities.
As soon as project is awarded and site visit is made

Preconstruction Phase
In preparing presentations to win the job if it is a tight site
During the early stages of precon serivices-usually during the Schematic design pahse
The Chase
Typically initial designs/discussions take place with the contractor during front end engineering development in which site planning and execution concerns are discussed.
During estimating, we analyze space availability during site visits
Site utilization plans are part of the Project Execusion Plan which is incorporated into the Project Study and Capital Cost Estimate which is submitted to the Board of Directors and Financial Institutions to get approval for the projects. In certain cases, this plan will as be reviewed by the government regulators who issue licenses and permits for the project.
Usually presented to the owner during the GC selection process (before the project is awarded)
When Estimating the job
initial considerations given during pricing phase, then once project is awarded, SUP priority along with sub awards.
Depending on the client's method of award, site utilization plans are many times a part of the GMP presentation by competing CM's prior to project award.
During preconstruction planing and estimating
As soon as the job is awarded.
Bid/Price Preparation
Preconstruction stage prior to bidding the subcontractor bid packages
As soon as the job is awarded
During project sales pursuit/prior to being selected for the project
Presentation & Precon
During Bidding or initial budgeting.
When the contract is signed. Or before if you want to WOW the Owner to show how interested you are in their project.
Preconstruction phase during budget development or bid process
For hard bid jobs, during the pre-bid stage, for pre-bid proposal presentations with the owner. Negotiated or cost + jobs, during pre-con.
Depends when the project is awarded. Site plans are discussed very early.
Varies by project design and impact of site limits.
Thought process will start early on but most of the planning will start once we arrive on site and see what we are working with. We have several international jobsites all around the world so you really don’t know what you will be working with until you arrive on site. Domestic jobs are usually much easier and most of the work can be completed upfront. Job scope and complexity have major factors in each plan.
At project award. Site utilizaion plays a factor in many aspects of the total project, including schedule so figuring out the site plan is always critical. On most cases, the preliminary site utilization plan is developed before the RFP Response or bid are turned in.
Preconstruction
Prior to bidding the Project - if offsite storage/parking/etc. is required, it must be included in the bid
Prior to mobilization.

At the time of preparing the presentation for the interview in which the contractor is selected.
After award of contract; prior to mobilization
As soon as project is turned over from estimating as an awarded job. Sometimes we do them during precon to help us show clients we have thought out a plan
Preconstruction, pre-contract
Inititial construction feasablity site visit.
Project start up or RFP response
Plans stage
Site Utilizationg Plan is started during the Budget Process and Preconstruction
Depends of the delivery method but from the very beginning. While developing the bid, presentation or at negotiations
Commencement of construction
in preconstruction at the earliest stage possible
Preconstruction - estimating and pre-planning
Pre- Construction phase
Upon project award...occasionally, the owner will want to see in the proposal stage.
At the earliest time... often, we prepare a preliminary site utilization plan for the sales presentation, before we even have the award for the project
Typically after award, but can be as early as estimating phase.
Preconstruction
After the project has been awarded but prior to mobilization to the site.
Beginning
During estimation/bid/negotiation phase
Even if it is not put to paper, the planning begins at conceptual.
during preconstruction. site logistics affect the schedule, efficiency, cost of a project
When the project is awarded to us.
Between contact execution and commencement of construction
Initial phases of preconstruction planning
project award
Estimating
Pre-Construction; Pre-Bid
Pre construction and planning phases
Prior to submitting the final cost proposal or GMAX
Pre-construction
prior to bids and or pricing
Proposal stage
Prior to the issuance or receipt of the notice to proceed.
after plans are approved for permit and upon executed contract.
It should be concurrent with phasing and staging development. depending on the size of the site multiple locations may be requried.
Between Schematic Design and Design Development
Planning Phase of the Project, so could be identify as part of the design and bid packages

Since we do 80% Negotiated work it starts almost immedatially post award
Prior to submittal of pricing.
Preconstruction
Pre-Construction Phase
Typically it is requried to be submitted with the RFP responce
before constrcution
Roughly a month before the project starts.
Bidding
Biddign document assembly.
On a program - multiple building site it begins with master planning
during the response to RFP
Design Development if not sooner depending on the constraints
RFP
Since we typically provide eng + procurement + construction services we begin at preliminary engineering using input from our construction manager and estimating department. Since most of our projects are large ($100m+) it is critical to have a good understanding of how much material storage space is needed including the number of containers that will be delivered and when. Often we define the delivery due dates to coordinate just in time delivery and material management logistics.
PFI
50% design, no later than 75%
Once the A/E is engaged.
At the design development phase
Upon selection of the Construction Manager for the project.
Site location / existing utility determination
early in the design development process
prior to contract award (in the case of the negotiated project) - this plan becomes a "selling" point. More detailed plans are developed immediately after award so details can be communited to trade contractors
pre-construction
As soon as we begin consulting onthe job and reviewing drawings.
design phase
Concept design
a few weeks before mobilization it is fine tuned - typically these might be prepared as early as during the pursuit proposal phase for an interview.
Once we have finalized the facility layout and access roads
during design
During solicitation of contractors
From the onset of design
Schemaiic Phase
At 30 % design completion.
During final design

30 to 60% design level.
per contract, as ofter the site utilization becomes part of the contract language.
As soon as the project is located horizontally and vertically in its approximate position
Pre-construction / Design
Prior to mobilization on site
At project award during preconstruction submittal phase
During Design Phase if possible for rough details; within 90 days of NTP after construction contract is awarded for detailed plans
notice to proceed
excavation site development, again at masonry/structural, again for roofing
Upon notification of earning the apparent low bidder designation
before a project is released for bid
40-60% of design documents
First meeting of the Design Charette
pre-project planning
30% design
mobilization
Preliminary Design Phase
design
Generally try and have initial drafts done 3-6 months prior to commencement of onsite activities.
After contract award during the detailed project execution plan preparation.
At the very beginning, during the design phase of the project.
shortly after project footprint is fixed
Beginning of Pre-Construction Services
At 30% design typically when the scope of the project is being developed
during land development planning and approvals
60% design (transportation projects)
Feasibility study or at proposal stage
30% design
Initially. We develop the plan while developing the CPM schedule and discussing building flow/access to project.
Prior to beginning the project starting with the field office
During the preconstruction process. The specific requirements for the site utilization plans needs to be considered while compiling the budget and schedule. It is best to have this plan nailed down prior to finalizing the budget and schedule.
Usually by the 60% design phase.
After the development of Design Development Drawings

27. At what point are site utilization plans completely developed?

#	Answer		Response	%
1	Prior to arriving on site		67	38%
2	After arriving on site		14	8%
3	The site utilization plans are continuously updated over the course of the project		88	49%
4	Other		9	5%
	Total		**178**	**100%**

Other
As needs change so can the plan
Again, work in a fabrication yard, so this is a unique situation.
Prior to start of work with the understainding that the need for modifications might occur
SWPPP dictates many items
In advertised contract documents
plans are updated as needed.
A & C or 1 & 3
prior to bid advertisement
If a D/B job site utilization plans are fixed shortly after project foot print is fixed. If a public bid, as GC, we used to have subs provide site utilization needs with their bid, and then sort out the conflicts after we won the job

28. Are site utilization plans developed for the entire project duration? For instance, developing site utilization plans that delineates space from the time the first contractor arrives on site until the last contractor leaves the site.

#	Answer		Response	%
1	Yes		123	69%
2	No		55	31%
	Total		**178**	**100%**

29. Are actions taken to ensure that subcontractors abide by the site utilization plans?

#	Answer		Response	%
1	Yes		168	95%
2	No		8	5%
	Total		**176**	**100%**

30. What actions are taken to ensure that the subcontractors abide by the site utilization plans? [Select all that apply.]

#	Answer		Response	%
1	Verbal warning		141	84%
2	Written warning		113	67%
3	Monetary penalties for noncompliance		54	32%
4	Disposal of items stored incorrectly		56	33%
5	Other		43	26%

Other
Poor Evaluation
Public Temper Tantrums
back charge - Moving stuff
working through the issues
Contractors & Subcontractors are required by their contract to coordinate delivery, storage, temporary facilities, etc.
We would have this written into their contracts and enforce the sub to abide by the rules.
Discussion of why we do it the way we do is usually enough
Specific inclusions in subcontract
No issues
Contractural terms
Contractual lnguage
Site Logistics plan typically is exhibit to subcontract.
As an example, subcontractors whose labor, vehicle/parking, dining/break area etc. does not comply with the site plan can be removed from site- either temporarily or permanently
Removal of subcontractor staff if they repeatedly do not comply with the rules.
If you have a team atmosphere, none of the above actions are necessary.
Included in subcontract agreement
Discussions during project OAC meetings/daily update with Superintendent on expected material/equipment deliveries, etc.
Incentives are preferred over punitive actions; however, site utilization plans are extremely important and can substantially impact the project.
The general super holds the sub accountable to follow and work the plan. We also try not to hirer incompetent subs
Projects are small and direction is followed.
Superintendent controls; depends on their site management approach
adherence is a contract requirement for subcontractors.
Usually included in subcontract rider
Subs are backcharged for failure to comply with the contract documents
Typically, issues can be addressed via verbal communication. However, if non-compliance becomes a continually issue the balance of the actions listed could be implemented.
contract language
I'm sure the general contractor (Prime) who controls the site starts with verbal and proceeds as necessary if problems are encountered.
Back Charges to Contract Termination
Not penalties, but charge backs if applied
site logistics meetings
Removal of subcontractor

Recognize that subs are provided the terms and conditions of what they are being provided. Sometimes this is adjusted during the negotiation process. And the biggest issue is always when will the site office be ready for mobilization and how much space do they get on-site., because if space is not available it can force subcontractors to lease their own space off site if needed.
loss of site priviliges for offending parties
Provide cost of relocation after written warning
Depends on the issue, most subs cooperate with the GC however plans are enforced as necessary
coordination meetings
the goal is to activily work with contractors to promote their success.
Potentially all of the above - C & D only when a written warning is not complied with/responded to
mostly self policed
Prime responsibility
Collaborative weekly working meetings confirming all participants are working to plan
Ideally as subs allocated site utilization plans are made part of their subcontract T's & C's. But if a rural project where owner has lots of space it may not be an item the GC burns a lot of brain cells on.

31. Are performance measurement metrics used to monitor the effectiveness of site utilization plans?

#	Answer		Response	%
1	Yes		26	15%
2	No		150	85%
	Total		**176**	**100%**

32. What performance measurement metrics are used to determine the effectiveness of site utilization plans? [Select all that apply.]

#	Answer		Response	%
1	Time spent in managing subcontractors		11	41%
2	Ability to access and move material around the site efficiently		21	78%
3	Flow of construction activities		27	100%
4	Other		7	26%

Other
Adherence to Schedule as it is effected.
Material management is the biggest issue we deal with...a lot of time has to be spent manaing the contractor to keep track of POs for materials and materials on site.
On vertical construction like a towered we measure the amount of picks on crane and how many loads get sent up on buck hoist. You know really quickly if your logistics plan sucks just by measuring installed work. Guys aren't getting material or slow to get material will pop up real quick
Lean construction measures
Safety statistics can also be impacted (positively and negatively) by the implementation of site utilization plans
Safety
typically, Owner and contractor feedback are the best measures. the reason that development is ongoing is to compensate for changing site conditions and changing contractor access requirments

33. Do you document the knowledge acquired (e.g., new ideas, lessons learned, etc.) on each project pertaining to site utilization plans for future use?

#	Answer		Response	%
1	Yes		102	58%
2	No		74	42%
	Total		**176**	**100%**

34. How are the records kept?

#	Answer		Response	%
1	Company Database		49	47%
2	Personal Files (e.g., filing cabinet, personal computer, etc.)		38	37%
3	Other		17	16%
	Total		**104**	**100%**

Other
Lessons Learned Notes
Both
End of job reports, staff meetings with division for sharing information
Company files/database
each superintendent and project team leaders keep their best practices and utilize on future projects
Distribution of end of job meeting reports
Thru the QA/QC program
Typically in “End of Job” reports that are filed in central locations for access to all
we try to keep a data base of lessoned learned on each project. If problems were encountered with site utilization a lesson learned would be included.
Both company database and personal files/memory
depends on what the lesson is.
All of the above
Jobsite files
All of the above, plus project final report
resides with lessons learned committee
Combination of company database and personal files

35. Has any formal training been provided on site utilization planning through your company?

#	Answer		Response	%
1	Yes		40	22%
2	No		138	78%
	Total		**178**	**100%**

36. How was the training conducted?

#	Answer		Response	%
1	On the Job		6	15%
2	In-House		25	63%
3	By External Experts (Please provide External Expert name.)		0	0%
4	Other		9	23%
	Total		**40**	**100%**

By External Experts (Please provide External Expert name.)	Other
	All above
	On the job, In house and by experts. We have numerous training on this.
	I periodically teach Project Planning classes that address the issue.
	It is the experience of the supervision that provides the training. We try to let the younger personnel develop the plan with input from the upper management.
	On job & inhouse training
	In-house and on the job
	I am not 100% certain on this one.
	Internal presentations and then shared to others via a sample to use on other sites as applicable.
	all of the above

37. List the top three things that can be done to improve the effectiveness of a site utilization plan.

Best Practice 1	Best Practice 2	Best Practice 3
Communication with owner and subs during development	Large scale version of site utilization plan posted onsite	Review site utilization plan with every employee during safety orientation
Need existing utility as builts to be correct	Have subs on board early enough to determine their needs for space	Try to anticipate all the unknowns that will impact site layout
Early Coordination with Customer	Carry over Lessons Learned from Similar Job	Get Proposed Layout from Contractor Early
Update continuously as construction progresses.	Make sure subcontractors have input.	Make sure safety is fully considered in site planning.
collaboration with stakeholders	just in time delivery	shared resources
Physical survey of site	Factor in weather patterns and environmental concerns	Determine best location for temporary and future utilities
good plan	emplment	
Update often	Post everywhere	Develop openly
Have it on paper	Include in Subcontracts	Part of OAC mtg agenda
owner's needs awareness	commuication with all parties	safety of the project
share lessons learned	communicate with affected parties early	follow and update the plan

Start early	Update on a regular basis	Equipment access
Prevent multiple material moves	Keep subcontractors and materials in plain view	Make strong, draining, temporary road where final road will be
locate fixed items such as trialers where least and last work is required	design specific laydown areas for each buidling product	locate work and equipment areas
No level of detail is too much.	Include SWPP details on the plan so that contractors can avoid them, lessening the chance for damage.	Understand that it is an evolving document. As the project changes, it may need to change.
Physical signage of different areas	Ensuring that contractors are aware of when areas are changed due to construction activities or making room for new subs	Discussing of the site plan regularly with the sub foreman
Experience	Sub / vendor input	Experience
Establish	Instill	Enforce
get all subcontractors input	if the job is done in phases update the site utilization plan to best accomodate each phase	enforce your plan from day one so everyone practices it
Begin planning as early as practical	Do not limit your review to the Construction Limits of the project. Review the area surrounding the project site as well	Plan/schedule long lead items, large quantity items, and large mass items as early as practical.
Include subcontractors in plan	Plan early (in estimating)	Buy-in from PM and Field team together
Construction team buy-in	Clear communication	Fresh emphasis as construction progresses
100% involvement from all participating	Utilize an accurate topo survey showing all utilities existing and new	Keep the SUP always up to date with any changes.
Get all relevant parties involved.	If you make a plan, use it and keep it current.	It needs to be easily read by all parties.
Make sure each team member buys into the plan.	Make sure the plan has been reviewed by all and all ideas for logistics have been reviewed by all.	Make sure the pricing is reviewed vs value of the plan.
Must be changeable		
A checklist of important items that most often need to be shown		
Everyone involved in development	Implement plan early	Enforce plan
Anticipate all activities	have back up plans / flexibility	Communicate to Owner and Subs
Too much detail can cause problems onsite. Address	Have all parties agree to plan upfront.	Maintain the plan throughout the job where needed.

the job needs broadly and provide only the level of detail needed for understanding.		
accurate original plan	adequate updates	proper posting
Walking time between facility and project	Properly sized crane swing radius and pad	Location of Material Unloading/Loading Area
Bim Modeling	Existing Utility locations	Owner Safety Concerns
Start as soon as possible and use collaboration among all parties involved.	maintain the plan, revise as needed but certainly don't abandoned the plan.	The more detail you include, the more control you will have.
Plan for entire job. Not just early stages	Entertain suggestions from subs	
Clearly define personnel access & parking areas	Review with owner before project start to confirm approval	Distribute to all subs/vendors prior to project start for input
Engage client in planning	Be flexible	Plan on removal, not just installation. Seen several times temp faculty was difficult to remove after construction completed.
Walk with Supt on Job	Know the Schedule	Get Sign-off from Owner
More detail	update plan	involve subs
Know the existing conditions	understand what is critical to the client/owner	Coordinate the site palnning with the flow of work and adjacent activities
Know your site	Understand your neighbors	Understand traffic flow
Material management system/database	Strict traffic protocols and safety procedures	Effective housekeeping is a MUST.
Site visits		
plan early	micro-manage utilization of plan	never forget that construction project change daily, thus ALL plans must be revisited often
Seperation of vehicular traffic and personnel	I always post the plan on the fence at each entrance	Detailed review with each sub during his start-up meeting
Early buy-in/review from Owner		
make the plan, work the plan	monitor the plan, adjust the plan	consider overall effectiveness of the plan and make corrections for future
understand the clients needs and expectations	know the regulation of the local justidiction	do not develop plan in a vacuum, get input from the entire project team (e.g. subcontractors)
Site supervision input	Willingness to adapt	Owner input
Track Effectiveness	incorporate Subs and Design Team	Stricter Adherence to plan
Project must be built "in the manager's head" first.	Take visualized construction of project and reduce it to paper.	Distribute that visualized/documented plan for

		construction and distribute it to all involved.
Early subcontractor input	incorporate during the bid process	modify plans as site conditions change
subcontractor input	owner input	understanding the site
Communication	Schedule integration	Construction sequencing
Locate items so they will not be required to be moved for the duration of the project.		
Get everyone's input.	All agree it will work.	Follow the plan.
Accurate input from Owners before project begins	Proper communication among GC and all subs during the development of the plan	Flexibility to make changes to the plan if issues are found during the construction phase
Have subcontractors input during planning stage.		
Early planning	Owner & Contractor involvement	Continued planning
Involve all stakeholders including owner	conduct multiple reviews during developmen	share with everyone
Owner participation	subcontractor buy-in	Distribution of the plan to all parties so everyone is informed.
Utilization of BIM	Communication to the Project Team including Owner, Subs, etc.	Have it done early and update / modify during the course of the project.
proper onsite execution of plan	ajusting plan to fit onsite changes	utilization of senior personnel knowledge base during planning & execution
Coordination	Implementation	Ability to adjust during the project
Understand the site logistics	Have a good schedule	Planning your work
Coordinate with Owner in advance	Create effective communication tool	Refine plan as required during project to ensure effective site utilization
More communication with subs		
Get buy in from all stakeholders	Plan and schedule deliveries and maintain this regularly	Hold all players accountable
Develop plans with those that must enforce it	Review with people not involved in the project but with knowledge of similar work	Stick to it but change if change can help
Define material laydown area	Define site access	Define parking areas
Understand the project and objective	Owners need to be involved from the start	Update plan on a daily to weekly basises
Thoughtful planning prior to arriving on site.	In person investigation not just Google Earth	Willingness to adapt

Early on planning		
Involvement of Site Supervision and buy-in to plan during preconstruction	taking into account all possible scenarios, phases of construction	implementation of BIM technology
Revit Models	Pre-Planning with contractors and vendors	Implement plan during the bidding process
Clear Communication	Understanding of topography	AHJ requirements
Make sure the plan is finalized before anyone arrives on site.	Obtain subcontractor buy-in and compliance on plan.	Consider the underground utilities in developing the SUP.
Involve the entire team - Supt, PM, Estimator	Involve the subs	Involve the Owner
Undersatnd owner expectations	Efficent flow	Avoid relocationg materials/trailers
Communication with the Owner	Communication with the AHJ or Municipalities	Enforcement throughout the project
Pre-planning for changing phases during the pschedule	Effective communication of plan to all parties involved.	Follow-up
Prepare comprehensive plan documents	Cover applicable plan details in subcontracts with penalties for failure to adhere to plan	Enforce penalties as applicable
Create the plan and provide to the bidders before the project is priced or even budgeted.	If onsite space is limited, identify offsite space that can be utilized.	Have the superintendent who is going to run the project get involved.
include as many stakeholders as possible - owner, arch, construction management team (various roles)	be efficient - you don't want to move temp facilities/ measures multiple times if at all possible - but you also want to consider everyday interaction	
Gain knowledge of the site	Learn what the Owner expects	Plan carefully
Owner's input	Planning before construction	Discussions with subs
Distribution to all parties prior to final pricing	Develop site utiliization plan with efficient flow as top priority	Confirm all crane and hoisting requirements early on
Form a plan and follow the plan from start to finish	Monitor your subs making sure that they are not receiving more materials than they have room for	Make sure your laydown areas and roads are maintained and kept free of trash and debris that would hender your subs from getting around the job site and to thier materials
Involve Superintendents as well as PM	Involve Subcontractors	Training sessions on it
Total Team Deveopment		

Completely develop an understanding of the building construction systems to develop a project specific plan.	Establish access requirements and any traffic control or protective measures required to keep the public safe.	Develop accessibility and use guidelines for the site including material storage, scaffoling, and equipment.
Understand major traffic patterns (Owner personnel, construction personnel, construction equipment	Attempt to locate storage areas in locations that offer close proximity to the task being performed, but not in a location that conjests the work activity	Consider how inclement weather can / will impact your site utilization plan
involve Superintendant	involve all subs	
deliveries take precedence	maintain traffic	perimeter protection
Consistent Communication	Flexibility to Adjust	Commitments kept
communication, adequate planning in order to limit heavy materials and large equipment to cross paths with school activities	ideally, materials would be delivered as needed (per building) in order to limit the shuffling of materials	
Early involvment of the CM for constructability	Schedule development as the design proceeds	Analysis of staging, phasing and constraints to the construction process such as working in an operating facility or environment
Concept Plan	Pre Bid Plan	GC's Construction Phase Plan
Contract lenguage to hold accountability from Project teams to respect and follow site logistic rules	Made site logistics item a point of discussion during coordination project meetings	Logistic site plans (Drawings) should be visual and available to all project team
Truly understand the site sensititvities	Understand project demands	collaboration
Obtain subcontractor input in advance	Review with local traffic authorities	review with Civil Engineer
Clean Travel Paths	Clear Walking Paths	Consideration of Cranes
know where your underground work is located	understand Subs needs like crane acess	communicate to subs
check list	past experience	envolve all subs
Address SWPPP	Address Material Storage	Address Equipment Not Used
Common sense		
Get owner input	Coordinate with adjacent construction projects	Conduct a real world check in the field of the layout
communication/outreach	owner involvment	ongoing revision
Disseminate as part of DD document design reviews	Include in bidding documents	Get subcontractors validation in post-bid post-award meetings

Collaboration with whole team	Coordination starting at design stages	Have all underground utilities mapped prior to plan development
As prime provide temp site utilities FTP handholds for all sub trainloads	Provide high speed network for final connections by subs	Define material lay down plan
underground utilitiy locates	temporary power transition for power replacement including temporary generators and switchgear	Realistic plant or utility shut downs, time out of service and clarity of intent
Get A/E involved early	Construction kick-off meeting	Weekly meetings
Early Owner involvement	Early Contractor input	Insuring that the site utilization plan is an integral part of the project design development process
Ensure site utilization planning is contained in Contracts and the Front-end Documents	Establish the priorities for site utilization and who determines the priorites	Establish the parameters for compliance and enforce measures that result for non-compliance
include it in the bid documents/contract	enforce the established plan once on-site	be flexible to make changes if a strong case is presented that was not envisioned
visit site early with SUP as the main reason for the visit	Invest the time and resources (correct people) early in the job to develop the initial SUP	Engage the Owner - to find out what is acceptable to them - FIRST
plan early	contractor imput	flexibility
Be thorough	Don't worry about costs ($1 spent now can save $1,000)	
Plan early	Integrate with CPM schedule	modify in field as needed
Ensure its consideration at initiation of the project.	Review and update the plan through the project duration.	Document lessons learned.
Consideration of Public	Storage & Access of Plan	Issuance of updated plans
Ensure staging of the project is allowed for	Move contractors if required - even at a cost	do not put contractors too close to the work and ensure that the largest contractors have sufficent space
location to site	access to site	site prep
Trade sequences established	A workable site construction plan	Coordinated material deliveries
Multiple owner meetings	Clear/concise site plans	Management of plan
Cooperation	Experience	Flexability
Access/Egress Points	Off site parking	On site short term material storage
Knowledge of site conditions	SIte access	work areas, now and future
Community / property owner input	Ensure alignment with permit conditions	
early planning	get the right people involved	activily monitor and improve the plan

encourage input from as many parties as appropriate	Keep the thing updated and communicated as much as possible	Make the thing "real world" and remember a plan that looks impressive isn't worth a dime if it doesn't work, isn't believable, isn't sellable, isn't inforceable and above all .....isn't kept current
Checklist	Map	Phases
Buy in by all stake holders on site	Firm enforcement	good housekeeping
Publish to all trades	Revise as site conditions change	
Early contractor feedback during design	Translate accurate site utilities to drawings for the site plan	Clarify environmental restrictions and incorporate into site plan
Confirmed material delivery dates	well thought out construction sequence	Contractor coordination ad buy in
Earlier Planning	Owner Involvement	Sub Input
ensure accurate as-builts are produced and maintained	obligate funds for thorough site investigation (borings, etc.)	
pre-plan the work	be ready to adapt to change	if it anin't broke, don't fix it
early planning	detailed understanding of the ongoing activities of the client on site	
involve all or more subs during the development of the plan	consistently and continually enforce the plan	change the plan if it can be improved
Survey and Plan accurately	enforce compliance unless conflict arises	be able to make changes to resolve conflicts without compromising the final results or goals.
Early planning	Owner involvement	Full team participation
Final plan early as possible	Communicate with Contractors	Maintain Flexability if possible
Detailed preparation at beginning of job	Weekly update of plan with all players	Posting of current plan on site information board
Meet with the Design Team during Design Development and construct the site logistics plan into the contract specifications (for bid & award))	Site Logistics Planning with the entire project team present; this includes subcontractors, design professional, and Owner's Representative (again during the construction phase	Update the Logistics plan throughout the construction phase at interim milestones
During project design development owner invite confidential industry review	Bring in scope specific experts and generalists to play devils advocate	During owner design development public comments and owner's designer solutions should be made available to contractors in a public bid situation

Delineate access routes for the plant owner and contractor early	set aside space for unforseen requirements *e.g. truck wash stations if contaminated soils are encountered)	Leave some space unallocated as everyone always needs more space then they are given and the RE needs some flex
more buy-in from affected trades	clearer understanding of owner activities during construction	rigorous enforcement of plan
familiarity with the site	understanding scope of work	knolege of environmental, utilities, other factors
Standards to follow	Buy in from subcontractors	Owner input
involvement during design	communication during mobilization	utilize scheduling to plan locations for equipment and material delivery
Develop prior to arrival	Involve multiple parties	
Plan early in the process	Study and identify all constraints affecting access and flow to the project both from outside and inside the project boundaries	Incorporate the project phasing and /or how far along you are into the project into your plan. (ie the plan may change as the project progresses)
Get full Owner input on site restrictions and usage.	Be generous in site space allowed for use by the contractors.	Establish clear contractual allowances and limitations for life on the project site by all parties.
Discussion with on going users	Discussion with potential contractors	Discussion with outside users

38. At what project value are site utilization plans developed?

#	Answer		Response	%
1	$0 - $100,000		34	20%
2	$100,000 - $500,000		20	12%
3	$500,000 - $1,000,000		28	16%
4	$1,000,000 - $10,000,000		58	34%
5	> $10,000,000		31	18%
	Total		**171**	**100%**

39. On an average, what percent of the total project cost is allocated to temporary facilities?

#	Answer		Response	%
1	0% - 2%		97	56%
2	2% - 5%		59	34%
3	5% - 10%		12	7%
4	10% - 15%		3	2%
5	> 15%		1	1%
	Total		**172**	**100%**

Appendix C

Follow-Up Best Practices Survey

AUBURN UNIVERSITY

Thank you for participating in the first survey on Site Utilization Planning. From the results of the survey, I was able to identify the following 13 practices to be important for effective Site Utilization Planning. I will be grateful if you could provide your opinion on the following SUP Best Practices.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Conduct an in-person investigation of the site prior to the Site Utilization Plan (SUP) development.	○	○	○	○	○
Start Site Utilization Plan development as early as possible.	○	○	○	○	○
Involve stakeholders (e.g., owner, subcontractors, project manager, superintendent, management personnel, CM) throughout SUP development.	○	○	○	○	○
Consider impact of inclement weather and safety regulations during the SUP development.	○	○	○	○	○
Communicate and distribute the SUP to all stakeholders.	○	○	○	○	○
Ensure that all stakeholders buy-in to the SUP.	○	○	○	○	○
Clearly communicate SUP enforcement polices to all subcontractors at the site.	○	○	○	○	○
Implement and enforce the SUP from day one of construction.	○	○	○	○	○
Monitor the SUP effectiveness regularly.	○	○	○	○	○
Remain flexible on site space allocation throughout the project.	○	○	○	○	○
Update/modify the SUP as needed; communicate the updates with all stakeholders.	○	○	○	○	○
Document and share lessons learned with others in the organization.	○	○	○	○	○
Utilize BIM technology for SUP development if available.	○	○	○	○	○

Appendix D

Follow-Up Survey Results

#	Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Total Responses	Mean
1	Conduct an in-person investigation of the site prior to the Site Utilization Plan (SUP) development.	49	8	1	0	0	58	1.17
2	Start Site Utilization Plan development as early as possible.	37	19	2	0	0	58	1.40
3	Involve stakeholders (e.g., owner, subcontractors, project manager, superintendent, management personnel, CM) throughout SUP development.	30	26	2	0	0	58	1.52
4	Consider impact of inclement weather and safety regulations during the SUP development.	24	28	6	0	0	58	1.69
5	Communicate and distribute the SUP to all stakeholders.	33	21	3	1	0	58	1.52
6	Ensure that all stakeholders buy-in to the SUP.	23	26	6	2	0	57	1.77

7	Clearly communicate SUP enforcement polices to all subcontractors at the site.	40	16	1	0	0	57	1.32
8	Implement and enforce the SUP from day one of construction.	40	18	0	0	0	58	1.31
9	Monitor the SUP effectiveness regularly.	22	35	1	0	0	58	1.64
10	Remain flexible on site space allocation throughout the project.	25	28	5	0	0	58	1.66
11	Update/modify the SUP as needed; communicate the updates with all stakeholders.	27	28	3	0	0	58	1.59
12	Document and share lessons learned with others in the organization.	25	24	9	0	0	58	1.72
13	Utilize BIM technology for SUP development if available.	16	14	25	3	0	58	2.26