Investigating Implementation Level of Phase-Based Strategies in Transportation Infrastructure Projects

Elnaz Safapour, Ph.D.[1], Sharareh Kermanshachi, Ph.D.[2], and Amirhosein Jafari, Ph.D.[3]

[1] Department of Civil Engineering, University of Texas at Arlington, 425 Nedderman Hall, 416 Yates Street, Arlington, TX 76019. Email: elnaz.safapour@mavs.uta.edu

[2] (Corresponding author) Department of Civil Engineering, University of Texas at Arlington, 425 Nedderman Hall, 416 Yates Street, Box 19308, Arlington, TX 76019. Email: sharareh.kermanshachi@uta.edu

[3] Department of Construction Management, Bert S. Turner Department of Construction Management, Louisiana State University, 3319 Patrick F. Taylor Hall, Baton Rouge, LA 70810. ajafari1@lsu.edu

ABSTRACT

This research performed phase-based studies to determine effective project management tasks, strategies, and outsourcing activities for transportation infrastructure projects. A comprehensive literature review was conducted to discover phase-based project management strategies, tasks, and activities that can be adopted or outsourced by state transportation agencies (STAs), then a survey was designed and distributed nationally through an online platform to STAs. The results of the 96 survey responses were analyzed and demonstrated that team qualifications and environmental planning are the project management strategies that STAs adopt most often. The outcomes of this study will help decision-makers and project managers assess the effects of adopting effective strategies and outsourcing some activities on delivering transportation infrastructure projects on time, within budget, and with the desired level of quality.

Keywords: Transportation Infrastructure; Cost Estimation; Management Strategy; Construction Project; Project Success.

1. INTRODUCTION

The number of transportation infrastructure projects in the U.S. has significantly increased over the last decade. State transportation agencies (STAs), including state departments of transportation (DOTs), deal with hundreds of small-to-large projects on any given day, with a common goal of ensuring that commuters can navigate transportation networks safely and easily (American Association of State Highway and Transportation Officials 2007). Transportation agencies, therefore, are experiencing unprecedented pressure to deliver projects successfully, i.e., on time, within budget, and with an adequate level of quality (Love et al. 2019). An obvious response to this pressure is to improve the project delivery process by implementing proven successful project management practices (Silva et al. 2019; Kermanshachi et al. 2020), as well as by contracting out some of the work to the private sector and even to other levels of government, such as county transportation agencies (Hensing 2003). Understanding these practices plays a vital role in the successful delivery of transportation projects.

Researchers and practitioners have conducted several studies to improve project delivery of construction of transportation projects. Alias et al. (2014) stated that successful project delivery

greatly depends on how the project has been managed and controlled; Barners (2013) argued that cost, schedule, and output (i.e., quality and scope) are the triple constraints of project management. Construction project management has evolved rapidly in recent years, and many researchers and practitioners have tried to find the most appropriate project management approach to constructing transportation projects (e.g., Alias et al. 2014; Kermanshachi and Safapour 2020). In addition, to successfully deliver a construction project, there is the debated question of whether it is more cost-effective for the design, construction, and management to be conducted in-house or outsourced. Several researchers and practitioners, including Moore et al. (2000) conducted studies in an effort to find the answer to this question. Griffis and Choi (2013) claimed that many STAs target a design workload of 25% in-house to 75% outsourced, and the decision depends on many factors such as the STA's policy, staffing capacity, schedule constraints, availability of special expertise, the need for innovation, better risk management, enhancement of quality, and cost-effectiveness.

Due to the unique nature of management activities of transportation projects, each STA develops guidelines for its project management process that are based on their local regulations and conditions. Understanding project management practices, including the tools and methods that have proven successful, is very important for project managers and stakeholders in transportation agencies. The ratio of consultants to in-house designers varies from one STA to another, and there are many differences in how delivery times are determined and how projects are managed. Comparing the project success and performance management of in-house services to those of outside suppliers can produce valuable information, even when the decision is made to refrain from outsourcing the services.

Multiple researchers and practitioners believe that adopting appropriate project management tools, techniques, and software can improve a project's performance (Dahlgaard-Park and Dahlgaard 2007; Taghinezhad et al. 2021). One of the common approaches taken by researchers and practitioners is to improve the phase-based performance (Karunakaran et al. 2019), and some of the owners and project stakeholders prefer to outsource one or more of the construction phases (Ikediashi and Ogunlana 2015). Studies have been conducted to determine the phase-based effective strategies that will be effective in efficiently managing and successfully delivering the targeted service(s) (Wang et al. 2015). After reviewing the previous studies that address this issue, it was concluded that there are multiple gaps in the existing literature: (1) the implementation level

of effective managerial tasks and strategies associated with various phases of projects, and (2) the ratio of outsourced to in-house activities and the reasons behind outsourcing decisions.

To address these gaps, this study aims to synthesize the STAs' best practices for project delivery processes by looking at all pertinent factors, including time estimation, project management, and suggested ratios of in-house versus consultant design. The main objectives of this study are to (1) examine the phase-based outsourced/in-house activities, (2) identify the phase-based effective managerial tasks and determine their implementation levels, and (3) determine the effective managerial strategies and investigate their implementation levels. This study contributes to the body of knowledge by providing a baseline for selecting and adopting effective phase-based managerial tasks and techniques that can help project managers deliver transportation infrastructure projects successfully.

2. LITERATURE REVIEW

2.1. Criteria for Successful Transportation Infrastructure Projects

In 1987, Pinto and Slevin conducted a study in which they stated that a project can be considered successful if it is completed on time, within budget, meets all of its objectives, and satisfies the client. Various studies have been performed on construction projects that were considered successful, based on that definition (Wang et al. 2017; Imran et al. 2019; Ghribi et al. 2019). Sohail and Baldwin (2004) proposed five dimensions that determine a construction project's success: schedule, budget, cooperation and partnership, quality, and socioeconomic. Almost all researchers believe that staying within the budget, adhering to the schedule, and achieving a quality project performance, referred to as "the iron triangle" by Atkinson (1999), are necessary for a successful construction project (Kissi et al. 2019; Viswanathan et al. 2019; Narayan and Tan 2019; Silva et al. 2019), and several studies have been conducted, based upon these criteria, to improve the performance of construction projects (Heravi and Gholami 2018; Kog 2019).

2.2. Project Management Practices in Transportation Infrastructure Projects

The project management body of knowledge (PMBOK) describes the project management procedure as "a five-stage process, including initiation, planning, execution, monitoring and

controlling, and closing" (Project Management Institute 2008). Many researchers and practitioners believe that project management plays a major role in the successful completion of a construction project (Wilmot et al. 2013; Pekuri et al. 2015; Oyewobi et al. 2016; Safapour et al. 2020). For instance, Chovinchien and Nguyen (2013) stated that the successful conclusion of a construction project is an outcome of effective monitoring and management.

Adopting the most effective management practices for each phase of a project is vital to a project's successful completion (Alias et al. 2014). It is also considered one of the major challenges that practitioners face in transportation infrastructure projects (Chan et al. 2004; Bausman et al. 2014), as each project is unique, and practices that are effective for one project might not work for another (Kermanshachi et al. 2018). Integration, scope, time, cost, quality, human resources, communications, risk, and procurement (Pereira et al. 2013) are part of project management and require technologies and tools, i.e., computer-based tools such as Primavera, MS Project, Geographic Information System (GIS), and building information modeling (BIM).

2.3. Project Management Dimensions in Transportation Infrastructure Projects

The authors of the present study thoroughly reviewed the existing literature to determine the project management dimensions used by other researchers. Cost management, time management, quality control and inspection, right-of-ways (ROWs), environmental and safety processes, change orders, utilities, value engineering, outsourcing, types of contracting, workforce qualifications, and operation and maintenance were those most commonly mentioned in the literature.

2.3.1. Accurate Cost Estimation in Transportation Infrastructure Projects

Accurate cost estimation plays an important role in delivering a transportation infrastructure project within budget, (Alias et al. 2014). STAs estimate the budget for highway projects by appraising the cost of preliminary engineering, ROWs, and the construction phase (Torp et al. 2016; Gardner et al. 2016) in two steps: initial cost estimations and final cost estimations. Initial cost estimations are conducted by using information obtained from similar completed projects and developing predictive models, using the regression method or neural networks (Juszczyk et al. 2018). Final cost estimations are commonly conducted when the design phase has been completed so that the resources can be allocated effectively. Although many studies have been conducted on

techniques and methods to be implemented in construction projects, few have investigated the methods and approaches adopted by STAs to estimate the phase-based costs of transportation infrastructures.

2.4. Effective Managerial Tasks and Strategies in Transportation Infrastructure Projects

To successfully deliver a transportation infrastructure project, project managers commonly adopt one or more project management strategies, including multiple managerial tasks (Kissi et al. 2015) that consist of time management, cost management, safety management, quality management, etc. (Prabakaran et al. 2017). Three time-management techniques and methods that are frequently used in construction projects are Gantt charts, the critical path method, and the program evaluation and review technique (Perira et al. 2013; Chen et al. 2020). A systematic review of the materials and technical specifications is often employed for quality management (Acebes et al. 2014). The implementation of safety management includes tasks such as training the laborers and/or ensuring the safety of the equipment and the workplace (Pedro et al. 2016; Li et al. 2018). Multiple studies have focused on project management strategies and tasks that are commonly adopted by STAs, but there is still a lack of literature about phase-based managerial tasks and strategies that have been used by STAs to deliver projects successfully.

2.5. Outsourcing Transportation Infrastructure Projects

A multitude of tasks are involved in successfully delivering a transportation infrastructure construction project on time and within budget. Therefore, it is vital to adopt appropriate project management tools, techniques, and methods that enable the planning, strategic monitoring, and control of all of the tasks and activities that fulfill the project's objectives (Gibson and Wallace 2013). Several practitioners and authors have espoused that STAs often optimize the chance of success of their transportation infrastructure projects by outsourcing one or more stages, such as administration, planning, design, construction, maintenance, operation, and/or ROWs (Warne 2003; Dlesk and Bell 2006; Gibson and Wallace 2013; Yusuf and O'Connell 2014). In 2015, Ikediashi and Ogunlana stated that the main reason for outsourcing is the lack of a workforce that possesses the skills, knowledge, and familiarity with innovative tools, methods, and techniques that are necessary for a successful completion of the project. Warne (2003) conducted a study that

revealed that an inadequate workforce and unsatisfactory facilities are the key reasons that various stages of projects are outsourced by STAs. Moore et al. (2000) discovered that 34 STAs use outsourced services for design, construction, maintenance, and other related services. Although a few studies have investigated the outsourcing of various stages and activities of projects by STAs, the existing literature still lacks a comprehensive study that covers phase-based outsourcing activities.

2.6. Knowledge Gap

Despite the many studies that have been conducted on delivering a transportation infrastructure project successfully, there are still two main gaps in the literature: (1) a comprehensive study of phase-based effective managerial tasks and strategies, and (2) a comprehensive study of phase-based outsourcing activities. To address these gaps, this study targets the strategies for STA project delivery processes and focuses on project delivery factors such as time estimation, project management, and suggested ratios of in-house versus consultant designers. The outcomes will benefit all of those involved in the completion of a project by providing insight into effective project management tasks, strategies, and outsourced activities for each phase of transportation projects.

3. METHODOLOGY

To fulfill the objectives of this study, a structured research framework was developed, as shown in Fig. 1. First, a comprehensive literature review was conducted that focused on published articles and STAs' websites to identify: (1) outsourced activities in STAs projects; (2) the reasons behind outsourcing activities; (3) cost estimation methods, techniques, tools, and tasks; (4) effective project management strategies; and (5) managerial tasks associated with the' planning, preliminary design, design, construction, inspection and testing phases. Then, a structured survey was developed, based on information derived from the literature as well from suggestions made by four experts who participated in the pilot program. The final survey included 31 questions, consisting of three primary sections: (1) a descriptive summary of the project and the participants' goals; (2) general information pertaining to the participants, such as job position, level of expertise, STA location, etc.; and (3) a collection of technical responses to both open- and close-ended questions

targeting project management approaches, time estimation tools and techniques, cost estimation methods, management practices, and outsourcing activities and their relationship to project success. Terminologies used in the survey instrument were clearly defined for the participants, to ensure that accurate and precise data were collected. More than 300 expert representatives from 52 STAs were invited to participate in this study. After two follow-up emails, 96 completed surveys were collected, and the data was analyzed to examine the ratio of outsourced to in-house activities in STAs and the reasons behind such decisions. The implementation level of effective managerial tasks in STAs' transportation infrastructure projects was also determined for the projects conducted in-house.

4. DATA COLLECTION

A structured online survey was used to obtain the required data from the STAs' expert personnel. The survey targeted information related to identifying outsourced activities and the reasons that contributed to their being outsourced, cost estimation methods, techniques, tools, and in-house tasks conducted by STAs for transportation construction projects. It also aimed to identify project management strategies and managerial tasks for facilitating the planning, preliminary design, design, construction, inspection, and testing phases of transportation projects.

4.1. Survey Respondents

The research team identified experts and professionals from 52 STAs who were potential participants and contacted them by email, asking them to complete the survey. A total of 96 completed surveys were collected, and the demographic information of the respondents, presented in Table 1, shows that approximately 90% of them had more than ten years of experience with a state agency, while 16% were project managers in various STAs.

The regions and the corresponding frequency of the survey responses are shown in Fig. 2, which illustrates that the respondents from STAs in Washington, Idaho, South Dakota, Nebraska, Minnesota, Vermont, Kentucky, Oklahoma, Texas, Louisiana, Tennessee, Maine, Maryland, and Connecticut provided at least one response; respondents from STAs in Iowa, Oregon, North Carolina, New Mexico, and Alabama provided at least three responses. Finally, experts located in Florida, Arizona, Utah, Colorado, Virginia, and Ohio provided at least five survey responses.

4.2. Survey Projects

The respondents were asked to select a recent transportation project and to use that project as the basis for completing the survey questions. Highway projects were selected by 46%, bridge projects were selected by 32%, and roadway projects were selected by 22%.

In addition, the survey participants were asked to provide knowledge and data about the types of contracts used in the design, procurement, and construction phases, and the responses indicated that most of the STAs perform the design and procurement phases of the infrastructure projects under cost plus fee and lump sum contracts (Fig. 3). Unit cost and lump sum contracts are used primarily for the construction phase.

When asked to provide information about the delivery methods used in the design, procurement, and construction phases of their STA's transportation infrastructure projects, the survey participants named six methods: design-bid-build (DBB), design-build (DB), construction management at risk (CMR), multiple primes (MP), construction manager general contractor (CMGC), and public-private partnerships (P3). According to the survey results, DBB (58%) and DB (30%) received the highest percentages among the delivery methods; the other methods received less than 5%.

5. RESULTS AND DISCUSSION

5.1. Outsourced Activities and their Ratios

One of this study's main objectives was to investigate the outsourced activities and the reasons behind them for highway, roadway, and bridge projects. In general, no transportation agency and company in the U.S. can claim that they have all of the technical expertise and resources necessary to accomplish every phase of a transportation infrastructure project in-house. In the survey, the respondents were asked to determine the outsourcing activities in their project's service life (i.e., administration, planning, design, construction, maintenance, operation, right-of-way, and environmental) and estimate the ratio of in-house versus outsourced services. The survey results are shown in Table 2, which illustrates that most STAs prefer to outsource some or most of the design, construction, and environmental works for roadway, bridge, and highway projects. As the STAs choose to be anonymous regarding outsourcing activities, the list of STAs is presented in

Table 2 based on numbers, and each number belongs to one specific STA. As presented in Table 2, the activities of administration, planning, design, and right-of-way (ROW) were outsourced more often for highway projects than for roadway and bridge projects, and the activities of construction, operation and environment were outsourced more often for bridge projects than for roadway and highway projects.

The experts participating in the survey were also asked why their STAs contracted out parts of their projects, and their answers are presented in Fig. 4.

As shown in Fig. 4, the reason for outsourcing most often cited was the lack of sufficient personnel/workforce. Not having enough qualified staff puts a lot of pressure on those who are responsible for completing and delivering the project and can result in reduced productivity and an increased number of reworks, which only exacerbates the problems and leads to delays. Consequently, transportation agencies contract out their projects to prevent significant delays.

Fig. 4 shows that a lack of sufficient special expertise was the second-highest ranked reason that activities are outsourced. Since the execution of a transportation project requires the application of technical knowledge, skills, and techniques for timely delivery, it is essential that a sufficient number of experts are available who possess the needed manual and technical skills and are able to make sound decisions. Therefore, it stands to reason that STAs outsource the parts of their projects for which they lack an adequate number of experts.

5.2. Cost Estimation

The survey asked respondents to provide information about the design and construction cost estimation methods used in transportation infrastructure projects. As shown in Fig. 5, three cost estimation methods were mentioned for the design phase: similar projects, number of hours required for the design, and historical percentage of construction. Similar projects ranked first with 57%, and number of hours needed for the design ranked second with 36%.

Fig. 5 also presents that three methods were used for estimating the construction cost: similar projects, historical bid data, and parametric estimating. Among these methods, historical bid data received the highest percentage (84%), and similar projects ranked second at 10%.

Table 3 presents that conducting a review of the cost estimation was ranked as the second most important task among those pertaining to effective cost estimation. Since multiple risks and uncertainties are usually involved throughout the execution of transportation infrastructure projects, a review of the cost estimates helps project managers ensure that project uncertainties and risks that could result in significantly decreasing cost overruns in later stages of the project are being considered,

Since utilization of new software and/or innovative technologies for cost estimation in construction projects has multiple benefits, such as improving its efficiency and effectiveness, the respondents were asked to provide information about their experiences with using new software and technologies. They were given five options: BIM, GIS, data management systems (DMS), multi-agency permit team (MAP Team), and efficient transportation decision making (ETDM). The results showed that 47% of the respondents use DMS most frequently, 32% use GIS, and 11% use BIM in their highway, roadway, and bridge projects. In addition, 10% of respondents use ETDM and MAP Team for transportation infrastructure projects.

5.3. Project Management Strategy

The survey participants were asked to provide data regarding their STA's adoption of various project management strategies for team qualification, quality management, scope verification, communication plan, environmental planning, risk management, safety management, document management, and repair prevention. The questions were presented on a five-point Likert scale, and the results are shown in Fig. 6.

The survey participants were also asked to provide information about their STA's implementation level of *team qualification* strategies. Fig. 6 depicts that roughly 60% of the respondents said that their STAs highly implement team qualifications in their projects; about 20% of respondents stated that their agencies moderately adopt the team qualification strategy. Since a construction project's successful completion, delivery, and life-cycle strongly depends on its project team's qualifications, the development and integration of the project team is critical. Unqualified team members will result in decreased productivity, increased reworks, and schedule and cost overruns.

5.4. Effective Managerial Task

In the last section of the survey, the respondents were asked to determine the implementation level of effective managerial tasks in the project life-cycle phases: planning, preliminary design, design, construction, and inspection and testing.

5.4.1. Effective Managerial Tasks in the Planning Phase

As successfully completing a planning phase is very important to the delivery of an infrastructure construction project, the survey participants were asked to provide knowledge and data about their STA's adoption of the effective managerial tasks that are shown in Table 4, during the planning phase.

Table 4 presents that more than half of the survey participants believe that the tasks of communication, project scoping, internal estimate review, delivery and procurement, and ROW are adopted by their STAs during the planning phase of transportation infrastructure projects. Additionally, 69% of the respondents stated that effective communication is practiced at their STA throughout the planning phase of highway, bridge, and roadway projects. Since the productivity of the staff strongly depends on the efficiency of data and information exchanges throughout the execution of a project, the adoption of effective communication practices in the planning phase leads to the timely transfer and exchange of vital data, skills, and information, and ultimately reduces the number and cost of design changes and increases the probability of project success.

5.4.2. Effective Managerial Tasks in the Preliminary Design Phase

The respondents were asked to provide information about the adoption of managerial tasks throughout the preliminary design phase of highway, roadway, and bridge projects at their STAs. This request was based on the tasks identified from the existing literature, as shown in Table 5.

Table 5 illustrates that more than half of the survey respondents believe that their STA implements nine of the listed tasks throughout the programming and preliminary design phase: establishment of effective communication practices, estimation of design costs, review of constructability, project scoping, budget control, internal estimate review, utilization of innovative software, estimate/document review, and ROW clearance needs.

Table 5 shows that the most frequently adopted task is *estimation of design cost,* with 65% of the survey respondents indicating that their STA implements it. This task facilitates the proactive control of most of the cost challenges and issues encountered in the construction of transportation infrastructure projects, thereby decreasing the number and cost of reworks and improving the schedule performance.

5.4.3. Effective Managerial Tasks in the Design Phase

Successful completion of the design phase is very important to large-scale transportation infrastructure projects, such as highways, bridges, and roadways. The tasks considered by the survey question pertaining to the management phase are shown in Table 6, which indicates that more than half of the survey's participants confirmed that their STA adopts six of the tasks during the design phase: constructability review, budget control, internal estimate review, ROW clearance needs, plan specifications and estimates, and communication.

As indicated in Table 6, 85% of the respondents said that their STA adopts constructability in their bridge, highway, and road projects. In 1986, the Construction Industry Institute (CII) introduced the task of *constructability* and defined it as "*the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives*." Implementing constructability strategies in the design phase leads to the development of improved plans and specifications, increased total project cost savings, fewer site laborers, and better resource utilization. To enhance effective coordination in complex projects, architectural and engineering disciplines should be reviewed and applied to decrease the number of design changes and/or modifications.

5.4.4. Effective Managerial Tasks in the Construction Phase

Since the construction phase is the most critical phase of a project, it is important to identify and complete the tasks that enable project managers to deliver it successfully. The tasks identified by the authors of this study and the results of the survey are presented in Table 7.

Of the listed tasks in Table 7, *holding a pre-construction meeting with a defined agenda* was ranked highest (88%), as it assists in confirming the sources of funds, imparting technical advice,

reaching an agreement and consensus, achieving cooperation among the parties involved in the construction process, conforming to standard specifications, and ensuring the availability of sufficient craft laborers. The adoption of this task leads to a proactive plan to prevent significant schedule delays and cost overruns.

5.4.5. Effective Managerial Tasks in the Inspection and Testing Phase

Oversight, inspection, and testing ensure that each phase of a project conforms to its requirements (Torres, 2014). Accordingly, the research team designed a question in the survey to investigate the level of implementation achieved by STAs for the tasks inherent in inspection and testing procedures for highway, bridge, and roadway projects. The tasks and results are presented in Table 8.

Table 8 indicates that more than half of the respondents believed that their STA adopts all of the managerial tasks during the inspection and testing phase of transportation infrastructure projects. Verification of personnel certification training, independent quality assurance (QA) inspections and material testing, and inspection of ongoing construction activities were ranked the highest by 85% of the respondents. Cohen et al. (1988) conducted a study involving 1,241 injured construction field laborers. The results of the study revealed that 26% of the injured labors had not been trained on construction safety, and the rest of them had less than one year of construction experience. It can therefore be concluded that ensuring that construction personnel have the appropriate certification training prevents many safety issues from arising and consequently prevents related schedule delays.

5.4.6. Discussion of General Findings

The results demonstrated that the primary project management strategies that are adopted by STAs are workforce qualification, quality management, environmental planning, safety, and document management. Strategies such as scope verification, risk management, and repair prevention strategies are not well-implemented in transportation projects even though they have a significant impact on project performance. The most frequently initiated project management practices in transportation projects were identifying major project components and ROW clearance needs in the *scoping phase*; developing a project scope and communication plan in the *planning phase*;

enhancing communication and design estimation in the *programming and preliminary design phase*; conducting a constructability analysis and budget control in the *design phase*; holding a pre-construction meeting with a defined agenda, promoting a safe working environment, and complying with civil rights regulations in the *construction phase*; and assurance of personnel certification training, independent QA inspections and material testing, and inspection of ongoing construction activities in the *inspection and testing phase*. STAs utilize many tools and methods for cost estimation and management; however, the methods are usually based on their use in similar projects and on historical data. The review of estimates and early identification of project risks and uncertainties have been identified as the best cost estimation practices in STA projects.

The outcomes illustrated that the outsourced to in-house ration vary widely with the project type. For example, the ration of outsourced to in-house service is higher in bridge projects than in roadway and highway projects and is lower in highway projects than in roadway projects. The results also indicated that the main reasons that STAs contract out parts of projects are: (1) insufficient in-house personnel, (2) lack of required expertise, and (3) time constraints.

In 2003, Warne showed that the need for special skills, staffing, and equipment are the main reasons that STAs outsource, and he applauded the overall satisfaction that is derived from outsourcing practices that facilitate the STAs' successful delivery of projects by meeting the schedule commitments, bringing complex projects to fruition, and meeting legal requirements. In 2000, Moore et al. explained that the potential benefits of outsourcing include accommodating peak demands, improving quality, enhancing the speed of project delivery, gaining broad access to expertise, improving efficiency, decreasing costs, and benefitting from better innovations and risk management.

In 2002, Deis et al. offered five factors for consideration when contemplating outsourcing: (1) economic impact; (2) vendor service, reliability and service quality; (3) legal ramifications; (4) impact on strategic core competencies; and (5) sociological factors. Warne (2003) stated that STAs typically consider the type of contractors used, prequalification procedures, the contract management process, the selection process, and payment methodologies.

6. CONCLUSIONS AND RECOMMENDATIONS

The three main objectives of this study that are associated with STAs' highway, bridge, and roadway projects were to investigate the: (1) outsourced activities/stages, (2) implementation level of project management strategies in each of the life-cycle phases, and (3) implementation level of effective managerial tasks during each of the life-cycle phases. Based upon the respondents' personal experience, it was concluded that the design, construction, and environmental activities of transportation infrastructure projects are usually contracted out by their STAs, and the effective project management strategies most often implemented by STAs are team qualifications, environmental planning, and quality management. The results clearly show that the establishment of effective team communication is the managerial task that is most adopted by STAs throughout the planning phase. Design cost estimations and constructability reviews are the most highly implemented tasks during preliminary design and design phases, respectively.

The findings of this research will help decision makers and project managers greatly improve their understanding of the benefits of effective managerial tasks, strategies, and outsourcing activities associated with transportation infrastructure projects. As a result, they will be able to allocate resources at the right time to deliver transportation infrastructure projects on time, within budget, and with a reasonable level of quality.

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8. DATA AVAILABILITY STATEMENT

All data that support the findings of this study are available from the corresponding author upon reasonable request.

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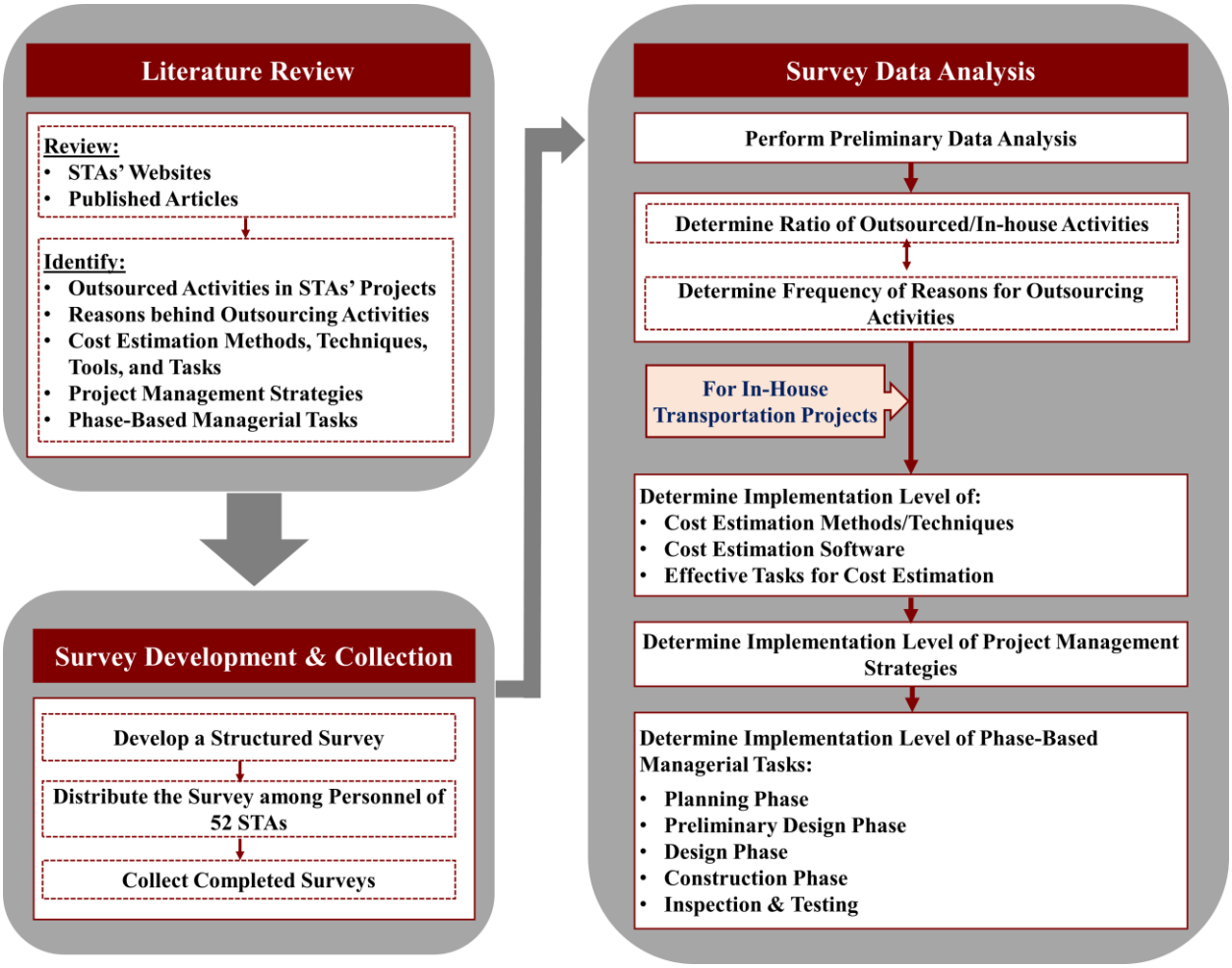

Fig. 1. Research framework

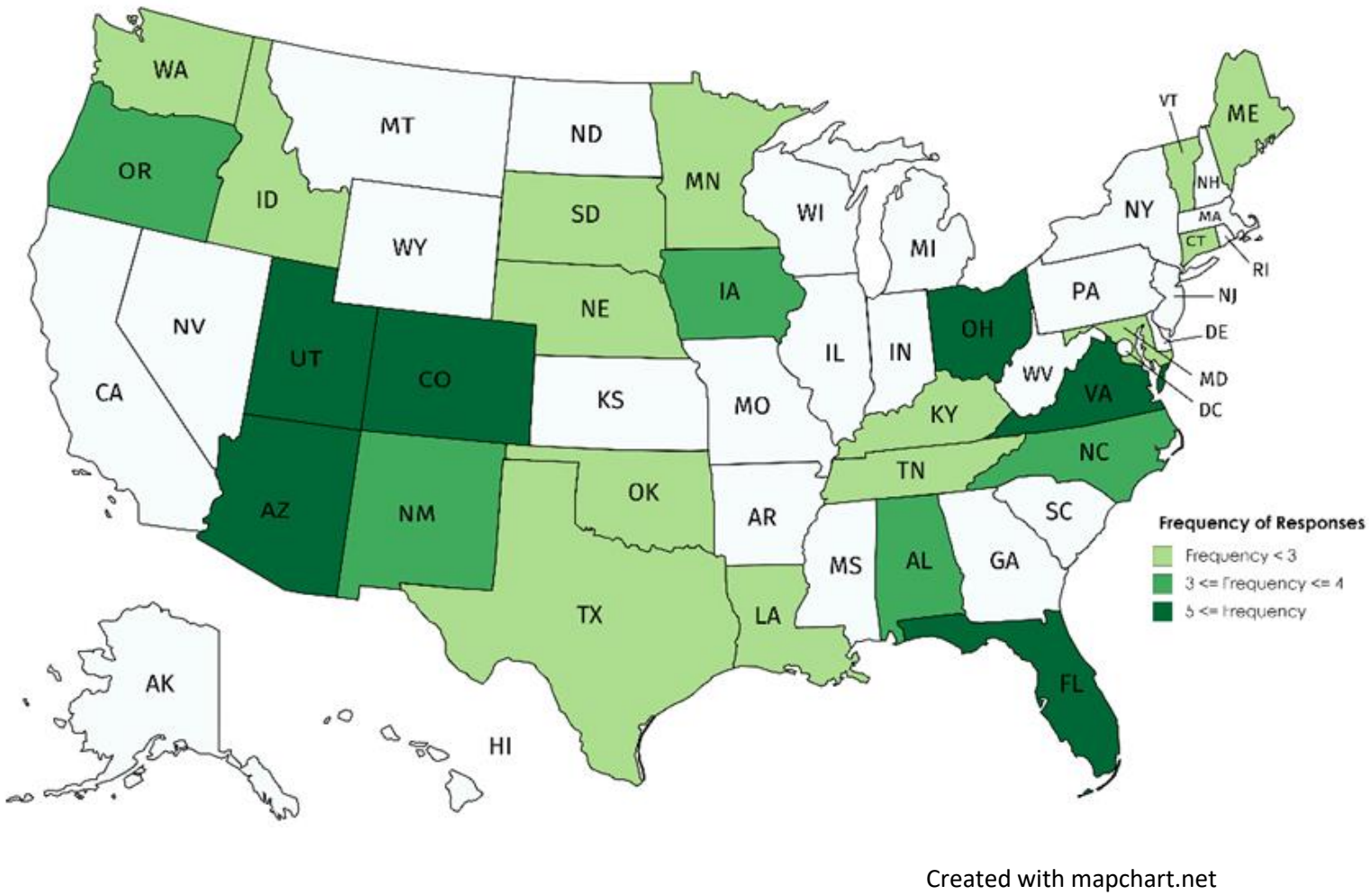

Fig. 2. Frequency of survey responses

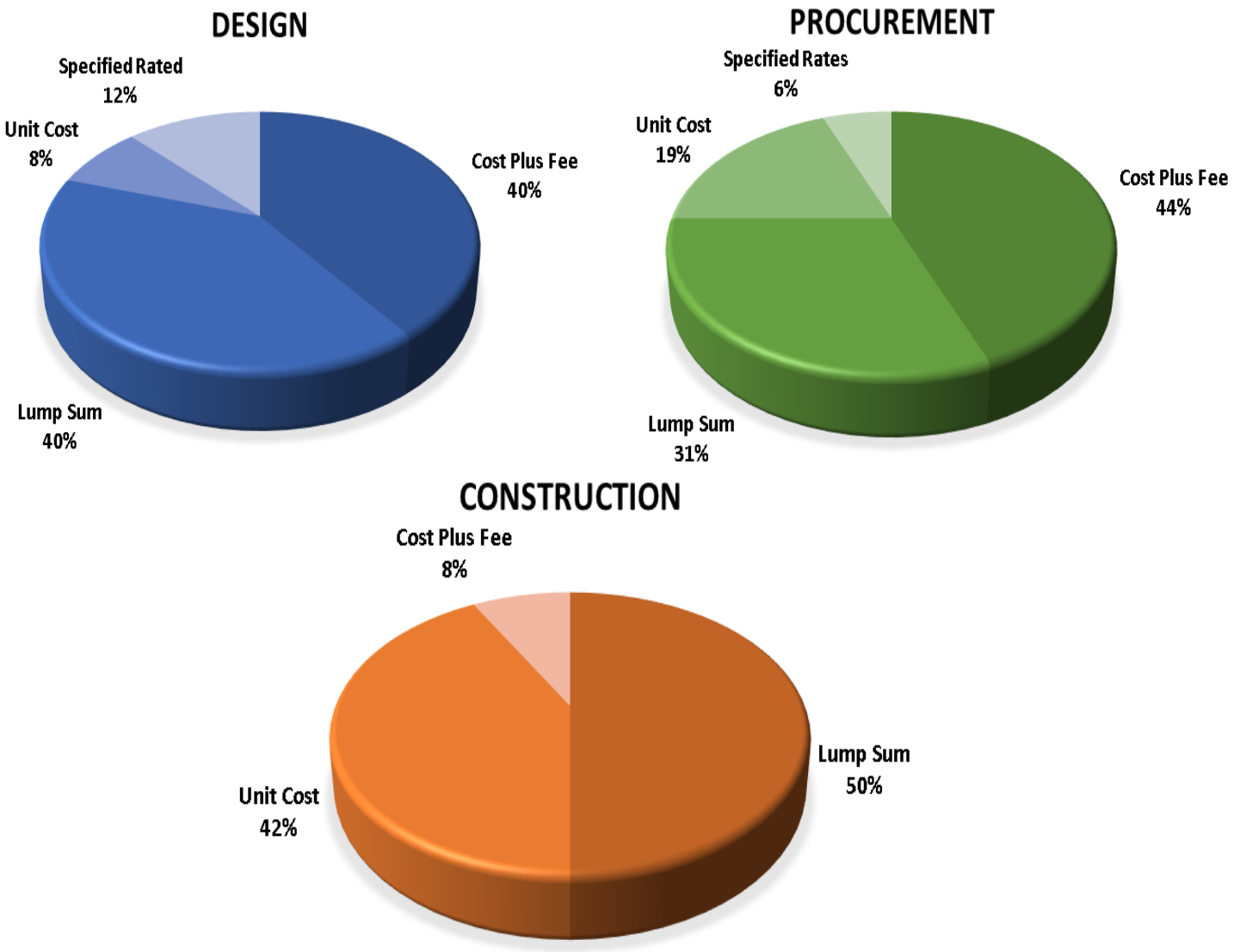

Fig. 3. Contract type

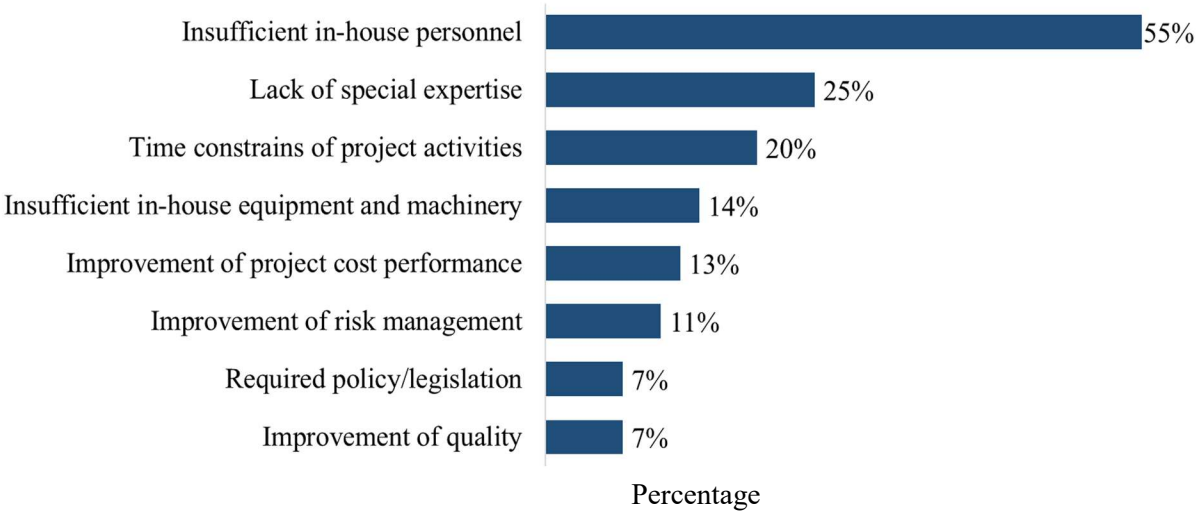

Fig. 4. Reasons for outsourcing

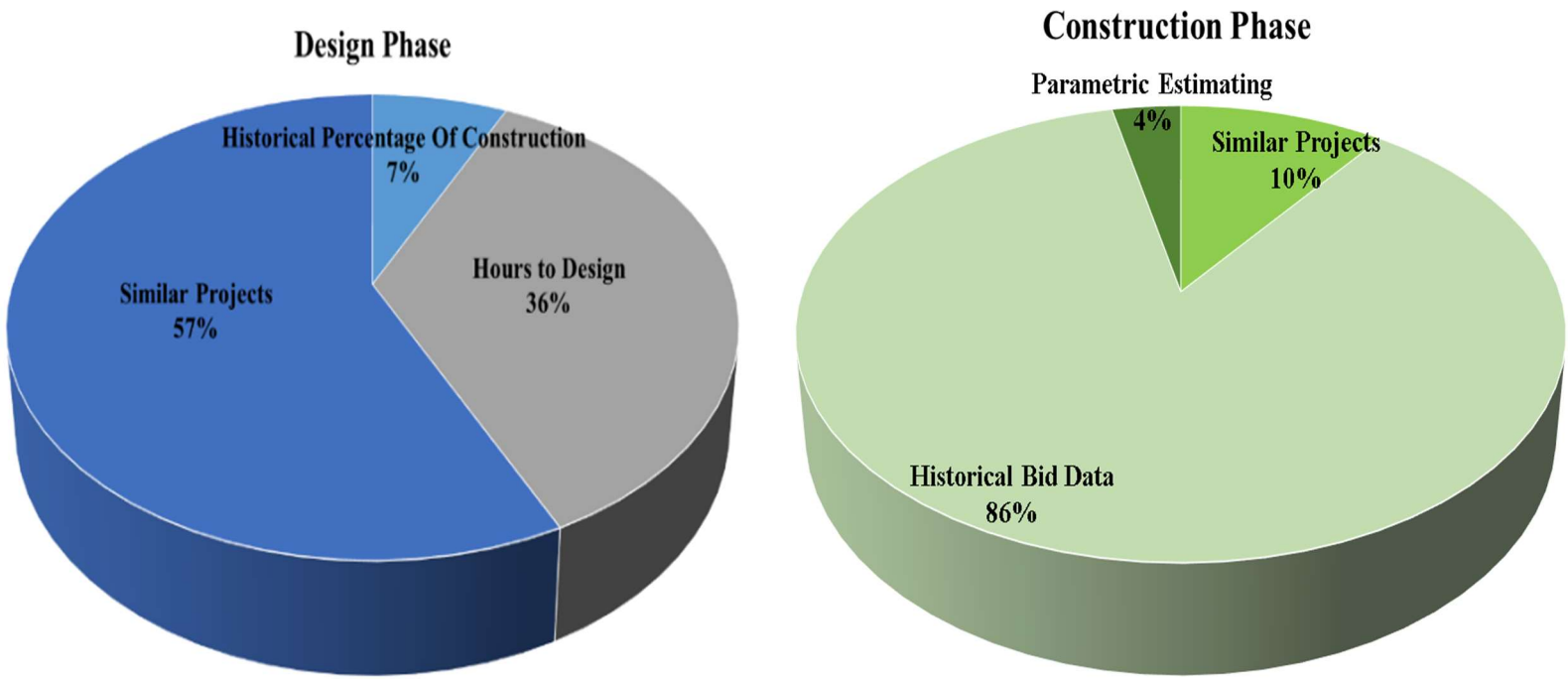

Fig. 5. Cost estimation methods

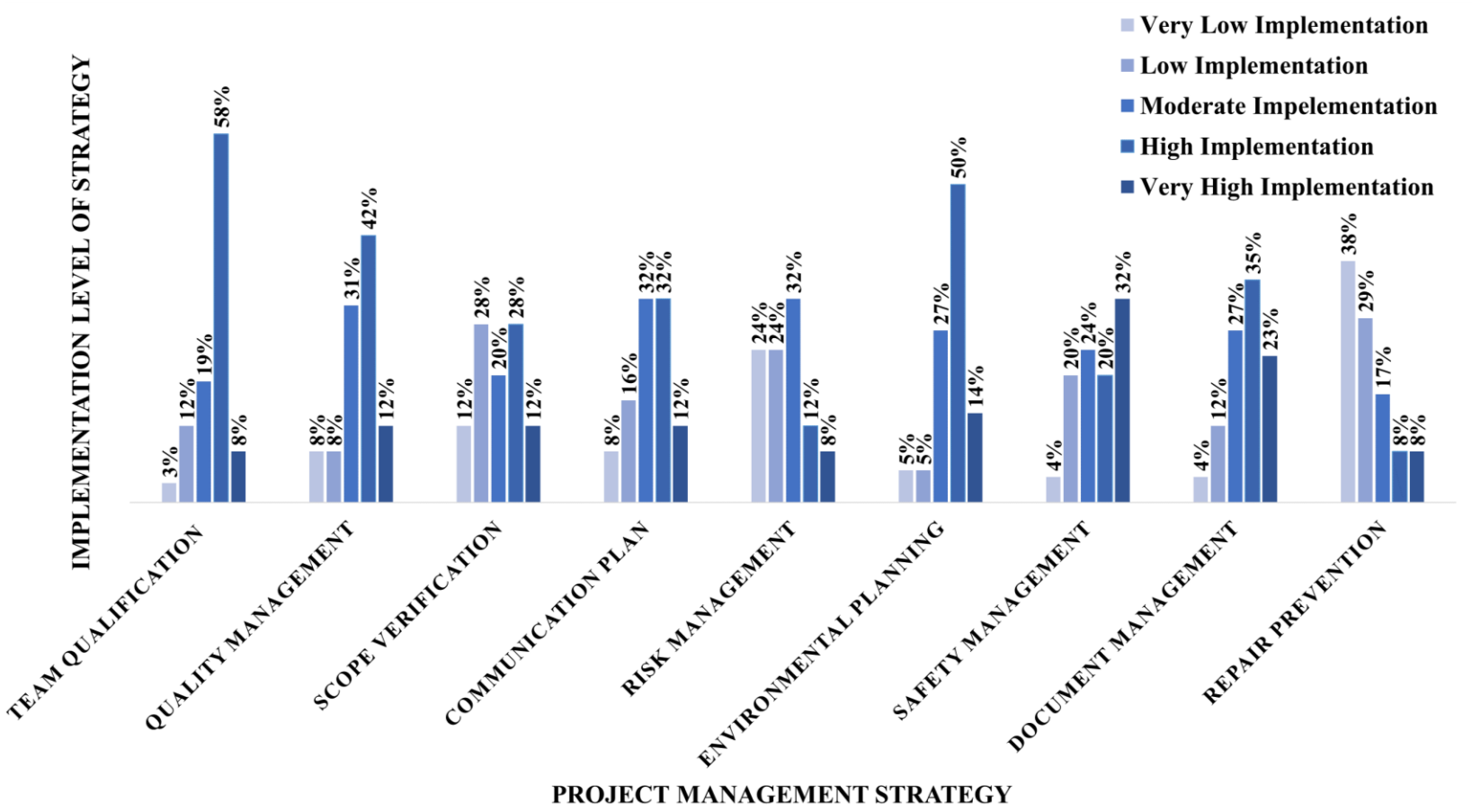

Fig. 6. Implementation level of project management strategies

Investigating Implementation Level of Phase-Based Strategies in Transportation Infrastructure Projects

List of Tables:

Table 1. Demographic Information of Survey Respondents

Position	Experience	Percentage
Director	More than 10 years	7%
Project Manager	More than 10 years	13%
	Less than 10 years	3%
Construction Manager	More than 10 years	23%
Engineer	More than 10 years	48%
	Less than 10 years	6%

Table 2. Outsourced Activities and Their Ratios for the Selected Projects

Project Type	State	Outsourced Phase								Ratio In-house/Outsource
		Administration	Planning	Design	Construction	Maintenance	Operation	Right-Of-Way	Environmental	
Roadway	STA 1			√					√	0%-20%
	STA 2				√	√	√	√	√	60%-80%
	STA 3			√	√	√				20%-40%
	STA 4			√	√				√	20%-40%
	STA 5		√	√	√					60%-80%
	STA 6			√	√					20%-40%
	STA 7			√	√					20%-40%
	STA 8			√	√					60%-80%
	STA 9			√	√		√			60%-80%
Bridge	STA 1			√	√				√	0%-20%
	STA 2			√	√	√	√	√	√	40%-60%
	STA 3	√	√	√	√	√	√	√	√	0%-20%
	STA 7			√	√				√	40%-60%
	STA 10			√	√		√		√	20%-40%
	STA 11		√	√	√				√	60%-80%
	STA 12			√	√				√	20%-40%
	STA 13			√	√				√	60%-80%
	STA 14			√	√					60%-80%
	STA 15				√					80%-100%
Highway	STA 1			√	√			√	√	20%-40%
	STA 2		√	√	√			√	√	60%-80%
	STA 5			√	√			√	√	20%-40%
	STA 7		√	√	√			√	√	0%-20%
	STA 9	√		√	√		√			40%-60%
	STA 10			√						20%-40%
	STA 16	√	√	√	√	√	√		√	0%-20%
	STA 17		√	√					√	20%-40%

Table 3. Implementation Level of Effective Cost Estimation Tasks

#	Cost Estimation Tasks	Percentage
1	Set a project baseline cost estimate during planning phase	62%
2	Review of estimation	58%
3	Early identification of early project risks and uncertainties	46%
4	Document estimate basis, assumptions, and back-up calculations	31%
5	Make estimation a priority by allocating time and staff resources	31%
6	Create transparency by disciplined communication of the uncertainties	23%
7	Complete every step in the estimation process during all phases of project	19%
8	Anticipate external cost influences	19%
9	Create cost containment mechanisms for timely decision making	8%
10	Protect estimators from internal and external pressures	8%

Table 4. Implementation of Managerial Tasks during the Planning Phase

#	Managerial Tasks	Percentage
1	Establishment of effective communication	69%
2	Documentation of project scoping	68%
3	Estimate review - internal	62%
4	Delivery and procurement method	50%
5	Environmental analysis	50%
6	ROW* preservation	50%
7	Recognition of project complexity	46%
8	Budget control	46%
9	Document estimate basis and assumptions	39%
10	Risk identification	39%
11	Conceptual estimation	31%
12	Risk analysis	31%
13	Estimate review - external	27%
14	Using innovative software	27%

**ROW refers to right-of-way*

Table 5. Implementation of Managerial Tasks during the Preliminary Design Phase

#	Managerial Tasks	Percentage
1	Estimation of Design cost	65%
2	Establishment of effective communication practices	65%
3	Review of constructability	58%
4	Project scoping	58%
5	Budget control	58%
6	Estimate review - internal	54%
7	Using innovative software	50%
8	Estimate/document review	50%
9	ROW* clearance needs	50%
10	Risk identification	38%
11	Creation of project baseline	31%
12	Risk analysis	27%
13	Recognition of project complexity	27%
14	Verify scope completeness	19%
15	Estimate review - external	19%
16	Document estimate basis and assumptions	19%
17	Validate costs	15%
18	Value engineering	15%
19	Identification of changes	12%

**ROW refers to right-of-way*

Table 6. Implementation of Managerial Tasks during the Design Phase

#	Managerial Tasks	Percentage
1	Review of constructability	85%
2	Budget control	62%
3	Estimate review - internal	50%
4	ROW* clearance needs	50%
5	Plan specification and estimates	46%
6	Establishment of effective communication	46%
7	Using innovative software	42%
8	Estimate/document review	42%
9	Standardize estimation and cost management procedures	38%
10	Risk identification	38%
11	Document estimate basis and assumptions	31%
12	Identification of changes	27%
13	Estimate review - external	23%
14	Value engineering	19%

**ROW refers to right-of-way*

Table 7. Implementation of Effective Managerial Tasks in the Construction Phase

#	Managerial Tasks	Percentage
1	Hold a pre-construction meeting with a defined agenda	88%
2	Promote a safety working environment	85%
3	Comply with civil rights regulations	85%
4	Follow the procedures outlined in the STA construction manual	81%
5	Know procedural requirements	77%
6	Adhere to schedule	77%
7	Follow the STA process for change orders	77%
8	Comply with all federal procurement requirements	77%
9	Develop and escalation process to resolve conflicts and issues	73%
10	Adhere to STA – approved environmental mitigation	73%
11	Construct the project according to PS&Es	62%
12	Maintain consistent and detailed recordkeeping and reporting practices	62%
13	Establish contractor use areas	42%

**PS&E refers to plans, specifications, & estimate*

Table 8. Implementation of Managerial Tasks during the Inspection and Testing Phase

#	Managerial Tasks	Percentage
1	Assurance of personnel safety training certification	85%
2	Independent QA inspections and material testing	85%
3	Inspection of ongoing construction activities	85%
4	Inspection frequencies	81%
5	Documentation of field activities and recordkeeping	77%
6	Assurance of safety condition on-site	77%
7	Review of past inspection documents and on-site records	50%