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Research on the mechanics of successful collaborative partnering in roadway construction is relatively scarce; however, there is general agreement that successful partnering can result in better budget and schedule control as well as increase safety and quality. Although it is well established that good, collaborative partnerships can lead to lower construction cost, shortened project schedules, we still need to better understand which mechanisms will increase the probability that a successful partnership can be established and maintained. This research aims to further Caltrans understanding of those specific processes embodied in collaborative partnering that have the strongest positive influence on project outcomes. Equipping the staff with this information and empowering them to apply it through out the project phases will not only lead to better project delivery but also improve staff morale.

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Partnering Activities - guidelines, process, meeting, performance. Data analysis, complexity metrics, budget.

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EXECUTIVE SUMMARY

This report presents the results of a study on the effectiveness of project level collaborative partnering on project outcomes, specifically that of on budget. Using data from Caltrans construction projects completed between 2006 and 2012, we identify and quantify the use of partnering on major capital projects; we also quantify the benefits of the partnering process on budget performance. In addition, perceptions of partnering were collected from Caltrans personnel who have been involved in the partnering process. Our findings show that partnering activities are used at far lower levels than prescribed in the Caltrans Field Guide to Partnering and that collaborative partnering does not appear to be improving the odds of a project being completed on budget. A survey of current Caltrans staff suggests that, of the 5 partnering activities used by Caltrans, only the kick off and follow up meetings are believed to improve project operations; partnering training, monthly staff surveys, and close out meetings are considered useless or even a distraction. It should come as no surprise that the partnering activities that were rated as the most useful in the survey are also the most highly implemented in the field. Using data mining to analyze the extensive project data that we collected shows that budget and schedule thresholds governing mandatory partnering do not adequately identify those projects that would benefit most from the partnering process.

Collaborative Partnering on Caltrans Projects

Caltrans' recent push to train field personnel in the partnering process and to mandate partnering on projects based on budget size ($10 million or higher) and schedule length (100 working days or greater) signals a renewed dedication to a program that has existed within the agency for nearly a quarter of a century. The changes in policy have improved participation rates among large projects from 58% in 2006 to 87% in 2012. We have assembled one of the largest and most comprehensive comparative datasets of partnered and non-partnered projects in the literature. Our study includes 274 projects, of which 192 were partnered and 82 were not partnered. We collected extensive data quantifying project characteristics that capture project operations, size, location, and local traffic and land use conditions as a way of controlling for unique challenges experienced by each project. This allowed us to isolate the effect of the partnering process on project outcomes.

Because we were able to quantify elements of partnering on each project at a level of detail not seen in previous research, we found some surprising things. For example, the typical partnered project hosts a kick off and a few follow up meetings, generally ignoring the other activities that are considered elements of successful partnering. Training, monthly staff surveys, and close out meetings were only sporadically used; we found that not one project in our dataset of projects fully complied with Caltrans' partnering guidelines. The low level of partnering activity seen on partnered projects may also account for the lack of correlation between partnering and project budget performance.

The Effect of Partnering on Project Outcomes

Our modeling results show that engaging in partnering activities does not significantly improve the odds of on-budget project completion. Instead, the district in which the project is located and the total number of bid contract items included in a project have statistically significant effects on whether a project is completed on or below the estimated project budget. We also note that very few projects actually conducted the full range of recommended partnering activities. We suspect that the low level of compliance to the requirements for partnering on projects could act as a serious barrier to realizing the potential benefits of the program.

Perception of the Partnering Process

A small group of 54 Resident Engineers and Structure Representatives responded to an online survey administered across all 12 of the Caltrans' Districts. The respondent pool consisted of personnel experienced with both project management and the partnering process. The survey queried respondents on their impression of partnering in general as well as specific activities and aspects of the partnering process. Not surprisingly, the results indicate that the kick-off and follow up meetings are considered useful by field personnel, while respondents perceived that training, monthly staff meetings, and close out meetings have little utility in maintaining smoothly running projects. A subset of the respondents were Resident Engineers on projects included in our dataset, and from these we were able to discern that there is a strong association between the perception of usefulness and level of partnering activity implementation. This reflects both the autonomy of resident engineers in using the partnering process, and perhaps the lessons that they have learned about which activities work best in the field.

Mandatory Partnering Guidelines

We used data mining to determine whether mandatory partnering based on a bid threshold of $10 million or higher and schedule threshold of 100 working days or greater accurately identifies those projects benefitting from the partnering process. We categorized project line item budgets into 22 work categories and created complexity metrics based on the distribution of project budgets to project work types; our computed metrics provide a reasonably objective measure of individual project complexity. The results of this analysis show that very specific work types and complexity metrics have the strongest effect on project budget performance. That is, just a few things need to be known in order to determine if a project would tend to benefit from partnering. Based on the intuitive assumption that partnering should be implemented on projects with characteristics that are known to negatively impact performance outcomes, the results of this analyses suggest that work type and project complexity should be incorporated into the process that is used to decide whether or not partnering is mandatory for a specific project. The application of the partnering process to projects that do not benefit from the process may explain why the partnering process was not associated in improving budget performance in the projects studied. The budget data and complexity metrics used in this analysis are available to project planners prior to the award of a project, thus allowing the easy application of guidelines developed from our analysis during project planning.

Partnering Policy Implications

The results outlined above point to two changes that will increase the beneficial impact of resources dedicated to collaborative partnering. First, mandatory partnering should be changed from using absolute threshold values of budget and schedule to project-based characteristics including the specific types of construction operations and our computed complexity metrics. This would tend to shift partnering resources from expensive, but relatively straightforward projects, such as large highway paving operations, to less expensive but more complex projects. The resources required for partnering (both time and cost) grow as the project size grows, so removing unnecessary partnering requirements on a large project frees up resources for many smaller projects.

Secondly, partnering training and monthly staff surveys should be eliminated from the partnering process. Both of these activities are unpopular with experienced field staff and are implemented at very low levels on construction projects. Partnering training focuses on professional and fair conduct, open communication, and “win-win negotiations” as an alternative to antagonism, posturing and other self-serving behaviors that can be seen in construction. And while the aspirations of the training are useful, the organizational cultures are entrenched and unlikely to be changed in a single afternoon of partnering training. Alternatively, the use of monthly surveys presents a paradox. If communication between project stakeholders is so poor that surveys are required to understand working relationships, then partnering has failed. On the other hand, if collaborative partnering is working and open lines of communication exist between stakeholders, monthly surveys are not needed. That is, the need for surveys signals a breakdown of working relationships, while a project with even minimal levels of collaborative partnering has no need for surveys.

Incorporating these two changes to the collaborative partnering program will improve the benefits of partnering, in general. Mandating partnering on projects based on complexity rather than using a budget or schedule threshold will free up partnering resources for a larger pool of projects. Reducing the number of partnering activities to those which are effective in improving project operations and supported by field staff will streamline the partnering process and reduce partnering costs on individual projects allowing more projects to benefit from the program.

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INTRODUCTION

The use of project level collaborative partnering on U.S. construction projects is well established (1). Government agencies, such as the Army Corps of Engineers, the Armed Forces, and Departments of Transportation, often charged with large infrastructure construction were early champions of the process (2), and most continue to endorse collaborative partnering as a way to promote communication and cooperation between project stakeholders (3). The main goal of collaborative partnering is to quickly identify and resolve jobsite conflicts before they become intractable (4). The mechanics of partnering generally focus on improving job site communication both horizontally (between stakeholders of similar levels of responsibility) and vertically (between levels of management). Ideally, with improved communication not only are field staff provided with the information they need to efficiently perform their duties, but there is also a sense of shared responsibility for project outcomes that can be fostered (5). At its core, collaborative partnering is an attempt to address the notoriously antagonistic work environment found on typical construction sites, a significant amount of which stems from demanding budget and schedule goals.

Partnering activities on construction projects have been credited with improving a variety of traditional project performance measures. Yet, the results of construction management research examining the relationship between partnering and project outcomes have produced conflicting findings in terms of the effects on projects budgets, schedules, quality, and many other metrics of project success. At least some of the difficulty in unraveling generalizable conclusions about the effect of partnering on project performance stems from the evaluation methods used in previous research. Case studies and surveys are prevalent in partnering research, and limit the generalizability. Large comparative studies are surprisingly rare. Our literature review found only eight comparative studies in the last 24 years. A large comparative study of partnered and non-partnered projects is the best way to assess whether collaborative partnering is improving project performance outcomes.

In Chapter 2, we highlight an almost universal, embedded assumption made by researchers. All but one of the studies failed to quantify partnering levels on the projects being studied. This implies that the partnering process is being implemented in exactly same way across partnered projects. This may be valid with a handful of projects, but seems very unlikely for the few studies that include hundreds of projects. To address these issues, and further our understanding of project level collaborative partnering, we articulated four objectives for this research.

Research Objectives

First, in order to understand how project partnering affects project outcomes, the outcomes and the project details must be highly resolved. Our first objective was to assemble a highly resolved database that included, among others, partnering expenditure records, meeting minutes and other material generated at partnering meetings, as well as conducting an agency wide survey of field personnel. Partnering expenditure data including dollar amount of transactions, the date of transaction, the organization being paid, and a brief description was provided by Caltrans and included every transaction expensed to the partnering budget line item. Partnering meeting records were collected and digitized from archived materials located in each District's records warehouse. The archived records also included many invoices for partnering expenses which provided further detail on the expenditure data provided by Caltrans. A very accurate picture of partnering activities for each project was created by combining the various data sources. This picture revealed that partnering activity is highly variable and that even projects dedicated to the partnering process do not fulfill all the requirements set forth in the Caltrans partnering guide. The data showed that Resident Engineers are largely responsible for implementing the partnering process and can modify or even omit large parts of the program. Many projects with mandated partnering did not engage in any partnering activities.

Our second objective was to directly assemble the experiences of field personnel in order to identify possible weaknesses and strengths of the current partnering policy. To this end, the survey administered to Resident Engineers and other field staff included questions about the utility of the partnering process in general as well as perceptions about individual activities. Opinions on the mandatory partnering rules were also collected. The relationships between perceptions of the partnering process and the use of partnering activities on projects was explored by linking individual responses from personnel to the projects they had worked on in the project sample. The results of the survey showed that field personnel generally had positive perceptions of the partnering process, but expressed reservations about individual partnering activities. Perhaps not surprisingly, the popularity of individual partnering activities closely mirrored the implementation rates of activities. For instance, survey respondents thought kick off meetings were the most useful part of partnering, and kick off meetings were also the most commonly implemented partnering activity.

Our third objective was to identify associations between partnering on projects and the corresponding project outcomes, particularly that of budget. Statistical models were specified using the data describing project characteristics, project performance, and project partnering. The modeling allowed the examination of how a variety of variables describing the level of partnering on projects affected the odds of an on budget project completion. We hypothesized that the partnering process was improving construction project outcomes. We also hypothesized that timely and consistent use of partnering activities over the course of a construction project's lifetime will maximize the positive effect of the partnering process on project performance. Lastly, we hypothesized that the variables used by Caltrans to determine mandatory partnering on a project were optimal for predicting which projects would most benefit from the partnering process.

To explore these hypotheses, we developed partnering variables characterizing the types of partnering activities used, the number of times partnering activities were used, how a project's partnering levels compared to Caltrans guidelines as well as total expenditures on partnering activities. Our modeling results are described in Chapter 4. The findings indicate that collaborative partnering, as implemented between 2006 and 2012, does not significantly improve the odds of a construction project being completed on budget.

Our final objective was to provide Caltrans with actionable suggestions to improve current collaborative partnering implementation policies. Informed by the data collected and our modeling results, we focused on using project budget and planning data available prior to project execution to determine projects that would be most likely to benefit from the partnering process. Each project's line item budget was divided into categories differentiating the types of construction operations conducted on the project. After compiling the total percentage of project budgets represented by the different work type categories, we used data mining techniques to identify important predictor variables of project budget performance as well as project partnering. This analysis serves two purposes. First, identifying which types of construction activities are affecting project budget performance provides guidance as to which projects should engage in partnering activities. Those projects with large proportions of construction activities associated with poor budget performance are candidates for partnering. Projects with large proportions of construction activities associated with good budget performance may not benefit from partnering. Secondly, comparing the important predictors of project performance with important predictors of project partnering reveals how closely partnering use is aligned with project challenges. Our random tree forest analysis shows that the strongest budget performance predictors are linked to specific construction operations as well as measures of project complexity. However, the strongest predictors of project partnering are related to variables that reflect changes in partnering policy and variations in management practices between individual Districts and counties. These results suggest that the partnering policy guidelines are not well aligned with project challenges. Furthermore, budget size and the number of working days, the two project variables currently used to decide whether partnering should be mandatory do not accurately reflect a project's need for partnering.

Our research represents the first known effort to include individual partnering activities and their effect on project outcomes. The project partnering data collected clearly shows that the ways in which project partnering is implemented, even on projects where partnering is mandatory, is highly variable. We found that not even one project in our sample (N=274) implemented the five partnering activities prescribed in the Caltrans partnering guide. In fact, the typical Caltrans construction project employs only two partnering activities: the kick off meetings and follow up meetings, and the use of follow up meetings were generally held at much lower rates than recommended. These results provide a strong argument for including partnering activity variables when examining the efficacy of partnering, but further it calls into questions the conclusions of previous research. By controlling for differences in construction project technical and spatial properties, we diverge from the 'typical' studies of partnering, with some surprising findings.

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CHAPTER 1: LITERATURE REVIEW

Over the past twenty years partnering has become an established management technique in the American construction industry. The motivation for partnering lies in the belief that open lines of communication and a cooperative job site atmosphere will help project staff identify threats to a successful project and collaboratively devise solutions in a timely and cost effective manner. By aligning the goals and expectations of project stakeholders, the adversarial atmosphere associated with owner-contractor relations can be diffused and replaced with a more congenial and productive rapport. Partnering activities on construction projects has been credited with improving a variety of traditional project performance measures including cost control, schedule control, safety, and quality. A host of less tangible benefits such as improvements to trust, morale, and job stress has also been documented on partnered construction projects. As industry experience with partnering activities has increased and the theoretical basis for partnering has matured, researchers are now attempting to fine tune partnering processes in order to better understand which activities most benefit from partnering while using the minimum amount of project staff's valuable time. Efforts to date include surveys of industry experts, case studies of projects, a few comparative studies of partnered and non-partnered projects, and the development of new conceptual frameworks with which to analyze management organization and communication.

A number of topic specific literature reviews have been done in the past few years synthesizing the state of research on construction partnering research trends (1), partnering relationships (2), trust in the construction industry (3, 4), and conflicts in the construction industry (5). However, these reviews generally focus on the conclusions of contemporary research with less attention spent on the research methodologies used to reach the conclusions, particularly in quantifying the effects of partnering on project performance. Furthermore, most of these previous literature reviews begin their analysis with the perspective that partnering is an end in and of itself, with impacts to project performance only briefly mentioned. The purpose of this paper is to review how partnering activities and their associated effects on project performance are being measured within the context of both the history of partnering in the United States and the current state of practice in construction industry partnering. Reviewing the activities and mechanics associated with project partnering currently utilized in the United States will illustrate where research methodologies can be improved. We will also explore some of the metrics that have been suggested to determine the usefulness of partnering as well as the performance of partnering across construction projects. Finally, we will discuss the few quantitative studies that have been undertaken analyzing the effects of partnering on project performance.

History of Partnering in the U.S.

Partnering in its current form originated in the mid-1980's and came about largely as a response to growing litigation expenses associated with construction projects (6). The United States Army Corps of Engineers (Corps of Engineers) used a partnering process in two of its projects; the projects, both of which involved the construction of navigational locks, came in on time and on budget with no claims or litigation as the primary measures denoting success. In addition, the construction staffs of both projects spoke very highly of the process and noted a decline in paperwork (6). In 1991, the Corps of Engineers formally implemented a partnering program and many other federal and state government agencies soon followed. The unbridled optimism of the early 1990's, supported by a growing number of success stories, was tempered somewhat by quantitative research indicating more modest but still positive effects of partnering on project performance (7-10) and reducing construction project claim rates (11-13).

By 1999, despite mixed findings, some 47 state Departments of Transportations (DOTs) (11) as well as agencies developing projects ranging from water service (14) and contaminated site remediation (10) to clean room construction (15) reported having a project partnering program in place. As the use of project partnering has evolved, so has its basic definition. More recent research has positioned partnering on the continuum of dispute resolution tools, re-emphasizing the importance of strictly adhering to partnering activities throughout the life of a construction project (16). Understanding the constituents of a partnering program, and when it is likely to be most effective is important; improperly implemented or disingenuous attempts at partnering can limit its effectiveness (11).

Definition and Mechanics of Partnering

In the context of construction projects, partnering refers to activities and management practices intended to encourage communication and cooperation between project stakeholders, which primarily refer to the sponsors or owners of a project and the contractors performing the work. By their very nature, construction projects are subject to a wide variety of uncertainties, many of which require the flexibility that arises from well-developed methods and relationships, to resolve (16). The major project issues that construction managers are combating with the use of project partnering are slow response times to problems and the inability to resolve conflicts in the field. By addressing these two issues, cost, schedule, and quality control are more easily maintained. The widespread adoption of the partnering process by industry practitioners means that there is necessarily variation in its implementation. However, our review has identified certain elements that are present in all partnering methods.

In general, most DOTs have simply adopted, with some minor variation, guidelines published in 2005 by the American Association of State Highway and Transportation Officials (AASHTO) as see in Table 1. AASHTO specifies a certain process which begins with a kick off meeting before the beginning of field work. The kickoff meeting brings the owners of a project together with the management of the relevant contractors. In this meeting, a charter is developed that covers the basic project goals, creates a dispute resolution ladder, and identifies ongoing activities that will maintain and strengthen the partnership. The kick off meeting is also supposed to provide a forum for discussing any concerns or project issues that stakeholders anticipate arising. It is important to note that the charter is not a binding contract, but instead is a personal commitment made by all parties to the partnering process. The project goals allow the owner and contractors to discuss project priorities and individual expectations. The dispute resolution ladder formalizes the process in which disagreements are elevated through the managerial hierarchy. For example each level of management, starting with construction managers and ending with project executives, are allotted a certain amount of time, money or number of attempts at agreement to solve a problem (17). If an issue cannot be resolved within this predefined and agreed upon framework, the next level of management will become involved. Lastly, a schedule of periodic follow up meetings for the duration of the project is agreed upon to regularly review the progress of the project, identify upcoming issues, and strengthen working relationships.

An important, if somewhat underutilized, component of the follow up and close out meetings is the collection of project performance data. Ideally, performance metrics are agreed upon during the kick-off meeting with the project goals in mind, and staff surveys are used to gauge the health and effectiveness of the partnering program. However, a recent survey of state DOTs by AASHTO found that of the departments that have implemented partnering programs, only roughly half are actually collecting data through employee surveys and only 42% are collecting actual project performance data (18).
There is general consensus that applying a one size fits all approach to the partnering process hampers the effectiveness of the partnering process, and on many projects the partnering process may not be warranted (19). Some DOTs have also implemented specific guidelines further defining key aspects of the partnering process such as the length of kick off meetings, the required attendees, whether meetings should have a facilitator, and how often follow up meetings should be scheduled (20-22). Most of these guidelines are oriented toward more costly or complex projects. Finally, many DOTs leave the type and quantity of partnering activities to the discretion of the project managers and resident engineers (23, 24), which results in uneven application of the partnering elements and spotty data collection processes

TABLE 1: Basic Elements of Construction Project Partnering. Source: AASHTO 2005 Guidelines

Partnering Event	Activities	Purpose
Kick Off Meeting	Agenda	- Insure that meeting addresses need of project
	Charter	- Identify mission of project team - Identify goals for project - Develop channels of communication - Develop conflict resolution ladder - Agree on frequency and type of future partnering activities
	Measurement	- Agree on performance monitoring measures to track project and partnering performance
Follow Up Meetings	Review	- Identify project issues and discuss origins and solutions - Identify project partnering issues and discuss origins and solutions - Review performance measures
	Evaluation	- Measure health of project and partnering to identify areas of concern
	Showcase Successes	- Identify successful conflict resolution to maintain partnering momentum
Close Out Meeting	Review	- Review performance measures - Identify lessons learned over the course of the project
	Showcase Successes	- Identify successful problem solving and conflict resolution over the course of the project

Barriers to Partnering

The basic structure of the partnering process as described earlier has remained unchanged since being adopted by the U.S. Army Corp of Engineers in the late 1980's, however significant effort has been expended in identifying where project management should be focusing their energies. It comes as no surprise that many surveys of industry professionals find that partnering is most effective when all parties are committed to the partnering process (11) and that all the levels of management are equally dedicated (17, 25). There is also general acknowledgement that traditional attitudes and structures of construction companies hinders the adoption of partnering processes (16, 26) and that market pressure and concerns about the bottom line are a constant threat to successful partnering (27). The short-term nature of construction projects coupled with uniqueness of projects also creates barriers to relationship building (19). Even when business leaders and other high level managers adopt the partnering ethos there is difficulty in disseminating the knowledge to lower level employees (26, 28). For example, a survey of the Texas DOT found that a majority of staff thought follow up and close out meetings were important enough to be mandatory, but only 20% had the opportunity to participate in such meetings (11). Similarly, the use of facilitators is widely encouraged, but rarely used in practice (16). Adding to these difficulties, partnering requires constant effort and reinforcement to keep relationships healthy (25). This may explain why optimism about the partnering process "is seldom sustained through the project lifecycle" (27). Creating and maintaining working relationships, the ultimate goal of partnering, require open communication and high levels of trust which are both subjects of intensive research.

Communication

Communication has both a quantitative aspect (number of emails, meetings, etc.) and a quality aspect (clarity, accuracy, etc.). There is evidence that the quality of communication is much more important than quantity when analyzing job site coordination (29) and that face to face communications are the most productive, while emails generated the most confusion (30). In a study of 25 public-sector projects, Pocock and fellow researchers found that the degree of interaction between designers and builders closely and positively tracked a wide variety of project performance indicators (12); these findings are consistent with other recent research using construction practitioner survey data (31). The link between communication and trust is undeniable, but identifying the underlying mechanisms and the temporal relationships between communication and trust are very difficult.

Trust

In their review of trust in the construction industry Gad and Shane find a wide variety of construction project variables that affect trust including onsite social interaction, macroeconomic factors, project contracts, project cost, and project delivery methods (3). But the evidence on trust has suggested that some factors will limit the amount of trust that can be built on a project for any of these project variables. First, the short term nature of construction projects coupled with constant shuffling of management teams for new projects reduces the 'relational background' needed for trusting partnerships (32). In other words, people trust those who they have worked with more than strangers. As such, previous working experience between project team members is a strong indicator of trust levels (33). Yet, prior experience can also be problematic. For example, a study of railroad construction in the Netherlands suggests that professionals who have worked in adversarial environments have difficulty in adopting the more cooperative working habits required for successful partnerships (34).

Behavior

Project partnering is implemented in order to offset ingrained behaviors that are strongly represented in the construction industry, but may nevertheless jeopardize project success. The suggestions to overcome trust issues on construction projects such as writing less binding contracts (32) or focusing on long term benefits instead of short term gains (26) have gained little traction in the field. This is not surprising, as one interviewee notes "For trust to arise, you have to take a vulnerable position yourself first, so that your project partners can subsequently demonstrate their trustworthiness by not abusing your openness (34)." Cacamis and El Azmar have speculated instead that emotional intelligence training for project managers would improve trust, citing their findings that Virginia DOT projects run by managers with low scores in emotional intelligence performed worse than projects run by managers with high emotional intelligence scores (35).

Measuring the Effects of Partnering

There are some specific methods in which investigators have quantified the effects of partnering on construction projects. To date there have been three approaches to gathering data for measuring the impacts of partnering: surveys, case studies, and comparative studies. The reality of the construction process is that each construction project experiences countless variations on every axis of categorization and this has given rise to at best quasi-experimental comparisons using groups of projects that are similar across a few easily measured metrics.

Surveys and case studies are far more common than comparative studies in the realm of construction partnering research. Surveys have been used to explore subjective aspects of partnering such as staff interaction, communication, trust, and morale. And while being less suited for this role, surveys have been pressed into service to collect project performance data. The use of surveys to collect both qualitative and quantitative project data is attractive due to the potentially large sample population and the relative ease of collecting and manipulating the data set (particularly for web based surveys). By utilizing contact lists from trade groups and licensing authorities, surveyors have the potential for tapping into large populations of experienced practitioners. The disadvantage of this approach, collecting quantitative project data through surveys includes the possibility of self-selection bias; that is, the accuracy of self-reported project data from heavily involved practitioners will undoubtedly introduce biases of unknown breadth and depth. When asked to provide project data on 'recently completed projects' will project managers give successful and unsuccessful projects equal representation? Will their views on partnering in general influence which projects are reported? Even if the survey asks for information on both partnered and non-partnered projects "it is still hard for respondent[s] to recap old projects and give objective answers. In the same way it is hard to extract the unique effect of partnering, despite being the person with the most knowledge about the project (often the project manager) (36)."

A perfect example of the problem of bias appears in a survey of Danish building professionals representing developers, client design advisors, architects, engineers, and contractors (30). When asked which construction profession provides the most solutions to conflict, all but one category of professionals overwhelmingly answered that their own profession created the most solutions. The lone outlier was the 'client design advisor' who still responded that they provided the most solutions but were gracious enough to admit that their clients created solutions almost as often as themselves. Similar results were found when the groups were asked to identify the most trust worthy profession.

Surveys are not the best method for measuring the effects of partnering on project performance. The dependence on self-selected respondents puts the survey method at a disadvantage when attempting to compare partnered and non-partnered construction projects where objective data are vital. In addition, with little control over project parameters, researchers using surveys are forced to either reduce the number of observations (that is, accept smaller sample sizes for comparison), or compare a large group of dissimilar projects. However, surveys excel at showing the perceptions and expectations that practitioners have of project partnering (27) as well as exploring which metrics and procedures are perceived to be most useful to project management. Using interviews and Delphi surveys, researchers in Hong Kong developed quantitative indicators and ranges for these indicators to build an objective Partnering Performance Index so that project managers can monitor partnering performance (37, 38). Earlier work to develop Key Performance Indicators for construction projects found through surveys that performance measurements differed between construction sectors (e.g. general, heavy, and industrial) and management levels (39). More recent surveys have sought to identify the most effective modes of communication and coordination (29) and to minimize transaction costs throughout the many phases of construction projects (40).

Case studies are also used widely in construction project partnering research to delve deeply into the internal workings of the project staff on a particular project. With a combination of interviews, observations, and questionnaires scholars can develop fine grained pictures of project partnering, incorporating a host of project specific details which would be lost in either surveys or large scale comparative studies. Important intangible aspects such as relationship dynamics, working atmosphere, and organizational cultures can be observed and recorded in order to add texture and context to otherwise impersonal analyses. Case studies of the UK construction industry (41), subway construction in Hong Kong (25), railway construction in the Netherlands (34), and clean room construction in Canada (15) provide perspectives from a wide range of stakeholders and reveal the day to day challenges and rewards of implementing the partnering process. The narrow focus of case studies hampers the methods ability to develop generalizable observations of the effects of partnering on project performance. The strength and value of case studies lie in their ability to extend our understanding of the practical application of project partnering and in turn develop new lines of inquiry to further partnering effectiveness.

Comparative studies represent perhaps the best research method for truly extending our knowledge about the underlying mechanisms associated with the project partnering processes. Thus, given the potential to distill and isolate the effects that project partnering has on project performance using comparative studies, makes the scarcity of such studies extremely puzzling. We were able to find only a handful of comparative studies that relied on objective project performance data rather than survey responses. Most of the studies were based on construction projects in the United States and used data from the 1990's and early 2000's. Two more recent studies examining road construction in the UK and

Swedish publicly procured projects were also found. The factors used in these studies generally focused on project cost, project schedule, the number and value of change orders, the number of lost time incidents, and liquidated damages as listed in Table 2. A concise explanation of these factors and how they are used to develop performance metrics can be found in Gransberg et al. In addition to project data, many of the studies included surveys and interviews to also identify perceptions and experiences of project personnel. All but one of the studies found statistically significant improvements in partnered project performance, but the categories of the improvements differed among the studies, which creates difficulty in generalizing outcome results. Two studies found improvements in all performance measures, one study found across the board improvements only in partnered projects valued above $5 million, while the remaining comparisons show mixed results. The generally positive results also come with some important caveats.

TABLE 2: Review of Quantitative Partnering Studies

Title	Author	Date of Publication	Data (N)	Factors/Variables	Project Description	Method of Project Categorization	Conclusions
An Analysis of Project Performance for Partnering Projects in the US Army Corps of Engineers	David Charles Weston	1993	16 partnered projects, 29 non-partnered projects, 15 interviews with staff on partnered projects	project cost, change order cost, value of claims, value engineering savings, schedule	Mix of military and civilian projects spread across the 37 Corp of Engineers districts.	project cost, geographic location of project	Partnered projects performed better across all performance measurements
Partnered Project Performance in the US Naval Facilities Engineering Command	Kelly Joseph Schmader	1994	39 partnered project and 100 randomly selected non-partnered projects. Surveys were also collected	project cost, change order cost, value of claims, value engineering savings, schedule	A mix of civil and military projects commissioned by the US Naval Facilities Engineering Command	project length, project cost, geographic location of project	Partnered projects perform better in schedule control, claims avoidance, value engineering savings. Partnering had no effect on project cost or change order cost.
Relationship Between Project Interaction and Performance Indicators	James B Pocock, Chang T Hyun, Liang Y Liu, Michael K Kim	1996	25 projects and 25 surveys to determine DOI	project cost, change order cost, value of claims, value engineering savings, schedule, contract type, Degree of Interaction (DOI)	Military projects.	projects required a minimum value of $500K	Partnered projects scored higher in Degree of Interaction (DOI) than traditional projects. Higher DOI scores corresponded with less schedule growth, fewer modifications, and lower average cost.
Quantitative Analysis of Partnered Project Performance	Douglas D Gransberg, William D Dillon, Lee Reynolds, Jack Boyd	1999	204 pairs of partnered and non-partnered projects. Partnered from 1992-96. Non-partnered from 1987-91. Survey of 500 TxDOT and contractor personnel	project cost, change order cost, number of change orders, value of claims, value of liquidated damages, schedule	Texas DOT projects	Two categories: less than $5million and greater than $5million contract value	Partnered projects above $5 million performed better across all categories.
Partnered Project Performance in Texas Department of Transportation	Kenneth M Grajek, G Edward Gibson Jr, Richard L Trucker	2000	54 partnered projects, 107 randomly selected non-partnered projects, 894 survey responses	project cost, change order cost, number of change orders, value of claims, value of liquidated damages, schedule	Texas DOT projects	project cost, geographic location of project, completion date, project type	Partnered projects performed better in schedule control and number of claims. No difference in project cost or change order cost
Partnered Project Performance in the City of Phoenix	Eric McFadden, James J Ernzen	2003	16 partnered and 41 non-partnered projects	project cost, change order cost, number of change orders, value of claims, value of liquidated damages, schedule, cost of partnering	City of Phoenix Water Services Department projects	Three categories: $0-$5 million, $5-$15 million, and $15-$40 million contract value	Partnered projects performed better in cost control only in $0-$5 million category. Partnered projects performed better in schedule control and liquidated damages across all categories.
A Quasi-Experimental Evaluation of Partnering	Johan Nystrom	2008	10 partnered and 10 non-partnered projects, contract documents and meeting minutes from projects analyzed	project cost, schedule, contract disputes, indicators of quality	Swedish road and railway maintenance projects and housing projects	project cost, geographical location, project type, contract type, client and contractor type	No significant trends.
Collaborative Working in Highways Major Maintenance Projects	Mary Ansell, Rees Evans, Mike Holmes, Andrew Price, Christine Pasquire	2009	2 highway maintenance projects on the same stretch of road, questionnaire results	project cost, schedule, site safety, customer satisfaction, quality, client satisfaction with product, client satisfaction with service	Highway resurfacing in the UK	Only two projects compared	Partnered project performed better across all performance measurements

In order to develop generalizable conclusions about project partnering the comparison of construction projects must be very carefully structured. As mentioned earlier, construction projects vary in countless ways and these variations dictate to a large extent how easily study results can be compared. Two methods of comparison are generally used in the studies we reviewed. The more common approach creates two groups of projects, partnered and non-partnered, and compares the aggregate values of the various project performance metrics to identify the effects of partnering. Attempts are made to make the two groups reasonably representative by assuring the average value of projects, the distribution of geographic location, and in some cases the distribution of project types are similar. These must be balanced by the countervailing demands of creating statistically significant sample sizes and making sure that the samples represent analogous construction projects. We did not find any research identifying which parameters best align projects for comparison, and it may be a moot point given the data that has been used in previous studies.

The less common and much more difficult method of comparing projects involves creating pairs of projects with similar attributes and analyzing each set of matching projects. We found only two studies that apply this method with one comparing a single pair of projects (42) and the other including 10 pairs of projects(43). For the first approach, Ansell's study resembles a case study of a specific construction crew rather than a comparative study of the partnering process. The study compares two almost identical highway resurfacing projects and both of the projects use the partnering process and the same construction crew. The major difference is that the construction crew had little experience with partnering on the first project and two years of experience in the second project. The study primarily captures the effects associated with the learning curve of the crew more than the effects of partnering.

In the second study, the only one to report no findings of partnering benefits, Nystrom, the study author, went to great lengths to find near identical pairs of projects using the following criteria: procurement method (public vs. private), project type, project size, delivery method (design-and-build vs. traditional), contract type (cost-plus, fixed price, and incentives based), contractor and client size, and geographic closeness. By reviewing meeting minutes from the projects, Nystrom sought to find examples of partnering tools being used to resolve disputes. The study conclusions are mixed, but one of the interesting things he uncovered in the review of project documents was the fact that five of the projects that had partnering clauses in the contract did not follow through with partnering activities. Analyzing only the project pairs with 'real' partnering projects (those that engaged in partnering activities as indicated in project meeting minutes) reveal no project performance benefits as a result of partnering. Another layer of complexity is added to the analysis when projects do not fulfil their obligations to partnering activities.

Of the remaining eight comparative studies that we reviewed, only two addressed partnering using more than a binary variable. The other six studies grouped projects as either partnered or non-partnered, and discussions of partnering in regard to level of commitment by the project team or quantification of partnering activities were absent. Nystrom's study determined partnering levels on projects by reviewing project meeting minutes. While not explicitly measuring partnering activities, Pocock and his fellow researchers measured 'degree of interaction' through surveys of project staff who estimated how many hours per month they interacted with other members of the project team through the various phases of construction. While far from objective data, the survey results do give a general impression of staff communication and fall in line with the expectations that personnel on partnered projects communicate more often than those on non-partnered projects. Nystrom's and Pocock's studies reveal a gap in the research methods used for comparative studies: the assumption that partnering activities are being carried out in a uniform and satisfactory manner on all projects labeled as 'partnered' is not valid. This finding is consistent with surveys conducted by AASHTO indicating that state DOTs with partnering programs are inconsistently applying partnering processes (18, 44). For example, almost all DOTs with partnering programs reportedly hold kick-off meetings, but only half actually administered staff surveys or some type of feedback mechanism and only one-third hold close-out meetings at the end of projects. Even these self-reported levels of partnering activities are not robust considering the fact that a mere 14% of DOTs reported actually measuring partnering performance.

Areas of Further Research

Partnering on construction projects is a method which theoretically encourages communication and fosters trust, an assumption that is now regularly accepted as fact by both the construction industry and academics. The growing body of research devoted to partnering has been overwhelmingly positive in regards to project performance improvements. But as we have shown, there are some important limitations to past research, namely poor study designs and the lack of a consistent project partnering definition and objective data collection processes.

Research is needed to isolate the effects of partnering on project performance to help fine tuning the partnering process and improve the effectiveness of partnering activities. The review of partnering performance studies using surveys, case studies, and comparative studies identified areas where further research is most needed. This literature review revealed a significant lack of robust comparative studies using objective project performance data to understand the effects of project partnering on construction projects. Relying solely on self-reported survey information to understand the effects of partnering has the potential to skew conclusions with unknown biases. And while case studies can reveal a wealth of contextual information about project partnering, the results of such narrow studies cannot be generalized. Large scale comparative studies are required to fully understand the intricacies of partnering. Attention must be paid to find partnered and non-partnered construction projects similar enough to make meaningful comparisons. The widespread adoption of partnering in the United States gives hope that data will be available for such studies. Furthermore, objective measures of the partnering process must be included in future comparative studies to control for the uneven application of partnering activities on construction projects. It is possible that partnered project performance has been suppressed in previous studies because of a lack of control over the actual level of partnering activity on partnered projects.

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CHAPTER 2: COLLABORATIVE PARTNERING - IMPLEMENTATION, IMPACT, AND FIELD STAFF PERCEPTIONS

Introduction

The use of Collaborative Partnering (CP) on U.S. construction projects is well established. Government agencies charged with large infrastructure construction, e.g., the Army Corps of Engineers, the Armed Services, and many Departments of Transportation (DOT), were early champions of the process and continue to endorse partnering as a way to promote communication and cooperation between project stakeholders. Project level collaborative partnering's main goal is to establish a process that facilitates quick identification and resolution of jobsite conflicts before they become intractable (1). Thus, the communication structures put in place through the partnering process are geared toward improving working relationships between project stakeholders. Partnering activities on construction projects has been credited with improving a variety of traditional project performance measures including cost control, schedule control, safety, and quality.

Post-adoption of partnering in the 1990's indicated that partnered projects had better schedule and budget performance when compared to non-partnered projects (2, 3). Partnered projects also experienced fewer change orders and project claims (4, 5) indicating that disagreements between project owners and contractors over issues such as the scope of work, work schedules, project administration, and site conditions were resolved without litigation. Subsequent studies have produced mixed findings on how the partnering process is impacting project performance metrics. Grajek, Gibson, and Trucker's study of Texas DOT projects found that partnering improves schedule control and reduces claims but has no impact on total project cost or the total change order cost (6). Similarly, McFadden and Ernzen found that partnered water infrastructure projects in the city of Phoenix had improved schedule control and liquidated damages, however only the smallest project category (0-5 million) showed increased budget control (7). Lastly, an in depth comparison of 10 partnered and 10 non-partnered projects by Nystrom found no difference between the projects when considering project cost, schedule, contract disputes, or the quality of the completed projects (8). Some researchers question whether true collaboration is even necessary on relatively short lived construction projects (9).

However, there are some limitations to the more recent research. One of the more significant problems is that projects designated as 'partnered projects' are assumed to be of a consistent type and that the number of partnering activities take place relatively uniformly over the life of the project. These assumptions arise as a result of the literature on partnering, which stresses the importance of timely and consistent use of partnering activities to ensure maximum benefit from the partnering process (10, 11). Maintaining the partnering relationship through regular meetings and careful monitoring of relationships are seen as a crucial elements of the partnering process (12, 13).

Typical of much of the partnering used by government agencies in the United States, the California Department of Transportation (Caltrans) endorses a partnering process that includes five formal activities: a kick-off meeting, training in partnering, follow up partnering sessions, close-out meetings, and staff surveys. The kick-off meetings are held at the beginning of a project and structured so that project stakeholders can communicate their expectations and develop communication strategies for early identification and resolution of project-related issues. Training in partnering concepts is often conducted simultaneous to project kick-off meetings to ensure that all stakeholders understand, and buy into the partnering process. Subsequent partnering sessions are held at regular intervals over the project lifetime, both to maintain relationships and to head off potential problems. Staff surveys are also used to measure the health of partnering relationships and the project in general, and are administered at regular intervals (Caltrans recommends monthly) over the course of the project. Kick-off meetings and follow up partnering sessions frequently employ a professional facilitator to guide the meetings. Finally, close-out meetings, held at the end of a project, are meant to be used as a way to learn from the successes and failures of a project.

Caltrans has been encouraging the use of CP on its construction projects since the 1990's, and over the intervening decades has developed standardized guidelines, trained thousands of field staff in partnering concepts (e.g., The Fundamentals of Partnering Training), and gradually made partnering mandatory on a growing proportion of construction projects. In the early days of implementation, training in partnering was required for personnel on projects with bids of $25 million or more. More recently, in 2012, partnering became mandatory on projects with total bids equal to or greater than $10 million and 100 working days or more were required to implement partnering. In addition, the average amount allocated for partnering has also grown by 115% between 2006 and 2012.

Underpinning the evolution of Caltrans partnering program is an agency certainty that collaborative relationships between project stakeholders can be created through a rigorous application of partnering mechanisms (14, 15). However, as we noted earlier, the recent push for a more structured, consistent partnering program comes at a time of growing acknowledgment from construction and project management scholars that CP may not produce the gains in productivity and predictability originally envisioned (16-18).

One of the major gaps in our understanding of the procedural aspects to partnering is that there is very little research that either defines or quantifies 'consistency,' or measures the actual effect that variation in partnering implementation has on project outcomes. This gap in research makes it impossible to accurately identify connections between partnering activities and their impact on project performance. In this paper, we are interested in exploring an underlying assumption of those advocating collaborative partnering: that timely and consistent use of partnering activities over the course of a construction project's lifetime will maximize the positive impact of the partnering process on project performance.

To conduct this research, we worked with Caltrans to assemble a comprehensive dataset of completed construction projects completed between 2006 and 2012; our data includes descriptive information on project characteristics, project performance, and project partnering activities. From this, we are able to characterize the trends in partnering implementation, including how many projects are using the partnering process, the levels of funding being spent on partnering, and what type of partnering activities are being deployed. We then use these trends to explore how variations in type and timing of partnering activities affect project outcomes. Finally, we place our analytical results in the context of how project managers qualitatively perceive CP. To do this, we conducted an agency-wide survey to assemble information on the perceptions and experiences of Caltrans' field personnel using CP.

Our results show that partnering is becoming more common on Caltrans projects with the number of partnered projects rising and the use of many specific partnering activities such as kick off and follow up meetings becoming widespread. However, the growth in partnering implementation is uneven and some components of the process such as training and close out meetings are still not seeing wide spread use. Spending on partnering, as a percentage of the allotted partnering budget has held steady across the study period as total allocations have grown. The pattern of implementation closely mirrors the popularity and perceived usefulness of activities as captured in the survey. Respondents to the survey indicate that they see partnering as having potential to improve project performance but are less sanguine when presented with specific project challenges that partnering should help overcome. The subgroup of Resident Engineer respondents who oversaw projects from the data set reinforce how strongly perceptions of the partnering policy impact implementation regardless of mandates set by Caltrans. Logistic regression models capturing the effects of differing partnering levels on the probability of a project being completed on budget find that the partnering process did not have a statistically significant effect on budget performance for the projects considered in this research. Instead, the location of the project (the district) and the number of bid items included in a project were found to have significant correlation with budget performance.

Empirical Data and Methods

Project Sample

Our data includes information on 4303 construction projects completed between 2006 and 2012. From this, we focus on a subset of 274 projects having bid values of $10 million or greater. Of those, approximately 70% had partnering activities and 30% did not (Table 3), despite a Caltrans policy requiring partnering on projects with expenditures of $10 million or greater (19). The expenditure and partnering data suggest that Resident Engineers have a fair degree of autonomy in implementing the partnering process. There does not seem to be any recourse for RE's who decide not to implement partnering. Partnered projects tend to be larger in both budget and working days and have more contract bid items. The projects included in this study represent a wide variety of construction activities such as bridge construction and maintenance, road rehabilitation, road widening and realignment, construction of safety structures (such as guardrails), as well as drainage systems.

Partnering Expenditures

Partnering activities on Caltrans projects are typically funded through a Contract Change Order (CCO) which allocates a specified total sum of money to be spent on partnering activities. Caltrans staff indicates that partnering budgets are determined in a two-step process. First, Caltrans uses the dollar amount of a project budget and the length of the project in working days to determine the maximum amount of supplemental funds that is available for partnering activity. The Resident Engineer, who is Caltrans' counterpart to the contractor's Project Manager, then decides how much of the supplemental funds to include in the partnering CCO based on the anticipated partnering activities over the life of the project. Although each project gets an allocated amount for partnering, our spending data suggests that RE's are rarely spending as much as has been allocated. In our project sample, the average project is spending only half of partnering budget. CCO's provide a lump sum to be used on partnering activities and allow the project Resident Engineer to use the funds as they see fit. Of the 274 projects in this analysis, 192 of the projects included a partnering CCO and 82 of the projects did not have a partnering CCO. For the 192 projects with a partnering CCO, the total partnering budget ranged from $2,000 to $225,000.

TABLE 3 Characteristics of Partnered and Non-Partnered Projects

Project Characteristics	Partnered Projects	Non-Partnered Projects
Number of Projects	192	82
Miscellanies	2%	2%
Bridge Work	22%	15%
Drainage	3%	1%
New Construction	18%	22%
Resurfacing/Rehabilitation	28%	39%
Road Widening	21%	7%
Safety/Noise	4%	6%
Support Structures	2%	7%
Average Bid Amount	$40 Million	$23.2 Million
Average Number of Planned Working Days	514	431
Average Number of Contract Bid Items	153	121
Project Length (Miles)	8.7	6.6
Project Location (District)		
1	5%	4%
2	3%	7%
3	13%	11%
4	33%	10%
5	2%	4%
6	5%	6%
7	13%	27%
8	9%	9%
9	1%	1%
10	6%	4%
11	7%	15%
12	5%	4%
Average Total Claims Value	$ .78 Million	$1.03 Million
Average Total CCO Value [a]	$6.1 Million	$3.2 Million
Average Budget Growth	7.90%	9.20%
Average Schedule Growth	7.60%	11.10%

[a] CCO Value represents the dollar amount of Contract Change Orders

Our data also included an exhaustive list of expenditures made through project partnering CCO's for every partnered project in the project sample; these data were compiled from transactions as well as archived partnering documents and included invoices, extra work tickets, and receipts. Each item in our project data includes a project identifier, the date of the transaction, and a brief description of the funded activity. Among the kinds of activities that were funded were professional facilitators, space to host partnering activities, and development of meeting materials. Groundbreaking and ribbon cutting ceremony expenses were also charged to the partnering CCO.

Partnering budget allocations on individual projects grew from an average of $11,800 in 2006 to a peak of $35,540 in 2009 before falling to $25,403 in 2012. Between 2008 and 2009, there is a significant increase in available funds, which reflects a shift in Caltrans partnering policy. In 2008, Caltrans made partnering mandatory on projects with bid equal to or greater than $10 million; prior to this, the partnering process was voluntary. Caltrans also undertook a large training program in 2009 and 2010, which resulted in approximately 3,000 field personnel being trained in partnering techniques. In 2012, Caltrans mandated partnering on projects with greater than or more than 100 working days. This change was to facilitate contract administration.

Partnering Activities

The percentage of projects with partnering CCO's has been slowly growing over time. In 2006, 58% of projects with values of $10 million or more had funds allocated to partnering activities; by 2012, this had grown to 87%. However, the use of individual partnering activities varies considerably. Kick-off meetings are by far the most common partnering activity, with implementation steadily rising from 30% to 77%. The use of follow-up partnering sessions fluctuates, but is generally becoming more common as are staff surveys. Partnering training and close out meetings are the least popular partnering activities.

Survey Data

We also distributed a short online survey in order to gauge the perceptions and experiences of Caltrans staff using the collaborative partnering process. Using a Likert scale ranging from strongly disagrees to strongly agree, questions focused on the perceived utility of the partnering process in general, the usefulness of each of the partnering activities specifically, whether the requirements for mandatory partnering were appropriate, and how staff experiences affect the perceived usefulness of partnering. At the end of the survey, demographic information regarding job experience, age, and education levels were collected. An open written section was also provided to allow respondents the opportunity to discuss aspects of partnering not covered in questions.

Because collaborative partnering is intended to be used during the construction phase of roadway projects, we focused our survey outreach efforts primarily on Caltrans resident engineers and structures representatives (BR's). Caltrans provided the names and email addresses for currently active RE's and BR's in its 12 District Offices. Additionally, contact information was collected from sign in sheets of partnering meetings collected during the document analysis. We sent out invitations to participate in the survey to approximately 954 Caltrans RE's and BR's. We received 67 responses, but only 54 of these were complete enough to be included in the analysis, resulting in a response rate of 5.7%. The low response rate may be partially attributable to a lack of participation incentive (which is not allowed for government employees) and/or apathy about the survey topic. Regardless, the response rate is extremely low and survey findings should be considered exploratory.

Those who did respond were generally male (85%), middle aged (31%), experienced in the construction field, and college educated. The average age of respondents was 41-50 years old which was also the largest single group of respondents (31%) with the next largest groups aged 51-55 (23%) and 56-60 (20%). The average career length with Caltrans was 16-20 years with a minimum of 6-10 years and a maximum of 36-40 years. The respondents have worked on an average of 25-30 projects with a minimum of 6-10 projects. Just over half of respondents (51%) worked on more than 40 projects. While respondents have generally worked on many projects the rate of being the RE on projects was much lower, averaging 11-15 projects with the largest group of respondents having no RE experience (20%) or experience being an RE on 1-5 projects (20%). 4% of respondents had a high school diploma, 77% an undergraduate degree, and 20% had a master's degree.

When asked to reflect on their experiences with the individual components of the partnering process, respondents clearly perceived kick-off meetings and follow-up sessions as the most beneficial part of partnering (Figure 1). In fact, there were stark differences in popularity of the various components of the partnering process. Evaluation surveys and close-out workshops were generally viewed the least positively. Close-out workshops seemed unfamiliar to many respondents, which probably reflects the fact that it has one of the lowest implementation rate of any of the partnering activities. Interestingly, the popularity of the individual components of partnering has a strong association with the rates of implementation on projects. It appears that field staff are only implementing the partnering activities that they feel are valuable. The association between popularity and implementation rates combined with the large differences in partnering budget allocation and actual expenditure highlights the discretion that RE's have in the execution of collaborative partnering.

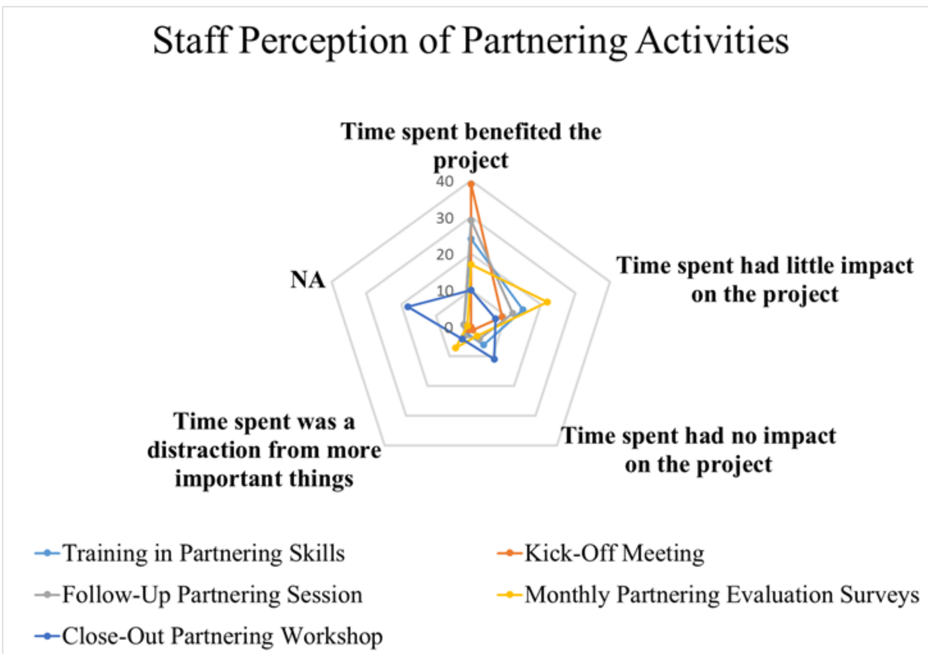

FIGURE 1 Perceived utility of partnering activities

When asked more specifically about the usefulness of each partnering activity an interesting trend emerges. Respondents were instructed to indicate how much they agree or disagree with a group of statements around each of the partnering activities. Each group of statements includes one general statement focused on whether a particular activity is fulfilling its intended goal. This statement is accompanied by other statements exploring more specific scenarios where the activities may have been helpful. For example, the general statement for kick-off meetings asked respondents to rate how strongly they agreed/disagreed that kick-off meetings encouraged "stakeholders to identify potential problems that the project may experience," which is explicitly stated as a goal of the kick-off meeting in the Caltrans Partnering Manual. The accompanying statements then focused on whether kick-off meetings were useful on either the coordination of construction operations or when new production techniques are used on a project.

Respondents were more positive in their responses for the general questions than for their responses for the more specific scenarios. This trend holds true for all of the partnering activities. Perceptions of partnering were more positive when respondents were asked to evaluate a general statement about partnering activities, but tended to shift to a more neutral and even negative tone when asked about the usefulness of the respective partnering activity in specific situations. This pattern of responses suggests that Caltrans staff think the activities have the potential to help projects, but when confronted with specific challenges the activities are not useful.

We note also that job experience and age seems to play an important factor in Caltrans staff perceptions of the partnering process. A Chi-Squared analysis of the responses indicate a statistically significant relationship between respondents' job experience and their opinion of certain partnering activities. With the number of projects a respondent worked on as a proxy of job experience, respondents were divided into two groups: those who worked on 35 or fewer projects and those who worked on more than 35 projects. The two groups were roughly equal in size. We found that that respondent with less experience are significantly more enthusiastic (87%) about the usefulness of kick-off meetings than respondents with more experience (55%). In contrast, 48% of respondents with higher levels of experience indicated a positive perception of close-out meetings compared to 25% of less experienced respondents, which could reflect more experienced staff placing a higher value on reviewing the successes and failures of the project. Note, however, the relative sparsity of close-out meetings undertaken may indicate that less experienced staff have simply not had enough exposure to these meetings and consequently, have not formed strong opinions. This speculation is supported by the fact that 75% of less experienced respondents were neutral when asked about the effectiveness of close-out meetings, while only 34% of more experienced respondents were neutral. Finally, experienced respondents perceived the effectiveness of evaluation surveys slightly more negative (60%) than those with less experience (55%).

We also looked in more detail at a subset of the respondents who worked on projects in our data (N=31). In addition, 10 of the 31were identified as the project (RE) for their respective project. As discussed earlier, the RE decides on the type and quantity of partnering activities. Thus, we carefully analyzed the responses of these 10 respondents to better understand the relationship between perceptions of the partnering process and implementation of partnering on projects. The demographics of the RE's were similar to the total respondent population for age and length of time working for Caltrans with the RE's having slightly more experience holding the RE position on projects. Interestingly, RE's survey responses were largely similar to the rest of the respondent sample responses. One important difference we noted was that RE projects were different from the typical partnered project in terms of project type, size, performance, and partnering activity.

On average, the RE projects tended to have smaller budgets, shorter durations, and fewer contract bid items than the typical partnered projects. The type of projects represented in the RE respondent sub group also tended toward the less complex and generally better performing types of road construction with a majority (N=7) of projects focusing on repaving or road widening operations. These project characteristics may explain the lower total claims amount, lower total CCO amount, and less schedule growth at project completion than partnered projects in general. Partnering activity on these projects was also lower than average partnered projects.

Metrics to characterize project partnering were developed in order to gauge activity levels. First, a general measure of partnering over a projects lifetime was created by determining what percentage of project quarters (3 month intervals) had partnering activity. This metric allows projects of varying length to be compared. Similarly, the next two metrics compare how many evaluation surveys and workshops took place on a project against the total number of surveys and workshops that should have taken place as described in the Caltrans' Field Guide to Partnering. The guide requires that partnering evaluation surveys should be administered on a monthly basis and recommends that partnering workshops be held at least every quarter. By using these recommendations and the length of a project, we can see how closely projects are following the partnering process. The average partnered project implemented activities in only 33% of project quarters, completed 9% of the monthly surveys, and 16% of the required workshops. The RE respondent projects had less partnering by all three metrics when compared to the general partnered project population.

Comparison of the RE respondent survey responses and their implementation of partnering reinforces the connection between opinion and action with three examples. The only project in the RE subgroup to hold a kick-off meeting strongly agreed with the statement that kick off meetings encourage project stakeholders to identify potential problems that the project may experience. A majority of RE respondents agreed or strongly agreed that follow up meetings encourage productive conversations between stakeholders to resolve job-site issues. Rates of follow up meetings were highest among projects whose RE's strongly agreed and second highest with RE's who agreed. Lastly, the only project of the subgroup to use monthly evaluations had an RE who strongly agreed that evaluation surveys provide valuable information for RE's.

The fact that RE's are only implementing partnering activities that they deem useful is not completely surprising. Project RE's have significant autonomy in the implementation of collaborative partnering and, judging by expenditure and activity levels, are capable of circumventing requirements mandated by the Caltrans administration with little repercussion. Unfortunately, this heavily scaled back version of partnering may also be affecting the usefulness of the process. As we show below, partnering does not appear to improve the probability of a project being completed on budget.

Logistic Regression Model

Although relatively uncommon in construction management research (20), we use logistic regression models to better understand the effectiveness of management techniques, such as collaborative partnering (21). This type of regression provides a method for examining relationships between data taking on different forms (categorical and continuous variables) and having non-normal distributions (22). In addition, the dichotomous dependent variable and the ability to interpret logistic coefficients as probabilities lend itself to the main focus of this research: does the collaborative process improve the odds of a project coming in on budget. That is, project success is largely determined by whether the project is completed on budget (as determined by initial estimates and contractor bid amounts) and on schedule (23). We coded the dependent variable for the model as on budget (1) or not on budget (0). This designation was decided by comparing the bid amount for the project and the final cost of the project. If the final cost of the project was more than 105% of the bid amount the project was labeled as not on budget. The 5% growth over the bid amount was chosen because when Caltrans budgets for a project they normally include a 5% contingency amount to address any minor cost escalations that may be encountered during the course of the project. The independent variables in the model attempt to control for a range of factors that have the potential to impact project performance (e.g., in a dense urban area).

A common idea espoused in the construction management literature when explaining the challenges of improving project performance is the unique and one-off nature of each project (24, 25). Even identical construction projects will face very different challenges if their respective locations are substantially different. This is especially important when comparing projects in California, where there is a wide variety of geographies, climate, and population densities. We specified logistic models that include the critical variables that characterize factors such as location and site conditions of the projects. For example, we included the Caltrans district in which the project was located, the Urban-Rural classification (as designated by the National Center for Health Statistics for the county in which the project was located), and peak hourly and monthly traffic levels. Project characteristics included the length of the project in miles, the work type (designated by the project descriptions provided by Caltrans), and the number of bid items. Although we had information on a number of financial and schedule characteristics such as budget size, the number of working days, and the dollar value of claims and CCO's, these were collinear and/or endogenous to budget performance.

We initially characterized project partnering using 6 variables. We created a dichotomous variable identifying whether a project was partnered or non-partnered, and four continuous variables representing 1) the percent of quarters in which a partnering activity took place, 2) the percentage of completed workshops, 3) the percentage of completed monthly evaluations, and 4) the percentage of the partnering budget spent. In addition, a sixth variable measuring the time between the beginning of a project and the first partnering activity (in days) was also included. A step wise approach to remove the insignificant project, location, and partnering variables resulted in two location variable, one project variable, and one partnering variable (Table 4).

Our modeling results indicate that whether or not a project was partnered does not have a statistically significant effect on the project budget outcome. Variables that are statistically significant in affecting budget outcome include the location of the project – both the district and the size the metro area in which the project is located - as well as the number of bid items for the project. The effect of partnering on project budget outcomes is weak (α=0.90). Following Baccarini's synthesis of construction project complexity which identified the quantity of unique actions or tasks in a project as an important aspect of technological complexity, the number of bid items on a project was used as a proxy for project complexity (26). When interpreting the model coefficient for the number of bid items, it is important to remember that the average number of items for the project population in 143, so there will be only a small change in the odds ratio with additional bid items.

TABLE 4 Results of Logistic Regression Model

Deviance Residuals						
	Min	1Q	Median	3Q	Max	
	-1.886	-1.054	0.573	1.006	1.843	
Variable		Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)		-1.492	1.208	-1.235	0.21682	
factor(District)10		2.415	1.244	1.942	0.05219	.
factor(District)11		2.046	1.247	1.641	0.10081	
factor(District)12		2.514	1.328	1.892	0.05844	.
factor(District)2		1.434	1.124	1.276	0.2021	
factor(District)3		3.036	1.119	2.713	0.00667	**
factor(District)4		2.728	1.179	2.313	0.02071	*
factor(District)5		3.237	1.421	2.278	0.02273	*
factor(District)6		2.156	1.275	1.691	0.09079	.
factor(District)7		3.235	1.224	2.643	0.00821	**
factor(District)8		3.038	1.233	2.464	0.01373	*
factor(District)9		17.185	623.193	0.028	0.978	
factor(NCHS.Scheme)Large Fringe Metro		-0.964	0.442	-2.181	2.92E-02	*
factor(NCHS.Scheme)Medium Metro		0.181	0.494	0.367	0.71376	
factor(NCHS.Scheme)Micropolitan		1.390	1.001	1.388	0.16515	
factor(NCHS.Scheme)Noncore		-0.302	0.937	-0.322	0.74741	
factor(NCHS.Scheme)Small Metro		0.256	0.683	0.374	7.08E-01	
No.Of.Bid.Contract.Items		-0.008	0.002	-3.846	0.00012	***
factor(Partnered)YES		0.305	0.313	0.975	0.330	
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1						
Null deviance: 368.16 on 266 degrees of freedom						
Residual deviance: 327.08 on 248 degrees of freedom						
AIC: 365.08						

Discussion

Partnering implementation and field staff perception of partnering are closely aligned. The survey responses indicate that the partnering activities most likely to be implemented on a project are also the most popular among Caltrans field personnel. Conversely the least popular parts of partnering are also the least likely to be implemented. Our surveys results also show that as job experience increases, positive attitudes around formal partnering decline. When combined with a pattern of survey responses that indicate project staff were more positive about the *potential* of partnering activities than its real world impact of partnering, clearly suggests that collaborative partnering *in action* may not be living up to expectations. Regardless, partnering is having an insignificant, but positive impact on project outcomes. The dissatisfaction with the partnering process may be a symptom of policy implementation, rather than an underlying flaw in the process itself. The risk of negating the benefits of partnering by over prescribing activities without proper consideration of the project environment has long been a point of contention among researchers (14) and has been reinforced in more recent studies (18). Caltrans faces this same risk with its recent policy changes, which mandate more widespread and uniform use of partnering. The RE's survey responses demonstrate a pragmatism brought by the complex realities of managing road construction projects.

Resident Engineers who have been educated on collaborative partnering by Caltrans, and then mandated to use the process, are implementing a highly modified version of the policy. We show that partnering implementation is heavily dependent on RE's opinion of partnering, but these perceptions are rooted in their not insubstantial experience with project management and the partnering process itself. This flexible and ad hoc method of partnering, while clashing with directives from Caltrans, is improving project performance. The successful use of partnering requires a properly receptive atmosphere from project stakeholders, a sentiment echoed in collaborative partnering literature (27, 28) and the written responses of the Caltrans survey:

> *Partnering will not succeed if there's no buy-in. No amount of checklists, training, or surveying will really change that.*
> *Partnering is only beneficial if the contractor is willing to work with the State for a successful project.*

Responses also indicate that attempting to force a collaborative partnership between hostile stakeholders creates situations where the process is ineffectual:

> *I have found that everyone goes through the process as dictated by the project and management. Participants (contractor as well as contract administrators) feel forced. I see goals set and problems discussed often fall away as soon as everyone leaves the room.*

In a worst case scenario partnering activities may even heighten the level of animosity on a project, as described here by a Caltrans employee:

> *Before most, if not all partnering meetings, there are complaints by participants representing all different parties about how big a waste of time these meetings are.*

Given these experiences, it is not surprising that partnering implementation differs drastically from Caltrans ideal.

Our logistic regression model indicates that the implementation of project level partnering does has only a weak effect on project budget outcomes. Further, when we included partnering intensity variables, we found no correlation with budget performance.

Limitations

The existence of a partnering CCO determined whether a project was labeled 'partnered' or 'non-partnered.' Caltrans has indicated that a limited number of projects participated in "self-directed" partnering activities. No evidence of partnering activities was found in the project archives for those projects that lacked a partnering CCO. Because these "self-directed" projects did not generate partnering CCO's or other records of partnering events there is no way to identify them through the records collected by the research team. Lack of data prevents the identification of "self-directed" projects however, the small number of such projects is not expected to effect the study's conclusions.

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CHAPTER 3: USING RANDOM FORESTS TO GUIDE MANDATORY PARTNERING

Introduction

Collaborative partnering on construction projects is a well-established management tool in American infrastructure construction (1). State Departments of Transportation (DOTs) across the United States have adopted collaborative partnering to improve owner-contractor relations. By identifying clear channels of communication as well as procedures for dealing with inevitable job site conflicts, issues that might otherwise affect schedule or cost can be dealt with in a timely and efficient manner (2). The communication structures and operating procedures that constitute collaborative partnering have the potential to improve project outcomes in a variety of ways. Studies have found that project partnering can improve traditional performance measures of construction project success such as project cost (3) and on time completion (4). And while there exists a healthy debate over the strengths and weaknesses of the partnering process (5, 6), the wide spread adoption of collaborative partnering speaks to a general acceptance that project level partnering is helping government agencies execute and complete construction projects in a satisfactory manner. However, collaborative partnering does impose costs to projects in the form of monetary expenses and project staff time commitments.

Collaborative partnering requires a front loading of project resources to establish the communication structures and operating practices which are fundamental to the process and necessary to sustain over a project's lifetime (7). Early investment is usually in the form of facilitated kick-off meetings and partnering training. This is followed by facilitated follow up meetings which are typically held at regular intervals over the life of a project. Monthly staff surveys and a close out meeting at the end of the project are also often part of the partnering process. These practices require significant time and money investment to be successful; to give a sense of the cost scale associated with partnering, and this does not include staff time, California DOT (Caltrans) allocated $4.19 million for partnering activities on 192 projects during a six year period.

It is reasonable to assume that not all projects need, or would even significantly benefit from collaborative partnering. Although the research on the appropriateness of collaborative partnering to specific kinds of construction projects is sparse, two distinct streams have emerged in recent years. In the first, the emphasis is on the organizational aspects of project stakeholders. That is, asking the question: does partnering make sense in the context of larger company strategic goals and management styles (8). Any investment in the partnering process is predicated on the relative importance of a project in generating future work, entering new markets, or burnishing the reputation of the contractor. In contrast to a government agency perspective, organizational support in the form of upper management engagement and resources for partnering activities is the ultimate deciding factor in the successful implementation of partnering (9-11).

In the second stream of research identifying what projects would benefit from partnering, the construction project characteristics play a prominent role in deciding when to partner. There is a general consensus that only 'complex' projects merit the time, cost, and effort required to implement collaborative partnering, and that longer duration construction projects are more conducive to partnering (9, 12). Despite frequent use in the characterizations of construction projects, the concept of complexity is rarely quantified beyond *less* and *more*, and in many cases, the project budget is turned to as a simple proxy for complexity. Research findings on the usefulness of partnering to projects characterized by the project budget are mixed. An early study of collaborative partnering found that only those projects with budgets greater than $5 million benefited from the process (13). In contrast, others have argued that small projects face the same challenges as larger projects, but have fewer resources to manage issues, which makes the partnering process valuable (14).

Practically speaking, many DOTs establish project cost/time thresholds, above which partnering is mandatory, and those below are encouraged but not required to partner. For example, Caltrans' partnering policy reflects the belief that long and/or complex projects are most suitable for partnering and has mandated project level collaborative partnering on projects with a budget equal to or greater than $10 million or a schedule of 100 working days or more. Despite the use of proxies for directing implementation of project partnering, there is very little evidence suggesting that the use of thresholds are optimal, nor is there concrete guidance on which projects are likely to benefit most from the partnering process.

This paper forwards a new approach to identifying projects that are most likely to benefit from the partnering process. We use financial and technical data that are available to planners and project managers very early in a project's development. The foundation of this method is the intuitive assumption that partnering should be implemented on projects with characteristics that are known to negatively impact performance outcomes. Conversely, construction projects with characteristics associated with successful performance outcomes are more likely to be able to forgo partnering without loss of performance. We expand the concept of technical complexity by closely examining the type and variety of construction operations taking place on projects. Specifically, we use the line item budget of a project and categorize each entry into a specific work type; this gives us a simple, objective method for characterizing project complexity. Both the individual types of construction operations and the total number and proportion of different operations that make up a project's budget are important in determining project complexity.

We apply the method using data collected on Caltrans construction projects. Caltrans has been using collaborative partnering on its road construction projects in some form since the early 1990's (15). Starting in 2008 Caltrans began strengthening the partnering policy by mandating partnering on construction projects valued at $10 million or greater (16). The following year, Caltrans began a large training program to educate field staff on collaborative partnering philosophy and mechanics, eventually training approximately 3,000 personnel. In conjunction with training and mandatory partnering requirements, Caltrans also significantly increased funds available in project budgets for partnering activities, with the average project allocation growing 115% between 2006 and 2012 (17). Then, in 2011, partnering became mandatory on projects with 100 or more working days. In a survey, we conducted of Caltrans field staff, a slim majority of respondents (55%) thought that the current project budget requirements for mandatory partnering were appropriate, while 32% responded that the requirement was too high. Similar sentiment was expressed about the schedule requirements for mandatory partnering, with 58% of respondents agreeing with the policy, 13% believed the requirement is too high, and 28% believed the requirement was too low. Many of the written responses to our survey suggested that the budget and schedule parameters did not adequately reflect the depth of considerations necessary to truly assess the optimal implementation of collaborative partnering; many respondents thought that other aspects of construction projects, such as the types of operations and complexity, should be also considered.

Using project data provided by Caltrans and a random forest data mining technique we found that the most important project variables predicting budget performance were the specific types of operations, such as bridge work and road striping, undertaken during a project as well as the value and spread of a project's budget dedicated to different construction operations. We demonstrate that collaborative partnering on projects has only been driven by recent Caltrans policy changes and the project location, rather than whether a project would truly benefit from partnering. Our calculations provide a method for developing guidelines that more efficiently target those construction projects which have the highest chance of benefiting from collaborative partnering, and thereby maximizing the impact of resources dedicated to the partnering process.

Empirical Data and Methods

Project Data

For our analysis, we use 274 Caltrans construction projects with budgets of $10 million or greater that were completed between 2006 and 2012. Approximately 70% of the projects had partnering activity, while the remaining 30% did not (Table 6). Projects from all 12 of Caltrans' districts are represented in the sample. While the majority of projects in our dataset are directly related to building and maintaining the state's highway system, the data also include project operations such as landscaping, moving historical monuments, and irrigation systems.

TABLE 6: Characteristics of Project Sample

Project Characteristics	Partnered Projects	Non-Partnered Projects
Number of Projects	192	82
Average Bid Amount	$40 Million	$23.2 Million
Average Number of Planned Working Days	514	431
Average Number of Contract Bid Items	153	121
Project Length (Miles)	8.7	6.6
Project Location (District)		
1	5%	4%
2	3%	7%
3	13%	11%
4	33%	10%
5	2%	4%
6	5%	6%
7	13%	27%
8	9%	9%
9	1%	1%
10	6%	4%
11	7%	15%
12	5%	4%
Project Performance		
Average Total Claims Value	$ 0.78 Million	$1.03 Million
Average Total Contract Change Order Value	$6.1 Million	$3.2 Million
Average Budget Growth	7.9%	9.2%
Average Schedule Growth	7.6%	11.1%

Categorization of Construction Operations

For each project, we reviewed and categorized all of the budget line items. The line items were taken from the budgets of the winning bidder, however Caltrans conducts its own project cost estimates referred to as the Engineers Estimate. While there is a small amount of variation between the Engineers Estimate and the final low bid amount (18), the estimate is accurate enough to calculate the proportions of work types included in a given project. There were a total of 38,309 budget line items across all projects, with 5,451 unique line item descriptions that were categorized into 22 separate work activities (Table 7).

The line items covered both material quantities, such as sand, steel, and piles, as well as labor activities such as deck cleaning, pile driving, and clearing and grubbing. We developed categories to: 1) differentiate between the wide varieties of construction operations itemized in the budgets, and 2) determine how much of a project (in dollar terms) was dedicated to each category. Specifically, the categorization focused on separating construction activities that require different labor skills, construction equipment, materials, and inspection processes where appropriate. This differentiation provides a simple way to understand the relative complexity of construction projects.

TABLE 7: Work categories with examples from project budgets

Work Type Categories	Example Line Items
Administrative	progress schedules, document management systems
Pavement Placement	placing hot mix asphalt, concrete pavement
Pavement Removal	cold planning asphalt, grind concrete pavement
Barriers and Guard Rails	concrete barrier, metal beam guard railing, crash cushion
Demolition	remove unsound concrete, remove metal railing
Environmental Mitigation	prepare water pollution plan, protection of migratory birds
Excavation and Earth Work	roadway excavation, earth retaining structure, structural backfill
Road Striping and Signage	thermoplastic traffic stripe, install roadside sign, milepost marker
Temporary Structures	temporary gate, temporary traffic screen, temporary lighting
Traffic Control and Monitoring	detector loop, closed circuit television system, fiber optic system
Landscaping	furnish plants, mulch blend, prune existing plants
Mobilization	mobilization
Culvert and Drainage	perforated plastic pipe, reinforced concrete pipe, down drain
Structural Concrete	wing walls, retaining wall, concrete slab, concrete channel
Miscellaneous	relocate historical monument, relocate mailbox, bus shelter
Other Concrete	curb, gutter, sidewalk, architectural texture (fluted fin)
Piling	driving pile, steel piling, cast-in-drilled hole piling, micro pile
Structural Steel and Rebar	bar reinforcing steel, traveler rail, structural steel plate
Other Steel	stainless steel screen, equipment access steel cover,
Lighting and Electrical	flood lighting, conduit, pull box, splice vault, navigational lighting
Bridge Work	PTFE bearing, seismic joint, grind bridge deck, remove rivet
Plumbing and Irrigation	water meter, ductile iron water pipe, backflow preventer assembly

After categorizing the budget items for each project, dollar amounts for each work type category were summed and converted into a percentage of the project's total budget. It is important to understand that we are using the concept of complexity in both the technological sense and the organizational sense. Following Baccarini's review of project complexity (19), the categorization of project operations represents organizational complexity in the form of *division of labor* and *personnel specialization* as well as technological complexity in the form of *differentiation,* which includes the number of unique tasks required to complete a project.

Project Complexity Metrics

Three metrics were developed to describe project complexity using our project line item data. First, a simple tally of the number of work types used in each project was compiled. The number of work types gives a general sense of the scope of a project. Comparing partnered and non-partnered projects, the average number of work categories is very similar with 14.3 and 13.6 respectively (Table 8). Our second metric, the largest work type, in terms of project budget percentage, was identified for each project. This metric is a simple indicator of the main effort-related focus of a project. For example, at one extreme, 100% would indicate that the project is focused exclusively on one work type. Conversely, a very low value would indicate that a project is responsible for overseeing many different work types which would likely require many different workers, equipment, and processes for project completion. This would imply that coordination could be much more difficult when compared to a project with a single work effort focus. This metric is strictly a measure of organizational complexity, and as such measures the relative proportion of a project made up by the largest work type; that is, we ignore the actual work type category. As seen in Table 3, the largest work category makes up roughly the same amount of the average project budget across both partnered (39.4%) and non-partnered project (42.4%).

For our third metric, we calculated coefficient of variance (CV) for the top ten work types for each project. This metric provides insight into the distribution of a project's budget across the largest ten work categories. Since the categories we used for this calculation represent the ten largest for each project, a large CV suggests that a few categories are much larger than the rest. That is, a project with a large CV has a few categories that make up the bulk of the construction operations. Conversely, a small CV suggests that the top ten categories of a given project are more or less equal in value, potentially increasing the efforts required to coordinate operations. The CV calculation was limited to the top ten categories, rather than all of a projects categories because the size of the individual categories generally becomes very small after the tenth category. The average value for the tenth largest category is 1.9% of the project budget after which the category values continue to decline. Summing the values of the first ten categories describes approximately 93% of a projects budget, on average. Partnered projects showed slightly less variance than non-partnered projects, at 87% and 93% respectively. Taken together, these three metrics provide a more nuanced understanding of the complexity and corresponding challenges facing a project than total budget and schedule length alone can provide.

TABLE 8: Construction project complexity metrics.

Project Characteristics	Partnered Projects	Non-Partnered Projects
Average Number of Work Categories	14.3	13.6
Average Budget Proportion of Largest Work Category	39.4%	42.4%
Average Coefficient of Variance	87%	93%

Data Mining Algorithm

Tree based models, and the ensemble method of random forests, are data mining techniques used in research as diverse as genetics (20), business management (21), and detecting credit card fraud (22). These techniques have also been used in construction management for such efforts as analyzing traffic safety (23) and construction site injury factors (24, 25). Tree based models consists of "root" node which includes all observations. Observations are then divided into two groups which create two new nodes based on the value of a predictor variable. Successive nodes are created until some criterion is met that stops the splitting process (26). The splitting criterion used in this research was developed by Breiman and Cutler and uses the sum of squared residuals and the Gini index to determine how the observations are split. The final result is an inverted tree structure with many branches growing from the “root”, which allows an easy to understand interpretation of important variables impacting the dependent variable. Tree models are useful due to their ability to identify complex interactions between variables and the robustness of results regardless of outliers or missing values, as well as the ability to handle continuous and categorical predictor variables (27). The random forest application generates many such trees and classifies the individual trees as weak learners and produces a single tree from the ensemble, which is referred to as the strong tree (e.g., using a count, an average or weighted average) (28).

We used the random forests to identify the important variables in predicting the budget performance of construction projects. Randomness is introduced into the process in two ways; a random sample of observations from the data set is used for each tree and a random sample of predictors is used at each node when determining the best split in individual trees (29). In cases of classification, where the dependent variable is categorical, the variable importance is determined by majority rules, where each tree has one vote. In cases of regression, where the dependent variable is continuous, the variable importance is determined by averaging the results of all the trees.

RESULTS

We generated two random forests with our project data. In addition to the categories in Table 7 and the performance metrics previously described, we included seven additional project variables (Table 9): the original number of working days, the original estimated cost of the project, the year the project was awarded, the rural classification for the location of the project, the projects’ district, traffic levels at the construction site, and project partnering status (only in the case of the random forest predicting project budget performance). The work type proportions, performance metrics, and six of the seven additional variables were chosen because the information would be available to (or could be calculated by) project planners prior to bidding, meaning that partnering implementation guidelines using these project variables could be applied by planners in the same way that the current guidelines are used with a minimum of additional work. The project award year will have little use in formulating new partnering guidelines but does provide a way to capture the changes to Caltrans’ partnering policy over the six year time frame of the study. The original bid amount in dollars and the original number of working days were included to explore whether the current Caltrans mandatory partnering rules reflect a useful threshold for determining when to partner. The original number of bid contract items for each project was included as previous research has shown a strong association with project budget performance(17). The Caltrans District, county, urban density, and peak hourly traffic counts at the jobsite were also included to explore the differences that population density and geographic variations have on the dependent variables.

TABLE 9: Variables included in random forests

Variable Name	Description
Budget.Perf	Percentage change in final budget compared to original estimate
Partnered	Indicates whether a project used partnering (Yes/No)
Orig.No.Working.Days	Number of working days originally estimated for project
Base.Line	Dollar value of project budget originally estimated for project
Award.Year	Year that project was awarded to contractor
NCHS.Scheme	National Center for Health Statistics rural classification scheme
District	The Caltrans District where project was located
AHEAD.PEAK.HR	Peak hourly traffic levels at project site
No.Of.Bid.Contract.Items	Total number of bid items in project contract
CoV	Coefficient of Variance of work categories
Top1	Percentage of project budget of the largest work category
NumCat	Number of work categories making up project
AdminPerc	% of project budget dedicated to Administrative activities
Barriers.Guard.RailsPerc	% of project budget dedicated to Barriers and Guard Rail activities
Culvert.DrainagePerc	% of project budget dedicated to Culvert and Drainage activities
DemolitionPerc	% of project budget dedicated to Demolition activities
Env.MitigationPerc	% of project budget dedicated to Environmental Mitigation activities
Excavation.Earth.WorkPerc	% of project budget dedicated to Excavation and Earth Work activities
LandscapingPerc	% of project budget dedicated to Landscaping activities
LightingPerc	% of project budget dedicated to Lighting and Electrical activities
Misc.Perc	% of project budget dedicated to Miscellaneous activities
MobilizationPerc	% of project budget dedicated to Mobilization activities
Other.ConcretePerc	% of project budget dedicated to Other Concrete activities
Other.SteelPerc	% of project budget dedicated to Other Steel activities
Pavement.PlacementPerc	% of project budget dedicated to Pavement Placement activities
Pavement.RemovalPerc	% of project budget dedicated to Pavement Removal activities
PilingPerc	% of project budget dedicated to Piling activities
Road.Striping.SignagePerc	% of project budget dedicated to Road Striping and Signage activities
Structural.ConcretePerc	% of project budget dedicated to Structural Concrete activities
Structural.Steel.RebarPerc	% of project budget dedicated to Structural Steel and Rebar activities
Temporary.StructuresPerc	% of project budget dedicated to Temporary Structures activities
Traffic.Control.MonitoringPerc	% of project budget dedicated to Traffic Control and Monitoring activities
BridgePerc	% of project budget dedicated to Bridge activities
Plumbing.IrrigationPerc	% of project budget dedicated to Plumbing and Irrigation activities

Prior to reviewing our results, it is useful to note that we used two different forms of dependent variable. The first, budget performance, is a continuous variable describing the percentage difference between the original budget estimate and final cost of a project. A positive value indicates that the project cost increased over initial estimates, while a negative value indicates the final project cost was below the original budget estimate. Our second dependent variable, project partnering, is a categorical variable (Yes/No), indicating whether a project is partnered or not. The determination of whether a project is partnered or not was decided by the presence of a partnering contract change order which is how partnering budgets are allocated on Caltrans projects. As previously mentioned, the random forest algorithms handle continuous and dichotomous variables differently when determining variable strength. The regression model uses the change in mean square error to make its tree cuts and the classification model uses the change in model accuracy when determining tree cuts. The results from each of these modeling approaches are not directly comparable, but we can examine the rankings of the variables to understand their relative importance in predicting the dependent variable.

We hypothesized that the relative rankings for the variables used in the budget model would be approximately the same as those used in the partnering model. That is, we expect that those factors important to partnered projects would also capture the key factors determining budget performance. Our results indicate that the relative rankings are, in fact, quite different (Figure 3). Of the five strongest predictors of project budget performance, two are work categories (Bridge, Pavement Removal), two are complexity metrics (Top1 and CoV), and one is the number of bid items (No.Of.Bid.Contract.Items), which can also be considered a measure of project complexity. Our modeling approach does not indicate the direction of the association between the dependent variables and the various factors. For this, we first examined the correlations between the top 5 variables and budget performance; there is a positive correlation for Bridge percentage and the number of bid contract items, indicating that higher values for these variables tend to be associated with poor budget performance (recall that our dependent variable is the percentage change between final budget and original budget). Conversely, Top1, CoV and Pavement Removal operations all have a negative correlation, indicating that higher values are associated with good budget performance.

Both of these correlations make intuitive sense. Difficult construction operations tend to produce budget overruns while straightforward operations and indicators of low complexity tend to reduce budget overruns. It is also worth noting that the variables describing project budget size (Base.Line) and project duration (Orig.No.Working.Days) are 12th and 29st of 33 variables in the budget performance model. This suggests that budget size and schedule length are relatively weak predictors of a project's budget performance. In fact, of the top five predictors, the budget performance model shares no variables with the partnering model.

Implementation of partnering on Caltrans construction projects is much more dependent on management practices and evolving policies rather than on project characteristics. The strongest factor in predicting partnering implementation is the year in which the project started. This is purely a function of Caltrans incrementally adding partnering requirements between the years 2006 and 2012, which is the time frame of the available projects within the sample. The second strongest factor signaling partnering is the project budget size of the project (Base.Line); this reflects Caltrans mandatory partnering guidelines. The county and District where the project took place are the third and fourth factors determining partnering and likely reflect the uneven distribution of large highway projects across California. The model also indicates that project variables describing the construction operations and relative complexity of the project are not very important in the decision to implement partnering. Our modeling indicates that the current "threshold" approach to determining partnering is not adequate for capturing the kinds of project-related factors that would truly benefit from partnering.

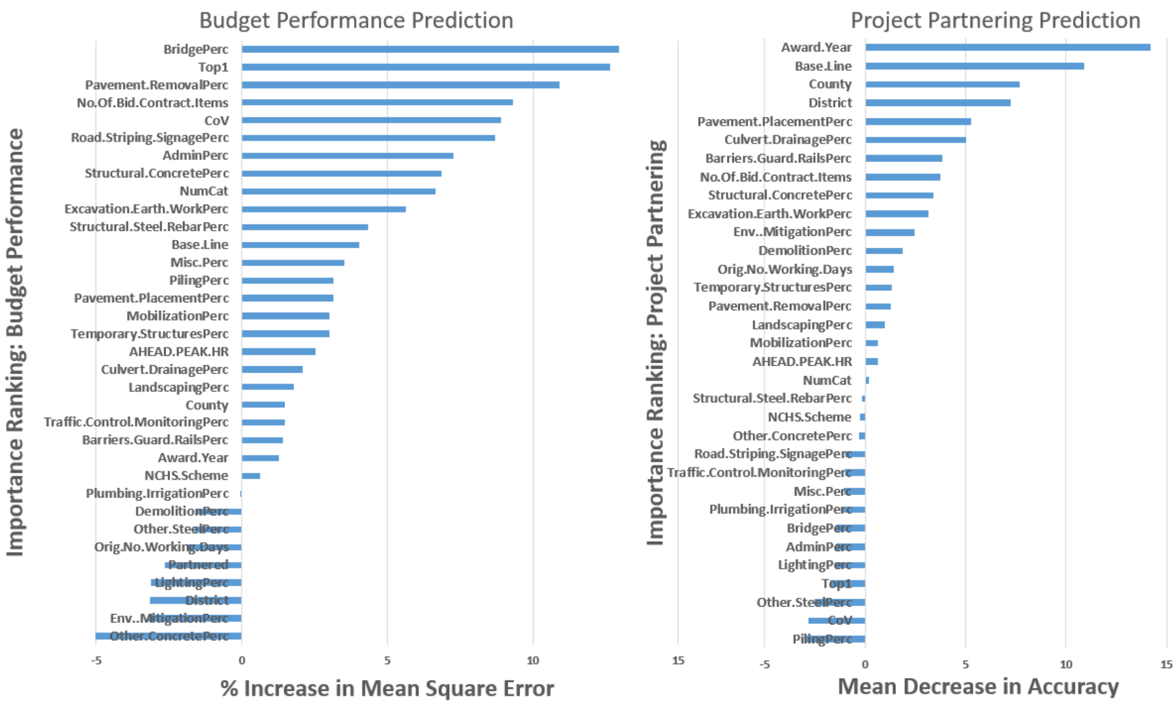

FIGURE 2: Variable importance outputs with project budget performance (left) and project partnering (right) as outcomes.

Conclusion

Caltrans thresholds for mandatory collaborative partnering on projects are a total budget of $10 million or larger and/or 100 or more working days. Our variable importance analysis of Caltrans construction projects indicates that a project's budget size or schedule length is relatively weak predictors of a project's budgetary performance. It is much more likely that type of construction operation and/or the complexity of the project will have an influential effect on budget performance. Working on the assumption that partnering activities are optimal for projects with challenging characteristics, our results indicate project complexity metrics and budgetary information regarding construction operations could be used to refine the collaborative partnering implementation process. We note that the variables we used in our modeling are all available prior to the award of a contract allowing the easy application of guidelines developed from these data points during project planning. For these reasons, decisions regarding mandatory partnering on construction projects should use the work types and complexity metrics rather than simple thresholds such as budget size and schedule length. Using these variables to distinguish the relative complexity of projects would allow cost and labor savings by using partnering on those projects most likely to benefit from the partnering process. These results also reinforce the experience of Caltrans field staff who has found that current partnering policies do not accurately identify construction projects which would benefit from the partnering process.

We would expect that the inclusion of complexity metrics and construction types in the mandatory partnering guidelines would shift partnering resources from expensive but straightforward projects such as large highway paving operations to less expensive but more complex projects. The impetus of this research is not to suggest a change to the total outlays made on collaborative partnering by

Caltrans but rather to make the most of existing resources to improve the performance of as many construction projects as possible. The cost of partnering grows as project size grows, so removing unnecessary partnering requirements on a large project frees up resources for many smaller projects. However, creating the guidelines, with multiple threshold values for each of the metrics to determine whether a project should require partnering and then determining the size of a project's partnering budget is beyond the scope of this research. The creation of new partnering guidelines would benefit from further research on multiple fronts.

Our study has a few limitations and from these, we can also identify additional research needs. The project sample size (N=274) is a relatively small, but representative fraction of the construction work that Caltrans oversaw between 2006 and 2012. We also only included projects with budgets of $10 million or greater. Future research could examine all 4303 of the projects completed in the time frame as well as projects which have been completed since 2012. This would help to identify what project characteristics drive budget performance across a much larger variety of project types and sizes. Specifically, looking at the challenges faced on projects with smaller budgets, which currently implement partnering at far lower levels, would help to determine appropriate guidelines for using the project metrics presented in this research. There is also a need to quantify the levels of informal partnering activity taking place on projects. Partnering activities undertaken without a facilitator or other expenses were not captured in this research due to a lack of data. It is not hard to imagine that informal partnering activities could provide similar benefits to facilitated partnering activities; however, the lack of data in project archives makes it impossible to measure such activities which could change the partnering status of many projects. Lastly, we examined 33 metrics, which were all tied to project budget performance. Future research should explore other forms of project performance. While project cost is an important performance metric, there may be many other parameters of success, such as timely completion, quality of the final product and the amount of disruption to surrounding communities, which might warrant consideration.

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CONCLUSION

The objectives of this research focused on addressing two gaps in the knowledge of project level collaborative partnering and applying the lessons learned to develop policy recommendations. A detailed literature review identified two important weaknesses prevalent in previous partnering research. First, much of the work done in quantifying the potential benefits of partnering relies on anecdotal evidence from case studies or subjective data gathered from survey responses, rather than comparative studies of partnered and non-partnered projects. Second, there is an implicit assumption among previous research that all projects using collaborative partnering do so in a uniform and consistent manner.

We addressed these limitations through three complementary lines of investigation that aimed to answer the following: 1) is partnering improving project outcomes, 2) how is partnering being used in the real world, 3) how does field staff perceive the partnering program, and finally, 4) how can the current partnering process be improved. A comparative study of Caltrans partnered and non-partnered projects that included a large amount of project specific partnering data was conducted to answer the first two questions. An agency wide survey of Caltrans field staff was administered to answer the third question. And finally, application of data mining techniques to identify project metrics which have the potential to improve Caltrans mandatory partnering policy addresses the fourth question.

The comparative study conducted for this research included 274 projects, one of the largest studies of its kind. Only one other study included a large data (N=408), however the projects were only differentiated by a budget size of above or below $5 million (1). As part of our analysis, we collected more project characteristics than previous research, which allowed us to specify a model that better accounts for project variation when identifying the effects of partnering on project budget performance. For instance, while half of the comparative studies identified in Chapter 2 included the geographic location of the projects (2-5), we contextualized location by including variables such as the local population density and traffic levels on the roads under construction. We also collected detailed partnering activity data for each project, which confirmed that partnering activity levels vary from project to project, even among those where partnering is mandatory.

In Chapter 3 we show that partnering has only a weak effect on project budget performance. We find instead that the district in which the project was located and the total number of bid contract items have a strong and statistically significant effect on budget performance. Variables representing the individual partnering activities and their specific levels of use did not have a statistically significant impact on performance.

The original motivation for taking partnering activity levels into account when studying the effect of partnering on project performance was the notion that partnering levels varied considerably among projects, which in turn affected the usefulness of the process. This appears to be incorrect, but in a surprising way. It turns out that partnering activity levels are relatively consistent among the 192 partnered Caltrans projects used in our study, but they are consistently very low. This does not invalidate the assertion that partnering levels should be taken into account when exploring impacts to project performance.

The survey in Chapter 3 revealed partnering activities that were rated as the most useful were also the activities that were most used in the field. Kick off and follow up meetings were perceived as the most worthwhile activities to engage in, while training, surveys, and close out meetings were perceived to have little utility in maintaining a smoothly running project. This association between usefulness and implementation reflects both the autonomy that resident engineers have in using the partnering process and the lessons that they have learned about what activities work best in the field. Responses from a small sample of resident engineers on projects reinforced the strong relationship between perceived usefulness of activities and actual implementation of activities as seen at the agency wide level. The survey responses of Caltrans' experienced field staff also highlighted a potential issue with the agencies partnering policy.

Two of the questions included in the survey focused on the project thresholds required for mandatory project partnering. Caltrans threshold for mandatory partnering are: 1) a budget of $10 million or higher and/or 2) an estimated schedule of 100 working days or more. We asked respondents whether they agreed with these policies. While a majority of respondents agreed with the budget requirements (55%) and schedule requirements (58%), many thought that the requirement should be changed. In the written section of the survey, many respondents suggested that budget and schedule were too coarse of a project characteristic to accurately guide the use of partnering. Other project metrics such as work type and the level of complexity were mentioned as important when considering whether implement partnering.

In Chapter 4, random forests modeling indicates that the variables that strongly predict project budget performance are all technical in nature. Of the five strongest predictors, two are work categories (Bridge and Pavement Removal), two are complexity metrics (the largest single category and the CV of the top ten work types), and one is the number of bid items. The project budget and schedule length were 12th and 29th of the 33 variables included in the model, suggesting that these variables are not a good indicator of a projects need for partnering. In contrast, the variables that predict project partnering reflect the recent changes in Caltrans partnering policy and the location of the project. The top predictors of partnering include the project award year, the project budget, and the county and district in which the project is located. The fact that the results of the budget performance model are so drastically different from the partnering model indicate that the mandatory partnering guidelines are failing to recognize projects that would likely benefit from the partnering process.

Policy Recommendations

Based on the results of this research, we recommend two changes to Caltrans collaborative partnering program. First, mandatory partnering should be changed from the threshold values of budget and schedule to characteristics describing the specific types of construction operations and complexity metrics of a project. Secondly, partnering training and monthly staff surveys should be removed from the partnering process.

Operating under the assumption that partnering activities are optimal for projects with challenging characteristics, the random forest modeling results provide a path towards increasing the effectiveness of mandatory partnering guidelines. The results suggest that the simple thresholds in budget size and schedule length are not accurately identifying construction projects that would benefit from the partnering process. The inclusion of complexity metrics and work types in the mandatory guidelines would more accurately assign partnering to projects that stand to most benefit from the process. The project data required for the new guidelines would be available during the project planning phase, which would allow planners to apply the guidelines in a similar manner to the existing guidelines. We predict that using these new variables when deciding on mandatory project partnering would shift partnering resources from large (in terms of budget and schedule) but relatively straightforward projects to smaller, more complicated projects. Because partnering costs are closely tied to the size of a project, reducing partnering on a single large project would free up resources for many small projects.

Chapter 3 has shown that kick off and follow up meetings are the most popular and commonly implemented part of the partnering process. Conversely, partnering training, monthly surveys, and close out meetings are not valued by field staff and used at considerably lower rates. Kick-off and follow up meetings are common activities on construction projects and have been around since long before collaborative partnering was developed. Indeed, it is hard to imagine even simple road construction projects progressing without some type of preconstruction meeting and regular meetings between owner, contractors, and other stakeholders over the project's lifetime. What collaborative partnering has added to these processes are a formalized communication structure, standardized meeting agendas and a professional third-party facilitator to insure that meetings stay on track and important topics are covered.

Partnering training, staff surveys, and close out meetings are rarely used on Caltrans' partnering projects. Respondents to the partnering survey indicate that field personnel do not perceive these activities as being nearly as helpful as kick-off and follow-up meetings. For training and staff surveys, the lack of buy in arises from flaws in the underlying issues meant to be solved. Partnering training focuses on professional and fair conduct, open communication, and "win-win negotiations" as an alternative to antagonism, posturing and other self-serving behavior found on construction sites (6). And while the goals of the training are noble, the organizational cultures being combated are the product of "powerful economic imperative and well established traditions (7)" whose momentum will not be dissipated in a single afternoon of partnering training.

Caltrans partnering guidelines describe monthly staff surveys as a way to measure partnering health and the health of working relationships. There are two problems that have become apparent with the staff surveys in the course of collecting archived partnering documents. The first problem is that when surveys are administered, they are used for very short periods of time and response rates are very low for both Caltrans staff and contractors. Both of these findings suggest that the surveys were of limited use to project managers. The more important problem with the monthly surveys is the basic premise of why they are useful in the first place. The idea that project managers need a monthly survey to understand how each of the stakeholders are feeling about the project creates a paradox. If channels of communication between stakeholders are constricted to the point that project managers need a survey to understand the health of working relationships, then there cannot really be collaborative partnering and the process has failed. Having arrived at this point, it seems doubtful that survey responses from stakeholders would help in reestablishing working relationships and the collaborative spirit. On the other hand, if collaborative partnering is working and open lines of communication exist between stakeholders, monthly surveys are not needed. Normal work interactions should alert project managers to worsening partnering health. The need for surveys signals a breakdown of working relationships, while a project with even minimal levels of collaborative partnering has no need for surveys.

Lastly, close out meetings, by their very nature cannot improve an individual project's performance. The fact that these meetings are held at the end of projects prevents them from having an impact on project performance. This may be why project managers tend to skip this part of the partnering process. However, close out meetings do hold promise for individual staff professional development by allowing time to discuss project successes and failures. This learning process is no doubt beneficial to Caltrans as an organization and older project managers seem to value this process more than their younger colleagues do. The more positive perception of close-out meetings shown by older and more experienced field personnel in survey responses may reflect a growing recognition in the value of identifying lessons learned and introspection.

Based on the discussion above, the immediate project specific benefits of collaborative partnering most likely stem from the highly structured and facilitated kick off and follow up meetings. For the time frame of 2006 thru 2012 these two activities are an accurate representation of Caltrans partnering. Because partnering training and monthly staff surveys have not proven valuable in the eyes of field staff and have an unconvincing rationale in the context of construction project management, we suggest that Caltrans consider alternative strategies for accomplishing the same objectives. Close out meetings are also unpopular among field staff, however the potential for long term professional development of Caltrans staff through the identification of project failures and success justify their continued use.

Limitations and Future Research

Our research has shown that collaborative partnering on Caltrans construction projects does not improve the odds of an on budget project completion. Exploring partnering's impact on schedule, the dollar amount of claims, and the number and dollar amount of Contract Change Orders failed to identify statistically significant associations. The lack of associations between seemingly related performance measures help to illustrate the complexity and compromises that construction projects must grapple with. For instance, depending on the priorities of a given project, timely completion may be more important than staying on budget, resulting in budget overruns which are acceptable to stakeholders. The 'iron triangle' of cost, speed, and quality are carefully balanced on each project according to the demands of the project stakeholders. Unfortunately, data were not available to determine the priority of individual construction projects. Future research should focus on ways to quantify and measure alternative forms of project performance when considering the impacts of partnering on project outcomes.

The projects included in this research all had budgets of at least $10 million which significantly narrowed the project sample size from 4303 projects (in total) to 274 (in our sample). Inclusion of smaller projects would improve our understanding of challenges and work type compositions on a much larger variety of project types and sizes. Smaller projects implement partnering at much lower levels than the projects included in this research. By including these types of projects in future research we will better understand how partnering can be tailored to smaller projects.

Lastly, lack of data on informal partnering also hampered this research. Informal partnering does not produce project records in the same way that formal partnering does. There are no financial records of informal partnering activities, unlike the contract change order dedicated to partnering which made tracking activities and expenditures relatively easy and allowed the in depth analysis in this research. However, informal partnering has the potential to improve project performance and should be accounted for in collaborative partnering research.

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Appendix 1: Data Sources and Locations

Data Source	Major Variables Collected	Number of Projects Included	Collected/ Compiled By	Location of Data	Collected for Dissertation
Original data set provided by Caltrans	Project EA, Award and Acceptance Date, Original and Actual Number of Working Days, Bid Amount, Number of Bid Items, Postmiles, County	4303	Caltrans	Caltrans Data Base	Yes
Traffic Counts	Peak Hourly, Peak Monthly, and Annual Average Daily Traffic Counts	274	UC Davis	http://www.dot.ca.gov/trafficops/census/	Yes
Partnering Expenditure and Activity	Performed Date, Description of Activity, Organization being Paid, and Total Cost of each charge made to the partnering CCO	192	Caltrans	Caltrans Data Base	Yes
Project Partnering Records	Facilitated Partnering Meeting Presentations, Monthly Staff Survey Results, Correspondence Between Facilitators and Project Staff, Receipts for Partnering Expenses	128	UC Davis & Caltrans	District archives	Yes
Project Line Item Budgets	Description of Project Operations, Quantities of Materials, Total Cost of Operations	274	UC Davis	http://www.dot.ca.gov/hq/asc/oap/payments/	Yes
Rural Classification Scheme for Counties	Population Density for Each County	274	UC Davis	http://www.cdc.gov/nchs/data_access/urban_rural.htm	Yes
Caltrans Staff Survey	27 Questions Related to Partnering, 7 Demographic Questions, and an Open Written Response Section	54 Complete Responses	UC Davis	UC Davis Data Base	Yes

Appendix 2: Variable Names, Description, and Locations

Variable Name	Description	Data Location	Collected for Dissertation
EA	Project Identifier	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
District	Caltrans District	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Partnered	Yes/No based on existence of a partnering CCO	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
CCO.Number	CCO number which specifies partnering funding	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
CCO.Allotment	Dollar amount specified in CCO	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Facilitation.Company	Organization hired to provide partnering services	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Date.of.First.Event	Date of first partnering event	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Award.Date	Project Award Date	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Award.Year	Project Award Year	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Acceptance.Date	Project Acceptance Date	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Acceptance.Year	Project Acceptance Year	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Desc.Of.Work	Description of project operations provided by Caltrans	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
CCOs.Total.Number.Of	Total number of CCO's generated on a project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Orig.No.Working.Days	Original estimate of project length	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Actual.No.Days.Worked	Actual number of working days required to finish project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Change.Order.Days	Number of working days specified in CCO's	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
No.Of.Bid.Contract.Items	Number of bid items in original project contract	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Contractor.Name	Name of main contractor who was awarded project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Resident.Engineer.Name	Name of the Resident Engineer for the project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes

Bridge.Rep.Name	Name of the Bridge Representative for the project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
NCHS.Scheme	National Center for Health Statistics designation for county in which project was performed (Large Central Metro, Large Fringe Metro, Medium Metro, Small Metro, Micropolitan, Noncore)	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
County	County where project was performed	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Rte.Proj	Route number of road on which project was performed	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Postmile.Ahead	Post mile ahead of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Postmile.Back	Post mile behind project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
BACK.PEAK.HR	Traffic Count Data gleaned from Caltrans Data (Award date year used to determine traffic data year)- Peak hourly volume for year	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
BACK.PEAK.MONTH	Traffic Count Data gleaned from Caltrans Data (Award date year used to determine traffic data year)- Peak monthly volume for year	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
BACK.AADT	Traffic Count Data gleaned from Caltrans Data (Award date year used to determine traffic data year) - Annual Average Daily Traffic	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
AHEAD.PEAK.HR	Traffic Count Data gleaned from Caltrans Data (Award date year used to determine traffic data year)- Peak hourly volume for year	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
AHEAD.PEAK.MONTH	Traffic Count Data gleaned from Caltrans Data (Award date year used to determine traffic data year)- Peak monthly volume for year	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
AHEAD.AADT	Traffic Count Data gleaned from Caltrans Data (Award date year used to determine traffic data year)- Annual Average Daily Traffic	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes

X0.Quart	Number of Partnering events before project is awarded	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
X1.Quart	Number of Partnering events during first quarter of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
X2.Quart	Number of Partnering events during second quarter of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
X3.Quart	Number of Partnering events during third quarter of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
X4.Quart	Number of Partnering events during fourth quarter of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
X5.Quart	Number of Partnering events after project is completed (acceptance date)	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Total	Total number of partnering events performed during project lifetime	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
X1.Half	Number of Partnering events performed in first half of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
X2.Half	Number of Partnering events performed in second half of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Perc.0.Quart	Percent of Partnering events which took place before project was awarded	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Perc.1.Quart	Percent of Partnering events which took place during first quarter of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Perc.2.Quart	Percent of Partnering events which took place during second quarter of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Perc.3.Quart	Percent of Partnering events which took place during third quarter of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Perc.4.Quart	Percent of Partnering events which took place during the fourth quarter of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Perc.5.Quart	Percent of Partnering events which took place after project is completed	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Perc.1.Half	Percent of Partnering events which took place in the first half of the project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Perc.2.Half	Percent of Partnering events which took place in the second half of the project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes

Total.Training	Total number of training events	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Total.Workshops	Total number of workshops (meetings led by professional facilitator)	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Total.Executive.Meetings	Total number of Executive Meetings	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Total.Meals	Total number of meals (BBQ, Picnics…)	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Total.Meetings	Total number of meetings (held without professional facilitator)	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Total.Training.and.Kickoff	Total number of combined training and kickoff meetings	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Total.Ribbon.Cutting.Ceremony	Total number of ribbon cutting ceremonies (to mark completion of project)	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Total.Ground.Breaking.Ceremony	Total number of ground breaking ceremonies (to mark beginning of work on project)	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Total.Close.Out	Total number of close out meetings	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
X0Q.Surveys	Number of staff surveys administered before project began	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
X1Q.Surveys	Number of staff surveys administered during first quarter of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
X2Q.Surveys	Number of staff surveys administered during second quarter of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
X3Q.Surveys	Number of staff surveys administered during third quarter of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
X4.Q.Surveys	Number of staff surveys administered during fourth quarter of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
X5Q.Surveys	Number of staff surveys administered after project completion	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Total.Surveys	Total number of surveys administered over the project life time	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
X1.Half.Surveys	Total number of survey administered during first half of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes

X2.Half.Surveys	Total number of surveys administered during second half of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
X1.Half.Communication	Total number of 'communication' events (Kickoff, training, meetings, workshops, executive meetings) held during first half of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
X2.Half.Communication	Total number of 'communication' events (Kickoff, training, meetings, workshops, executive meetings) held during second half of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Total.Communication	Total number of 'communication' events (Kickoff, training, meetings, workshops, executive meetings) held during life time of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
X1.Half.Recreation	Total number of 'recreation' events (Meals, ground breaking ceremonies, ribbon cutting ceremonies) held during first half of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
X2.Half.Recreation	Total number of 'recreation' events (Meals, ground breaking ceremonies, ribbon cutting ceremonies) held during second half of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Total.Recreation	Total number of 'recreation' events (Meals, ground breaking ceremonies, ribbon cutting ceremonies) held during life time of project	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Bid.Amt	Amount the winning contractor bid on the bid item work	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Suppl.Work.Amt	work that may be needed during construction but was not included in the bid item work	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
State.Furnished.Material.Amt. Total	Potential dollar amount of material that will be supplied by the State so the contractor does not have to purchase these items	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes

SFM.Total	Total State Furnished Material expenditures made by projects	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Contingency.Amt	Funds to cover unexpected project costs (generally 5% of combined Bid Amt, Suppl Work Amt, State Furnished Mat Amt	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Engineer.s.Estimate	the estimated amount that the engineer estimates the job will cost prior to the bid submittal. Includes item work, supplemental work and state furnish material and contingency.	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Final.Est.Amt	Amount paid to contractor-bid item work + CCO's	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Orig.Contract.Allot.Amt	Sum of Bid Amount, Suppl Work Amt, SFM, Contingency	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Total.Amt.All.Contract.CCO	Total of all CCO expenditures	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Amount.SUM.1	Amount of Claims paid	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Event.Date.1	date claims paid	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Comments.1		Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Amount.SUM.2	Amount of claims paid	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Event.Date.2	date of claims paid	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Comments.2		Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Total Claims	Sum of Amount.SUM.1 and Amount.SUM.2	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Final.Project.Cost	Sum of Bid Amount, CCO's, Claims, SFM	Final Caltrans Project Data 10 Mil and Over.xlsx	Yes
Admin	Dollar amount each project spent on Admin	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Barriers/Guard Rails	Dollar amount each project spent on Barriers/Guard Rails	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Culvert/Drainage	Dollar amount each project spent on Culvert/Drainage	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Demolition	Dollar amount each project spent on Demolition	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Env. Mitigation	Dollar amount each project spent on Environmental Mitigation	Complete Project Expenditure with Perc Calcs.xlsx	Yes

Excavation/Earth Work	Dollar amount each project spent on Excavation/Earth Work	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Landscaping	Dollar amount each project spent on Landscaping	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Lighting	Dollar amount each project spent on Lighting	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Misc.	Dollar amount each project spent on Misc.	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Mobilization	Dollar amount each project spent on Mobilization	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Other Concrete	Dollar amount each project spent on Other Concrete	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Other Steel	Dollar amount each project spent on Other Steel	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Pavement Placement	Dollar amount each project spent on Pavement Placement	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Pavement Removal	Dollar amount each project spent on Pavement Removal	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Piling	Dollar amount each project spent on Piling	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Road Striping/Signage	Dollar amount each project spent on Road Striping/Signage	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Structural Concrete	Dollar amount each project spent on Structural Concrete	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Structural Steel/Rebar	Dollar amount each project spent on Structural Steel/Rebar	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Temporary Structures	Dollar amount each project spent on Temporary Structures	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Traffic Control/Monitoring	Dollar amount each project spent on Traffic Control/Monitoring	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Bridge	Dollar amount each project spent on Bridge	Complete Project Expenditure with Perc Calcs.xlsx	Yes
Plumbing/Irrigation	Dollar amount each project spent on Plumbing/Irrigation	Complete Project Expenditure with Perc Calcs.xlsx	Yes

Appendix 3: Computed Metrics, Description, and Locations

Variable Name	Description	Data Location
Budget.Perf	Budget Performance Metric = (Final.Project.Cost-Base.Line)/Base.Line, 0=project completed on budget, - = project completed under budget, + = project completed over budget	Final Caltrans Project Data 10 Mil and Over.xlsx
Base.Line	Original Contract Allotment - contingency	Final Caltrans Project Data 10 Mil and Over.xlsx
Project.Length	Difference of Postmile.Ahead and Postmile.Back	Final Caltrans Project Data 10 Mil and Over.xlsx
Work.Category	Work Categories created by me from Desc.Of.Work (created at very beginning of project)	Final Caltrans Project Data 10 Mil and Over.xlsx
V2Work.Category	Second version of work categories created late 2015	Final Caltrans Project Data 10 Mil and Over.xlsx
Schedule.Change	Percentage difference between Orig.No.Working.Days and Actual.No.Days.Worked, 0=on time, - = completion ahead of schedule, + = completion behind schedule	Final Caltrans Project Data 10 Mil and Over.xlsx
CCO.Amount.Spent	Dollar amount spent from CCO	Final Caltrans Project Data 10 Mil and Over.xlsx
CCO.Spent	Percentage of partnering budget spent	Final Caltrans Project Data 10 Mil and Over.xlsx
Time.to.Partnering	Time between Award.Date and Date.of.First.Event	Final Caltrans Project Data 10 Mil and Over.xlsx
CoV	Coefficient of Variance of work categories	Final Caltrans Project Data 10 Mil and Over.xlsx
Top1	Percentage of project budget of the largest work category	Final Caltrans Project Data 10 Mil and Over.xlsx
NumCat	Number of work categories making up project	Final Caltrans Project Data 10 Mil and Over.xlsx
NumCat25	Number of the largest categories making up 25% of a projects budget	Final Caltrans Project Data 10 Mil and Over.xlsx
NumCat50	Number of the largest categories making up 50% of a projects budget	Final Caltrans Project Data 10 Mil and Over.xlsx
NumCat75	Number of the largest categories making up 75% of a projects budget	Final Caltrans Project Data 10 Mil and Over.xlsx
AdminPerc	Percentage of project budget dedicated to Administrative activities	Complete Project Expenditure with Perc Calcs.xlsx
Barriers.Guard.RailsPerc	Percentage of project budget dedicated to Barriers and Guard Rail activities	Complete Project Expenditure with Perc Calcs.xlsx

Culvert.DrainagePerc	Percentage of project budget dedicated to Culvert and Drainage activities	Complete Project Expenditure with Perc Calcs.xlsx
DemolitionPerc	Percentage of project budget dedicated to Demolition activities	Complete Project Expenditure with Perc Calcs.xlsx
Env..MitigationPerc	Percentage of project budget dedicated to Environmental Mitigation activities	Complete Project Expenditure with Perc Calcs.xlsx
Excavation.Earth.WorkPerc	Percentage of project budget dedicated to Excavation and Earth Work activities	Complete Project Expenditure with Perc Calcs.xlsx
LandscapingPerc	Percentage of project budget dedicated to Landscaping activities	Complete Project Expenditure with Perc Calcs.xlsx
LightingPerc	Percentage of project budget dedicated to Lighting and Electrical activities	Complete Project Expenditure with Perc Calcs.xlsx
Misc.Perc	Percentage of project budget dedicated to Miscellaneous activities	Complete Project Expenditure with Perc Calcs.xlsx
MobilizationPerc	Percentage of project budget dedicated to Mobilization activities	Complete Project Expenditure with Perc Calcs.xlsx
Other.ConcretePerc	Percentage of project budget dedicated to Other Concrete activities	Complete Project Expenditure with Perc Calcs.xlsx
Other.SteelPerc	Percentage of project budget dedicated to Other Steel activities	Complete Project Expenditure with Perc Calcs.xlsx
Pavement.PlacementPerc	Percentage of project budget dedicated to Pavement Placement activities	Complete Project Expenditure with Perc Calcs.xlsx
Pavement.RemovalPerc	Percentage of project budget dedicated to Pavement Removal activities	Complete Project Expenditure with Perc Calcs.xlsx
PilingPerc	Percentage of project budget dedicated to Piling activities	Complete Project Expenditure with Perc Calcs.xlsx
Road.Striping.SignagePerc	Percentage of project budget dedicated to Road Striping and Signage activities	Complete Project Expenditure with Perc Calcs.xlsx
Structural.ConcretePerc	Percentage of project budget dedicated to Structural Concrete activities	Complete Project Expenditure with Perc Calcs.xlsx
Structural.Steel.RebarPerc	Percentage of project budget dedicated to Structural Steel and Rebar activities	Complete Project Expenditure with Perc Calcs.xlsx

Temporary.StructuresPerc	Percentage of project budget dedicated to Temporary Structures activities	Complete Project Expenditure with Perc Calcs.xlsx
Traffic.Control.MonitoringPerc	Percentage of project budget dedicated to Traffic Control and Monitoring activities	Complete Project Expenditure with Perc Calcs.xlsx
BridgePerc	Percentage of project budget dedicated to Bridge activities	Complete Project Expenditure with Perc Calcs.xlsx
Plumbing.IrrigationPerc	Percentage of project budget dedicated to Plumbing and Irrigation activities	Complete Project Expenditure with Perc Calcs.xlsx