UNIVERSITY OF CALIFORNIA

Review of the Project Resourcing and Schedule Management (PRSM) System used by Caltrans

A Research Report from the University of California Institute of Transportation Studies

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16. Abstract

The California Budget Act of 2016 included a provision to "complete a post-implementation review of the Project Resourcing and Schedule Management (PRSM) information technology system upgrade completed by the Department of Transportation". The PRSM system referenced is Commercial-Off-The-Shelf (COTS) software deployed at Caltrans in 2014 and intended to enable Caltrans to effectively plan State employee and consultant time spent on activities related to projects in its Capital Outlay Support (COS) program. A team of researchers in the Engineering Project Management Program at UC Berkeley was selected to conduct the review of PRSM. This report summarizes the team's findings. Looking inside Caltrans at how the agency is using PRSM, Section I reports on the researchers' review of Caltrans documents and the interviews they conducted with sample groups of Caltrans staff. The study shows that PRSM has become a well-established system: it is now used agency-wide by approximately 3,000 Caltrans users with read/write access and many others with read-only access. Caltrans staff are using PRSM for project resourcing, especially for annual budgeting, but are not using all its scheduling functions to their potential. Looking outward for practices different from those of Caltrans that may reveal opportunities to improve Caltrans' project management practices with PRSM support, Section II reports on findings from the researchers' scan of comparable software, survey of state departments of transportation, interviews with private engineering firms, and review of recent developments and best practices in project management. The study shows that PRSM is but one of several possible- but still among the most highly-rated software system choices. Study recommendations include: continuing with ongoing PRSM training for District personnel to ensure consistency in use across the State, engaging more directly with the system vendor to voice Caltrans' needs for future software enhancements, changing the current Caltrans workflow to include systematic project baselining, and developing task management practices using the Last Planner® System to enhance work flow reliability and thereby improve efficiency and project performance. This Report ends with a summary of all findings and lays the foundation for scope to be pursued in subsequent, applied research with Caltrans, aiming to further leverage the support that PRSM use can provide in its project management practices.

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ABOUT THE UNIVERSITY OF CALIFORNIA INSTITUTE OF TRANSPORTATION STUDIES (ITS)

The University of California Institute of Transportation Studies (UC ITS) is a network of faculty, research and administrative staff, and students dedicated to advancing the state of the art in transportation engineering, planning, and policy for the people of California. Established by the Legislature in 1947, ITS has branches at UC Berkeley, UC Davis, UC Irvine, and UCLA.

ABOUT THE PROJECT PRODUCTION SYSTEMS LABORATORY (P2SL)

The Project Production Systems Laboratory (P2SL) at UC Berkeley is a research institute dedicated to developing and deploying knowledge and tools for project management. The Laboratory is housed under the umbrella of the Center for Information Technology Research in the Interest of Society (CITRIS).

Projects are temporary production systems. P2SL is dedicated to developing and deploying knowledge and tools for the management of project production systems and the management of organizations that produce and deliver goods and services through such systems. Project production systems include for example construction, product development, software engineering, air and sea ship building, work order systems, job shops, performing arts productions, oil field development, and health care delivery.

Companies worldwide, and especially those involved in the Northern California construction industry, are invited to team up with P2SL staff and students, and use our resources to advance the theory as well as the implementation of the lean construction philosophy, principles, and methods in the industry, its companies, and its projects. Our goal is to advance and deepen understanding of how to deliver lean projects. All members of the industry are invited to become contributors and to participate in the Laboratory: owners, regulators, architects, engineers, contractors, unions, suppliers, insurers, financiers, etc.

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This study was made possible through funding received by the University of California Institute of Transportation Studies from the State of California via the Public Transportation Account and the Road Repair and Accountability Act of 2017 (Senate Bill 1). The authors would like to thank the State of California for its support of university-based research, and especially for the funding received for this project.

The authors of this study have benefited from research support provided by Dr. Glenn Ballard, Research Director of the Project Production Systems Laboratory, by Messrs. Eshan Jayamanne Mohottige Don and Ahmad El Merhebi, graduate students in Engineering and Project Management, and administrative support from Mr. Benjamin McKeever from PATH, all from UC Berkeley. Furthermore, they owe many thanks to the numerous people who helped them obtain data to analyze and report on, and those offering feedback on this written report.

For Section I, thanks are due to employees of Caltrans who assisted the authors in their research. James E. Davis and his staff in the Division of Project Management were most helpful in making arrangements and providing comments. Thanks are also due to Monica Kress, James Monroe, and Dr. Amir Taba for sharing their insights. Dr. Taba, Edmond Matevosian, and Anup Khant provided us with a valuable introduction to the PRSM system.

The authors had informative discussions and demonstrations of PRSM use in the North Region and District 3 (Marysville), District 4 (Oakland), the Central Region and District 6 (Fresno), and the Division of Engineering Services in Sacramento. Thanks are due to the managers and coordinators in each of these locations and the teams who participated in each meeting. Our visits were coordinated by Karl Dreher and Pauline Dixon in Marysville, Harlan Woo in Oakland, Tony Hunt in Fresno, and Jeff Wiley at the Division of Engineering Services.

For Section II, thanks are due to those who helped us distribute the survey to the states. Cathrina Barros, the Caltrans liaison to AASHTO, submitted the survey to AASHTO for distribution; James E. Davis, Chief of the Caltrans Division of Project Management, distributed it to the members of the AASHTO Technical Committee on Project Management; and Gary Vansuch of the Colorado Department of Transportation distributed it to the Transportation Lean Forum (an informal association of the Lean and Continuous Improvement offices in 30 states, 4 Canadian provinces, England, and the Netherlands). We thank the representatives of the 29 states and 2 Canadian provinces who responded to the survey and all individuals who participated in follow-on telephone interviews.

Finally, thanks are also due to the managers of engineering design organizations in private practice who generously shared their experience and reflections with the researchers on their use of project management software and practices pertaining to project resourcing.

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December 2018

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EXECUTIVE SUMMARY

The California Budget Act of 2016 included a provision (Item 6440-001-0046 provision 2 (b) (2)) to "complete a post-implementation review of the Project Resourcing and Schedule Management (PRSM) information technology system upgrade completed by the Department of Transportation" (California State Legislature 2016). The PRSM system referenced is Commercial-Off-The-Shelf (COTS) software deployed at Caltrans in 2014 and intended to enable Caltrans to effectively plan State employee and consultant time spent on activities related to projects in its Capital Outlay Support (COS) program.

Tasked with responding to this provision, the Institute of Transportation Studies (ITS) at the University of California designated a team of researchers in the Engineering Project Management Program at UC Berkeley to conduct this review. The team defined the scope of work for this three-year review and broke it down into two parts, one looking inside Caltrans at how the agency is using PRSM, the other looking outward for practices different from those of Caltrans that may shed light on opportunities to improve Caltrans' project management practices with PRSM support. Findings from each part are presented respectively in Sections I and II of this Report on the review conducted to respond to the aforementioned provision.

In Section I, the researchers report on their study of PRSM, deployed at Caltrans since 2014. They reviewed Caltrans documents and conducted interviews with sample groups of Caltrans staff. The desired outcome of this part of the research was to produce a factual, non-judgmental description of how PRSM is used and what it is used for.

In Section II, first, the researchers report on the high-level scan they conducted of software available on the market today, considered akin to various degrees in functionality and use to PRSM. The goal was *not* to search for a replacement for PRSM but, rather, to get a sense of how PRSM is "holding up" in a changing information-technology marketplace and to identify uses of enterprise project management software that could inspire Caltrans to deepen and broaden the use of PRSM capabilities that are currently already available. Second, the researchers report on their survey into if and how other state departments of transportation use software agency-wide to perform functions that are similar to those Caltrans performs in PRSM. The goal was to discover if other states might be using software that could inspire more in-depth as well as broader use of PRSM's capabilities. Third, the researchers interviewed managers at a select number of engineering design organizations in private practice, performing somewhat similar project management functions, including project resourcing. They also searched the literature for methods and data pertaining to project resourcing. The goal was to gain perspective on industry practices related to project resourcing. Fourth, the researchers present developments in project management theory and practice in organizations other than Caltrans. In particular, since the PRSM Feasibility Study Report (FSR) was written in 2000, such developments include the publication of several national and international standards; the growth in worldwide interest

in portfolio management; the spread in adoption of Lean, Six Sigma, Lean Six Sigma, Agile, and other innovative practices in project management with new thinking that falls under the broad umbrella of project production management. The desired outcome of Section II of the Report was to shed light on the state-of-practice regarding software use to manage engineering design projects in public- as well as in private organizations, and to help find potential enhanced uses of such management software. Caltrans personnel can thus view their current use of PRSM in this light and be inspired to further advance its management practices.

This Report ends with a summary of all findings and recommendations. These lay the foundation for scope to be pursued in subsequent, applied research with Caltrans, aiming to further leverage the support that PRSM use can provide in its project management practices.

Finding 1: Data shows that PRSM has become a well-established system: it is now used agency-wide by approximately 3,000 Caltrans users with read/write access and many others with read-only access. Given the vast amount of training delivered to date as well as on-going training needed to get such a large user group to adopt and skillfully follow the current PRSM project management workflows, it is unlikely that all PRSM features are as-of-yet used consistently and at their fullest throughout the Caltrans organization. The researchers found that headquarters trainers appear to understand the software better than the District staff, and CA (the developers of PRSM) demonstrated features that the researchers had not seen demonstrated in Caltrans.

Recommendation 1: Caltrans users mentioned the need for continuing training in PRSM. Headquarters staff has performed valiantly in providing vast amounts of start-up training, but training cannot stop. In order to address incoming staff needs (due to attrition and turn-over of staff) training in PRSM's technical capabilities must continue be provided on an on-going basis to District staff.

Finding 2: Users in various organizations that use the CA PPM system (that program that underlies PRSM), gather at regular times in a "Big Room" to meet with CA leadership and help them decide on software upgrades. Caltrans appears to not be well-represented there.

Recommendation 2: Caltrans should obtain a seat in the CA PPM "Big Room" to provide a voice different from the voices of other CA PPM users. Both Caltrans and CA would benefit from such direct engagement even if the California State Chief Information Officer (CIO) has a seat in the "Big Room," since most users of CA PPM are drawn from the information technology sector, which is well represented by the CIO. Caltrans PRSM is a tool to help deliver projects in the design-bid-build construction industry which has needs different from those of the information technology sector.

Finding 3: Caltrans is not using the baselining process that was envisaged in the PRSM Request For Proposals (RFP) and Feasibility Study Report (FSR) (see Section I.3.4).

Recommendation 3: The researchers recommend that Caltrans develop and implement a process for establishing and recording in PRSM a revised Headquarters (HQ) Baseline for each project

whenever HQ approves a project change (which, it is understood, may occur at the start of each phase and when a District submits a Project Change Request). The PRSM FSR envisaged that the HQ Baselines would replace the "January 9 file" described in Section I.3.1.2 with consequent savings in Caltrans effort. Whether or not this replacement is feasible in practice has yet to be determined. It cannot be determined, however, if a HQ Baseline is not saved whenever HQ approves a project change.

Finding 4: Caltrans staff are using PRSM for project resourcing, especially for annual budgeting, but are not using all PRSM scheduling functions to their potential.

Recommendation 4: The researchers recommend that Caltrans conduct pilot projects to test innovative scheduling and task management practices. These can be tailored to Caltrans needs and, if and when successful, scale for use in its project portfolios. In particular, the researchers recommend that Caltrans test the Last Planner® system described in Section II.5.3. This system has been used successfully on projects around the world. It has led to better management of workload fluctuations, more reliable completion of tasks according to schedule, and less rework, while employees have experienced less stress and felt more accomplished with their work. We expect that similar results can be achieved in Caltrans.

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BACKGROUND – PRSM REVIEW

The Institute of Transportation Studies (ITS) at the University of California's Berkeley (its.berkeley.edu), Davis (its.ucdavis.edu), Irvine (www.its.uci.edu), and Los Angeles (www.its.ucla.edu) campuses was tasked with responding to the provision in the California Budget Act of 2016 that stated:

> "At a minimum, the funds shall be used to complete a post-implementation review of the Project Resourcing and Schedule Management (PRSM) information technology system upgrade completed by the Department of Transportation."

Budget Act of 2016 (Chapter 23, California Statutes of 2016; Senate Bill 826)
pages 526-527 Item 6440-001-0046 provision 2. (b) (2)

Accordingly, ITS designated a team of researchers in the Engineering Project Management Program at UC Berkeley to conduct this review and report on their findings. This team comprises three internationally-recognized experts in engineering project management, two student researchers, and a staff member. Appendix I presents their credentials.

The PRSM system referenced in this provision is Commercial-Off-The-Shelf (COTS) software deployed at Caltrans in 2014 and intended to enable Caltrans to effectively plan State employee and consultant time spent on activities related to projects in its Capital Outlay Support (COS) program. This program "funds environmental studies, design services, construction engineering and right-of-way acquisition services for State Highway projects" (Caltrans 2005:1). For fiscal year 2017-18, COS funding amounts to about $1.8 billion-per-year, which is half as much as the $3.6 billion-per-year funding Caltrans receives for the Capital Outlay program itself. The COS program is about 90% staffed by State employees (about 8,000 people) and the remaining 10% by consultants.

The provision left it up to the researchers to determine the specifics of the review, so the researchers considered the post-implementation evaluation of PRSM (Caltrans 2015:1) further studies that Caltrans has already conducted in-house (2015:2, 2016:2) and then defined their own scope and approach. Accordingly, this review focuses on how Caltrans is using various PRSM software capabilities in their specific implementation setting, how PRSM enables Caltrans staff to realize their project management workflows, and what—if any—other, new project management practices Caltrans might consider for future implementation to drive continuous performance improvement within their organization.

The team broke their scope of research work down into two parts, each one presented in a section of this Report. This Report responds to the aforementioned provision.

Section I reviews the history and intended use of PRSM at Caltrans. It presents the researchers' observations of PRSM as implemented and in practical use, based on a Caltrans document review and interviews they conducted with sample groups of Caltrans staff. The desired outcome of this

part of the review was to produce a factual, non-judgmental description of how PRSM is used and what it is used for. The study shows that PRSM has become a well-established system: it is used agency-wide by approximately 3,000 Caltrans users with read/write access and many others with read-only access. Caltrans staff are using PRSM for project resourcing, especially for annual budgeting, but are not using all PRSM scheduling functions to their potential. Section I offers no specific recommendations for improvement of PRSM use or project management practice at Caltrans. The researchers provide such recommendations at the end of this Report after they have summarized current best practices, standards, literature, and research on project management with an eye on articulating opportunities for improvement of Caltrans project management processes.

Section II first offers a high-level scan of software available on the market today that is considered akin—to various degrees—in functionality and use to PRSM. This review is based on information publicly available on the internet and market surveys. The goal was *not* to search for a replacement for PRSM but, rather, to identify potential opportunities for deepening and broadening the use of PRSM capabilities that are currently already available. Second, Section II presents data the researchers obtained by administering a survey to other state departments of transportation on their agency-wide use of software to perform functions that are similar to the functions Caltrans performs in PRSM, and, in general terms, how other agencies use their software. The goal was to discover if other states might be using software that could inspire more in-depth or broader use of PRSM's current capabilities. Third, Section II summarizes findings from conversations the researchers had when conducting telephone interviews with managers at a select number of engineering design organizations in private practice, performing somewhat similar project management functions, including project resourcing. They also searched the literature for methods and data pertaining to project resourcing. The goal was to gain perspective on industry practices related to project resourcing. Fourth, Section II presents developments in project management theory and their use in practice in organizations other than- but pertinent to Caltrans. In particular, since the PRSM Feasibility Study Report (FSR) was written in 2000, such developments include the publication of several national and international standards; the growth in worldwide interest in portfolio management; the spread in adoption of Lean, Six Sigma, Lean Six Sigma, Agile and other innovative practices in project management; and new thinking that falls under the broad umbrella of management of projects and management of project production systems. The desired outcome of this Section II of the review, informed by a high-level market-scan, survey, telephone interviews, and literature, was to shed light on the state-of-practice of design and engineering project management and software use in public and private organizations, so that PRSM can be reviewed in this context.

This Report lays a foundation for scope to be pursued in subsequent applied research with Caltrans.

SECTION I – ADOPTION AND DEPLOYMENT OF PRSM IN CALTRANS

I.1 Research Methodology, Work Plan, and Outline of Section I

The methodology followed to conduct the research for this Section I included reviewing PRSM-related documents produced in-house by Caltrans, gathering data on PRSM use in meetings with Caltrans and PRSM software-development staff, describing observations, and then obtaining feedback from Caltrans on these observations to ensure their factual correctness prior finalizing this document.

The work plan for Section I included the following research steps:

1. Meet with Caltrans Headquarters project management staff and with PRSM staff.
2. Conduct interviews with PRSM users in selected Districts.
3. Review Caltrans in-house documents pertaining to PRSM, and other relevant literature.
4. Prepare draft Report.
5. Circulate draft Report to Caltrans managers for their input into the observations made to-date and direction for the follow-on research.
6. Finalize Report Section I.

Shedding light on how the PRSM software is currently used at Caltrans, Section I has 6 subsections and 3 appendices. Subsection 2 gives an overview of project management at Caltrans. Subsection 3 presents a history of software use at Caltrans that informed the request for proposals for project management software that ultimately resulted in the selection and deployment of PRSM. Subsection 4 summarizes PRSM-user-reported successes and challenges of the PRSM software and current project management practices at Caltrans. Subsection 5 offers a summary of the review of PRSM use at Caltrans, though defers spelling out specific recommendations to Caltrans; the researchers offer their recommendations later in the Report. Appendix I gives the researchers' credentials and standard of ethical conduct, Appendix II abbreviations and acronyms, and Appendix III references and bibliography.

I.2 Overview of Project Management at Caltrans

A review of the use of project management software in an organization must be grounded in that organization's project management needs, practices, culture, and context. These evolve to address the complexities of the projects being delivered by the organization and the socio-technical context in which the projects unfold (e.g., reflecting advances in computational hardware and software). In addition, project management success depends on the extent to which people in the organization have management knowledge and skills as needed to address the complexities of the projects they engage in. Recognizing the need for grounding the ideas presented, while this document focuses on the use of the PRSM software by Caltrans, this Section

provides an overview of the Caltrans organization and project management practices of its Capital Outlay Support (COS) staff.

I.2.1 Caltrans Organization: Functional- vs. Project-based Structure

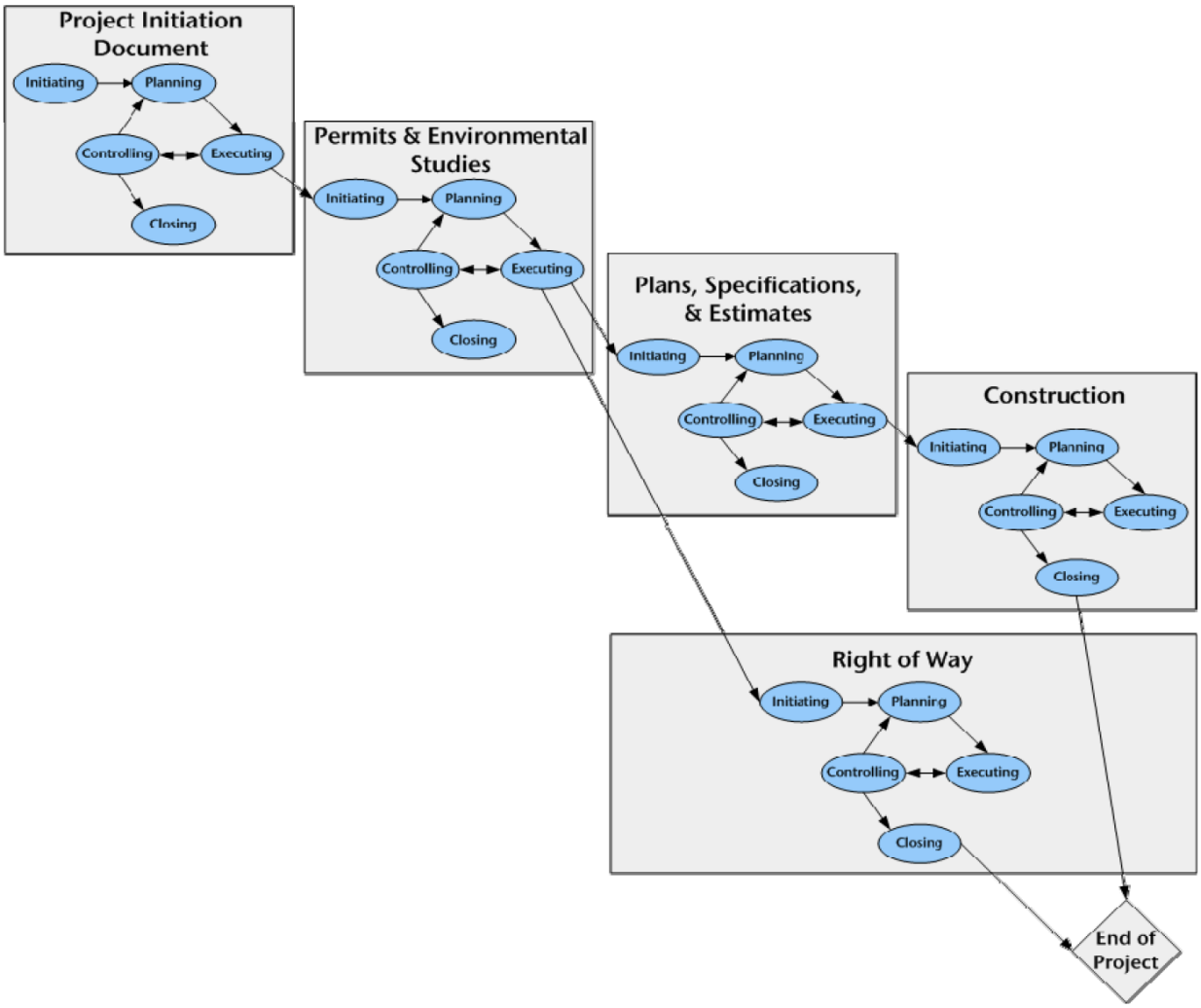
The projects that Caltrans manages in its COS program comprise distinct elements. In accordance with Federal Highway policies, these elements distinguish between "preliminary engineering," that starts at project initiation and ends with the award of a construction contract, and "construction engineering" that starts at contract award and consists of the management of construction contractors through the completion of construction (FHWA 2015). Until 1989, Caltrans made a clear distinction in the management of these two elements. The project engineer managed preliminary engineering, and then handed the project over to a resident engineer who managed construction engineering. The project management literature describes an organization that is structured in this way as a "functional organization" (PMI 2017:1). A functional organization can reap the benefit of specialization within disciplines (e.g., bridge design), however, it may encounter challenges when delivering projects because the priorities of the functional organizational structure may be in tension with those of the project. Many organizations that deliver projects, including Caltrans, adopt some matrix form of organization, somewhere in-between the spectrum ranging from purely functional- to purely project-based organization.

In 1989, Caltrans Director Robert Best announced that Caltrans would be adopting "project management," in which a single designated project manager would manage each project from "cradle to grave," including both preliminary engineering and construction engineering (Caltrans 2017). This demarcation of the project as a larger whole, elevates the locus of power and control to a higher level so that management can aim for more comprehensive, broadly optimal project delivery.

The current Caltrans conceptualization of project delivery of all state highway projects comprises 5 components (Figure 1): (1) Project Initiation Document (PID), (2) Project Approval and Environmental Document (PA&ED), (3) Plans, Specifications, and Estimate (PS&E), (4) Right of Way, and (5) Construction.

Caltrans differs from most state departments of transportation (DOTs) in the US in that the preponderance of its preliminary and construction engineering is performed by State employees; most other US state DOTs hire private engineering firms as consultants to perform a large part of this work. A significant effort of Caltrans project management therefore goes into managing in-house resources involved in preliminary and construction engineering; whereas other US state DOT's management focuses more on managing external consultants.

Figure 1: Project Component Lifecycle (Figure 2 in Caltrans 2007)



Caltrans is geographically organized in 12 Districts, each one staffing and managing its own projects, though (on occasion) staff in one District could be working on a project in another District. The Caltrans Headquarters are located in Sacramento and of course serve the entire State.

The Caltrans Project Management Handbook (Caltrans 2007) describes project management roles and responsibilities. Project managers are generally assigned to all major capital projects, including the following:

- State Transportation Improvement Program (STIP), State Highway Operation and Protection Program (SHOPP), seismic, locally funded, and toll projects,
- Projects with multiple functional unit involvement, and
- Projects with a significant amount of local or private entity involvement.

Caltrans' current organization is described in project management literature as a "weak matrix" (PMI 2017:1). This means that, although each project has a project manager with overall responsibility for the project, project managers must negotiate with organizational unit supervisors for staff to perform work on projects. At the planning stage of a project, deciding on hours needed to deliver that project is done in a bottom-up fashion (as the researchers were told while interviewing users of PRSM) with functional units estimating the numbers of hours (by job title or named individual) they anticipate needing to deliver the project at hand. This project management practice builds responsibility and accountability as those involved in estimating also are involved in execution with PRSM being used to track expenditures by project. The alternative approach, top-down estimating, e.g., using a (resource-loaded) schedule and a cost template based on a historic project database (which may serve in conceptual estimating), may not provide the custom-tailoring needed to address the specifics of the project and leaves those responsible for execution potentially less committed to meeting the estimate that isn't theirs.

Caltrans uses three terms to denote project management roles (Caltrans 2000:3, 2007):

- **Project Manager (PM):** the individual responsible for managing a project.
- **Functional Manager (FM):** the immediate supervisor of the staff who work on a project.
- **Task Manager (TM):** an individual who is delegated the responsibilities of both the Project Manager and the Functional Manager for the production of particular elements of the project Work Breakdown Structure.

Caltrans staff in these roles are the key users of the PRSM system. About 3,000 Caltrans staff read/write PRSM data for their management decision making. Anyone with a Caltrans Intranet account has read-only access, even if they do not play any of these roles.

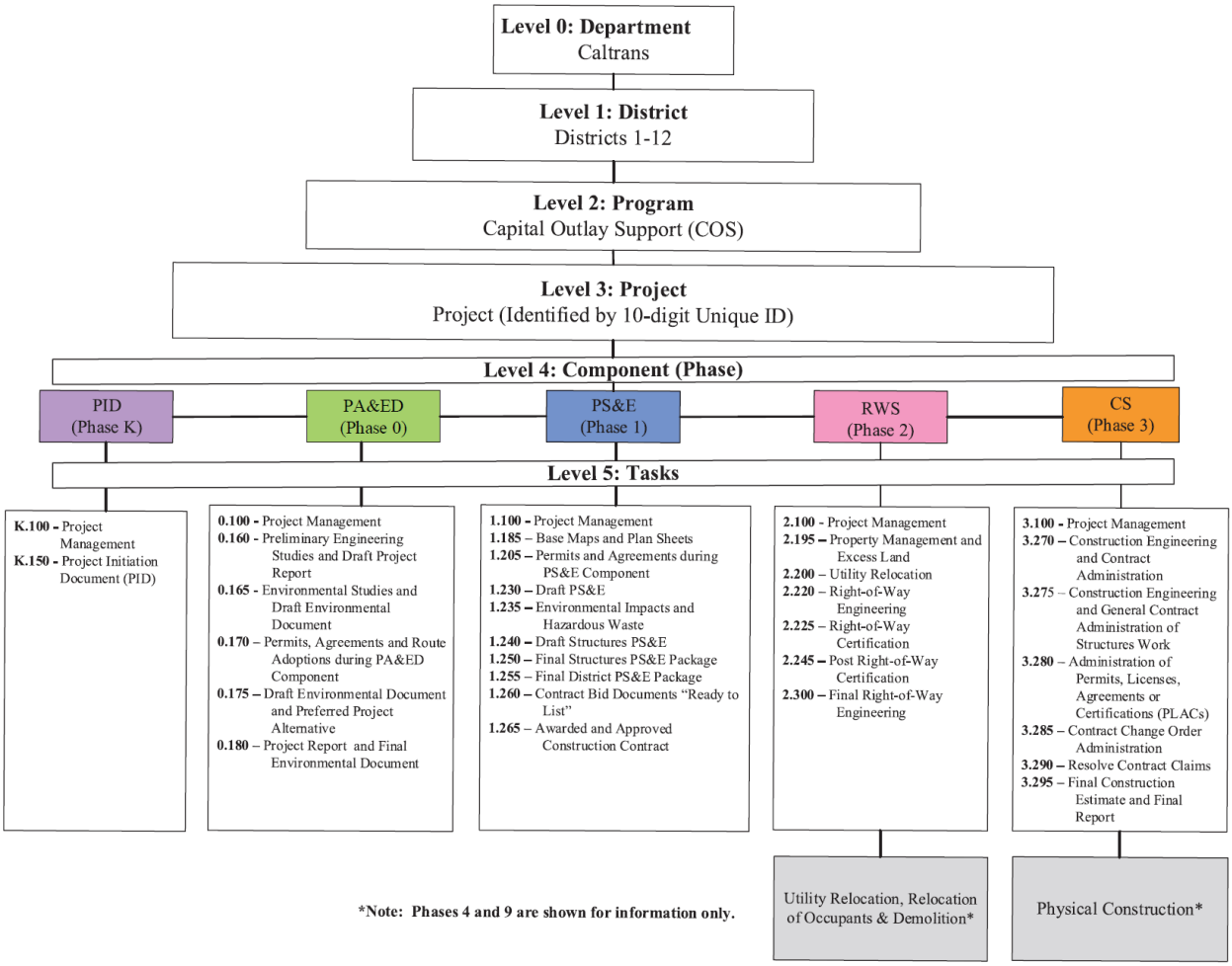
"In the early 1990s, several task forces and Peer Reviews recommended that the Department establish a modern project management process and develop the tools to help improve the Department's project delivery. Caltrans issued the first version of the Department's Capital Outlay Support (COS) [Work Breakdown Structure] WBS in July 1994." (Caltrans 2016:2 p. 1) The standard has been updated numerous times to address deficiencies and changing practices; Caltrans issued the current Version 11.2 in 2016.

A Work Breakdown Structure (WBS) is a tool used in project management for planning and controlling work. PMI (2006) states "The WBS organizes and defines the total scope of the project. The WBS subdivides the project work into smaller, more manageable pieces of work, with each descending level of the WBS representing an increasingly detailed definition of the project work." A WBS focuses on deliverables and who is responsible for them, usually not on sequencing of work.

Caltrans uses its WBS to enumerate presumably every deliverable type that its employees might need to produce on a State Highway Project (Figure 2). It mandates that project managers detail

their projects to at least level 5 by task name as illustrated, and leaves the use of levels 6, 7, and 8 as optional. The Caltrans WBS serves as the backbone for reporting and tracking project data in PRSM.

Figure 2: Work Breakdown Structure Diagram (Figure on p. 7 in Caltrans 2016:2)



I.2.2 Project Management Competence Development

Caltrans has structured its organization according to regionally-distributed functional units to meet the needs of the projects it delivers. In addition, it has created a Division of Project Management (www.dot.ca.gov/projmgmt/) and put a project management backbone in place, i.e., the Caltrans (2016:2) Workplan Standards using a WBS. Finally, Caltrans continues to encourage individual staff to engage in professional development of their project management competence so as to increase the organization's capacity and capability to deliver State Highway Projects. E.g., Caltrans (2007 p. 53) promotes staff certification as Project Management Professional (PMP):

> "The Project Management Institute's (PMI) PMP certification is widely recognized and accepted throughout the world as evidence of a proven level of education, knowledge and experience in project management. The Division of Project Management encourages qualified Project Delivery staff to pursue their PMP and provides a course that includes intensive on-line review and the PMP exam."

With this foundation for practicing project management outlined, the next Subsection presents the processes and computational support that Caltrans has been deploying and improving over the years.

I.3 PRSM Predecessors and History

In the 1970s, Caltrans staff began to develop and use software systems to support their organizational practices. The early, mainframe systems had to be programmed in-house as no commercial programs existed to suit Caltrans needs; over time, commercial off-the-shelf (COTS) systems on desktop computers have become increasingly available and versatile, and thus potentially suitable for use by Caltrans. Caltrans workflows accordingly have evolved thanks to better definition of their project management requirements in combination with increasing capabilities of computing and communication hardware and software to support them, not in the least the flourishing of the Internet.

I.3.1 Caltrans Project Management Software Prior to PRSM

Caltrans made decisions in specifying the requirements for PRSM and its implementation, informed by how it used its predecessor systems. PRSM was to maintain some prior system functions ("received tradition") while also offer new capabilities.

I.3.1.1 PMCS and PYPSCAN

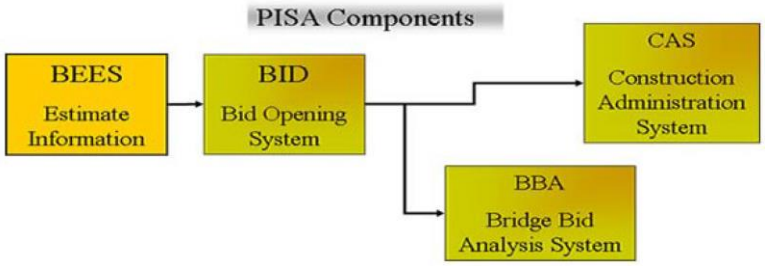
Caltrans employees created the Project Management Control System (PMCS) database on the Department's mainframe computer and started using it to manage their projects in 1976 (Caltrans 2017). Although Caltrans has since introduced newer project management systems, namely XPM in 1994 and PRSM in 2014, these did not fully replace PMCS. PMCS continues to be a source of data for several legacy systems in Caltrans, including the Project Information and System Analysis (PISA) software that also dates back to the 1970s.

Caltrans uses PISA to manage its construction Capital Outlay program, which accounts for the largest slice of their budget, about $3.6 billion in fiscal year 2017-18, vs. PRSM to manage its Capital Outlay Support (COS), which is-about half in size. PISA has four subsystems (Figure 3):

1. Basic Engineering Estimating System (BEES) to estimate construction costs.
2. Bid Opening System (BID) to manage the process of analyzing construction bids.
3. Bridge Bid Analysis System (BBA), supplementing BID with a focus on structures.

4. Construction Administration System (CAS) to manage finances and track awarded construction contracts, including monthly payment to construction contractors.

Figure 3: Components of the PISA Software System to Manage Caltrans Capital Outlay



After developing PMCS, Caltrans staff developed an automated project planning system, called Person-Year Project Scheduling and Cost Analysis (PYPSCAN), and placed it in service in 1980 (Caltrans 2017). PYPSCAN addressed Caltrans' resource forecasting and allocation problem, as described by McManus (1981):

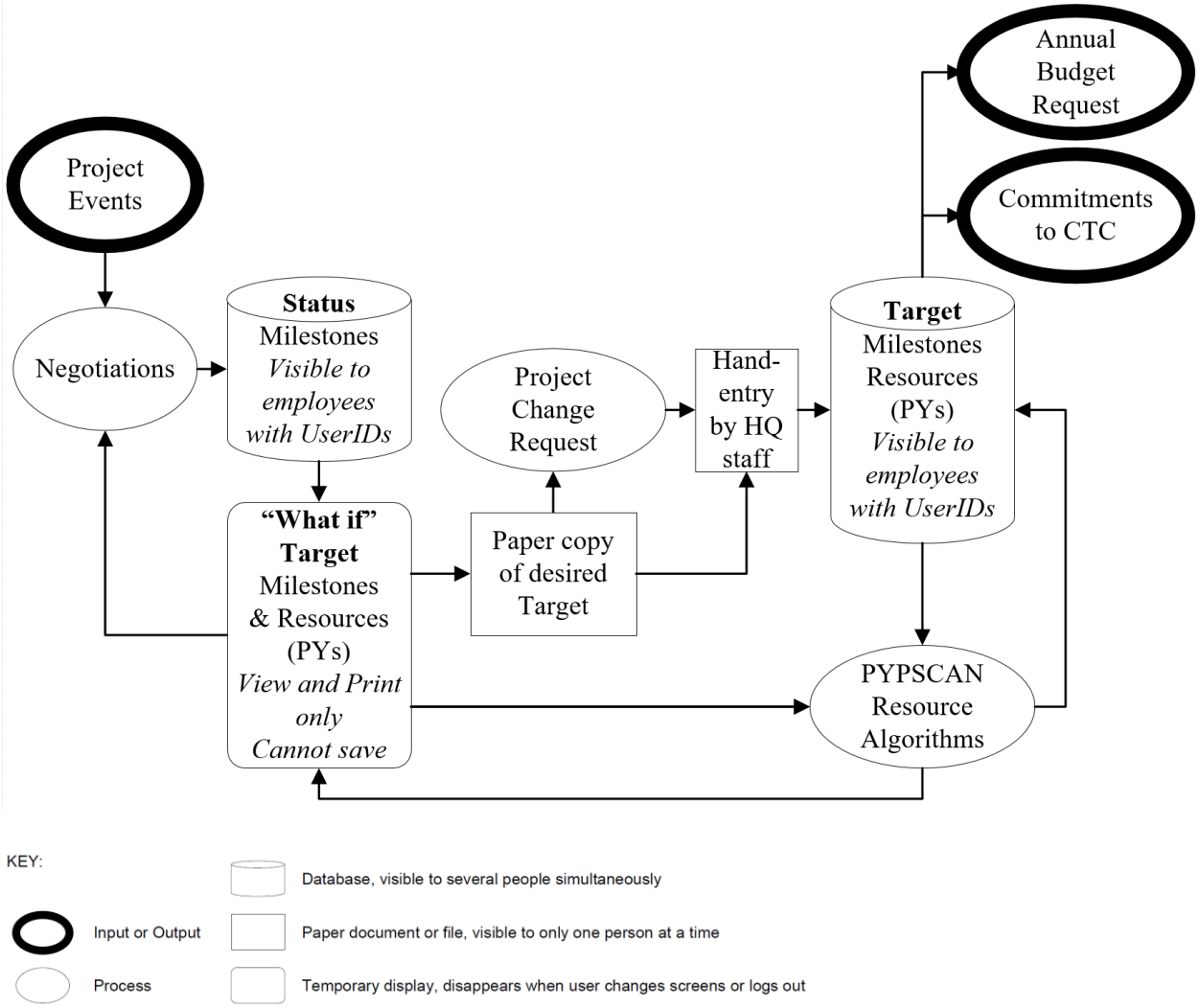
> "Once a year, a gigantic manpower intensive effort was launched statewide for from one to two months when all the manpower estimating was tied to project schedules. Under the decentralized process of that time, this effort was undertaken in eleven District offices and numerous headquarters units. Between redundancy on the one hand and omissions on the other, the whole exercise was suspect—and this became the base of the Governor's Budget. Manpower allocations were transmitted six months later and were pitifully out of date with everything. When all this was loaded into the computer, we were able to produce beautiful management reports fraught with totally incredible information."

Figure 4 illustrates the Caltrans process for project resourcing and schedule management using PMCS and PYPSCAN from 1980 onward. This process consisted of 9 steps:

1. Project Events: Events occurred, whether or not according to plan, given the reality that:
   - Plans are forecasts, and forecasts are always wrong,
   - The further out in the future we plan, the more wrong we are, and
   - The greater detail at which we plan, the more wrong we are.

2. Negotiations: As events deviating from the plan occurred, they were made known to project team members who discussed and negotiated their responses to them. The forum for such negotiations was the monthly project status meeting, but meetings, discussions, and negotiations could be held at any time.

Figure 4: Project Resourcing and Schedule Management Process using PMCS and PYPSCAN



3. Status: Agreed project milestones were recorded as the "status" in PMCS, which had fields for standard project status milestones. Relative to a given reporting date, actual dates of milestones accomplished in the past were recorded in mm/dd/yy format, and those in the future or milestones not yet accomplished in mm/__/yy format. Target dates, appearing below status dates, were recorded in mm/yy format; they could not, and did not, include a specific day of the month. For example, Figure 5 shows, relative to the "LAST PYPSCAN" date of 10/30/80, status dates immediately below each milestone: "BEG STDY" started 08/16/78 (a date in the past) whereas "RW&SITE" was to start in 04/ /81 (April 1981, a date in the future) and has a target date of 12/81 (December 81).

   To view PMCS data, Caltrans staff required a UserID and password. These were issued to many, although their availability fluctuated as managers decided who had a "need to know."

Figure 5: PYPSCAN "What if" Screen from PMCS (McManus 1981 slide 14)

```
PYRS 01:155900:                                NEXT:    MEN-101-30.8   *  A C S P  *
S U P P O R T  BY  F I SC A L  Y E A R  WINDOW YR __  LAST PYPSCAN 10/30/80
   MONTHS  79-80  80-81  81-82  82-83**83-84  84-85  85-86  86-87**87-88  AFTER
 PJD  83    .92    .58   5.90   6.37    .44
 RWO  43                10.22    .93    .32    .15
 STD  13                 1.17   1.75
 STC  16                                1.59   2.30
 CON  16                                6.06  10.81
 D/L   4                                        .45
TOTAL        .92    .58  17.29   9.05   8.41  13.71
M I L E S T O N E S  (* COMPUTED BY PYPSCAN)    PHASE COMPLETE
   BEG STDY STG1 WP  STG2 WP  CIRC DPR SUBM PR  APTR PR  CIRC ED  HEARING
   08/16/78                               09/18/79 09/   /80
 *                                        09/79 X  12/79    12/79    07/80   <- (3)
   REQ PROJ PA&ED CL RW&SITE  REG APPR FNL MAPS GNL PLNS DMY PLNS ENV REVL
   06/   /80 08/   /81 04/   /81 06/   /80 10/   /81
 * 02/81    08/81    12/81    12/81    02/82 _  04/82    08/82    04/83 _
   BR PS&E  DT PS&E  RW CERT  HQ PS&E  HQ ADV   APR CNTR JOB COMP FNL RPT
   03/   /84 04/   /84 02/   /85        02/   /85
 * 05/83 _  06/83 _  08/83 _  09/83 _  10/83 _  02/84 _  04/85 _  06/85 _

                STAGE 1   2   3 _   OVERRIDE X <- (2)                    UPDATE _
RW CONTROLS BY 012 MONTHS <- (1)
807 INFO- CALCULATION COMPLETE. CONSIDER OVERRIDE OR UPDATE
```

4. "What if" Target: The user could run PYPSCAN (step 6), starting from a selected start date, to generate a so-called "average" schedule and person-year (PY) resources based on the actual performance of projects deemed similar, selected from a database of over 12,000 previously-completed Caltrans State Highway projects. The PY resources were distributed between milestones based on PYPSCAN algorithms (Caltrans 1992).

Figure 5 shows a "What if" output. It begins the schedule from the submittal of the project report (SUBM PR) in September 1979 and generates an average schedule that is expected to run through June 1985 (FNL RPT). This provides the PY resource estimate for fiscal years 1979-80 through 1984-85 that appear in the upper part of the screen.

However, Figure 5 shows an advertisement date of February 1985 (02/__/85) rather than the PYSCAN-generated October 1983 (10/83). When overriding the PYPSCAN schedule with their Status schedule, PY resources were kept constant in total, but got redistributed by fiscal year in accordance with the new milestone dates. Users in the Districts could see the changes on their screens, but could not save them.

5. Paper copy: Upon completing the "What if" analysis, and before leaving the screen (Figure 5) the user would print a copy of the screen showing the desired milestones, and consequent PY distribution by fiscal year.

6. PYPSCAN calculated an average project milestone schedule and PY resource needs based on:
   - Project Type: each project in a database of over 12,000 projects was identified as having a project type; each project could have only one project type (Caltrans 1992). The original

database had 107 project types (McManus 1981) and this number increased to 119 by 1992 (Caltrans 1992).

- Weather zone: one of five, ranging from Zone 1 (the driest), to Zone 5 (the wettest).
- Location: Urban or Rural.
- Environmental type: one of the three standard types of environmental document in Federal and State law respectively (NEPA and CEQA): (1) Environmental Impact Statement /Environmental Impact Report (EIS/EIR), (2) Finding Of No Significant Impact / Negative Declaration (FONSI/ND), and (3) Categorical Exclusion / Exemption (CE).
- Function: For PYPSCAN purposes, PY resources were calculated for six "functions": (1) highway preliminary engineering (or "project development," PJD), (2) right of way (RWO), (3) structures design (STD), (4) structures construction (STC), (5) highway construction (CON), and (6) day labor (D/L) (but this D/L formula was later dropped from PYSCAN) (McManus 1981 compared with Caltrans 1992).
- Capital Cost: Three capital costs were considered (adjusted for inflation using the Caltrans Construction Cost Index): (1) total construction cost, (2) right of way capital, and (3) structures construction cost. A specific capital costs was used for each phase. PJD, CON and D/L used total construction cost; STC and STD used structures construction cost; and RWO used right of way capital.
- Right of way information, including numbers of appraisals, acquisitions, utilities, relocation assistance cases, demolitions, railroad agreements, and condemnations.

The typical PYSCAN formula had the form:

$$P = a X^b$$

where P is the PY resources
a is a constant
X is the applicable capital cost, and
b is a constant such that $0 < b < 1$

This produced a possible 12 separate formulae for each of 119 project types (6 for PJD: 2 location types * 3 environmental types STD, STC, and CON). A single formula, regardless of project type, was developed for RWO based on the number and complexity of the Right of Way parcels that were affected. This produced a possible (12 x 119 + 1) = 1,429 formulae. Each formula was developed by regression analysis of projects from the database that matched the particular combination of factors. In practice, fewer than 1,429 formulae were in use because some project types could not include structures and most had only one possible environmental type.

Separately, PYPSCAN calculated an average project milestone schedule that used the same factors as the resource estimates, plus weather zone (which affected only the construction-phase milestones).

7. Project Change Request (PCR): If the project team, with approval of District management, wanted to permanently change the target milestones and distribution of PY resources, they

would submit a project change request to headquarters. This was accompanied by the paper copy of the desired target milestones and resource distribution (step 5).

8. Hand entry in headquarters: If the PCR was approved, headquarters staff would enter the new target milestones into PMCS, run PYPSCAN, and save the resulting data. Only certain headquarters account-holders had the ability to save the target milestones and consequent PY distributions.

9. Target: The target milestone schedule was the headquarters-approved schedule. PY resources were distributed, through PYPSCAN, to match this target schedule. If the status milestone for the end of the project was later than the target, Caltrans nevertheless received a PY budget that was based upon the target, and no resources were provided beyond the target end date. Likewise, if the status date was earlier than the target, Caltrans received the resources based upon the target and thus, to an extent, after they were actually needed. If they chose, project team could address these discrepancies, with District management approval, by submitting a new PCR.

   The target milestones were used in making commitments to the CTC, and the PYPSCAN PYs distributed between those milestones were used for the annual budget request to the Legislature. The Caltrans commitments and budget requests were in sync.

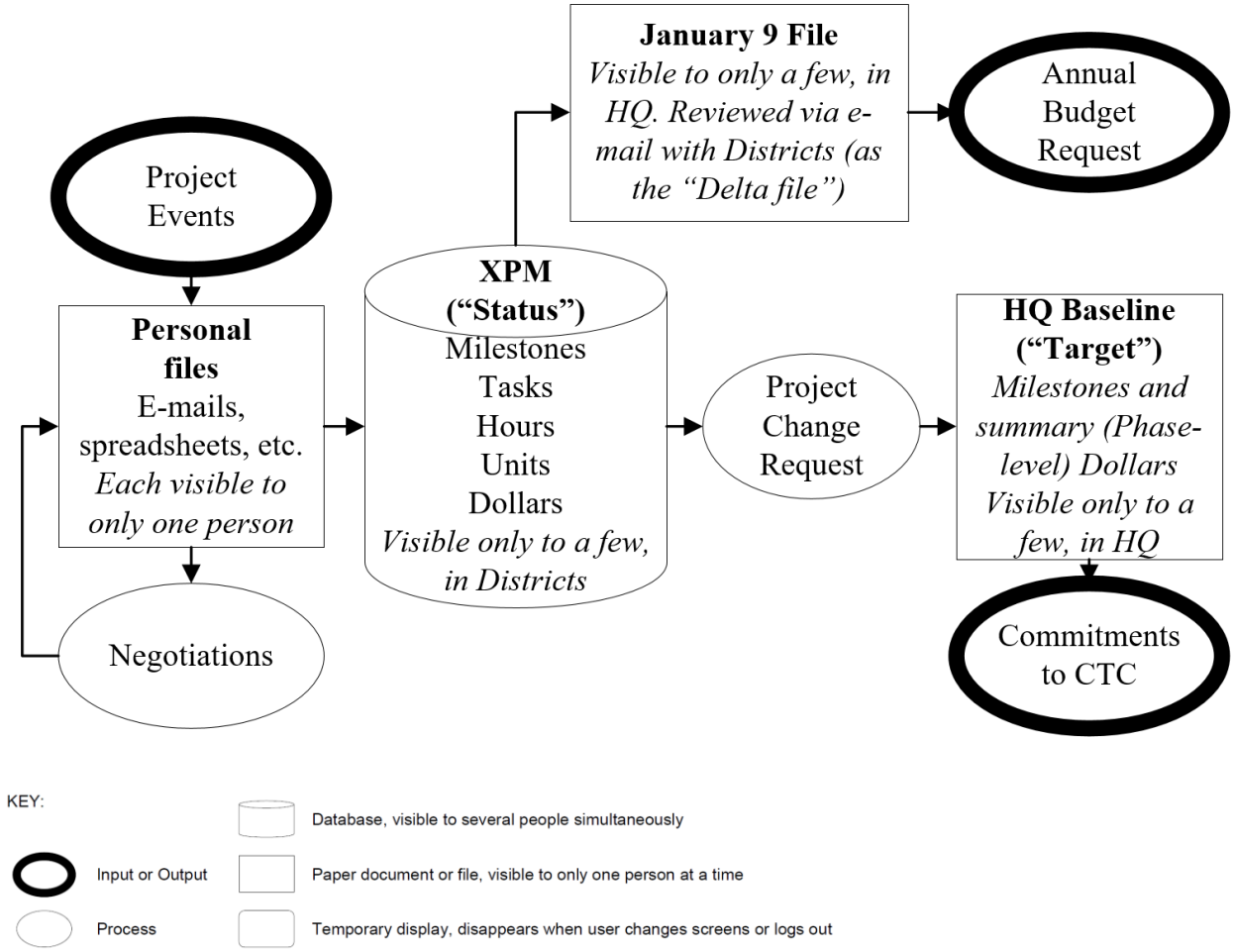
Because target milestones could be changed only through a PCR, the intensive process described by McManus was eliminated. Districts could run reports on their multi-year expected budgets at any time and plan for upcoming work accordingly. Caltrans could also provide the Legislature with multi-year project-by-project budget projections, e.g., Figure 5 shows a six-year budget plan from 1979-80 to 1984-85. A project's year-by-year numbers could be changed only through a PCR. If a number changed, there would always be a PCR that documented the reasons for the change.

I.3.1.2 XPM

Recognizing limitations of their existing systems, the 1980s hardware revolution from mainframe computers to client-server configurations leveraging the availability of desktop computers, as well as Caltrans' desire to enable PMs and first-line supervisors to manage their projects at a detailed level (with resources provided in person-hours to each organizational unit for each task), Caltrans arranged for series of demonstrations and ended up procuring the XPM project management software in 1994. It was soon found that XPM was cumbersome in use: only a handful of employees in each District could have direct XPM access and it was impossible to provide direct access to every PM and supervisor. As the company that produced XPM went bankrupt (certainly before 1999), Caltrans received no upgrades nor support. Caltrans was the only known user of XPM when the PRSM FSR was written in 2000.

This situation required that project teams work outside of XPM to address project changes. Figure 6 illustrates the process that developed, consisting of 7 steps:

Figure 6: Project Resourcing and Schedule Management Process with XPM



1. Project events: These continued to occur as described for PMCS and PYSCAN.
2. Personal files: Because direct access to XPM was not possible, employees in the Districts developed a variety of tools on their desktops to manage project events, such as e-mails and spreadsheets. Some Districts addressed the problem of access to project data by building so-called "shadow systems" which all their employees could see on the Caltrans Intranet. Data from XPM was downloaded to the shadow systems, together with cost data from the Caltrans accounting system, and programming data from Transportation Programming. Due to the difficulties with XPM, arrangements were made to directly upload data from the shadow systems to XPM, avoiding almost all needs for hands-on access to XPM.
3. Negotiations: These continued to occur as they had with PMCS and PYPSCAN. Districts that had built shadow systems frequently used those systems to facilitate negotiations.

4. XPM: Project milestones and tasks were loaded into XPM along with the units that would work on each task, the estimated hours required to perform the task, the average cost per hour of the staff in each unit, and the consequent estimated support dollar cost of each project.

Access to XPM required that this software be loaded onto the user's computer and that the user have a UserID. Only a few such computers were available in each District, and the software was not widely available. Users of XPM were normally rank-and-file workers; in contrast, first-line supervisors were not "users" in that they did not have the software on their personal computers.

5. Project Change Request (PCR): If the project team, with approval of District management, wanted to permanently change the target milestones and estimated cost of a project phase, they would propose a PCR and submit it on paper to headquarters.

6. Headquarters baseline: If approved, the PCR data were recorded by headquarters using a desktop system that was accessible only to headquarters staff, in much the same was as District staff was performing work in systems that were not broadly visible. The headquarters data was provided to the CTC as the Caltrans commitments.

7. January 9 file: PMCS and PYPSCAN continued to be used to develop the annual budget until the 1996-97 Fiscal Year. In 1997, the budget began to be downloaded from XPM. This was done on January 10 of each year, with Districts given until January 9 to update their data in XPM. The intent of that date was to give District staff a full week in January to update files and avoid requiring intense work over the holidays. In practice, the updating took more than a week. Caltrans returned to the practice described by McManus (see Subsection 3.1.1.). Some Caltrans staff refer to this period in November and December as "the Fall Classic."

On January 9, XPM data was downloaded to an Excel spreadsheet, named the "Delta File," and sent to the Districts for review. In due course, the updated "Delta File" provided the resource needs that Caltrans submitted to the Legislature as the "May Revise" of the annual budget.

The XPM process meant that there was no correlation between the annual budget submitted to the Legislature and the commitments made to the CTC. Using XPM, Caltrans submitted annual projects budgets to the Legislature, that could, when accumulated over the years of a project's life, be considerably larger or smaller than the life-of-project support budget that Caltrans submitted to the CTC.

The Districts and Caltrans had no way to do reliable multi-year project-by-project planning because XPM plans changed without clear consistent documentation.

I.3.2 Feasibility Study Report for PCSM and PRSM

PCSM and PRSM came about in response to a business process review by Bein et al. (1996). This review informed and was informed by the Statewide Project Management Improvement Team (SPMIT), comprising more than 100 Caltrans employees, divided into sub-teams that considered

Caltrans project management processes and proposed improvements. SPMIT members had experience in Caltrans processes together with formal training in project management. Some improvements were implemented immediately; others required the development of a statewide project management system. The PCSM Feasibility Study Report (FSR) was written to provide that system.

In 2000, Caltrans developed a FSR for a project management software system to be named "Project Cost and Schedule Management (PCSM)" (Caltrans 2000:1). PCSM was to address three business requirements:

1. Project Initiation and Tracking
2. Project Programming and Functioning
3. Project Resourcing and Scheduling

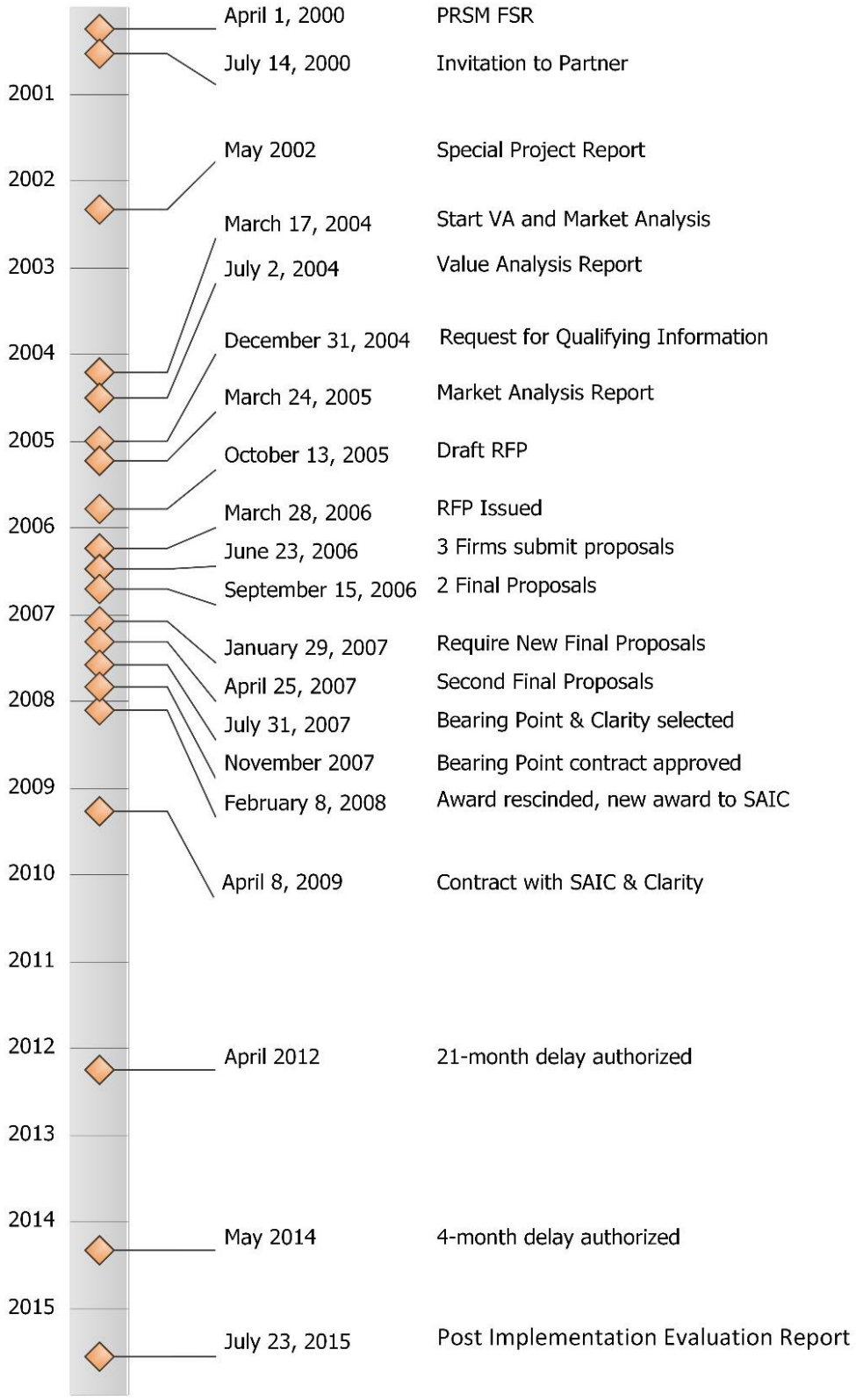
The Department of Finance (DOF) rejected the PCSM FSR and instructed Caltrans to return with a down-scoped FSR. In response, Caltrans submitted to DOF soon thereafter (Caltrans 2000:2) the PRSM FSR that addressed only the third one of PCSM's business requirements. PRSM had ten objectives:

1. Meet the reporting requirements of SB45 for 100% of the State Transportation Improvement Program (STIP) projects.
2. Provide project status data such as: plan vs. actual, earned value, cost performance indexing, etc. to transportation partners on a near-time basis.
3. Realize efficiencies associated with entering initial workload estimates by WBS into an integrated, validating scheduling tool.
4. Reduce the manual effort required to compile information for the Program Resource Management semi-annual reviews.
5. Provide an enterprise scheduling tool to reduce the need for various shadow systems.
6. Provide project and functional manager desktop access to a statewide resource and scheduling tool to plan and status projects at WBS level 7.
7. Provide a tool that allows project team members to continually forecast and optimally commit resources.
8. Provide supervisors with current critical path and individual prioritized task information in order to reduce project completion times.
9. In order to utilize fixed cost resources more effectively, ensure that the staff with the most relevant skill-set is assigned to the right task.
10. Provide the required numbers of software licenses and system security

I.3.3 PRSM Timeline

PRSM had an eventual 15-year procurement and delivery timeline (Figure 7).

Figure 7: PRSM Procurement and Delivery Timeline



Milestones along this timeline were the following:

- April 14, 2000: Caltrans submits the PRSM FSR and receives approval on June 7, 2000. Total project cost $13.4 million.
- July 14, 2000: Department of General Services (DGS) issues an "Invitation to Partner." Two firms respond: (1) Niku (later renamed CA Clarity, and now named CA PPM) and (2) Primavera (now Oracle Primavera).
- May 2002: Caltrans submits a Special Project Report (SPR) reflecting an increased cost. Total project cost $26.1 million. Some increased costs are attributed to a lack of competition (there was only one finalist vendor, Primavera), increased vendor rates, increased COTS software cost, a requirement for new hardware, and a longer time required for development.
- March 17, 2004: After several rounds of discussion, DOF instructs Caltrans to carry out an eight-step process that includes a Value Analysis and a Market Analysis.
- July 2, 2004: Caltrans submits the Value Analysis Report.
- December 31, 2004: DGS publishes a Request for Qualifying Information. Twelve firms respond, all are invited to make a 2-day scripted presentation and six firms make presentations.
- March 24, 2005: Caltrans submits the Market Analysis Report.
- October 13, 2005: Caltrans submits a draft Request for Proposals (RFP) to DGS.
- March 28, 2006: DGS publishes the RFP for PRSM.
- June 23, 2006: Three firms submit draft proposals for discussion with Caltrans.
- September 15, 2006: Two firms submit final proposals: (1) SAIC using Planisware and (2) Bearing Point using CA Clarity. The third proposer, Deloitte using Primavera, had withdrawn.
- January 29, 2007: DGS instructs firms to submit new final proposals.
- April 25, 2007: Teams submit second final proposals.
- July 31, 2007: DGS and Caltrans select Bearing Point, using CA Clarity.
- November 2007: DGS approves Bearing Point contract.
- February 8, 2008: Award to Bearing Point rescinded, notice of intent to award the contract to SAIC using Planisware.

- March 5, 2009: Contract signed with SAIC, using CA Clarity, with implementation to be completed within 18 months.
- April 2012: Delay of 21 months authorized to allow PRSM to interface with Caltrans new accounting system eFIS / AMS.
- May 2014: Roll-out delay of 4 months authorized.
- July 23, 2015: Post Implementation Review Report approved. Caltrans (2015:1 page 23/48 in PDF) shows the total project cost (Total One-time IT Cost) amounting to $29,084,972.

I.3.4 PRSM Process Model as Designed

The PRSM RFP issued in March 2006 included technical requirements that expanded on the ten objectives in its FSR. Caltrans maintained a traceability matrix to show how every technical requirement was rooted in the FSR. Each bidder's proposal described how they would satisfy the technical requirements through the use of their proprietary software; the exact methods varied from one bidder to another.

The CA solution, selected by Caltrans, was a suite comprising Clarity custom-tailored to Caltrans needs and augmented by Open Workbench (OWB, which functions like, e.g., Microsoft Project). This suite allows anyone within Caltrans with Intranet access to download PRSM data to OWB, run what-if analyses, and share analysis files with others.

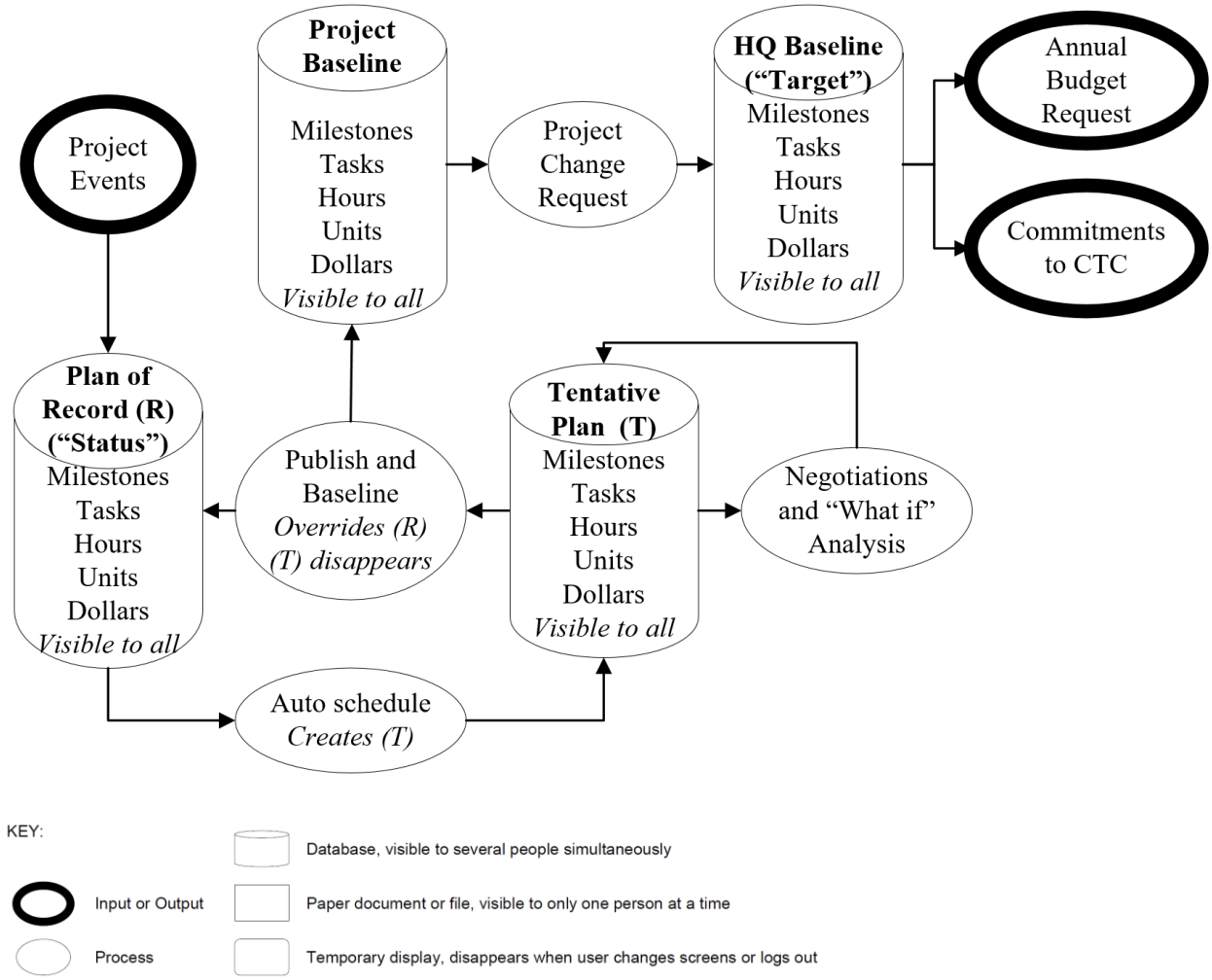
Figure 8 illustrates the steps of the Project Resourcing and Schedule Management process designed for CA Clarity (since renamed CA PPM), the software tool that is now PRSM. In the following description, active verbs refer to steps that Caltrans staff are currently taking, whereas "would" and "could" describes steps that reflect the PRSM design but are not (yet) taken:

1. Project Events occur as described for PMCS/PYPSCAN and XPM.
2. Plan of Record (more appropriately called "project status"): As events occur, project team members notify others on the team to take care of "action items." Team member actions result in changes in the "Plan of Record.".

   PRSM plans are visible to any employee with access to the Caltrans Intranet, using generic internet browsers that are loaded as a standard practice on Caltrans computers, and without needing special software or permissions.
3. Auto schedule: At appropriate times, the PM can select "Auto schedule" to create a new "Tentative Schedule."
4. The Tentative Schedule is a copy of the project plan that is used to discuss how to address the action items. Anyone can download this schedule to the OWB desktop application for manipulation and exploration of what-if alternatives. The OWB file can be sent to team members by e-mail and they can view the Tentative Schedule directly. Note that only the PM

can upload data back from OWB to PRSM; if the PM downloads a project to OWB, the project in PRSM is frozen until the PM uploads the OWB file back to PRSM.

Figure 8: Project Resourcing and Schedule Management Process as Designed, with PRSM



5. Negotiations: These occur with transparency as all team members can view the Tentative Plan, Plan of Record, and Baselines (see later steps regarding baselines). Changes are made in the Tentative Plan.

6. Publish and Baseline: When the PM is satisfied with the Tentative Plan, they can select "publish" and "baseline." The Tentative Plan then overrides the Plan of Record and automatically becomes the new Project Baseline.

7. Project Baseline: Each Project Baseline is saved as a new file, providing an audit trail for the project if needed. The most recent Project Baseline is the PM's current plan. It should represent the most recent agreement within the project team. The Project Baseline is

analogous to the negotiated "status" in PMCS, but it has considerably more detail than the milestone-only status that was found in PMCS.

PRSM / CA PPM provides tools to enable project team members to compare any baseline with the Plan of Record and to compare any baseline with any other baseline.

8. Project Change Request (PCR): As events transpire and are addressed, almost certainly the Project Baseline will begin to deviate from the Headquarters Baseline (see next step). If the project team, with approval of District management, wanted to permanently change the approved project plan, they would submit a PRC to headquarters. The PCR would request that the current Project Baseline be copied and saved as a new Headquarters Baseline.

9. Headquarters Baseline: The most recent Headquarters Baseline would be identical to the Project Baseline that was in use when the most recent PCR was approved. It would be the approved project plan and have all the details of that Project Baseline, including actual expenditures, actual milestone completion dates, start and end dates of completed tasks, as well as future milestone and task dates together with the estimated costs of each task by unit expressed in both dollars and hours.

Because the Headquarters Baseline could be changed only through a PCR, this eliminates the intensive "Fall Classic" process described by McManus. Districts could run reports on their multi-year expected budgets at any time, based on the Headquarters Baselines, and plan for their upcoming work accordingly. Caltrans could also provide the Legislature with multi-year project-by-project budget projections. The year-by-year numbers for any project could be changed only through a PCR. If a number for a particular project for a particular year changed from one year to the next, there would always be a PCR that documented the reasons for the change. For each detailed change, at the unit and task level, the documentation would include what change was made, when it was made, its magnitude, who requested the change, who approved the change, when it was requested, and when it was approved.

I.3.5 Comparison of PMCS/PYPSCAN, XPM, and PRSM Processes

In practice today, Caltrans is not using the PRSM process model as designed but, rather, a variation of the XPM process. XPM has now been replaced by the Plan of Record in PRSM, which has two advantages:

1. Unlike XPM, the Plan of Record can be viewed by any person with Caltrans intranet access. Information about the Plan of Record is readily available to those who need it.

2. Availability of the Plan of Record reduces the need to maintain data on individual desktops and reduces the need for shadow systems.

With this background in mind, on project management practices at Caltrans (Subsection 2) and the history of the determination of PRSM software capabilities and vendor selection (Subsection 3), PRSM has been deployed agency-wide at Caltrans since 2014 and now counts on the order of 3,000 users. The following two subsections present input from a selected group of current users, who were asked by the researchers to comment on successes and challenges in using PRSM. This input points at successes and challenges either in implementing the project management workflows that Caltrans has established or in using specific features and the capabilities of the PRSM software.

I.4 User-reported PRSM Successes

During data-gathering meetings with the researchers, Caltrans PRSM users reported satisfaction (as stated by users or as interpreted by the researchers) in performing a number of functions for project resourcing and schedule management.

I.4.1 Bottom-up Estimating and Annual Budgeting

Before the adoption of PRSM, Advanced Planning units in the Districts included support cost estimates in the Project Initiation Documents (PIDs) without consulting the responsible functional units and, indeed, the PIDs did not differentiate support costs by functions. These estimates were submitted to the CTC for programming. As a result, after the project was programmed several Caltrans staff reported contention when Task Managers (TMs) and Project Managers (PMs) found themselves trying to reconcile their needs to the PID estimate that had been developed without their participation and buy-in.

A major departure from pre-PRSM practices is that first-line supervisors (i.e., TMs), are actively engaged in estimating the hours required for their units' work from the inception of each project. This reflects both a change in project management workflow and the fact that this new workflow is effectively supported by PRSM. "Bottom-up estimating" ensures that TMs know before programming how many hours they will be allocated to complete each task (for the project as a whole, but also for each annual slice of hours that is incorporated into the yearly budget request) and it promotes accountability.

In keeping with generally accepted professional practices, TMs estimate their units' effort on each task in hours, usually not by named individual. These hours are then converted to a dollar estimate using each unit's average cost per hour. That average cost reflects the mix of civil service classes of the employees in a particular unit (units with a larger percentage of people in higher-paid classes have a higher average hourly cost). The cost averages are derived from actual employee data in the Caltrans accounting system eFIS (an acronym for "electronic Financial Information System" that was used during the procurement of the commercial AMS Advantage software, referred to as "AMS") and recalibrated each year based on that data.

Caltrans staff use PRSM to track resource needs at an aggregate District level, for individual units, and for the collections of units that make up the different levels of the District hierarchy. The Deputy District Director for Design, for instance, can obtain reports for the District Design organization which, depending on the District, may encompass many units.

I.4.2 Data Accuracy and Reliability

PRSM receives actual expenditure data, in both hours and dollars, from a weekly automatic downloaded from the Caltrans accounting system eFIS. The researchers learned during interviews with Caltrans staff that staff believe that this expenditure data is accurate and reliable. This reliability is borne out by audits conducted in 2015 and 2016 by the Caltrans Office of Audits and Investigations (Caltrans 2015:2, 2016:1). It is of utmost importance, indeed, that Caltrans staff be vigilant in ensuring only quality data gets entered into their systems.

PRSM provides a central and common source of data for resource planning at all levels in the Caltrans organization, including offline discussions of resources and resource needs.

PRSM is integrated not only with AMS, but also with the Caltrans employee system called Staff Central that uses Oracle's PeopleSoft software. PRSM receives employee information from Staff Central so that work can be assigned in PRSM to named individuals. PRSM also passes work assignments to Staff Central where Caltrans employees report their time. The PRSM feed enables Staff Central to prevent employees from reporting that they performed work on an assignment that is not listed in PRSM (i.e., TMs open and close tasks for charging).

This is a change in workflow from the pre-PRSM era, when employees could charge time to any open project, and that change was recorded if it was approved by a supervisor.

In addition to the interfaces with accounting and staff, PRSM provides an interface to the Caltrans Standard Tracking Exchange Vehicle for Environmental (STEVE). Environmental permits are recorded in PRSM and passed to STEVE, so that Caltrans employees can ensure that they keep the Department's environmental commitments. Although such commitments may be made in the early stages of a project, they can continue for decades after the project has been completed.

On a somewhat related note, PRSM provides a document management feature that allows Caltrans employees to upload project documents, such as reports and Project Change Requests, to PRSM. It was not clear to the researchers to what extent Caltrans staff use this feature to support their workflows.

PRSM addresses some of the weaknesses of XPM and replaces some residual functions of PMCS, by including fields that did not exist in XPM but did in PMCS. Example fields are the estimated construction capital cost, and the legislative and congressional districts, so that PRSM staff can use these to extract and sort data as needed to compile their reports.

Accessibility to the software together with the reliability of data make PRSM a valuable source of information.

Caltrans staff involved in PRSM deployment studied reports used by staff in Caltrans Districts statewide and, based on those, standardized on a limited number of them. Inevitably, some reporting needs (e.g., reports that district staff developed prior to PRSM) cannot be satisfied by standard reports and people may, in any case, be reluctant to adopt a standard. Managers develop affinities for reports that they have become accustomed to seeing, and the ability to download data from PRSM enables their staff to continue to create those reports. The standard reports, however, remain the official data and any custom reports must reconcile with the standard reports.

Some of these custom reports might give the appearance of the *shadow systems* that were developed in the XPM area, and they could even re-use some of the shadow system code, but they are not, in fact, shadow systems because they do not upload data back to PRSM.

I.4.3 Display Customizability

PRSM offers the ability to customize screens; any user can select the fields they wish to see. This enables each user to focus on those aspects of the overall portfolio of Caltrans projects within their workflow and responsibility.

This ability to customize screens allows staff to manage the hours and schedules for which they are responsible and to gain a perspective on the forthcoming work of their units.

Note that PRSM is used not only for the management of work by State employees but also the work of the consultants that Caltrans employs to assist on State highway projects. Districts and the Division of Engineering Services can add consultants to the project team and report their planned hours. Since October 2014, actual hours worked by consultants have been hand-entered into the AMS accounting system and uploaded to PRSM (Caltrans 2014).

The Division of Engineering Services indicated that it is having some success in getting project manager rights for its Project Liaison Engineers who assist in keeping project data up to date.

I.4.4 Cultural Assimilation of PRSM

As a result of the use and availability of PRSM, Caltrans supervisors and managers are now far more conscious of the hours needed and consumed to complete each project task. The use of bottom-up estimating, where individual supervisors provide estimates of hours, has greatly improved accountability from the situation before PRSM, when supervisors had no input, and little consciousness of the cost of tasks.

I.4.5 Increased Accountability and Awareness

Along with the increased awareness of the hours needed to complete tasks, PRSM has enabled Caltrans to place controls on the charging of unplanned activities. PRSM controls have brought a

focus to, and provided a solution for, charging problems that were known to exist in the past, but for which Caltrans had no effective solution in their pre-PRSM workflow.

The first time that a task is charged, that charge is passed to PRSM, and PRSM records the date of the charge as start date of the task. When the task is closed in PRSM, employees get a ten-day grace period to record their time. After ten days, PRSM accepts no further charges to the task.

PRSM passes authorized tasks, by unit, to Staff Central where Caltrans employees enter their time. If an employee enters a charge for a task and unit that is not currently authorized for charging, the system will immediately inform the employee that the charge is unauthorized.

This process is generally controlled by unit, allowing all employees who charge to that unit to make charges against the task. It can also be controlled at a more granular level in PRSM, by named employee, so that only they can charge time to the task.

PRSM has processes to allow TMs to open and close tasks for charging, update the percent complete for each task, and add units to the task (i.e., allow them to work on the task). More than one unit can be assigned to a task, with each unit having its own start and end date for its work on the task.

These controls and workflows based on PRSM have vastly improved the accountability of Caltrans employees in managing and recording their time.

I.5. User-reported PRSM Challenges

During data-gathering meetings with the researchers, Caltrans PRSM users reported challenges in performing a number of functions. These tend to be more project-management workflow related rather than stemming from PRSM software limitations.

I.5.1 Task Management

Task management appeared to have both project-management workflow as well as PRSM software support challenges. A recurring theme in meetings with Caltrans staff was that the process for updating the TM's estimate of hours to complete a task is challenging when TMs submit their changes through a "bolt-on" java portlet or "custom object" that is not part of the CA PPM software. After these changes are submitted, the PM may or may not approve them for inclusion into the Plan of Record.

Data the researchers obtained from Caltrans indicates that nine of the twelve Districts are making little use of the applet and a question is whether this applet is of value at all. TMs in these nine Districts appear to be submitting their changes directly to the PM or assistant PM, who can directly change the Plan of Record.

An additional challenge is that, because changes are processed through this external portlet, PRSM receives them as coming from a single external source and does not have a record of the name of the requester.

This external applet appears to have been developed with a goal of using PRSM as a direct substitute for XPM, following the process shown in Figure 6. In that process, the apparent intent is to use the Plan of Record as the Project Baseline (compare with Figure 8). The applet controls the Plan of Record, but because changes must be approved by the PM, direct recording of the actual unapproved events as they occur is inhibited. Actual events, by their nature, are seldom pre-approved.

The Plan of Record in CA PPM, which Caltrans uses as the principal element of PRSM, records two sets of hours for each combination of task and unit: (1) the actual hours expended to date and (2) the estimate to complete (ETC). As costs are incurred and hours recorded, the ETC is decremented down to 0; by definition it cannot take on a negative value. For example:

- If the original estimate for a unit to complete a task is 100 hours, the ETC will be 100 hours before the task begins.
- After 40 hours of work is performed, the actual cost will be recorded as 40 hours, with the ETC being the balance of 60 hours.
- When 100 hours have been performed, the actual cost will be recorded as 100 hours, with the ETC being the balance of 0 hours.
- When 120 hours have been performed, the actual cost will be recorded as 120 hours, with the ETC still being 0 hours.

A task management challenge occurs when tasks are reassigned from one unit to another. In an 8,000-person organization—in particular one with many specialists as is the case for Caltrans—some units inevitably will have an overload at any given time while other units will have a shortage of work. In order to balance workload, work must be shifted from one unit to another. This requires a change in PRSM to show the new unit responsible for the work, and to permit the newly-assigned unit to charge time to the project task. Some TMs use the aforementioned cumbersome portlet to perform this vital task. Alternatively, a PM could handle a TM's request to make such changes.

Another challenge comes as the ETC reaches 0. The researchers heard that some managers want to block further charges to a task when that is the case, as an ETC of 0 means that all hours estimated for a unit to complete their task have been used up. Several people also expressed concern that they lose the ability to track their original budget request after the ETC reaches 0. Indeed, PRSM's display shows the total hours consumed-to-date (irrespectively of the value of ETC) but not the budgeted hours that were approved. If a TM thinks more hours will be needed

to complete the task, they must ask their PM to approve additional hours. Upon approval these extra hours will be reflected in an updated ETC in PRSM.

Several respondents described experiencing difficulties in updating the Plan of Record and having developed workarounds to address these difficulties. This led to an inconsistency between Districts, and from one PM to another, in giving right to add new units to projects in the Plan of Record to TMs and Project Liaison Engineers. In several Districts, TMs ask PM Support staff to enter their data into PRSM rather than trying to deal with the "custom object."

The researchers also heard about occasional tensions between TMs and PMs. TMs expressed concerns about their estimated hours being changed by the PM without their knowledge and PMs feared losing control.

Concerns were expressed that resource estimates were required during the PID phase, many months before the work was required. Such early estimates are likely to be inaccurate.

The researchers also heard about difficulties in updating detailed milestones, especially the structures-specific milestones. A significant number of the issues raised are to be addressed in Caltrans project management workflows, irrespectively of whether or not PRSM is used.

I.5.2 Limited Schedule Management

PRSM is being used effectively for project resourcing, namely the entering of estimated resources and provision of data for the annual budget requests. However, it is not being used as effectively for schedule management (e.g., activities in PRSM have long durations but may require an allocated resource for only part of that duration, thus not allowing for intermediate controls).

In Caltrans' WBS, level 4 is the project phase, and the project phases match the phases, or components, that are specified by the Legislature (in Government Code 14526 (c), 14526.5 (c), 14527 (g), 14529 (b), and 14529.4) namely:

- Phase K: Project Study Report, also referred to as a Project Initiation Document
- Phase 0: Completion of all permits and environmental studies.
- Phase 1: Preparation of plans, specifications, and estimates.
- Phase 2: The acquisition of rights-of-way, including, but not limited to, support activities.
- Phase 3: Construction and construction management and engineering, including surveys and inspection.

Breakdown to a more detailed level requires that the collective elements of the more detailed level contain the entirety of the less detailed, or summary, level (they must be mutually exclusive and collectively exhaustive). Figure 2 shows that WBS level 5 is a first breakdown of each of the phases shown in WBS level 4. The number of level 5 elements varies from one phase to another,

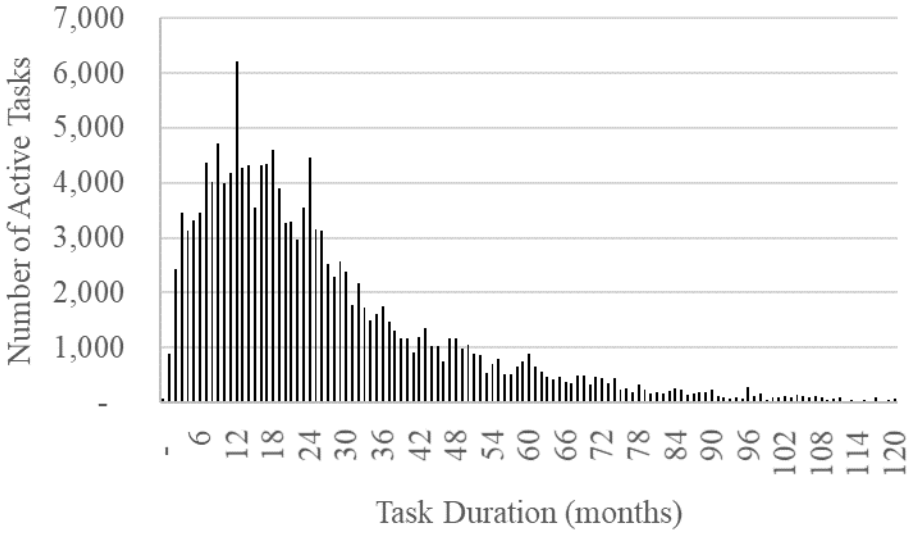
e.g., Phase K, the project initiation document, has only 2 possible level 5 elements, the fewest among the phases, whereas Phase 1, for "Plans, Specifications and Estimates," has 10, the most.

To improve understanding of the data available in PRSM, the researchers took a snapshot of the tasks that were scheduled in PRSM as "active" on January 31, 2017. A "task" is an assignment to an organizational unit to complete all or part of a WBS element. An "active task" in this context is a task started on or before the selected date but not yet completed by that date. On the said date, PRSM had:

- 3,265 active projects
- 19,758 active WBS elements, i.e., an average of 19,758/3,265 = 6.1 active WBS elements per project
- 154,573 active tasks, i.e., an average of 154,573/19,758 = 7.8 organizational units with assigned work on each WBS element

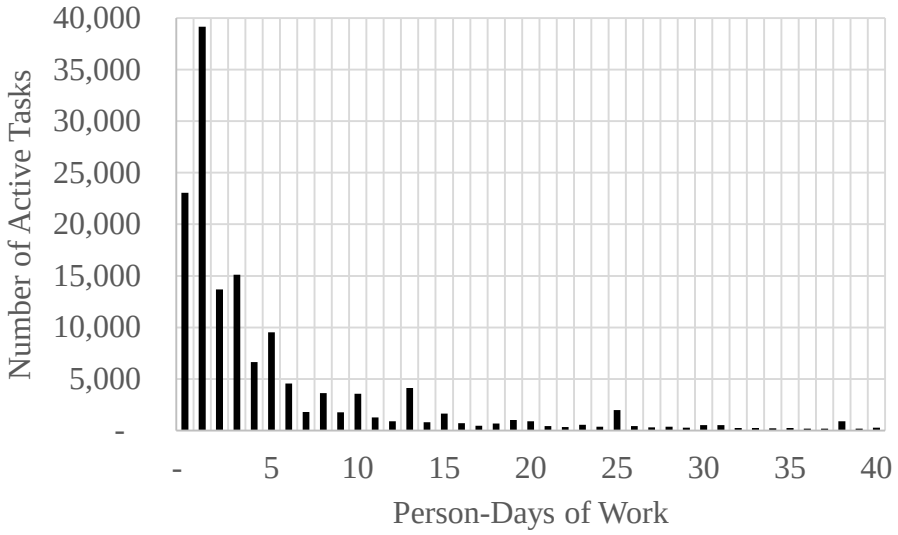
The data indicated that the average duration of an "active task" is 845 calendar days or about 28 months (assuming ~30 days/month). Figure 9 illustrates the distribution of task durations, rounded to the nearest month. Not shown are the 1,616 tasks with durations in excess of 120 months.

Figure 9: Distribution of Active Tasks in PRSM on January 31, 2017



The researchers also considered the work effort associated with each task. This is the amount of time that employees or consultants are expected to work on each task. Work effort may be expressed in, e.g., person-years, person-days, etc. The data indicates that the average work effort estimated for each task is 19.5 person-days. Figure 10 illustrates the distribution of work effort per task, rounded to the nearest person-day. Not shown are the 10,874 tasks (10,874/154,573 or about 7% of all active tasks) with an estimated effort in excess of 40 person-days.

Figure 10: Distribution of Work Effort of Active Tasks in PRSM on January 31, 2017



Most tasks are spread over several months. The work effort per task is relatively small as most tasks have estimated efforts of less than 3 person-days. PRSM's default setting is to spread work evenly over the duration of the task. At the average of 19.5 person-days over a duration of 845 calendar days, PRSM would show 15 person-minutes (sic) for the task on every working day for 28 months.

A project management question is: At what level of granularity should work be planned and for what planning purpose? PRSM data indicates unevenness in the granularity of tasks. Table 1 categorizes active tasks in PRSM: 49% required less than 20 person-hours of effort, and 21% required more than 80 person-hours of effort.

Table 1: Distribution of active tasks and effort in PRSM

Person-hours of Effort	Number of Tasks	Percentage of Tasks	Total Person-hours of Effort	Percentage of Total Effort
< 20	75,927	49%	530,358	2%
20-80	46,166	30%	1,836,260	8%
> 80	32,480	21%	21,710,618	90%
	Column Total 154,573		Column Total 24,077,236	

Although they accounted for almost half of the tasks, the tasks involving fewer than 20 hours of effort accounted for only 2% of the total effort of the active tasks. Tasks with more than 80 person hours of effort accounted for 90% of the total effort. Table 2 displays the active PRSM tasks according to the average weekly effort per task.

Table 2: Distribution of Active Tasks and Effort in PRSM by Average Weekly Effort

Average person-hours per week	Number of Tasks	Percentage of Tasks	Total Person-hours of Effort	Percentage of Total Effort
< 1	118,979	77%	2,921,442	12%
1-10	30,868	20%	7,861,585	33%
11-40	3,827	2%	5,948,010	25%
> 40	899	1%	7,346,199	31%
	Column Total 154,573		Column Total 24,077,236	

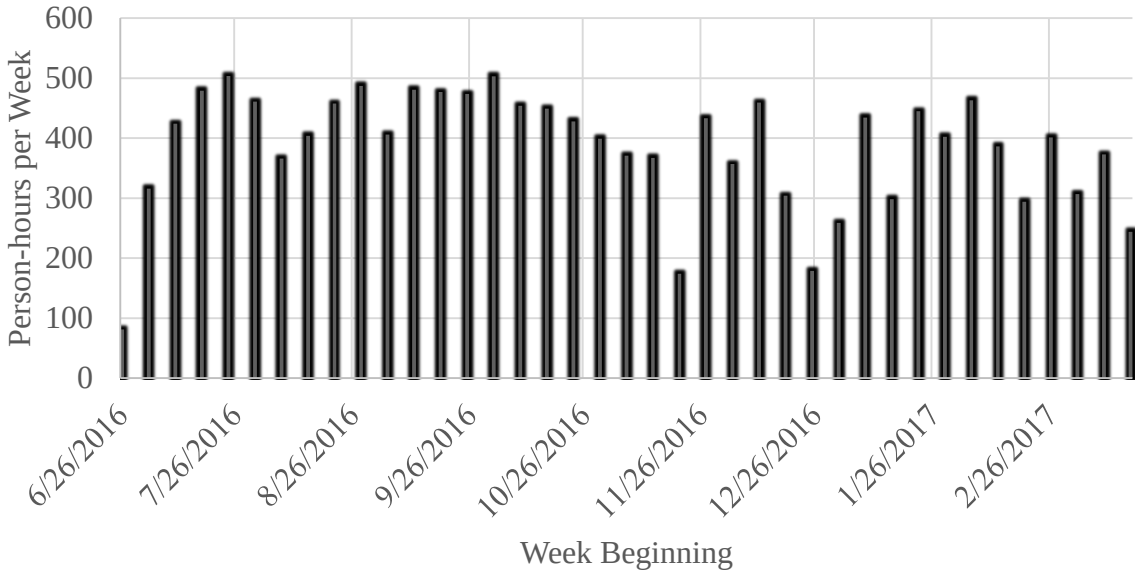
The data row at the top shows that 77% of the active tasks (12% of the total effort of all active tasks) in PRSM were distributed across such a long duration that their effort on average was less than 1 person-hour per week.

The data row at the bottom (next-to-last row) shows that 899 tasks involve an average of more than 40 person-hours per week, i.e., more than one person full-time for the entire duration of the task. This is less than 1% of the tasks, but it accounts for 31% of the total effort.

Although Table 2 shows an average number of hours per week, actual work performed varies from one week to the next. For example, focusing on one specific task in the PRSM system, completed in the period from June 2016 to March 2017, Figure 11 depicts the hours billed in each week to that task. Although the average weekly charges were 385 hours, they fluctuated between a high of 503 hours and a low of 81 hours. On smaller tasks, one would expect to find many weeks with no charges at all.

This unevenness in durations of tasks, hours estimated, and hours billed, indicates that Caltrans project management practices vary. More consistent breakdown and tracking of work in greater detail would benefit project management.

Figure 11: Hours billed per Week on a Specific Task Completed



Practices vary within and across Districts in regard to project managers' definition of tasks in PRSM at levels of detail per the standard Caltrans WBS (Figure 2), with planning at least to level 5 being mandated across the State. While some project managers further detail their work in PRSM at levels 6 or 7 (possibly down to 8) of the WBS, the management of day-to-day and week-to-week work assignments to employees "in the trenches," namely State employees doing the work and their supervisors, is not done using PRSM. This is not a matter of enforcing the use of pre-defined, more detailed levels in the WBS. Rather, such work requires tracking assignments and commitments to performing work based on the (design) methods used by those involved, identifying and removing constraints, confirming work completion and hand-offs, etc. These workflow management functions are not typically supported in project management software (like PRSM) but are the purview of (project) production management systems (more on this in Section II.5).

I.5.3 Reporting

The researchers heard several concerns about the types of reports available from PRSM. On the one hand, the reports they saw in District visits seemed to consist largely of tables of numbers with little summary data and little in the way of graphics. On the other hand, the reports they saw at headquarters depicted a greater amount of management-friendly summary information. Then, when the researchers spoke to CA Technologies, they were treated to "dashboards" of management data, with numerous charts and graphs. The researchers do not know whether the distinctions are rooted in inadequacies of the CA reports of which they are unaware, difficulties in developing the CA-type reports, Caltrans choices, lack of training, or in something else.

District staff expressed dissatisfaction with the PRSM reporting capabilities, particularly in areas such as:

- Comparison of Budget (Baseline) to actual expenditures.
- Inadequate summary-level reports for organizational units at any level.
- Inability to view summary data for multiple projects rather than one project at a time.
- Lack of graphical displays on reports.

They acknowledged, however, that 8,000 Caltrans employees have access to PRSM data and have the ability to customize their preferred data screens.

It appears to be common practice to download PRSM data and then display reports in tools that are preferred by District staff. These tools may be shared applications that display data on the Intranet, or desktop tools such as Excel for use in analyzing and drawing charts and graphs. Such downloads afford any of the 8,000 users customization to individual preferences and specific needs that cannot be met by a corporate system.

I.5.4 "Out of the Box" CA PPM Functionality

The researchers met with CA Technologies, the producer of the software system CA PPM that forms the core of PRSM. CA PPM offers visual tools including out-of-the box dashboards to report on project status. These are customizable. Caltrans might benefit from discussing these reporting tools with CA and possibly deploy them effectively.

Other tools that could be of benefit to Caltrans include the CA PPM elements that support planning, programming, portfolio management, and program management. As Caltrans considers these aspects of their management, it would then be useful to explore to what extent the CA PPM tools could be helpful to them.

CA PPM also has tools such as "story-boards," which have developed as part of the move toward "Agile" project management, and the CA Productivity Accelerator, a tool for just-in time training and assistance with compliance to standards. These appear to have potential uses in Caltrans.

The review team discussed the concept of "Software as a Service (SaaS)" with CA Technologies. In this model, CA would host the PRSM application on their "cloud" computers and be responsible for maintaining and upgrading the PRSM core software. Upon discussion with Caltrans, it was found that this had been discussed and considered at length by Caltrans and CA, and that Caltrans had found that CA was either not able or not willing to support in the cloud the Caltrans approach to PRSM in its current configuration. Despite this current finding, a move toward SaaS may be viable now and it may be inevitable in the future.

CA indicated that Caltrans is currently using an outdated version of CA PPM and advocated that Caltrans upgrade to the current version.

I.5.5 Participation with CA

During the procurement process, Caltrans had to maintain an arms-length relationship with CA Technologies to avoid favoritism. Now that Caltrans has purchased CA PPM, it needs to get the maximum benefit from its purchase. Caltrans must see CA as a partner, not an arms-length contractor, especially as it appears unlikely that Caltrans will abandon CA PPM in the foreseeable future (see Section I).

The researchers' discussed three venues for participation and partnership with CA Technologies:

1. CA PPM has a user community (communities.ca.com) that any Caltrans employee can join. Joining would enable the employee to learn more about the capabilities of CA PPM and to comment on possible upgrades to the software.

CA generally introduces twice-yearly upgrades to CA PPM. Priorities for the upgrades are driven in large part by feedback from the user community. Active participation by a large number of Caltrans employees would help to ensure that Caltrans needs, and especially the needs of front-line Caltrans users, are heard and receive adequate priority from CA.

E.g., an enhancement that Caltrans staff suggested for consideration by CA PPM is integrating the Caltrans Outlook calendaring system with PRSM, to enable PRSM assignments to appear on employee calendars as tasks to be performed.

2. CA PPM hosts a "Big Room," a gathering of major users of CA PPM who meet with CA leadership and help them decide on software upgrades. A Caltrans seat in the "Big Room" would provide a slightly different voice than that of other users. This would benefit both Caltrans and CA even if the California State Chief Information Officer (CIO) has a seat in the "Big Room," since most users of CA PPM are drawn from the information technology sector, which is well represented by the CIO. Caltrans PRSM is a tool to help deliver projects in the design-bid-build construction industry which has needs different from those of the information technology sector.

3. The CA PPM Sacramento user community, promoted by the information technology division at the California State Teachers' Retirement System (CalSTRS), could be one for Caltrans employees to participate in, even though that group is unlikely to have a design-bid-build construction industry perspective and the vast majority of PRSM users are not located in Sacramento.

I.5.6 Training

PRSM users mentioned the need for continuing training in PRSM. Headquarters staff has performed valiantly in providing vast amounts of start-up training, but training cannot stop. In order to address incoming staff needs (due to attrition and turn-over of staff) training in PRSM's technical capabilities must be provided on an on-going basis to District staff.

In particular, it appears that Caltrans staff are not using the CA PPM software to its potential. The headquarters trainers appear to understand the software better than the District staff, and CA demonstrated features that the researchers had not seen demonstrated by anyone in Caltrans.

I.5.7 Construction Management System

Although the following observation deviates from the PRSM review, the researchers did hear concerns about the fact that the Construction Management System (CMS) has not yet been replaced. Caltrans continues to use PISA with its four sub-systems (see Subsection 3.1.1.), to manage the construction Capital Outlay program. A project to replace PISA with a new CMS has been in process at least since 2005. The researchers did not follow up on this issue, but the outdated PISA system is an area of concern to them and, doubtless, of concern to Caltrans management as well.

I.6 Section I Summary and Findings

A draft of this Section I, providing a factual non-judgmental description of PRSM use, was sent for review by Caltrans staff as they have far greater understanding of their processes than the researchers do. Accordingly, people designated by Caltrans management provided feedback on that draft and the researchers made corrections to it prior to issuing the publicly-available report referenced as “Part A” (Blampied et al. 2017), and incorporating it as Section I of this Report.

Section I presented a description of project management practices at Caltrans, a historic overview of supporting work processes using a progression of software systems that ended with the most recent deployment of PRSM in 2014, and observations recorded by the researchers from interviews conducted with sample groups of Caltrans staff. The researchers’ desired outcome was to produce a factual, non-judgmental description of how PRSM is used and what it is used for. As observed, Caltrans is using PRSM for project resourcing, especially for annual budgeting, but is not using all its scheduling functions to their potential.

PRSM in used throughout all Caltrans Districts. It is customizable for use by all staff within Caltrans to meet their needs. Most notably, it enables Caltrans to align Headquarters Baseline milestones commitments to the CTC and budget requests to the Legislature.

From these PRSM review meetings, the researchers received confirmation that over the course of three years of deployment, PRSM has become a well-established project management system for about 3,000 Caltrans users with read/write access and many more with read-only access. This notwithstanding, PRSM is not yet fully living up to its title. PRSM is an acronym for “Project Resourcing and Schedule Management.” Caltrans is using it for project resourcing, especially for annual budgeting, but does not appear to have project management workflows in place to use PRSM’s scheduling functions to their potential.

SECTION II – PROJECT MANAGEMENT SOFTWARE USE AND NOVEL MANAGEMENT PRACTICES IN ENGINEERING DESIGN ORGANIZATIONS

II.1 Research Methodology, Work Plan, and Outline for Section II

The methodology followed to conduct the research for this Section II included (1) scanning the market at a high level for Commercial-Off-The-Shelf (COTS) project management software available today, (2) surveying public-agency staff at other departments of transportation to learn what software they use agency-wide to manage their projects and how they use it, (3) interviewing managers at a select number of private engineering-design organizations to learn about what project management software they use company-wide to fulfill project management functions similar to PRSM's, and (4) summarizing novel project- and project production management practices that are informed by Lean Thinking, (Lean) Six Sigma, Agile, and multi-project considerations.

The research work plan included the following steps:

1. Search for documentation (including literature in print and postings on the world wide web) to obtain a high-level overview of the commercial, enterprise project management software that is on the market today, to fulfill functions similar to PRSM's.

   The goal of this step was to potentially discover current uses of other COTS software that might inspire more in-depth or broader use of PRSM's current capabilities, or suggest enhancements in project management practices at Caltrans.

   The goal was *not* to conduct an in-depth study of all COTS project management software on the market today, nor to examine specific products in detail as one would do when purchasing software, as consideration of replacing PRSM is out of the question. PRSM has been deployed at Caltrans since 2014, that is, for slightly more than 3 years. Its use has, in the researchers' opinion, not yet come to full fruition. PRSM will likely be in use for many more years to come.

2. Conduct an on-line survey to learn what project management software is in use agency-wide at other departments of transportation, specifically American Association of State Highway and Transportation Officials (AASHTO) members, to fulfill functions similar to PRSM's.

   - Develop the survey instrument, informed by past surveys on related subjects.
   - Request Caltrans to distribute it to AASHTO members through their AASHTO liaison. The researchers also distributed it to members of the Transportation Lean Forum.
   - Follow up by telephone with those surveyed to ensure a high survey response rate.
   - Analyze the survey results and report conclusions.

The goal of this step was to gauge the use of PRSM by Caltrans relative to the use of project management software by other DOTs to fulfill more-or-less similar functions, and to identify opportunities to integrate project management software with other software systems in use by DOTs.

3. Conduct telephone interviews with managers at a select number of private engineering design organizations to learn what project management software they use company-wide for project management functions such as resource loading, staffing projection, etc.

   The goal of this step was to learn about software systems in use for such management applications especially at the company-wide level, and about methods and challenges managers encounter in performing these functions.

4. Identifying novel project management practices that are informed by Lean Thinking, (Lean) Six Sigma, Agile, and multi-project considerations, that may augment the PMI-based practices that have been implemented at Caltrans.

5. Draft Report Section II and circulate it to Caltrans managers for their input into the observations made to-date and direction for the follow-on research.

6. Finalize Section II and integrate it in this Report.

7. Distribute copies of this Report, including to people who participated in the surveys and requested a copy.

Section II has 6 subsections and refers to appendices IV through XI.

Subsection II.2 gives a high-level overview of drivers of software development over the last two decades and software available in the marketplace today. Subsection II.3 presents the results of the online survey and follow-up telephone calls conducted with staff at other departments of transportation, depicting what software they are using agency-wide to serve their project management needs. Subsection II.4 summarizes the input received from managers in a select number of organizations in private practice on how they use project management software, especially for project staffing (resource loading). Subsection II.5 offers insight into novel project management practices and software uses that Caltrans may want to consider implementing. Subsection II.6 summarizes the findings.

Appendices IV through XI pertain to the survey the researchers administered, and data from their survey as well as data from surveys conducted previously by others.

II.2 Overview of Marketplace for Enterprise Project, Program, and Portfolio Management Software

II.2.1 Aim of Marketplace Overview

The researchers scanned the commercial marketplace (as of May 2017) for enterprise Project, Program, and Portfolio Management (PPPM) software considered comparable, to various degrees, to PRSM, whether or not such software is in use by any US department of transportation (DOT). PMI (2017:1) defines project, program, and portfolio as follows:

1. **Project**: A temporary endeavor undertaken to create a unique product, service, or result.
2. **Program:** Related projects, subsidiary programs, and program activities that are managed in a coordinated manner to obtain benefits not available from managing them individually.
3. **Portfolio**: Projects, programs, subsidiary portfolios, and operations managed as a group to achieve strategic objectives.

Enterprise PPPM software here refers to software that is used systematically and agency- or company-wide for all projects the agency or company is engaged in, not just by a select few employees to manage only a few but not all projects. PPPM software enables the management of the timing and resources across projects, so as to support decision making about resource needs, prioritization, and allocation in order to serve the objectives of the overall organization.

The aim of conducting this scan was by no means to identify a replacement for PRSM, but rather (1) to get a sense of how PRSM is "holding up" in a changing information-technology marketplace and (2) to possibly identify uses of enterprise project management software that could inspire Caltrans to take advantage of more of the functionality that PRSM provides (but is currently not taking advantage of) and adjust their project management practices accordingly.

The researchers conducted this Section II study recognizing that, based on their findings reported in Section I of this study: (1) PRSM is meeting the requirements that Caltrans specified at the time of procurement of CA PPM and these requirements still hold today, and (2) PRSM has been deployed agency-wide at Caltrans since 2014 and has become a well-established project management system for approximately 3,000 in-house users with read/write access (and many more with read-only access). Given the vast amount of training delivered over the course of 3 years as well as on-going training to get such a large user group to adopt and skillfully follow the desired PRSM project management workflows, it is in fact unlikely that all PRSM features are as-of-yet used consistently and at their fullest throughout the Caltrans organization. For example, the researchers noted in Section I that Caltrans is using PRSM for project resourcing, especially for annual budgeting, but is not using all PRSM scheduling functions to their potential.

This scan of available commercial software was not meant to be deep: examining specific COTS software suites in detail would have taken substantial effort and—more importantly—would have missed the point of this PRSM review. The goal of the scan was not to identify a replacement

for PRSM but, rather, to describe in general terms what the current state is of the market for enterprise project management software.

In the subsections that follow, the researchers first describe how information technology (IT) infrastructure has changed since 2000 when Caltrans first submitted the PRSM FSR, and how the software marketplace has changed with it.

II.2.2 Marketplace Changes

In recent decades, huge changes have taken place especially in the world of IT. Following the emergence of the World Wide Web (WWW) in 1989 and then a decade of rapidly-accelerating growth in use and development of infrastructure (comprising both (personal) computers and their interconnectivity) up until the late 1990s, the dot-com market crashed around 2001-2002. Many service providers failed, freeing up overcapacity on physical networks that became available at bargain prices. Since then, computers have continued to become increasingly more compact, down to hand-held size and yet smaller to nano size, and communication has become ubiquitous thanks to short- and long-range wireless technologies leveraging satellite networks. The marketplace of software developers and service providers consolidated, with companies reaping the benefits of economies of scale while pursuing cloud computing for the delivery of Software as a Service (SaaS).

"In 2009, the availability of high-capacity networks, low-cost computers and storage devices as well as the widespread adoption of hardware virtualization, service-oriented architecture, and autonomic and utility computing led to a growth in cloud computing. Companies can scale up as computing needs increase and then scale down again as demands decrease. In 2013, it was reported that cloud computing had become a highly demanded service or utility due to the advantages of high computing power, cheap cost of services, high performance, scalability, accessibility as well as availability. Some cloud vendors are experiencing growth rates of 50% per year, but being still in a stage of infancy, it has pitfalls that need to be addressed to make cloud computing services more reliable and user friendly (Wikipedia 2017)."

Given these IT developments, the relative cost of hardware and software to support project management systems and other systems alike has decreased significantly while their availability has increased. At the same time, programming languages have become increasingly modular, so that software system development now means deciding which function will be fulfilled by which module and then integrating modules.

Today's challenges in project management organizations tend to be less on the side of hardware, software, or the cost of IT—especially with cloud-based mobile-enabled software and computation services being offered as a service (SaaS)—but rather with the cost of developing processes and work flows that suit their enterprise needs, customizing systems to fulfill those needs, and training everyone so that the level of understanding and supporting practices are shared and consistently applied throughout the organization.

II.2.3 Enterprise Project Management Software

A large number of software packages are on the market today to support businesses that manage their functions enterprise-wide. Such functions include human resource (HR) management, work load demand forecasting, employee work assignment, accounting, etc. In addition, as businesses are increasingly "project-izing" the work of their employees, project management software functions (e.g., planning, scheduling, budgeting, resourcing, and controlling) have been integrated in enterprise software suites.

Enterprise project management software is to support not only the management of individual projects but also programs and portfolios of projects. Nuancing PMI's (2017:1) definitions provided earlier, a **program** refers to a set of projects that are interrelated with each other based on project characteristics, for example due to their sequential timing or spatial adjacency. A **portfolio** of projects refers to multiple projects that tend to compete with each other for (enterprise) resources and expose the enterprise to management challenges (such as risk), which means that they must be considered in combination and managed in a coordinated fashion.

Hundreds if not more software suites are on the market today, that support PPPM to various degrees. Of course, the number of such suites that can support large (1000+) numbers of users simultaneously is more limited. However, this number is increasing thanks to the ubiquity of cloud-based computing, a significant enabler, which lowers the cost of investment in hardware and related maintenance, and allows for marketing SaaS.

While the PPPM market is to some degree segmented (e.g., construction, manufacturing, utilities, software development) many functions provided by competing software suites are similar if not the same. Software suites vary perhaps more in the way each one supports workflows to correspond to certain management needs (project-based vs. production-based work) and management mindsets and approaches (e.g., lean vs. traditional, management by means vs. management by results). For example—not intended as an endorsement, one way or the other—the enterprise database company Oracle (2008) acquired the project management software company Primavera in 2008 and claimed to thereby have created the "first, comprehensive enterprise project portfolio management solution for project-intensive industries" called Primavera Enterprise Project Portfolio Management. More recently, Oracle (2017) started to advertise Lean Task Management capability as part of its Prime Projects Cloud Service. The goal of their ongoing development is to combine traditional critical-path (CPM) method scheduling with support for lean, collaborative planning (informed by functions essential to the Last Planner® System (Ballard 2000)) using a digital planning board where work flows can be coordinated and reliable handoffs planned. As is expanded on in Section II.5 of this Report, new management methods such as those advanced by the lean construction community (e.g., use of the Last Planner® System for task management) are worthy of consideration by Caltrans.

II.2.4 Third-party Evaluations of Enterprise Project Management Software

Rather than searching for more detail on specifics of each of the numerous PPPM software suites on the market today, the researchers consulted two third-party evaluations of enterprise project management software products, that included an assessment of the CA PPM system that underlies PRSM. Two widely-quoted, independent research firms, Gartner and Forrester Research, periodically evaluate enterprise project management software. The following subsections present their findings.

II.2.4.1 Gartner's Magic Quadrant for Project and Portfolio Management (PPM) Software

Gartner conducts an annual review of Project and Portfolio Management (PPM) Software, evaluating each software product along two dimensions of strength:

1. **Completeness of Vision** evaluates the product and its fitness for purpose, and the firm's strategy for keeping abreast of costumer needs.
2. **Ability to Execute** evaluates the firm that produces the product and its commitment to it. Products with a high rating along this dimension are produced by firms that are financially stable, have dedicated significant resources to the support and develop the product, and clearly have a long-term commitment to the product.

Based on these, Gartner defines a 2-by-2 matrix, and then fits each product they reviewed in a quadrant thereof (Figures 12 and 13):

1. **Leaders:** Products rated high on both scales fit in the top-right quadrant. Gartner calls this "the Magic Quadrant" as it is the preferred position. Products in this quadrant are both market leaders in functionality and likely to continue to be produced and upgraded for a long time.
2. **Challengers:** Products rated high on Ability to Execute, but low on Completeness of Vision, fit in the top-left quadrant.
3. **Visionaries:** Products rated low on Ability to Execute, but high on Completeness of Vision, fit in the bottom-right quadrant.
4. **Niche Players:** Products rated low on both scales, fit in the bottom-left quadrant.

Figure 12: Magic Quadrant for Project and Portfolio Management Software 2004

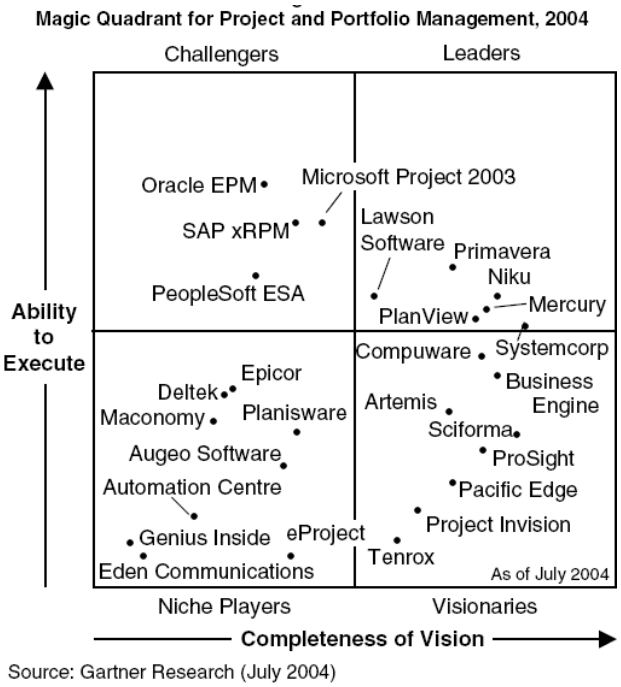


Figure 13: Magic Quadrant for Project and Portfolio Management Software 2016

The total number of products reviewed by Gartner decreased from 27 in 2004 to 9 in 2016. The number of products in the Magic Quadrant decreased from 6 in 2004 to 3 in 2016. While it is possible that Gartner chose to analyze fewer products in 2016 than in 2004, it seems more likely that this reduction in numbers is the result of market consolidation.

In its most recent evaluation, Gartner (2016) fit only three products in the Magic Quadrant, with CA Technologies' PPM being one of them. The Caltrans PRSM system is an installation of CA PPM so, based on Gartner's evaluation, Caltrans is using one of three leading products on the market today.

It appears that CA PPM is one of the dominant players in the PPM software market. Even if CA PPM were to be purchased by a competitor, its large market presence would ensure that the purchaser would likely continue to provide support and upgrades.

II.2.4.2 Forrester Wave Classification of Project and Portfolio Management (PPM) Software

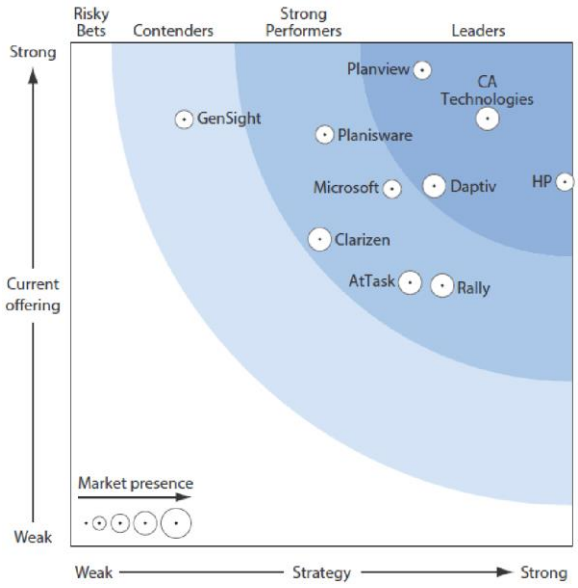
Forrester conducts an analysis similar to Gartner's, evaluating each product along two dimensions of strength:

1. **Current Offering**
2. **Strategy of the Firm** that produces the product.

Forrester designates products in successive waves. Products that are strong in both are "**Leaders**," those that are weaker on a combination of the two are "**Strong Performers**," and they are followed by "**Contenders**," and "**Risky Bets**." Forrester also identifies the size of each product's presence on the market.

In its latest evaluation, Forrester (2012) charted PPM software along those two dimensions (Figure 14). It identified four products as "Leaders," three of which are those in Gartner's 2016 "Magic Quadrant" and the fourth is Hewlett Packard's PPM software. Using circles proportional in size to each product's market presence, Figure 14 indicates that CA PPM and Daptiv PPM are the most frequently used "Leader" products. Forrester (2012), like Gartner (2016), indicates that Caltrans is using one of the leading PPM products on the market.

Figure 14: Forrester WaveTM for PPM Software (Forrester 2012)



II.2.5 Changes since 2005 Market Analysis Conducted by Caltrans and Department of General Services

As mentioned, the independent research firm Gartner indicated in 2004 that the PPM product selected by SAIC (the contractor who won the Caltrans procurement competition in 2009) was a leading PPM product on the market at that time, and subsequently indicated in 2016 that it is

still a leading product. The following paragraphs describe the process Caltrans followed to determine what PPPM software suites on the market in 2005 could meet its needs (out-of-the-box or with some additional programming). Because certain needs were specific to Caltrans, no product could meet all of them without some additional programming or configuration. The researchers speculate that a similar search conducted today, while considering enterprise PPPM software suites on the market now, might show that Caltrans' current software still is a strong contender.

In August 2004, the Department of Finance (DOF) instructed Caltrans to perform an analysis of software products on the market that might satisfy the PRSM requirements. In cooperation with the Department of General Services (DGS) Procurement Division, Caltrans prepared a Request for Qualifying Information (RFQI), published it on the State Contracts Register website in December 2004, and solicited responses by February 2005. During this time, Caltrans staff searched (using Internet search engines and advertisements in *PM Network*, the PMI magazine) for software companies that might qualify and brought the RFQI to their attention.

Twelve companies responded. Caltrans invited each one of them to make a two-day demonstration of their product, and provided a detailed script of requirements and scoring document in advance. Six accepted this invitation. Their subsequent comments indicated that each had at least two people work full-time for two weeks preparing for, and some brought more than 10 people to the demonstration (Caltrans 2005:2). Clearly, the competing companies invested a significant amount of staff time and money to prepare for their demonstration.

Each company was asked to demonstrate how their product met each scripted requirement out-of-the-box (i.e., without modification) or discuss how they could adapt their product to meet it. They were also asked to self-score their product using the following metrics:

- Can perform the function out-of-the-box (100%)
- Requires additional programming to perform the function (75%)
- Cannot perform the function, even after additional programming (0%)

A 13-member Caltrans team observed the demonstration, each member taking personal notes of any deviations from the self-score. After each demonstration, team members compared notes and agreed by consensus on any corrections to the self-score, which they then gave to each company.

The Market Analysis Report was submitted to DOF in May 2005. At the time, with procurement still underway, identities of companies were kept confidential to avoid discouraging anyone or giving anyone a competitive advantage. The Report identified the 12 vendors by letters A to L, assigned in the order in which submittals were opened. companies could identify themselves in the Report because they had received their own scores. When DGS awarded the PRSM contract in 2008, the identities of the firms became public record. Table 3 shows the companies and scores along with the names of the products as of 2005 and their current upgrades.

Table 3: PRSM Market Analysis (Columns 1-4 from Caltrans 2005:2)

Company ID	Name of Product in 2005	Percent of Caltrans Requirements met Out-of-the-Box	Percent of Caltrans Requirements met with Adaptation	Name of Product in 2016
I	Niku	80.00%	100%	CA PPM
H	Planview	78.59%	100%	Planview
J	Primavera	60.50%	100%	Oracle Primavera P6
G	MS Project	58.90%	100%	MS Project
D	Planisware	80.07%	98.68%	Planisware
C	Business Engine	46.43%	67.92%	Acquired by Planview (see above)

In the Market Analysis, Caltrans (2005:2) indicated that the 12 companies were evenly spread across the four quadrants of the then most-recent Gartner (2004) report (Figure 12); Caltrans findings roughly parallel Gartner's findings. Figure 12 shows six products in the "Magic Quadrant." Three of them were evaluated in Caltrans' Market Analysis. By a small margin, the highest score went to Niku. Niku was later bought by CA Technologies and is now CA PPM.

II.2.6 Use of CA PPM by Other Departments of California State Government

CA PPM is now used widely within California State Government. It is the only pre-approved PPPM software offered to state agencies by the California Department of Technology (CDT). State agencies are free to use CA PPM as a vendor-hosted subscription services (VHSS) at pre-agreed published prices (CDT 2017). Apart from Caltrans, major users in California government include:

- The California State Teachers Retirement System (CalSTRS) uses CA PPM for prioritization and visibility into resource use, resource management, schedule management and time tracking, and is considering its use for application portfolio management.
- The California Prison Industry Authority mandates the use of CA PPM on all projects, and its employees use it to obtain executive-level visibility of all work efforts, to track milestones and tasks, for ideation, project management, portfolio management, and centralized reporting using dashboards.
- The Department of Health Care Services uses CA PPM within its Medical Management Information system (CA-MMIS) for milestone and task tracking and project management.

- The Department of Food and Agriculture was an early user of CA PPM.

According to the CDT, Caltrans is the only California state agency that hosts CA PPM on its own servers. All other agencies use CA PPM through the CDT contract, which provides CA PPM as a "cloud based" SaaS hosted remotely on the CA PPM site. Section I of this report already mentioned the use of the SaaS version of CA PPM as an alternative to the use of a version hosted on Caltrans servers. It also mentioned the CA PPM Sacramento user community, which brings together several California government agencies to discuss their use of CA PPM, as a group for Caltrans personnel to voice input on further CA PPM feature development.

II.2.7 Conclusions on PPPM Software Evaluations

This review established (based on reviews by two independent research firms) that the PRSM software in use at Caltrans, an implementation of CA PPM, was and continues to be a leading COTS PPPM software product on the market. Without repeating Caltrans' 2005 analysis or conducting a new one, the researchers found no indication that any software product on the market today would be better than CA PPM in meeting Caltrans' need for PPM software. Every software product has unique features and no doubt competing systems perform some functions more effectively than CA PPM but, conversely, CA PPM is likely to perform other functions better than the competition does.

In addition, this review also indicated that software products continue to be enhanced (e.g., augmented to support lean construction planning) and combined with others. The researchers assume that, given the widespread use of CA PPM, that software too will continue to be enhanced and possibly combined with other products.

In the absence of compelling reasons to consider alternative software tools, the researchers take CA PPM as a given and will later in the Report, instead of focusing on software, focus on the work flows and processes that Caltrans uses and may want to consider in future in its project, program, and portfolio management.

II.3 Agency-wide Use of Project Management Software in Departments of Transportation

II.3.1 Introduction

In addition to collecting overview data describing the current state of PPPM software akin to PRSM on the market today, the researchers also collected data describing the current state of agency-wide use of project management software in departments of transportation other than Caltrans. This second data collection task, like the first one, had as objective to shed light on software uses to potentially inspire the use of more PRSM features by Caltrans.

Accordingly, in the Spring of 2017, the researchers designed and conducted a survey (henceforth referred to as the "PRSM Survey") to learn about the commercial software being used by

American Association of State Highway and Transportation Officials (AASHTO) member states to fulfill functions similar to PRSM's. AASHTO counts among its members all US states' department of transportation and several other organizations, and among its associate members yet other government transportation agencies (e.g., transportation ministries of Canadian provinces).

To inform the researchers' design of survey questions that would address the PRSM-review research needs, the researchers identified 4 previous surveys that had some overlapping contents in regard to the use of project management practices and related software:

1. A survey conducted by the AASHTO in 2005 on the use of consultants (AASHTO 2005).
2. A survey conducted by the Montana Department of Transportation in 2013 of state construction program tracking, monitoring and software (Montana DOT 2013).
3. A survey conducted by Caltrans in 2016 on the use of WBSs in state departments of transportation (Caltrans 2016:1)
4. A study commissioned by the Utah Department of Transportation and conducted by Cline in 2017 on project management practices in US state departments of transportation (Cline 2017).

Once the researchers had developed their survey instrument (included in Appendix IV), they asked the Caltrans AASHTO liaison to distribute it to AASHTO members. The researchers also made contact with DOT personnel in every state. Survey respondents represented 29 states and 2 Canadian provinces. A number of these respondents serve(d) on the AASHTO Technical Committee on Project Management (http://sp.design.transportation.org/Pages/Technical-Committee-on-Project-Management.aspx) or engage(d) in the Transportation Lean Forum (http://www.tpm-portal.com/community/tlf-home/ and https://www.codot.gov/business/process-improvement/multinational-transportation-lean-forum-tlf) so they were well positioned to answer the specific survey questions.

Appendix V lists the states that responded to one or several of these five surveys. In total, 47 states responded to at least one. The earliest survey, which focused on consultant use, has a small overlap with the PRSM Survey, but does not provide information about software or functions that are performed in PRSM. The three more recent surveys have a greater overlap with the PRSM Survey as they provide PRSM-related data. In total, 40 states responded to at least one of these 3 most recent surveys or the PRSM Survey.

II.3.2 PPPM Software Used by Other State DOTs

Appendix VI shows the responses by states and provinces to questions 6 and 7a in the PRSM Survey about if and what software they use. The researchers asked this question to learn if CA PPM is being used by other states or if some other software would stand out. As shown, only 25 states/provinces (including California) provided information on software that could be compared with PRSM.

Cline (2017) collected data on project management software used by 14 states, 7 of which did not provide software information in response to the PRSM Survey. By combining Cline's with the PRSM Survey data, a total of 32 states/provinces offered input on software that could be compared with PRSM.

The Montana DOT (2013) study received results from 26 states (one unidentified) and 2 provinces; 6 were not duplicates from Cline's report or the PRSM Survey. The Montana study, however, focused on the management of construction projects rather than on the management of preliminary engineering and construction engineering and the latter is what PRSM is mainly used for. Upon examination of the data, the researchers found none of the additional responses provided information on project management software.

Table 4 provides a count of the software products used by the states/provinces relative to the data previously provided in Figures 12, 13, and 14, and Table 3.

- **Oracle Primavera:** 11 states use this product as their project management system, making it the most common project management choice among the state DOTs. Primavera is widely used for the management of large construction projects and is well known in the civil engineering industry. It was ranked among the leading products in the field in the 2004 Gartner review and Caltrans found that it could meet 100 % of the PRSM requirements, although 39.5 % of those requirements would require some custom code. It was initially selected as the PRSM software in 2002, but that procurement was canceled. In the Caltrans procurement process in 2006, it was again submitted as a possible PRSM software, with Deloitte as the prime contractor. Deloitte withdrew, however, thus preventing Primavera from being considered further for PRSM.

The most recent Gartner and Forrester reviews do not consider Primavera among the PPPM contenders. It is unclear to the researchers as to why that is the case, but they recognize that Primavera is commonly associated with the management of individual large construction projects, in which a significant part of the cost is for materials and equipment rather than for (possibly subcontracted) labor. The PRSM application is for a portfolio of many coordinated projects, rather than individual projects, and it is used to manage labor (personal services), but not materials or equipment.

- **Software that is developed in-house** ranks as the second most common choice for project management software in state DOTs. 3 states have their own custom systems, and 5 have developed their own databases using commercial database software. 2 of these states use Oracle databases, and 1 each use SAP, Microsoft Access, and Excel spreadsheets. 1 Province uses a "Capital Improvement Delivery System", which the researchers understand to be an in-house system.

Table 4: Project Management Software used Agency-wide by Transportation Departments

	Number of States using Software [32 total]	Ranking in 2016 Gartner "Magic Quadrant"	Ranking in 2012 Forrester "Wave"	Ranking in 2004 Gartner "Magic Quadrant"	% of Caltrans Requirements met with Adaptation in 2005
Oracle Primavera	11			Leader	100%
Microsoft Project	6	Challenger	Strong	Challenger	100%
In-house system	3				
Planisware	2	Challenger	Strong	Niche Player	98.68%
In-house Oracle database	2				
CA PPM	1	Leader	Leader	Leader	100%
Hewlett Packard	1	Challenger	Leader		
SAP	1			Challenger	
Artemis Projectview	1			Visionary	
Microsoft Access	1				
"Capital Improvement Delivery System"	1				
Various, selected project-by-project	1				
Excel spreadsheets	1				
Planview	0	Leader	Leader	Leader	100%

- **Microsoft Project:** 6 states use this product as their project management system, mainly in the "Microsoft Project Server" form that provides the ability to manage multiple projects. Microsoft Project may well be the most common project management software in the world, being sold with the Microsoft Office Suite. It has consistently been ranked

as a “challenger” in the PPPM space, but it has not advanced to become one of the leaders. A “challenger” is a product that is produced by a firm with considerable ability to execute, but that currently has a limited offering. The consistent placement of Microsoft Projects into this category suggests that Microsoft has not invested the money to make Project fully competitive with the leaders. In 2005 Caltrans found that it could meet 100 % of the PRSM requirements, although 41.1 % of those requirements would require some custom code. It was not proposed by any firm in the procurement competition for PRSM.

- **Planisware:** 2 states use this product as their project management system. It has consistently been ranked in a tier behind the leaders in the PPPM space. In 2005 Caltrans found that it could meet 98.68 % of the PRSM requirements, although 18.59 % of those requirements would require some custom code. (The small deviation from 100 % resulted from the failure of the Planisware team to provide an adequate answer to one question.) In 2006, Planisware was submitted by SAIC as the possible PRSM software, and it was awarded that contract in February 2008. SAIC, however, changed software partners and CA PPM became the final PRSM selection.
- **CA PPM** is the software used in the Caltrans PRSM system. It was formerly named “Niku” and then “CA Clarity.” It has consistently been ranked among the leaders in the PPPM space. In 2005 Caltrans found that it could meet 100 % of the PRSM requirements, although 20 % of those requirements would require some custom code.

II.3.3 Software Used by Other States Compared with PRSM Specifications

The PRSM Survey included 42 questions (all yes/no questions) that were derived from the requirements for PRSM specified in the PRSM Feasibility Study Report (FSR) and Value Analysis Report (Caltrans 2000:2 and 2004). These questions asked states whether functions in the software they use agency-wide matched specific PRSM functions. This data indicates how similar each state is to California in its use of its project management software. Arguably, fulfilling more of the provided project management functions might indicate a higher level of project management maturity, but caution is in order in regard to expressing any value judgment or any form of criticism of states that use their software in a different fashion to Caltrans. To the contrary, states that have significantly different approaches are useful for benchmarking and learning from alternative approaches that could be useful. The researchers have done such comparative benchmarking in the past (Blampied and Tommelein 2016) and further such studies are in order.

The table in Appendix VII tallies which of the 42 PRSM functions transportation departments are fulfilling using the software they use agency-wide. The bottom part of this table shows what software each state uses for project management. In considering the “yes “answers noted by a checkmark, Caltrans responded “yes” when asked about each of the 42 functions, indicating that

PRSM does perform to its specifications. Table 5 presents the states with the largest number of "yes" answers.

Table 5: Number of PRSM Functions Fulfilled by States

Number of PRSM Functions Fulfilled	State	Project Management Software Used
42	California	CA PPM
36	Michigan	Planisware
30	Kansas	In-house software
26	Pennsylvania	In-house Oracle database
23	North Carolina	SAP
23	Utah	In-house software
17	Georgia	Oracle Primavera
15	Montana	Planisware
15	New Jersey	Oracle Primavera
13	Virginia	Microsoft Project Server

Observations about Table 5 include:

- Michigan, the state with the largest number of "yes" answers after California, uses Planisware, a software product that was at one time selected for PRSM.
- The next four states after Michigan all use their own custom-developed systems.
- The Oracle Primavera installation that is configured most like PRSM, in Georgia, has only 17 of 42 "yes" answers. This does not imply that Oracle Primavera cannot be configured to meet the PRSM requirements, but it does indicate that Oracle Primavera has not yet been configured by any state to meet requirements similar to those of PRSM.
- Montana, the second state that uses Planisware, ranks eighth in its similarity to PRSM, with 15 "yes" answers.
- Virginia has the Microsoft Project Server installation that is most like PRSM with 13 "yes" answers.

On examining the answers that tended to characterize states with installations that are most like PRSM, the researchers found that:

- The four states, including California, that had the highest numbers of "yes" answers were the only states that answered in the affirmative to question 11c, "Do you track ETC indirect (overhead) dollar costs by WBS?"

- The same four states were the only states that answered in the affirmative to question 11b, “Do you track ETC dollar costs by WBS?”
- The same four states plus only one other (Utah) were the only states that answered in the affirmative to question 11f, “Do you track ETC indirect (overhead) dollar costs by Phase?”
- The same four states plus only one other were the only states that answered in the affirmative to question 11a “Do you track Estimate-to-complete (ETC) person hours by WBS?”
- Four of the six states with the highest numbers of “yes” responses, plus only one other (Iowa) were the only states that answered in the affirmative to question 31, “Is your system integrated with Timekeeping?” Iowa’s system appears to include the timekeeping and accounting functions and it appears to be focus mainly on those functions rather than on project management.
- Three of the six states with the highest numbers of “yes” responses, and no other states, answered “yes”, to question 9i “Do you track actual named individual’s hours by WBS?”

In summary, the states with the largest numbers of “yes” answers appear to have systems that are integrated with timekeeping so that managers can compare actual hours spent with the estimates and do detailed estimating of support costs at a granular level (for each planned Work Breakdown Structure [WBS] element).

II.3.4 System Interfaces

II.3.4.1 Caltrans Systems Interfaces

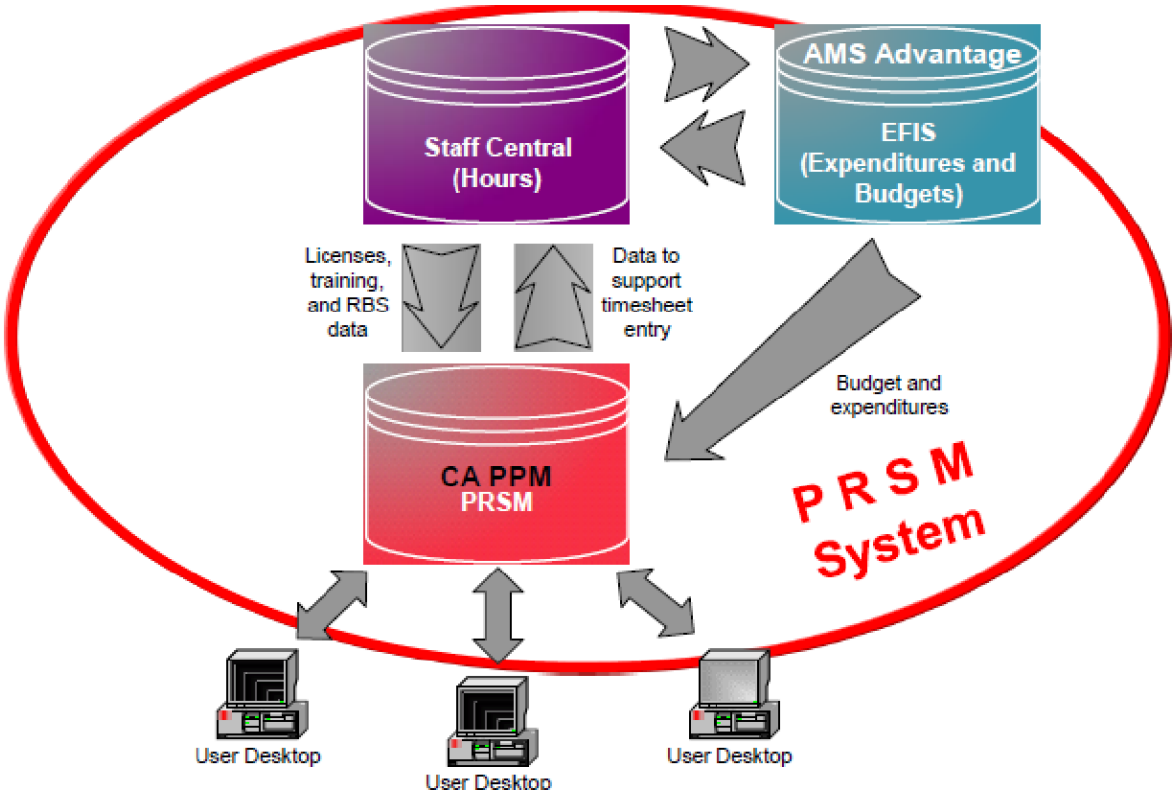
The PRSM system is comprised of three Caltrans systems that allow for electronic data interchange (EDI) (Figure 15):

1. CA PPM software and its related database.
2. Caltrans Staff Central personnel system, which includes timekeeping. This is an Oracle Peoplesoft installation.
3. eFIS accounting system, referred to in Caltrans by its commercial name, AMS Advantage.

Through these EDI interfaces:

- PRSM restricts which Caltrans units, and in some cases which named employees, may charge time to each active WBS element on a project.
- PRSM receives the actual hours and dollars charged to each WBS element, and the date on which each charge was made. The date of the first charge fixes the actual start date of each task. (A “task” here is defined as a WBS element assigned to a specific organizational unit, consulting firm, or individual.)

Figure 15: PRSM Interfaces (Caltrans 2016:4)



The PRSM Survey asked states what systems interface (i.e., allow for electronic data interchange) with their project management system. The researchers asked this question to possibly discover further opportunities to integrate PRSM with other systems. Appendix VIII shows the states' responses.

II.3.4.2 Interfaces Similar to PRSM's

A number of states have configured their system with interfaces similar to PRSM's. PRSM interfaces with the Caltrans accounting and personnel systems, and the personnel system includes timekeeping. Observations Caltrans' other state's interfaces are:

- **Timekeeping:** Only 5 states, including California, integrate their project management systems with accounting. As noted, states whose project management systems have the most features in common with PRSM do integrate their systems with timekeeping and then use that integrated data to prepare ETCs.
- **Accounting:** Along with programming, this is the most common interface as it being used by 13 responding states. In the Caltrans case, timekeeping hours are routed from Staff Central to the eFIS/AMS accounting system, where the hours are assigned a dollar figure (a function of the classification of the employee who charged their hours for doing the

work) and a factor is added for indirect costs. The hours and dollars are then transmitted to PRSM.

- **Personnel:** 8 responding states have interfaces between their personnel and project management systems. In the Caltrans case, this allows project managers to assign tasks to specific, named state employees.

II.3 4.3 Interfaces Different from PRSM's

While preparing the PRSM Survey, the researchers identified 7 possible interfaces that Caltrans currently does not use and asked other states if they have them. The researchers' observations on these responses to these interfaces are:

- **Programming:** Along with accounting, this is the most common interface, used by 14 responding states.

Caltrans proposed an interface between programming and project management in the Feasibility Study Report (FSR) for "Project Cost and Schedule Management (PCSM)" that it submitted in January 2000 (Caltrans 2000:1). The Department of Finance rejected the PCSM FSR and instructed Caltrans to return with a down-scoped FSR. That was PRSM, defined to focus on a portion of the PCSM scope.

A challenge in developing an interface with programming is that it must address the many-to-many relationships between programmed items and capital projects. At Caltrans, programming means developing a multi-year plan to establish what fund source will be committed to each phase of a capital project. Individual phases of projects can be funded from multiple funding sources, and an individual item in the programming system can provide portions of the funding for multiple capital projects. While in most cases a capital project phase is funded from only two sources, a federal source and a state matching source, this is not always the case. Large complex projects can have many funding sources. An extremely complex example was the replacement of the "Doyle Drive" south approach to the Golden Gate Bridge on State Route 101 which received funding from more than 50 sources.

- **Budgeting:** 10 states indicated that their project management systems interface with budgeting. Figure 15 illustrates that Caltrans budgeting information is stored in the eFIS/AMS system. In fact, this is a hand-entry of programming (not budgeting) information rather than being produced by an interface. At Caltrans, the distinction between programming and budgeting is that programming refers to the planned multi-year funding of project phases for their entire duration whereas budgeting is a one-year slice of the programming that is appropriated by the Legislature in the annual budget. In the Caltrans case, budgeting is not done on a project-by-project basis. Rather, the

Legislature appropriates just a few items[1] for the entire Capital Outlay Support program, which encompasses all support work on state highway projects. These items are complicated enough on their own without attempting to incorporate them into the project management system and, in the researchers' view, are adequately handled by the Caltrans budgeting and accounting systems.

- **Environmental Permit Data:** 8 states indicated that their project management systems interface with environmental permit data.

Caltrans records environmental permits in a Filemaker database named Standard Tracking Exchange Vehicle for Environmental (STEVE). Environmental permits can include conditions that last for a considerable time, sometimes decades, after a project is completed. For this reason, it is prudent of Caltrans to have a system such as STEVE with which to track those commitments. Repercussions could be significant if a commitment were to be forgotten because it is tied to a project that has long since been completed.

Nevertheless, for project management purposes it is important to note that each project-specific environmental permit is also an element of the WBS. No fewer than 182 elements in the Caltrans standard WBS have as one of their outputs to "Update STEVE database" (Caltrans 2016:3). Each

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[1] For the 2017-18 fiscal year, the Legislature appropriated 15 items for the Capital Outlay Support program:

1. 2660-001-0042-(1)1835010 from the State Highway Account;
2. 2660-001-0042-(14)1835010 for Reimbursements;
3. 2660-001-0365 from the Historic Property Maintenance Fund;
4. 2660-001-0890-(1)1835010 from the Federal Trust Fund;
5. 2660-002-0042-(1)1835010 for administration of Grant Anticipation Revenue Vehicles (GARVEE);
6. 2660-002-0890-(1)1835010 Federal funds for administration of GARVEE;
7. 2660-002-3007-(1)1835010 from the Traffic Congestion Relief Fund;
8. 2660-004-6055-(1)1835010 from the Corridor Mobility Improvement Account;
9. 2660-004-6056-(1)1835010 from the Trade Corridors Improvement Fund;
10. 2660-004-6058-(1)1835010 from the Transportation Facilities Account;
11. 2660-004-6060-(1)1835010 from the State-Local Partnership Program Account;
12. 2660-004-6064-(1)1835010 from the Highway Safety, Rehabilitation, and Preservation Account;
13. 2660-004-6072-(1)1835010 from the State-Route 99 Account;
14. 2660-005-0042-(1)1835010 for state office building financial services; and
15. 2660-007-0042-(1)1835010 for compliance with the National Pollution Elimination System.

permit is an essential project deliverable that needs to be planned, and requires an often quite significant effort on the part of Caltrans employees.

- **Right-of-Way Parcel Data:** 5 states indicated that their project management systems interface with right-of-way parcel data.

In Caltrans, this data is housed in a system named Right-of-Way Management Information System (ROWMIS). Utility relocations are included with right-of-way data. Every right-of-way parcel or utility relocation requires some effort on the part of state employees. This may range from obtaining a temporary right of entry to a major acquisition including formal condemnation and the relocation of tenants. It could also involve a complex utility relocation which would be a project in and of itself.

Depending on the complexity, effort, and criticality of a particular right-of-way action, it may be appropriate to assign a parcel- or utility-specific WBS element to portions of such work.

- **Geographic Information Systems (GIS):** 5 states indicated that their project management systems interface with a GIS. GIS are increasingly used for a wide variety of functions. In a project management system, users typically begin by mapping the start- and end post miles of the project to the GIS system, enabling the production of a locality map showing the project in its geographic context. This use can then be expanded to allow users to select an area on a map and view all projects within that area. A GIS can also be used to produce maps of the projects, perhaps of a particular type or delivery year, within the boundaries of a county, city, school district, or legislative district. It may also be used to identify utilities, environmentally sensitive areas, property zoning, types of agriculture, and a vast array of other data that could be relevant to the project and influence the project's outcome.

- **Personal Calendars:** One state, Virginia, indicated that its project management system interfaces with personal calendars. They use Microsoft Project and the Microsoft Office Suite that offers an interface between the Microsoft Project and the Tasks List in Microsoft Office. This makes it possible for tasks assigned to a worker in Project to appear in that worker's Task List in Outlook. Some Caltrans managers have expressed an interest in a similar interface in the past, but it is not currently available through CA PPM.

- **Computer-Aided Design and Drafting (CADD) or Building Information Modeling (BIM):** One state, Oregon, indicated that its project management system interfaces with CADD. CADD technology had advanced dramatically, going from 2-dimensional (2D) images to 3D models that permit users to "walk through" planned buildings or "drive" planned highways on-screen, to 4D models that add a time dimension and permit the users to simulate a construction sequence, to 5D models that comprise cost data. "Building Information Modelling" (BIM) is now used rather than CADD, because these systems are accomplishing a lot more than design and drafting.

To some degree BIM systems offer functionality similar to GIS. BIM systems are also becoming project management tools. Examples of BIM systems that embed project management functions with geometrical modeling include Constructware in the Autodesk suite, Projectwise and Synchro as part of Bentley, and Vico of Trimble.

Responses to these PRSM Survey questions point at several opportunities to further integrate PRSM with other software so as to create a more holistic, enterprise PPPM system for Caltrans. Such a system would more readily provide data Caltrans personal can use in decisionmaking (create value) that in currently the case, and would eliminate the need for manual data transfer (eliminate waste).

II.3.5 Use of Standard Work Breakdown Structures

The PRSM Survey asked states whether or not they use a standard Work Breakdown Structure (WBS). The WBS organizes and defines the total scope of the project. It subdivides the project work into smaller, more manageable pieces of work, with each descending level of the WBS representing an increasingly detailed definition of the project work (PMI 2017:1). Use of a standard WBS, deployed systematically agency-wide, allows project to be compared with one another and thus enables learning.

The project WBS is intended to include all the work necessary for the completion of a project and no unnecessary work. The work should be broken down to the point where each of the most detailed elements can be assigned to a person, known in Caltrans as the "Task Manager", who can be assigned responsibility for completion of that element according to a specific schedule. These most-detailed WBS elements are known as "Work Packages." Successful and efficient completion of a project requires that the work be broken down into work packages.

20 of the responding states indicated that they use a standard WBS. The Caltrans (2016:1) survey found 11 states using a standard WBS, although one (Louisiana) enforces the use of the WBS only on work by consultants. The reader may refer to that Caltrans report as it contains a considerable amount of detail. All but one of the 11 participating states identified by Caltrans also responded to the PRSM Survey, so that between the two surveys, 23 states[2] responded that they have a standard WBS.

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[2] States using a standard WBS are (1) California, (2) Colorado, (3) Delaware, (4) Georgia, (5) Idaho, (6) Indiana, (7) Kansas, (8) Louisiana, (9) Michigan, (10) Minnesota, (11) Montana, (12) New Jersey, (13) New York, (14) North Carolina, (15) Oklahoma, (16) Oregon, (17) Pennsylvania, (18) South Carolina, (19) South Dakota, (20) Utah, (21) Vermont, (22) Washington, and (23) Wyoming.

In the case of Caltrans and these other 22 states, the WBS and work packages are standardized throughout the Department in order to facilitate communication, and provide a tool to promote consistent, reproducible, results.

II.3.6 Estimates to Complete (ETC)

The cost of a project (or any part of a project) can be divided into (1) sunk cost and (2) cost to complete. Sunk cost comprises costs that have already been incurred and cannot be changed or recovered. Cost to complete comprises costs that will need to be incurred in order to complete the work. Of these two, only cost to complete can be managed to deliver the project (or part of a project) so as to—in the best possible way that is available—meet the project's conditions of satisfaction (in the most efficient and effective manner, within a pre-approved budget and time, etc.).

A critical part of project management is to maintain and update an "estimate-to-complete" (ETC) as the work proceeds. An ETC can be used both for budgeting (i.e., the allocation of funds to complete the work) and for identifying and prioritizing means and methods that might be used to complete the work more effectively.

A challenge is that ETCs—because they are forecasts—are hard if not impossible to determine with the desired accuracy. Different methods exist to forecast ETC, but all have considerable limitations.

Some methods project ETC using data of costs already incurred. A simple way to compute a task's ETC is to subtract costs already incurred for that task from the amount budgeted to perform it. A limitation of this method is that, depending on the quality of the budget and the realities of task execution, the ETC computed in that way may not suffice to actually complete the task. Nevertheless, this method to compute ETC is the one implemented in PRSM.

In contrast, other methods rely on people "in the know" (e.g., those directly involved in doing the work, people aware of contextual considerations of current and anticipated project conditions, etc.) to project ETC based on judgment in addition to being based on performance-to-date and possibly other data. Determination of a task's ETC can be more accurate when task managers have the opportunity to provide direct input in its estimation, as they will be aware of what work was done vs. remains to be done and who was involved vs. is available to do it. However, as mentioned, no method can forecast the exact amount of money or time it will take to complete a task.

Table 6 shows the 14 states that indicated they track ETC, and what ETC data they track. Most of these states do so by phase. Only 5 states track ETC person-hours by WBS as well as by phase, and ETC indirect costs by phase.

In services such as preliminary and construction engineering, the bulk of costs are for personnel. This being the case, cost management is the result of management of work hours. Despite ETC

being hard to determine, tracking and managing work hours at a level of breakdown where tasks span a few days or at most a few weeks, will help establish data to support project cost management. Work hours tracked by task where tasks span multiple months or more than a year, as Caltrans currently is doing in PRSM (Figure 9), do not yield data rich enough for detailed planning and forecasting.

Table 6: Estimate-to-Complete (ETC) Data Tracked by PRSM Survey States

CA	CO	FL	KS	MI	MN	NC	OH	ON	PA	UT	VA	VT	WA	TOTAL
Q 10. Do you track Estimate-To-Complete (ETC) data?														
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	14
Q 11. What Estimate-To-Complete (ETC) data do you track? Q 11e. ETC dollar costs by Phase														
✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	12
Q 11a. ETC person hours by WBS														
✓			✓	✓	✓				✓					5
Q 11f. ETC indirect (overhead) dollar costs by Phase														
✓			✓	✓					✓	✓				5
Q 11d. ETC person hours by Phase														
✓			✓	✓			✓			✓				5
Q 11b. ETC dollar costs by WBS														
✓			✓	✓					✓					4
Q 11c. ETC indirect (overhead) dollar costs by WBS														
✓			✓	✓					✓					4
7	1	2	7	7	2	2	3	2	6	4	2	2	2	

II.3.7 State Employee and Consultant Mix

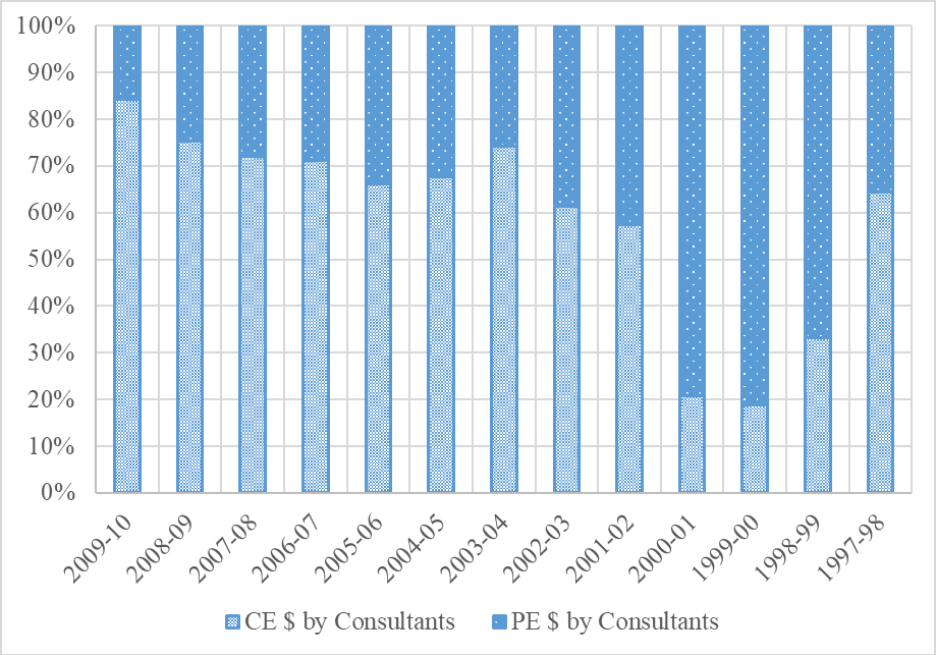
The decision by a DOT to adopt a standard WBS or to track ETCs is influenced by the degree to which the DOT uses state employees to perform its engineering vs. uses private engineering consultants. When work is performed by state employees, it is reasonable for the DOT to manage that work more closely than it would manage work that it contracts out to a consultant. To "manage more closely" means not only tracking individual staff assignments and work hours project-by-project, but also across the portfolio of projects, furthermore allowing for staff

professional development time and time to work on non-project work in-between projects. In contrast, when work is contracted out, the contractor is responsible for deciding on the means and methods of performing the work and the DOT may have sufficient management control of such work by setting contracting targets rather than though more precise tracking.

One PRSM Survey question asked states to provide the percentages of their preliminary and construction engineering work that is performed by state employees, private engineering consultants, local agencies, or other sources. Appendix X provides data from the 23 states that responded; it also shows the answers states provided to a somewhat similar question asked by AASHTO (2005). On the whole, the percentages of work performed by state employees and consultants seems to have remained stable for most states in the 12 years that have passed between the two surveys. However, two differences stand out between the 2005 and 2012 questions:

- The 2005 answers were provided in 10% ranges. If the 2017 numbers are within the 2005 range, the researchers assumed that no change occurred in the percentage of contracting. Similarly, the researchers calculated a percentage change by taking the difference between the closest number in the 2005 range and the new 2017 number.
- The 2005 question referred only to preliminary engineering (PE), while the 2017 question refers to the combination of PE and construction engineering (CE). If states were to provide separate numbers for PE and CE, one number would be larger- and the other smaller than the average of the two. In Caltrans, for instance, consultant expenditures have generally been in CE. Figure 16 presents the percentage split in PE and CE expenditures in each Caltrans transaction year from 1997-98 to 2009-10. Caltrans indicates (Appendix X) that 10 % of its PE and CE in 2015-16 was performed by consultants, so Figure 16 suggests that this number would be considerably less than 10 % for PE and more than 10 % for CE.

Figure 16: Caltrans Consultant Expenditures for Preliminary Engineering (PE) vs. Construction Engineering (CE) by Transaction Year



In considering whether the amount of contracting influences a state's adoption of a standard WBS, the researchers calculated that the median amount of state employee engineering in Appendix X is 40%: half of the participating states use state employees for 40% or more of their engineering. Table 7 shows which of these states have standard WBSs.

Table 7: WBS Use vs. % of Engineering by State Employees

	≤ 40% of engineering is by state employees	**> 40% of engineering is by state employees**	**Total**
DOT has standard WBS	8 states	8 states	16 states
DOT does not have standard WBS	4 states + 1 province	2 states	6 states + 1 province
Total	**12 states + 1 province**	**10 states**	

The data sample is small, but Table 7 suggests a slight correlation between the use of state employees and the adoption of a standard WBS. States that perform their work to a larger extent through state employees are more likely to have a standard WBS (8 of 10 = 80% have a standard WBS), while states that use more consultants are less likely to adopt a standard WBS (8 of 13 = 62% have a standard WBS).

Table 8 shows the results of a similar analysis of states that track ETC. Here too, the data sample is small, but it suggests a slight negative correlation between the use of state employees and the tracking of ETC. States that perform their work to a larger extent through state employees are less likely to track ETC (4 of 10 = 40% track ETC), while states that make more use of consultants are more likely to track ETC (7 of 13 = 54 % track ETC).

This data conceivably indicates that those "in the trenches," namely state employees doing the work and their supervisors, find ETC to not be useful in managing the actual work flows in their project production systems. As mentioned, any method of computing ETC is limited in its ability to predict project outcomes. Notwithstanding the limitations of the method, this data appears to also indicate that managers further removed from the work (i.e., contract managers and project controls personnel) resort to using ETC. Section II.5 later in this Report will expand on other means direct workers and their supervisors have to manage work flows so as to promote reliable execution.

Table 8: Tracking of ETC vs. % of Engineering by State Employees

	≤ 40% of engineering is by state employees	**> 40% of engineering is by state employees**	**Total**
DOT tracks ETC	6 states + 1 province	4 states	10 states + 1 province
DOT does not track ETC	6 states	6 states	12 states
Total	**12 states + 1 province**	**10 states**	

II.3.8 Consultant Use of PPPM System

The PRSM Survey asked whether DOTs require that consultants use the DOT's software suite for status reporting. Table 9 shows that the most common arrangement is for consultants to submit data on paper (they likely extract electronic data from their own software system and then print it) and for DOT employees to enter this data manually into their DOT's system. This is the process used in Caltrans. Since October 2014, actual hours worked by consultants have been hand-entered into the AMS accounting system and uploaded to PRSM, to level 5 of the Caltrans WBS (Caltrans 2014).

6 states indicated that they use some form of electronic data input from consultants without the need to have state employees hand-enter the data. This saves DOT employees the time and effort of having to re-enter data and making sure it is done correctly. Furthermore, electronic data transfer potentially permits recording of data at a more detailed level than WBS level 5.

Table 9: Consultant use of DOT Project Management Software

Q30. Do you require that consultants use your agency's software suite for status reporting?	Number of States
Consultants submit data on paper, and agency employees manually enter it into the system.	8
Yes, using the same software as the agency.	5
They provide schedules through ASTA software.	1
Design consultants enter project activity status updates through eTEAMS (a web-based system that updates the consultants projects on a monthly basis).	1
Some.	1
They report to an in-house project manager/coordinator.	1

II.3.9 Summary and Conclusions on Agency-wide Use of Project Management Software in Departments of Transportation

This Subsection II.3 and Appendices IV though X presented the results of the PRSM Survey the researchers conducted to investigate agency-wide use of project management software in departments of transportation in the US and Canada. The results suggest that not so many states/provinces are using project management software agency-wide, and that by comparison Caltrans is using a relatively comprehensive system supporting many project management functions, not so many of which are implemented by other DOTs. No other state appears to be using CA PPM, yet of note is that no other PPPM software clearly stands out either as the software of choice by DOTs to fulfill their PPPM functions.

Furthermore, the results suggest Caltrans may benefit from integrating its PRSM system with systems for budgeting, personal calendaring, GIS or BIM, and consultant data entry, as other states have. Such integration of systems may enable Caltrans employees to achieve greater functionality and work flow efficiency.

II.4 Engineering Design Organizations' Resource Loading (Staffing) Practices and Use of PPPM Software

II.4.1 Observations from Practices in Private-sector Engineering Design Organizations

Having reviewed the capabilities of PRSM and its deployment in Caltrans, and having conducted a survey of other departments of transportation on their software use for PPPM, the researchers set out to contextualize and to some degree calibrate their findings-to-date. The aim of the research described next was to offer perspective on resource management practices and

software use in engineering design organizations that may inspire Caltrans to further enhance its own.

Caltrans is a state department of transportation unlike many other such departments in the US in that it employs a large number of staff in-house to program, design, and then deliver its projects. Accordingly, Caltrans performs a number of activities that are similar to those performed in engineering design organizations that work in the private sector (e.g., in consulting companies that manage and produce engineering designs). Many other DOTs outsource engineering design work to consultants more so than Caltrans does.

Engineering design organizations in the private sector face management challenges similar to Caltrans. They too have to manage projects, programs, and portfolios, while considering their business strategy and needs, their engineering-design specialists' expertise and availability, and other resource capabilities and constraints. Key challenges for private engineering design organizations include determining how to acquire and prioritize projects and then staff them in order to meet project delivery goals and objectives, while simultaneously managing budgets and company overhead.

Admittedly, private firms compete for and are awarded projects rather differently from the way Caltrans does, because Caltrans serves as a state-owner organization. As an owner, Caltrans manages ongoing operations and maintenance of an extensive, existing infrastructure system, while at the same time executing on the vision of what the State's infrastructure systems should, can, and will offer.

With this in mind, the researchers conducted telephone interviews with a select number of managers in private-sector engineering design organizations to learn about company-wide use of software for PPPM to address management functions such as project resourcing (resource allocation, staffing projection, etc.). In addition, the researchers searched the literature for methods pertaining to project resourcing and data describing such practices.

II.4.2 Take-aways from Telephone Interviews with Engineering Design Managers in Private-sector Organizations

The researchers created a list of questions (included in Appendix XI) about management practices and software use (both for individual projects as well as company-wide to manage portfolios of projects) in order to poll a sample of managers in engineering design organizations in the private sector. Relying on the researchers' current contacts database of architecture-engineering-construction companies, and aiming for diversity, managers were selected and then contacted to request their willingness and availability to participate in this research. The sample selected included managers who were or had been employed by companies large and small, serving the public and/or private sector, while delivering infrastructure-, healthcare-, and other types of projects. They ranged in seniority and in experience with Caltrans projects from none to many years. The researchers then set up individual telephone calls with each manager. One or several

researchers on the team (based on availability) then conducted the semi-structured telephone interview, each one approximately ½-hour long.

The interviews with these engineering design managers in private-sector organizations provided anecdotal evidence that sheds light on the following challenges in regard to project management software selection and use organization-wide:

- Software systems in use to support project management functions varies widely. All managers use software of one kind or another, ranging from Microsoft Excel (in fact, quite commonly mentioned) to more dedicated project management systems. Few interviewees used a company-wide system to manage their portfolios of projects.
- Companies struggle with the question as to whether it is preferable to purchase COTS vs. develop software systems in-house. Concerns pertain to the system's customizability to customer specific needs, first cost and recurring costs to maintain functionality, ongoing training and support needs, longer-term access, and retraining needed when upgrades take place. One company was developing its own system for use in house and also to market to customers.

These responses mirrored the responses of the state/province departments of transportation that were previously surveyed. No single practice appeared to stand about above others.

The interviews also shed light on project resourcing challenges:

- Hiring new personnel and staffing engineering design projects with the "right" people is key to the success of the organization. Practices vary widely. None of the managers interviewed claimed to have any formulaic approach to fulfill this function.
- Practices of resource allocation recognize that projects require people with a variety of knowledge and skills at different times, people can be more-or-less specialized vs. multi-skilled, people develop their interests and hone their capabilities as they progress along their career path (e.g., they tend to become more knowledgeable and efficient over time), individual people's availability and project workloads as well as continuity of staffing in-between projects must be managed, billable and non-billable time (e.g., direct project work and professional development time) compete with one another, etc.
- A challenge management must address is personnel turnover and, related, ongoing and progressive training of new staff joining the organization. It is not uncommon to experience 10-15% staff turnover per year.
- A metric used to gauge company performance is resource utilization. It can be an accounting metric or a production metric, and would be defined differently when it is one vs. the other. Naively, one may say utilization should be approaching 100%. In reality, from a production standpoint, getting anywhere near 100% is impossible because systems subject to increasing amounts of uncertainty and variation will see diminishing

utilization rates. A company-wide average in the architecture-engineering-construction (AEC) sector may be on the order of 60% (see Section II.4.3). New and inexperienced staff tend to have a higher number of billable hours than more senior people do, as senior people move into supervisory roles and acquisition of new business. Billable time is furthermore constrained by time needed for workforce development, practice improvement, company learning, etc.

- PM software systems in use vary widely, e.g., AECOM has adopted Salesforce software and named it ePM (as Caltrans has adopted CA PPM and named it PRSM). Salesforce enables its users to manage each potential contract from the pre-enquiry stage to contract completion. Its purpose is to assist the seller in the buyer / seller relationship (hence "sales force"). Other companies use Procore (targeted to managing construction projects), etc. Again, no single PPPM system stood out as the best among peers or in any way more suitable to manage portfolios of projects of the kind Caltrans manages.

II.4.3 Literature on Staffing Practices in Engineering Design Organizations

Besides polling engineering design managers on their company's strategy for allocation of specialists' time and company-wide use of related project management software, the researchers also searched the literature for papers on management of staffing (company resource management and project resourcing) in organizations that involve engineering, design, and construction specialists, and they searched for data describing such practices.

It turns out that numerous reports and technical papers have been written on resource staffing and related management considerations. Many of these are focused on accounting rather than on project- or production management.

Caltrans itself is involved in extensive data tracking (especially for accounting purposes to comply with legal requirements) and has conducted numerous internal studies describing its staffing practices and related costs; in addition, other researchers have also conducted such studies on Caltrans (e.g., Ashley et al. 1992). These studies (as they also relate to time charging policies, accounting rules, etc.) were not reviewed as the researchers considered them to be outside of the scope of this PRSM review. This notwithstanding, a few additional paragraphs on company resource management and project resourcing are in order to highlight the need to document their impact on project production.

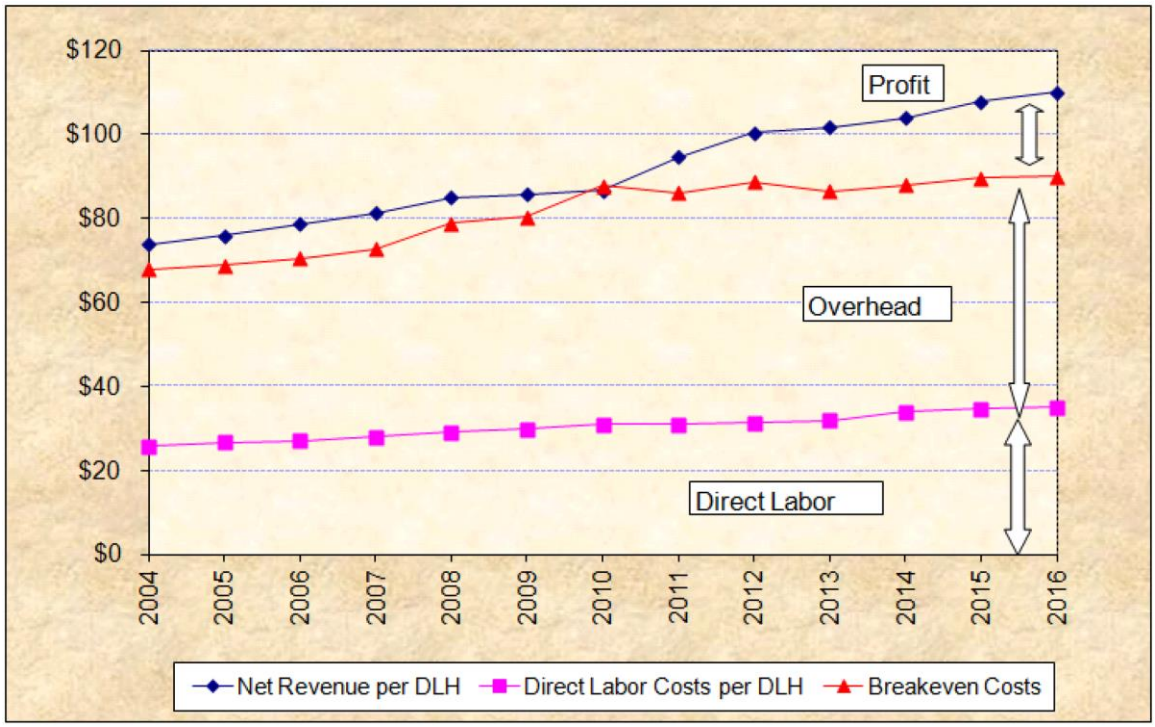
The scholarly literature tends to focus on staffing construction projects, rather than on staffing engineering design projects. Practices vary widely and no one appears to stand out as "best." Each company has their own vision and business strategy, operates in particular industry contexts, and faces numerous types of uncertainties and constraints, which makes it impossible to make many forecasts without great margins of error.

The literature also includes non-technical papers and survey data. In the course of interviewing engineering design managers on the telephone, one manager mentioned that his company benchmarked its practices using national survey data collected by PSMJ. PSMJ is a consulting firm that aims at "improving the business performance of [architectural, engineering, and construction] AEC organizations worldwide" (www.psmj.com). It conducts industry-wide benchmarking surveys. Further research is warranted to clarify to what extent their survey data relates specifically to accounting vs. production. The latter would be particularly relevant to practices of resource allocation as captured in PRSM plans.

PSMJ (2016) notes: "The 319 firms that responded represent what we believe is the largest base of information of this type currently available. This information was collected from February through April 2016, reflecting primarily financial performance and conditions as of December 31, 2015, or the participant's most recently completed fiscal year." Considering that the Caltrans organization has similarities with such AEC organizations, the survey results may offer some reference values to performance indicators and in any case supplement the studies that have focused on Caltrans staffing.

Figure 17 presents the trend of direct labor costs vs. overhead vs. profit from 2004 through 2016 for the private-sector firms that responded to the survey.

Figure 17: Direct Labor Benchmark Trends (Figure 2 in PSMJ 2016 p. 5)



The report (ibid p. 6 and p. 23) has data on chargeability (also referred to as utilization). To quote their definitions:

- **Labor Utilization Rate or chargeability** (Payroll Dollars): The labor utilization rate is calculated by dividing total direct labor charged to projects by total labor (i.e., including direct labor, indirect labor, vacation time, sick leave, holiday pay, etc., but excluding incentive/bonus payments). It is calculated using payroll dollars, not hours. The 2016 median result of this chargeable ratio is 59.84% and the mean is 60.81 %, a slight increase in comparison to the 2015 survey results.

  The 2016 data shows no direct relationship between firm staff size and chargeability. […] There is only a 0.3% difference between firms that support private and government clients.

  Firms that calculate chargeability using direct and total hours (rather than dollars) indicate utilization rates that are 2% to 3% higher than those calculated using this method. This is the preferred method when calculating labor utilization for two or more people to account for the difference in salaries.

- **Labor Chargeability Rate** (Payroll Hours): Firms calculate this chargeable ratio based on payroll hours by dividing direct labor hours by total hours (i.e., direct, indirect, vacation, sick leave, holiday, etc.). For 2016, the median is 62.00% and the mean is 61.00%. These are 2% to 3% higher than the ratios calculated using dollars because, in most firms, many of the higher-salaried personnel charge their time to overhead accounts.

- **Labor Overhead Rate** (i.e., Payroll Burden): Labor overhead (i.e., payroll burden) is the cost of mandatory taxes, holiday, vacation, sick leave, group insurance, pension, mandatory retirement contributions, etc., as a percentage of direct labor. The survey median is 52.14% and the mean, 52.18%. These rates are slightly higher than those reported in the 2015 survey.

Table 10 is an excerpt of the survey data on labor utilization. “The median COE firms report chargeability of 66.4%, and the median for overall firms was 59.8%. Increasing chargeability even by 1 % can have a dramatic impact on net revenue and the firm's overhead rate. There is only about a 13 % correlation between profitability and increased chargeability.” Similarly, the survey data also includes labor chargeability rates in payroll hours rather than in payroll dollars (ibid. Table 70 p. 164). For example, firms with more than 750 staff members have labor chargeability rates with mean value of 62% of payroll hours (25th percentile is 57% and 75th percentile is 66%).

Table 10: Labor Utilization Rate (Payroll Dollars) (Excerpt of Table 25 in PSMJ (2016) p. 66)

	Labor Chargeability Percentage (of Payroll Dollars)			
	25th Percentile	**Median**	**Mean**	**75th Percentile**
Overall	54.5%	59.8%	60.8%	65.9%
Staff Size 1 to 20	54.5	60.9	62.1	66.9
Staff Size 21 to 50	53.0	61.5	61.7	68.1
Staff Size 51 to 100	54.0	59.6	60.0	65.4
Staff Size 101 to 200	54.5	58.3	58.9	62.3
Staff Size 201 to 350	55.8	61.6	62.2	64.6
Staff Size 351 to 750	54.5	57.7	59.9	64.5
Staff Size over 750	53.9	56.2	58.5	62.9

Furthermore, the PSMJ survey reports on numerous other ratios, including:

- Technical Staff to Non-Technical Staff Ratio: "This ratio reflects the number of technical staff to the number of non- technical staff. The survey median.is 4.7:1 and the mean, 5.4:l (see Table 64)."

- Technical Staff to Project Managers Ratio: "This ratio reflects the number of technical staff supporting each project manager. The survey median is 3.3:1 and the mean. 4.2:1 The mean value is affected by a small proportion of firms that do not use – or make only limited use of – the title of project manager. The firms that use this title routinely should refer to the median values as being more representative.

  This ratio indicates the typical number of technical staff grouped in a project team (three or four) and reflects the typical supervisory responsibilities of project team leaders. The median value held steady in comparison to the 2015 survey."

The telephone survey and literature shed some light on common challenges and approaches used for project management in engineering design organizations. The literature cited data from a national survey of AEC organizations that private-sector companies use as performance benchmarks (e.g., labor utilization on the order of 60%). Data and metrics of this nature can help managemers lead improvement initiatives. Likewise, they can inform Caltrans efforts at improving its project management performance.

II.5 Novel Concepts and Approaches for Project Management as Opportunities for Enhancement of Caltrans Practices

II.5.1 Research Methodology, Work Plan, and Outline

A number of novel concepts and project delivery approaches are particularly relevant to mention in this Review. They offer opportunities to Caltrans managers and staff to enhance their project management practices, including some not readily supported in PRSM.

The methodology followed to conduct the research for this Subsection was to synthesize literature pertaining to new thinking about project delivery. This is based on identifying limitations of practices in project management and augmenting current project management practices with concepts from operations and production management (drilling down to the day-to-day execution level). The synthesis of the literature draws on the researchers' extensive expertise and research conducted over the course of their careers focused on new thinking to improve project-delivery performance.

Subsection II.5.2 introduces concepts and approaches in project delivery that supplement those commonly used in project management. Subsection II.5.3 presents the Last Planner® System (Ballard 2000). The researchers recommend that Caltrans consider implementing that system.

II.5.2 Novel Concepts and Approaches in Project Delivery: Lean, Six Sigma, Lean Six Sigma, and Agile Management

The term "Lean" was coined by John Krafcik (1988), a researcher in MIT's International Motor Vehicle Program to characterize the Toyota Production System (TPS). Over the course of 50-some years, Toyota had developed principles and methods to manage production, applicable in manufacturing as well as in new product design, that proved to be very different from then-current production system conceptualizations ranging from craft production to mass production. In the 1980s the TPS gained fame and notoriety because Toyota was outperforming many of its competitors and rising fast to become the world's top automobile manufacturer (Womack et al. 1990). The company continues to this date to apply and refine their Lean system, pursuing never-ending continuous improvement, "Creating more value for customers with fewer resources (LEI 2016)."

A strength of the TPS is its conceptual clarity on principles that promote "systems thinking." Supporting the principles are tools and methods, to be applied judiciously in any given system's context and leveraging one-another when used in combination. While Toyota developed its TPS with Lean Thinking to support their new product development and manufacturing of automobiles, the underlying Lean principles, tools, and methods have since been applied successfully in numerous other industry sectors other than large-scale manufacturing. Examples are service sectors such as healthcare, banking, retail, software development, postal services,

transportation as well as design and construction. Lean principles and practices have been adopted in public-sector as well as in private organizations.

Six Sigma was introduced in the mid-1980s as a business practice at Motorola and subsequently embraced as the business strategy for General Electric. The term Six Sigma stems from the practice of statistical quality control (SPC). It refers to a means to gauge so-called process capability, that is, the ability to reliably perform a process or produce a product or service that consistently achieves a certain standard of quality.

In the early 1990s, Lean Thinking was adopted and transformed to suit developers in the software industry. A team led by Jeff Sutherland articulated the Manifesto for Agile Software Development (https://agilemanifesto.org/) and many practice guides have been published since (e.g., PMI 2017:2).

Today's literature on the schools of thoughts labeled Lean, Six Sigma, Lean Six Sigma, and Agile shows that many of their concepts, tools, and methods overlap, though some differences exist based on areas of application. For example, Lean methods help to identify opportunities for improvement that may be identifiable well before a statistically significant number of observations has taken place, i.e., well before Six Sigma can be applied. The applicability of Lean methods to events that occur only once or occasionally is of particular importance especially in project settings. Project activities get performed once, or are possibly repeated a few times, but then finish and get followed by successor activities well before statistics can be used.

Given this blending of Lean Thinking with Six Sigma, it is not surprising that the State of California, Caltrans, and many other state- and private organizations call their continuous improvement efforts "Lean Six Sigma" initiatives. In their study of highway pavement rehabilitation (HPR) projects, Tommelein and Blampied (2018) identified a number of such initiatives in state transportation departments in the US and abroad. Lean Six Sigma methods can be applied to improve project delivery at Caltrans, with or without using PRSM.

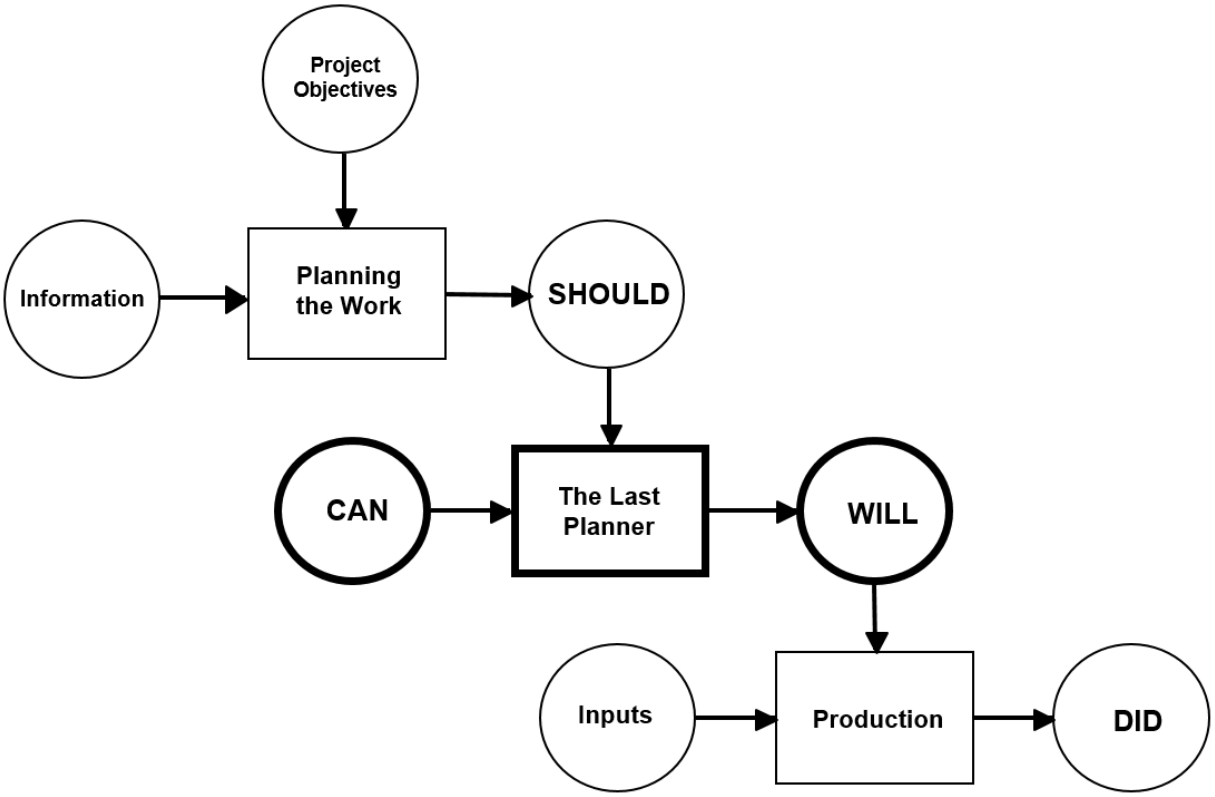
All schools of thought mentioned here promote continuous improvement and aim for value delivery. While novices may at first implement any of these approaches using a select number of specific tools and methods, they will soon realize that success is driven by systems thinking and adoption of the overarching philosophy. These schools of thought all advocate for practices known as "Management by Means" (e.g., Johnson and Bröms 2011)—which stresses the focus on developing people and processes—in contrast to more traditional practices that are known as "Management by Results" (e.g., focusing on schedule and project cost outcomes).

II.5.3 Last Planner® System

Lean applied to project delivery in the AEC industry and more generally, applied to project-based production, falls under the umbrella term "Lean Construction." Lean Construction combines and leverages project management practices with production- and operations management practices.

In the early 1990s, like a Lean Thinker, Glenn Ballard developed the Last Planner® System (LPS) to help increase workflow reliability (and thereby productivity) at the workface. The LPS has since evolved into an all-encompassing planning system (Figure 18) (Ballard 2000, Ballard and Tommelein 2018).

Figure 18: Should-Can-Will-Did Levels of Planning of the Last Planner® System



A way of understanding the relationship between prevailing methods of planning and the Last Planner® System stems from the realization that planners need a richer language than SHOULD (what the plan shows) and DID (what gets measured after execution).

The Last Planner® adds CAN and WILL, inserting a function that converts what SHOULD be done into what CAN be done, creating a backlog or inventory of sound assignments, from which selection can be made when forming weekly work plans, which are commitments to what WILL be done. Such weekly work plans will be much better predictors (than prevailing methods are) of what work will actually have been completed at the end of the plan week.

Ballard calls this “Last Planner” because the unit of analysis is the assignment and he wanted to emphasize the management responsibilities of everyone in the organization, down to the “last planner” who makes assignments to design squads and construction crews. He wanted to avoid getting stuck looking only at high level schedules and budgets produced away from the design floor or construction site itself. Accordingly, the starting point to improve system performance,

is to improve the quality of assignments; i.e., the commitments made each week by those doing production work.

At the highest level of the Last Planner® system is Master Scheduling, akin to scheduling done to populate the PRSM system, but the system "unfolds" plans down to the level of execution (e.g., weekly or daily work planning). The premise is that planning starts with the design of the entire production system and goes all the way down to the design of individual operations or tasks. Process design changes to generate product-based value. Product design changes to generate process-based value and to eliminate waste.

In the course of planning, all involved must answer the following so-called work structuring questions:

1. In what chunks will work be assigned to specialists?
2. How will work chunks be sequenced?
3. How will work be released from one specialist to the next?
4. Will consecutive specialists execute work in a continuous flow process or will their work be de-coupled?
5. Where will de-coupling buffers be needed and how should they be sized? (incl. How will tolerances be managed?)
6. When will different chunks of work be done?

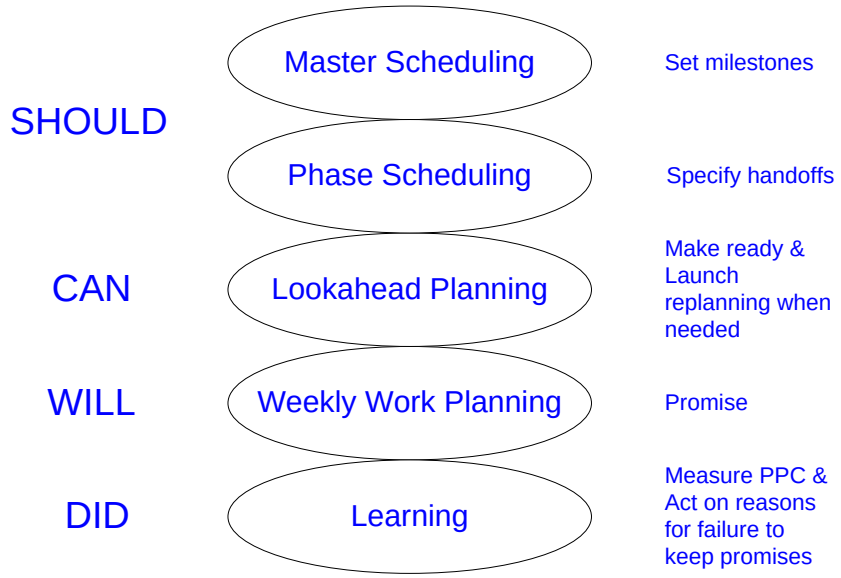
It is possible that work structuring results in chunks that align with a predefined WBS, however this is not necessarily a given; much depends on how that WBS was defined in the first place and what processes and work methods were presumed vs are actually used. Chunks must reflect units of work that make sense to those doing the work.

At each level of the Last Planner® System, planning serves a different, specific purpose (Figure 19):

1. Master Scheduling
    - Demonstrate the feasibility of completing the work within the available time.
    - Develop and display execution strategies.
    - Determine when long lead items will be needed.
    - Identify milestones important to client or stakeholders.
2. Phase Scheduling
    - Produce a plan for completing a phase of work that specifies the handoffs between work groups.

3. Lookahead Planning
    - Shape work flow sequence and rate.
    - Match work flow and capacity.
    - Maintain a backlog of ready work.
    - Develop detailed plans for how work is to be done (prototyping, conducting first run studies, developing standard work, etc.), while considering safety, quality, and environmental issues.
    - Make work ready by assessing task readiness and removing constraints.
    - Re-plan as needed
4. Weekly Work Planning aka. Commitment Planning
    - Commit to doing a task only when it meets five criteria:
        - Definition
        - Soundness
        - Sequence
        - Size
        - Learning
    - Assess task completion.
5. Learning
    - Measure Percent Plan Complete (PPC)
    - Improve performance by learning from successes and avoiding repeat breakdowns.

Figure 19: Functions Fulfilled at Different Levels of the Last Planner® System



The Last Planner® System is being used on numerous projects around the world, big and small, in design, construction, shipbuilding, and other domains of application. The conversations it helps shape among those involved in delivering projects have resulted in significant performance

improvement in project delivery. The researchers therefore recommend that Caltrans adopt this system for its use as well.

II.6 Section II Summary and Findings

Whereas Section I of this PRSM Review report looked inside Caltrans at how the agency is using PRSM, this Section II looked outward at practices other than those of Caltrans. The following summarizes the research that was conducted with this outward-looking focus, and highlights the findings.

Subsection II.2 presented an overview of COTS software available to support agency-wide PPPM. It showed that CA PPM is still among the most highly rated systems in the market today. The researchers noted the absence of compelling reasons to consider software alternatives to PRSM (CA PPM).

Given that PRSM has become an established system, Caltrans now has the opportunity to exploit the capabilities this system has and also to augment its management practices possibly beyond the functionality that is readily supported in PRSM.

Subsection II.3 offered a detailed analysis of data the researchers obtained by surveying departments of transportation in the US and Canada regarding the project management functions these departments support with software used agency-wide.

Subsection II.4 first presented anecdotal evidence and take-aways from management practices in private-sector engineering design organizations regarding the allocation and use of specialists' time and use of project management software. The researchers obtained this evidence via telephone interviews with a small but diverse group of practitioners. Second, it highlighted methods described in the literature pertaining to project resourcing and survey data collected by others related to utilization of resources that are managed in-house by design organizations. This survey data included performance indicators including staff turnover rates (averaging around 13%) and labor utilization (averaging around 60%) that can serve as references to Caltrans management upon initiation of improvement initiatives. When moving into more detailed planning of time people spend across projects, production metrics of this nature will be worth tracking and realistic targets must be set.

Last but not least, Subsection II.5 introduced novel concepts in project management and, more broadly, in project delivery. These concepts link project management to operations management and production management, all of which are management functions that are and have to be performed by Caltrans personnel. Several of these functions are currently not supported in PRSM. The functions that were specified in the selection process that led to PRSM stem from PMI's (1996) PMBOK® Guide, which did not mention the phrases "operations management" nor "production management." PMI's (2017) PMBOK® Guide explicitly states that it does not address operations management. Operations management is concerned with ongoing processes that are

not confined to a single project, so it is considered part of portfolio management, which has a separate standard.

A number of concepts of relevance to Caltrans are present in Lean thinking, Lean Six Sigma, and Agile project management. By augmenting its management practices, Caltrans personnel will be able to improve its project delivery performance (e.g., faster project delivery).

To that effect, the researchers recommend that Caltrans focus on its work flows and processes, that is, how people work individually and together, with personnel in-house and outside of Caltrans, when delivering projects. The researchers also recommend that Caltrans managers and staff start implementing the Last Planner® System. This system describes functionality to different levels of planning. At the highest level are plans akin to those currently shown in PRSM. Lower levels go down to planning done by people "in the trenches" that do the work. The functions of the Last Planner® System address the need for planning with plan adaptation and flexibility in mind as work progresses. The goal in using the Last Planner® System is to increase plan reliability and thus overall project performance.

SUMMARY – PRSM REVIEW FINDINGS AND RECOMMENDATIONS

The research conducted for this Review looked inside Caltrans at its current, agency-wide use of the PRSM software for transportation project management and looked outside Caltrans for concepts and ideas that might help enhance Caltrans use of this software system and related project management practices.

Looking inside Caltrans, research informing the Review started by shedding light on the history of the selection of the PRSM software. It took a long time to go from the Feasibility Study Report (FSR) in 2000 to selecting and then contracting with a vendor in 2009, and another 5 years for customization to get to agency-wide deployment in 2014. Now in use for nearly 4 years, PRSM appears to be capable of meeting the requirements that Caltrans specified at the time of procurement of CA PPM and these requirements still hold today.

The researchers reviewed PRSM-related documents and consulted with staff from Caltrans Headquarters on their deployment of PRSM and state-wide training program. They also consulted with task managers and other users of PRSM in selected Districts, obtained software demonstrations illustrating PRSM use practices, and collected feedback on successes and challenges. This review did not assess practices in all Districts.

Finding 1 – Training: Data shows that PRSM has become a well-established project management system for approximately 3,000 in-house users with read/write access and many more with read-only access. Given the vast amount of training delivered to date as well as on-going training needed to get such a large user group to adopt and skillfully follow the current PRSM project management workflows, it is unlikely that all PRSM features are as-of-yet used consistently and at their fullest throughout the Caltrans organization. The researchers found that headquarters trainers appear to understand the software better than the District staff, and CA (the developers of PRSM) demonstrated features that the researchers had not seen demonstrated in Caltrans.

Recommendation 1: Users mentioned the need for continuing training in PRSM. Headquarters staff has performed valiantly in providing vast amounts of start-up training, but training cannot stop. In order to address incoming staff needs (due to attrition and turn-over of staff) training in PRSM's technical capabilities must be provided on an on-going basis to District staff.

Finding 2 – Software Upgrades: Staff from various organizations that use the CA PPM system (that underlies PRSM), gather at regular times in a "Big Room" to meet with CA leadership and help them decide on software upgrades. Caltrans appears to not be represented there.

Recommendation 2: The researchers recommend that Caltrans obtain a seat in the CA PPM "Big Room" to provide a voice different from the voices of other CA PPM users. Both Caltrans and CA would benefit from such direct engagement even if the California State Chief Information Officer (CIO) has a seat in the "Big Room," since most users of CA PPM are drawn from the information

technology sector, which is well represented by the CIO. Caltrans PRSM is a tool to help deliver projects in the design-bid-build construction industry which has needs different from those of the information technology sector.

Finding 3 – Baselining: Caltrans is not using the baselining process that was envisaged in the PRSM Request For Proposals (RFP) and Feasibility Study Report (FSR) (see Section I.3.4).

Recommendation 3: The researchers recommend that Caltrans develop and implement a process for establishing and recording in PRSM a revised HQ Baseline for each project whenever HQ approves a project change (which, it is understood, may occur at the start of each phase and when a District submits a Project Change Request). The PRSM FSR envisaged that the HQ Baselines would replace the "January 9 file" described in Section I.3.1.2 with consequent savings in Caltrans effort. Whether or not this replacement is feasible in practice has yet to be determined. It cannot be determined, however, if a HQ Baseline is not saved whenever HQ approves a project change.

Finding 4 – Task Management and the Last Planner®: Caltrans staff are using PRSM for project resourcing, especially for annual budgeting, but are not using all PRSM's scheduling functions to their potential.

Recommendation 4: The researchers recommend that Caltrans conduct pilot projects to test innovative scheduling practices, for example to support task management. If and when successful, these practices can then be tailored to Caltrans needs and scale for use in its project portfolios. In particular, the researchers recommend that Caltrans test the four-level Last Planner® system described in Section II.5.3. This system has been used successfully on projects around the world. It has led to better management of workload fluctuations, more reliable completion of tasks according to schedule, and less rework, while employees have felt better about their work and experienced less stress. We see no reason to doubt that similar results can be achieved in Caltrans.

Caltrans supervisors must decide which people on their staff "in the trenches" will work on what aspect of a (level 5) task and when, track assignments and commitments to performing work, identify and remove constraints that may impede task performance, confirm work completion, deliverables, and handoffs to other departments inside and outside of Caltrans, and regularly adjust plans as the project unfolds while steering their teams' workflows, in light of the uncertainty they face and variation that inevitably will crop up. These workflow management functions are not typically supported in project management software (like PRSM) but are the purview of (project) production management systems. Software that Caltrans personnel is using to manage such day-to-day work (e.g., Microsoft Excel) is not to be viewed as a shadow system to PRSM, but rather as an enhancement and complement to it.

Looking outside of Caltrans, the research informing the Review included a high-level scan of project, program, and portfolio management (PPPM) software on the market today, offering functionality akin to various degrees to what is available in PRSM. The goal was *not* to search for

a replacement for PRSM but, rather, to identify potential opportunities for deepening and broadening the use of PRSM capabilities that are currently already available.

Reviews by two independent research firms established that the PRSM software in use at Caltrans, an implementation of CA PPM, was and continues to be a leading COTS PPPM software product on the market. Without repeating Caltrans' 2005 analysis or conducting a new one, the researchers found no indication that any software product on the market today would be better than CA PPM in meeting Caltrans' need for PPM software. Every software product has unique features and no doubt competing systems perform some functions more effectively than CA PPM but, conversely, CA PPM is likely to perform other functions better than the competition does.

In addition, this review also indicated that software products continue to be enhanced (e.g., augmented to support lean construction and production planning) and combined with others. The researchers assume that, given the widespread use of CA PPM, that software too will continue to be enhanced and possibly integrated with other systems. The researchers did not find any compelling reasons for Caltrans to consider alternative software tools to PRSM (CA PPM). Given that PRSM has been deployed now for a few years, agency-wide, and has thus become established, Caltrans has the opportunity to further exploit the capabilities this system has.

To explore extending the possible use of the PRSM system, the researchers surveyed other departments of transportation in the US and Canada to learn what software they are using in support of which project management functions. Results of this survey suggest that not so many states/provinces are using project management software agency-wide. By comparison, Caltrans is using a relatively comprehensive system that offers many project management functions, not so many of which are implemented by other DOTs. No other state appears to be using CA PPM, yet of note is that no other PPPM software clearly stands out as the #1 software of choice by DOTs to fulfill their PPPM functions.

The results of this survey of other departments of transportation suggest Caltrans may benefit from integrating its PRSM system with systems for budgeting, personal calendaring, GIS or BIM, and consultant data entry, as other states have. This may enable Caltrans employees to achieve greater functionality and work flow efficiency.

Taking a step back from IT system functionality, of note is that today's challenges in project management organizations tend to be less on the side of hardware, software, or the cost of IT—especially with cloud-based mobile-enabled software and computation services being offered as a service (SaaS)—but rather with the cost of developing processes and work flows that suit their enterprise needs, customizing systems to fulfill those needs, and training everyone so that the level of understanding and supporting practices are shared and consistently applied throughout the organization.

Caltrans is a state department of transportation unlike many other such departments in the US in that it employs a large number of staff in-house to program, design, and then deliver its projects. Accordingly, Caltrans performs a number of activities that are similar to those

performed in engineering design organizations that work in the private sector. Engineering design organizations in the private sector face management challenges similar to Caltrans'. They too have to manage projects, programs, and portfolios, while considering their business strategy and needs, their engineering-design specialists' expertise and availability, and other resource capabilities and constraints. Key challenges for private engineering design organizations include determining how to acquire and prioritize projects and then staff them in order to meet project delivery goals and objectives, while simultaneously managing budgets and company overhead.

With this in mind, the researchers conducted telephone interviews with managers in private-sector engineering design organizations to learn about their practices and use of software to support management functions such as project resourcing (resource allocation, staffing projection, etc.). No one offered formulaic solutions to address the challenges encountered when staffing projects with specialists. Some managers spoke to the need for flexibility and adaptation while managing the messy day-to-day and longer-range production- and project planning; some are using Lean and Agile practices, at times supported by spreadsheet software.

In addition, the researchers searched the literature for methods pertaining to project resourcing and data describing such practices. No formulaic method stood out as superior to others or as particularly suitable to Caltrans. What stood out was data from an annual industry-wide survey on staffing practices in design firms. It highlighted that organizations that deliver portfolios of projects by employing specialists pursuing their career paths, are challenged by balancing project workloads (direct work) with staff development and personal time (indirect or overhead). Especially in such organizations, staff turnover and labor utilization are key performance indicators. For organizations with a staff size over 750, the average staff turnover rate was 16.5%, and the average labor utilization rate was 62.6% (payroll dollars). Such performance indicators can supplement those Caltrans is using in-house, when assessing its current project portfolio management practices and potential improvements.

Opportunities exist for Caltrans to improve their project delivery performance by using PRSM with tasks defined with shorter durations than is currently the case. At present, Caltrans mandates that tasks be defined at least at level 5 of the WBS. Levels 6 or higher are only used by some. However, a word of caution is in order here: the researchers are *not* advocating that Caltrans mandate the use of greater levels of task breakdown as per its current WBS. This in-and-by itself will not lead to improvement in project or production management practices and performance. Day-to-day planning, execution, and adjustment—so-called *production planning* (rather than project planning)—tend to be messy due to high levels of uncertainty and variation. Task definition depends on the (design) methods used and production planning systems must allow for the exploration of alternative what-if scenarios, frequent updating, etc.

The researchers recommend that Caltrans teams adopt work structuring practices to break their work down in pieces that are manageable to them and use those with the Last Planner® System to create reliable handoffs and steady workflow.

Experimentation and study is in order with and by Caltrans personnel “in the trenches” while using the Last Planner® System. It will involve meeting with managers and staff to learn how they want to- and can work, what workflows and handoffs are in order to deliver different types of projects, to identify necessary and sufficient practices, and then to improve upon those. As Caltrans personnel establishes production management practices and related workflows, further investigation can then focus on if/how to use PRSM to support such production management functions and what other software systems can augment it. The desired production management practices must first be established before one can figure out how software can best support them.

The research findings presented in this Report, lay the foundation for scope to be pursued in applied, follow-on research with Caltrans. This aim of this research would be to further develop project management practices in Caltrans and establish production management practices in the organization, and then leverage the support that PRSM and complementary software can provide for it, the goal being to enhance Caltrans project delivery capability.

APPENDIX I: RESEARCHER CREDENTIALS AND ETHICAL CONDUCT

A.I.1 Biographies and Credentials of Research Team Members

The six-person research team that conducted the PRSM review and wrote this document comprises three internationally-recognized experts in engineering project management, affiliated with UC Berkeley's Project Production Systems Laboratory (P2SL – p2sl.berkeley.edu), two graduate students in Engineering and Project Management at UC Berkeley appointed at P2SL researchers, as well as a staff member from UC Berkeley's Partners for Advanced Transportation Technology (PATH – path.berkeley.edu) program.

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Professor Iris D. Tommelein, the Principal Investigator, teaches, consults, and conducts research to develop and advance the theory and principles of project-based production management, applied—but not limited—to the Architecture-Engineering-Construction (AEC) industry, what is termed "Lean Construction."

Professor Tommelein directs the Project Production Systems Laboratory at UC Berkeley (P2SL - p2sl.berkeley.edu), a research laboratory dedicated to developing and deploying knowledge and tools for project management, as well as a learning lab for the Northern California construction industry. She is active in the International Group for Lean Construction (IGLC - www.iglc.net) and serves on the Board of Directors of the Lean Construction Institute (LCI - www.leanconstruction.org). She served 4 years on the Executive Committee of the Technical Council on Computing and Information Technology (TCCIT) of the American Society of Civil Engineers (ASCE - www.asce.org), and is a member of the Construction Research Council of ASCE's Construction Institute.

In 2002, Professor Tommelein received ASCE's Walter L. Huber Civil Engineering Prize "for her research on civil engineering computing for managing project-based production systems in the engineering-architecture-construction industry," and in 2014 ASCE's Peurifoy Construction Research Award "for her contributions in developing Lean Project Production theory, methods and tools, and for successfully disseminating these theories, methods and tools into multiple large, complex projects in the US and worldwide." Last but not least, she received the Lean

Pioneer Award 2015 from LCI, recognizing an individual (or organization) who has moved the design and construction industry forward in embracing and implementing Lean tools and techniques on capital projects.

Professor Tommelein earned a 5-year Civil Engineer-Architect degree from the VUB in Belgium, where she is a Professional Engineer, and three graduate degrees (MS in Civil and Environmental Engineering (Construction Engineering & Management), MS in Computer Science (Artificial Intelligence), and PhD in Civil Engineering) from Stanford University.

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Dr. Glenn Ballard is a co-founder of the International Group for Lean Construction (1993) and the Lean Construction Institute (1997). He is the Research Director for the Project Production Systems Laboratory at UC Berkeley (P2SL - p2sl.berkeley.edu), a research laboratory dedicated to developing and deploying knowledge and tools for project management, as well as a learning lab for the Northern California construction industry. In 2009, Dr. Ballard received the Pioneer Award from the Lean Construction Institute. In 2018, he received the Outstanding Alumni Award from his alma mater, St. John's College, and was elected to the National Academy of Construction. Dr. Ballard graduated cum laude from St. John's College, has an MBA in operations management from Holy Names University, and a PhD in Civil Engineering from the University of Birmingham (UK).

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Nigel Blampied is a Doctoral student and P2SL researcher at UC Berkeley. He retired in 2011 from the position of Division Chief for Project Management and BATA Support in the Caltrans office in Oakland (District 4). Before his assignment in Oakland, he was project manager for PRSM from 2003 to 2008 and he played a significant role in writing the PRSM specifications.

Mr. Blampied has extensive experience in writing national and international project management standards. He was secretary of one of the three working groups that wrote the International Standard on Project Management, *ISO21500*. Since 1998 he has been active in writing American National Standards for project management and he also co-authored the American Association of State Highway Officials (AASHTO) *Guide for Consultant Contracting*. Mr. Blampied led the team that wrote PMI's *Government Extension to the PMBOK® Guide*; which appears to be the first book ever published specifically about project management in government (as opposed to project management in general, the private sector, or in a specific government agency). He has served

on the editorial and drafting committees for the *PMBOK® Guide, Practice Standard for Work Breakdown Structures*, and the *Construction Extension to the PMBOK® Guide*.

For his work in project management standards, PMI recognized Mr. Blampied with its Distinguished Contribution Award. In the 26 years since this 473,000-member organization began making this award, it has been given to only 102 people.

Mr. Blampied earned a BSc Eng degree in Civil Engineering from the University of Natal, a BA in Economics and Geography from the University of South Africa, an MA in Cross-Cultural Studies from Fuller Theological Seminary, and an MS in Civil Engineering from the University of California, Berkeley. He is a candidate for the PhD in Civil Engineering (Engineering and Project Management) at Berkeley. He is a registered Professional Engineer in California and South Africa.

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Mr. Eshan Jayamanne Mohottige Don is a Master's student in the Engineering and Project Management Program in the Civil and Environmental Engineering Department at UC Berkeley. He holds a BS degree in Civil Engineering from the University of Texas, San Antonio. He has been conducting research on workforce planning in engineering design organizations.

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Mr. Ahmad El Merhebi is a Master's student in the Engineering and Project Management Program in the Civil and Environmental Engineering Department at the University of California Berkeley. He holds a BE degree in Civil and Environmental Engineering from the American University of Beirut. His construction experience comes from a summer internship with the Arabian Construction Company on a project comprising three high-rise towers in Downtown Dubai, UAE.

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Ben McKeever is a Program Manager responsible for the development and growth of a robust and coherent program at PATH in the area of Connected and Automated Vehicle (CAV) research.

Prior to joining PATH, Mr. McKeever acquired over 18 years of experience working in both the private and public sector to deliver intelligent transportation system (ITS) solutions to improve

safety and mobility on our transportation network. Most recently, Mr. McKeever served as Team Leader at the FHWA Turner-Fairbank Highway Research Center in the Office of Operations R&D where he led a team of research engineers focused on developing and testing transformative safety, mobility and environmental applications in the area of CAV. Mr. McKeever is currently focused on advancing CAV technology and applications from research to deployment throughout the US.

Mr. McKeever holds a BS degree in Applied Mathematics from the University of Virginia and a MS degree in Civil Engineering from the University of Texas, Austin. He is a registered Civil Engineer in California and Missouri.

A.I.2 Ethical Conduct

UC Berkeley has Standards of Ethical Conduct that are "a statement of our belief in ethical, legal and professional behavior in all of our dealings inside and outside the University" (UCB 2016). These state that "University community members who have certain professional or financial interests are expected to disclose them in compliance with applicable conflict of interest/conflict of commitment policies. In all matters, community members are expected to take appropriate steps, including consultation if issues are unclear, to avoid both conflicts of interest and the appearance of such conflicts."

A perception may exist that researchers on the team potentially have conflicts of interest in conducting the research as described because of their current or past employment funded by Caltrans.

- Iris Tommelein is Principal Investigator on a research project with the University of California Center on Economic Competitiveness in Transportation (UCCONNECT - ucconnect.berkeley.edu) supported by Caltrans funds (Contractor agreement 65A0529 with UC Berkeley). This project titled "Mapping and improving the Delivery Process of Highway Pavement Rehabilitation Projects" was awarded a budget of $ 81,074 for the term May 1, 2016 through April 30, 2017. Nigel Blampied served as the Graduate Student Researcher on this research. Both Prof. Tommelein and Mr. Blampied were paid using these UCCONNECT funds.
- Nigel Blampied retired from Caltrans in 2011.
- Ben McKeever is a Program Manager with PATH. His salary is paid with PATH funds that originate from various sources including Caltrans-funded research projects.

In September 2016, prior to team members accepting to engage in this PRSM review research, Thomas West, Director of California PATH at UC Berkeley, consulted with Caltrans and concluded that no conflict of interest situation existed to prevent any team members from conducting the research in an ethical fashion.

APPENDIX II: ABBREVIATIONS AND ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
BIM	Building Information Modelling
CA PPM	A software program produced and marketed by CA Technologies, formerly called CA Clarity and, prior to that, Niku.
Caltrans	California Department of Transportation
CADD	Computer-Aided Design and Drafting
CDT	California Department of Technology
CE	Construction Engineering
CEQA	California Environmental Quality Act
CITRIS	Center for Information Technology Research in the Interest of Society, at UC Berkeley
COTS	Commercial-Off-The-Shelf: software readily-available on the market and to be custom-configured to meet the customer's needs
CTC	California Transportation Commission
DGS	Department of General Services
DOF	California Department of Finance
DOT	Department of Transportation
EDI	electronic data interchange
ETC	Estimate To Complete
FM	Functional Manager
FSR	Feasibility Study Report
GARVEE	Grant Anticipation Revenue Vehicles
GIS	Geographic Information System
IGLC	International Group for Lean Construction
ISO	International Organization for Standardization
ITS	Institute(s) of Transportation Studies (institutes at UC Berkeley, UC Davis, UC Irvine, and UC Los Angeles)
LCI	Lean Construction Institute
NEPA	National Environmental Policy Act
P2SL	Project Production Systems Laboratory (a research laboratory at UC Berkeley, housed under the umbrella of CITRIS)
PATH	Partners for Advanced Transportation Technology (a center within ITS at UC Berkeley)
PCC	California Public Contract Code
PCSM	Project Cost and Schedule Management (a software system that was proposed in 2000)
PE	Preliminary Engineering
PM	Project Manager

PMBOK® Guide	Guide to the Project Management Body of Knowledge, published by PMI
PMI	Project Management Institute
PPPM	Project, Program, and Portfolio Management
PRSM	Project Resourcing and Schedule Management (a software system)
PY	Person Year
RFQI	Request for Qualifying Information
ROWMIS	Right of Way Management Information System
SaaS	Software as a Service
SHOPP	State Highway Operation and Protection Program
SPMIT	Caltrans Statewide Project Management Improvement Team
SSTI	State Smart Transportation Initiative (an institute at the University of Wisconsin that is sponsored by several states, including California)
STEVE	Standard Tracking Exchange Vehicle for Environmental (a Filemaker database used by Caltrans)
STIP	State Transportation Improvement Program
TM	Task Manager
UC	University of California
UCB	University of California, Berkeley
UCCONNECT	University of California Center on Economic Competitiveness in Transportation (a center within ITS, supporting research at UC Berkeley, UC Irvine, UC Los Angeles, UC Riverside, UC Santa Barbara, and California Polytechnic State University at San Luis Obispo)
UCTC	University of California Transportation Center
US	United States (ISO standard two-letter country code)
WBS	Work Breakdown Structure

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APPENDIX IV: PRSM SURVEY INSTRUMENT

The instructions to PRSM Survey participants and the questions they were asked are shown in the following survey instrument. Subsection II.3 of this Report presents the results of the PRSM Survey.

Berkeley
UNIVERSITY OF CALIFORNIA

Survey of AASHTO member agencies on their agency-wide use of commercial software suites to manage highway projects

The California State Legislature has instructed the University of California (UC) to review the software system (called PRSM) that the California Department of Transportation (Caltrans) is using for *agency-wide* management of its portfolio of State highway projects.

As part of this review, UC would like to know what software other agencies are using *agency-wide* to perform functions that are similar to the functions Caltrans performs in PRSM, and, in general terms, how other agencies use their software. Toward this end, UC requests AASHTO member agencies to complete this survey.

This survey pertains to systems used the *agency-wide* management of preliminary engineering and construction engineering on State highway projects. Your agency may be performing these functions by using in-house staff, by hiring consultants, or by other means.

This survey does not refer to systems used to manage work performed by construction contractors, systems for financial accounting, or systems for human resource management. This survey does not refer to information technology projects and other projects that do not lead to highway construction work.

This survey has 34 questions; some of these questions are conditional, so you may not be asked all. Most questions in this survey have yes/no answers. Some offer answer options from which one- and sometimes several may be selected. Some questions ask for approximate numbers. Approximate numbers are all that is needed: please do not do extensive research or run special reports to find exact numbers. Any question (except question 1) may be skipped if no answer can readily be provided. Should a question be unclear or answer options not be adequate, please let us know!

If you have feedback or questions, please contact Nigel Blampied by phone at 510/479-7070 or via email at blampied@berkeley.edu.

We thank you in advance for taking the time to assist us and Caltrans in this research.

Respondent Information

Q1. State represented (required):

So we may be able to follow up with you if needed, please provide:

Q2. Your name:

Q3. Your e-mail address:

Q4. Your telephone number:

Nature of Project Delivery Resources

So we may be able to get an understanding of the functions you are performing in-house vs. using external resources (such as consultants or staff working for local agencies) for only state highway work:

Q5. Focusing on preliminary engineering and construction engineering work done on your State highways, and looking back at the most recently completed fiscal year, approximately what percentage of the expenditures (in $) on this work was performed by:

State employees

Consultants

Local agencies

Other – make sure total of the answers provided add up to 100%

Total

Software Suite Information

Q6. Do your state employees use a specific software suite to manage preliminary engineering and construction engineering on highway projects?

Yes

No

Q7a. What suite(s) do you use and what for?

Q7b. For how many years (approximately) have your employees been using this software suite?

Q7c. Is the use of this software suite mandated state-wide?

Yes

No

Q7d. Approximately how many highway projects currently underway do you track in this software suite?

Recording information by standard Work Breakdown Structure (WBS) elements.

So we may understand how the tracking of your projects is structured:

Q8. Do you use a standard Work Breakdown Structure (WBS) to manage all highway project work related to preliminary engineering and construction engineering?

Yes

No

Q9. What planned and actual data do you track? (please select all items that apply)

Planned total person hours (in-house, consultants, etc.) Planned in-house person hours

Planned named individual's hours Planned consultant hours Planned direct dollar costs

Planned indirect (overhead) dollar costs

Actual total (in-house, consultants, etc.) person hours Actual in-house person hours

Actual named individual's hours Actual consultants hours

Actual direct dollar costs

Actual indirect (overhead) dollar costs Other, please specify:

Forecasting and Reporting

We would like some information about how you forecast your future resource needs, in person-hours:

Q10. Do you track Estimate-To-Complete (ETC) data?

Yes

No

Q11. What Estimate-To-Complete (ETC) data do you track? (please select all items that apply)

	by WBS element	by Project Phase, whether or not you use a WBS
Estimate-To-Complete (ETC) person hours	☐	☐
ETC dollar costs	☐	☐

Q12. How are Estimate-To-Complete (ETC) hours established in your software suite? (please choose only one)

Entered manually as numbers

Percent complete entered and then ETC calculated using the formula % Complete = (Expended-hours-to- Date)/(Expended-hours-to-Date + Estimated-hours-to-Complete)

Other, please specify:

Q13. What methods do you use for estimating ETC hours? (please check all that apply)

The opinion of an agency expert (e.g., estimator)

Data from prior projects

Formulas or factors developed by your agency

Other, please specify:

Q14. How do you take uncertainty in the forecasting of ETC into account?

	Yes	No
Record three-point estimates (e.g., Optimistic, Pessimistic, and Most Likely)	○	○
Stochastic simulation (e.g. Monte Carlo analysis)	○	○
Not at all		
Other, please specify:		

Q15. How frequently do you update ETC hours? (please choose only one)

Daily

Weekly

Every other week

Monthly

Other, please specify:

Q16. Who updates ETC hours or percentages complete?

Project Manager

Project Management Staff

Supervisor of team doing the work ("Task Manager")

Each individual worker

Other, please specify:

Q17. Do you calculate Earned Value?

Yes

No

Project Resources

We would like to get some information about the level of detail with which you record your resource needs.

Q18. In your project management system, how do you allocate units of resources to projects, activities, or tasks?

As a single number for the duration of the entire project, activity, or task (so that, presumably, the resource will be used uniformly across time from its start to end)

In a non-linear fashion. Please describe:

Q19. Do you make resource forecasts for your portfolio of projects? (please check all that apply)

Yes, resource needs are forecast for the annual budget

Yes, resource needs are forecast for multiple years

Yes, resource needs are forecast as follows:

Q20. Do you allow project and functional managers to assign resources by type (i.e., civil engineer, geologist, structural engineer) to project activities or tasks based on availability of those resources?

Yes

No

Q21. Do you allow project and functional managers to assign project activities or tasks to named individuals?

Yes

No

Q22. Do in-house staff members record their own work time directly to projects?

Yes

No. Please say how you track hours:

Q23. Approximate number of people who do:

Project Planning

We would like some information about how projects are initiated, updated, and tracked.

Q24. Do you track the following items?

	Yes	No
Planned milestone completion dates	○	○
Actual milestone completion dates	○	○

Q25. Do you conduct what-if analyses of multiple scheduling/budgeting scenarios?

Yes

No

Q26. Do you develop an initial project plan by using any of the following approaches? (please select all that apply)

	Yes	No
Copying an existing plan and making modifications	○	○
Selecting a pre-defined project template	○	○
Creating a plan from a task database based on answers to posed questions	○	○
Other means. Please describe:	○	○

Q27. Does your software suite notify project team members (for example by sending an email) if there are issues that they must address?

Yes

No

Q28. Number of users of your software suite

We would like to have some information on the approximate numbers of people in your agency who use your software suite.

Number of People

Approximately how many professional employees do you have on your agency staff?

Approximately how many of your professional employees have write access to portions of your software suite?

Approximately how many of your professional employees have read-only access to portions of your software suite?

Q29. We would like to have some information on the approximate numbers of consultants who use your software suite.

Number of People

Approximately how many consultant employees work for your agency?

Approximately how many of these consultant employees have write access to portions of your software suite?

Approximately how many of the consultant employees have read-only access to portions of your software suite?

Q30. Do you require that consultants use your agency's software suite for status reporting?

Using the same software as the agency

Using compatible software

Consultants submit data on paper, and agency employees manually enter it into the system

Not required

Other, please describe:

Interfaces and Timekeeping

We would like some information about if and how your software suite interfaces with other software systems in your agency.

Q31. Is your system integrated with Timekeeping?

Yes

No

Q32. How frequently are Timekeeping hours uploaded or recorded in your software suite? (please choose only one)

Daily

Weekly

Every other week

Monthly

Other, please specify:

Q33. Does your software suite allow an electronic data interchange with (check all that apply):

Personnel

Programming

Accounting

Personal Calendars

Right-of-Way parcel data

GIS

CADD

Environment permit data

Budgeting

Other, please describe:

Q34. Would you like to receive a copy of our report on this survey? If so, please tell us where to send it to, if not, leave the field blank:

Please click on the ">>" button below to submit all your answers. Thank you for your participation.

APPENDIX V: STATE- AND PROVINCE TRANSPORTATION DEPARTMENTS RESPONDING TO FIVE SURVEYS

Table 11 tallies which US states and Canadian provinces (no territories) responded to any of the 4 surveys the researchers identified as relevant in scope to the PRSM survey they conducted.

Table 11.1: State and Province DOTs Responding to Five Surveys

US State or Canadian Province	AASHTO (2005) Survey	Montana DOT (2013) Survey	Caltrans (2016:1) Study	Utah Study (Cline 2017)	PRSM Survey	Total Responses	Total Responses post 2005
Alabama	✓					1	0
Alaska		✓			✓	2	2
Arizona						0	0
Arkansas	✓			✓		2	1
California	✓		✓	✓	✓	4	3
Colorado	✓			✓	✓	3	2
Connecticut	✓	✓				2	1
Delaware					✓	1	1
Florida		✓	✓	✓	✓	4	4
Georgia	✓		✓	✓	✓	4	3
Hawaii	✓				✓	2	1
Idaho	✓	✓	✓		✓	4	3
Illinois	✓					1	0
Indiana	✓				✓	2	1
Iowa	✓	✓			✓	3	2
Kansas	✓	✓	✓		✓	4	3
Kentucky	✓			✓		2	1
Louisiana	✓		✓			2	1
Maine	✓		✓			2	1
Maryland						0	0
Massachusetts	✓			✓	✓	3	2
Michigan	✓	✓			✓	3	2
Minnesota	✓	✓		✓	✓	4	3

Table 12.2: State and Province DOTs Responding to Five Surveys

US State or Canadian Province	AASHTO (2005) Survey	Montana DOT (2013) Survey	Caltrans (2016:1) Study	Utah Study (Cline 2017)	PRSM Survey	Total Responses	Total Responses post 2005
Mississippi	✓					1	0
Missouri	✓	✓				2	1
Montana	✓				✓	2	1
Nebraska	✓					1	0
Nevada	✓					1	0
New Hampshire	✓	✓		✓		3	2
New Jersey	✓	✓	✓	✓	✓	5	4
New Mexico	✓	✓				2	1
New York	✓		✓		✓	3	2
North Carolina	✓	✓		✓	✓	4	3
North Dakota	✓			✓		2	1
Ohio	✓	✓		✓	✓	4	3
Oklahoma	✓				✓	2	1
Oregon	✓	✓			✓	3	2
Pennsylvania	✓	✓	✓		✓	4	3
Rhode Island	✓					1	0
South Carolina	✓	✓			✓	3	2
South Dakota	✓	✓			✓	3	2
Tennessee						0	0
Texas	✓	✓				2	1
Utah	✓	✓	✓		✓	4	3
Vermont	✓	✓	✓		✓	4	3
Virginia	✓				✓	2	1
Washington	✓				✓	2	1
West Virginia	✓					1	0
Wisconsin	✓			✓		2	1
Wyoming	✓		✓		✓	3	2
Total US State Responses	44	21	13	14	29	47	40

Table 13.3: State and Province DOTs Responding to Five Surveys

US State or Canadian Province	AASHTO (2005) Survey	Montana DOT (2013) Survey	Caltrans (2016:1) Study	Utah Study (Cline 2017)	PRSM Survey	Total Responses	Total Responses post 2005
Alberta	✓					1	0
British Columbia		✓				1	1
Manitoba						0	0
New Brunswick						0	0
Newfoundland						0	0
Nova Scotia						0	0
Ontario					✓	1	1
Prince Edward Isl						0	0
Quebec						0	0
Saskatchewan		✓			✓	2	2
Total Canadian Province Responses	1	2	0	0	2	5	4
Total Responses	45	23	13	14	31	52	44

APPENDIX VI: SOFTWARE USED BY TRANSPORTATION DEPARTMENTS

Table 12 presents what software the surveyed transportation departments are using. States or provinces that did not answer a question are not shown.

Table 14.1: Software Used by Surveyed Transportation Departments

State or Province	Q6. Do your state employees use a specific software suite to manage preliminary engineering and construction engineering on highway projects?	
		Q7a. What suite(s) do you use and what for?
Alaska	✓	Site Manager/Construction Engineering. Building AASHTOWare for Preconstruction/bidding services, expect to deploy early 2018
California	✓	CA Clarity (customized and internally called PRSM), Managing Capital Outlay Support Cost of Highway Projects
Colorado	✓	AASHTOWare, SAP, Headlight, and Projectwise
Delaware	✓	Primavera P6 EPPM - Preconstruction Scheduling and Contractor CPM Reviews; Primavera Unifier - Electronic IDR, Construction Document Management, Construction Cost Management, with further expansion to more department functions in the future.
Florida	✓	ProjectSuite Enterprise (FDOT) for design requests and to pull information, Primavera for scheduling, Financial Management (FDOT) for $$.
Georgia	✗	
Hawaii	✓	Microsoft Access to track project status in preliminary engineering and construction
Idaho	✓	Microsoft Project Server PSS for development and AASHTOware Sitemanager for construction
Indiana	✓	
Iowa	✓	An Oracle database with VB interface that was developed in house
Kansas	✓	WinCPMS (a custom-built Comprehensive Program, Project and Production System) since 2009. Prior to WinCPMS, KDOT used CPMS (the Comprehensive Program Management System) – a custom-built management system implemented in 1992 – for program, project, production & funding.
Massachusetts	✓	
Michigan	✓	Planisware-Design Scheduling Primavera-Construction Scheduling JobNet(Proprietary)-Program Planning
Minnesota	✓	P6 for scheduling, Deltek for risk management and Monte Carlo analysis for costs

Table 15.2: Software Used by Surveyed Transportation Departments

State or Province	Q6. Do your state employees use a specific software suite to manage preliminary engineering and construction engineering on highway projects?	
		Q7a. What suite(s) do you use and what for?
Montana	✓	Planisware 6 software customized as MDT's Engineering Project Scheduler: Engineering project design task management; AASHTOWare Site Manager: Construction project management
New Jersey	✓	For Preliminary Engineering; Primavera and for Construction Engineering AASHTOWare/SiteManager
New York	✓	PSS - Financial, accomplishments, and milestones; P6 - Schedules; SiteManager-Construction payments and CI, Unifier - major Construction workflow and document management; ProjectWise - Document Management
North Carolina	✓	SAP
Ohio	✓	mostly tracking cost and milestones
Oklahoma	✓	Project and Portfolio Management, Hewlett Packard --General project tracking, status, and resource allocation. Microsoft Project for basic WBS.
Oregon	✓	MS Project 2013 Server, ProjectWise - Design collaboration and data management, FileNet - Right of way acquisition, management of final documents
Pennsylvania	✓	We use our own developed system called ECMS - Engineering and Construction Management System
South Carolina	✓	Oracle Primavera P6
South Dakota	✓	Oracle Primavera Professional
Utah	✓	ePM for preconstruction. PDBS for construction but this is being replaced by Masterworks
Vermont	✓	Artemis Projectview (for Preconstruction Scheduling); VPins (Vermont Project Information Navigation System) for project tracking information - written in-house; and Trns*prt suite from Bid Opening thru end of Construction
Virginia	✓	MS Office for communication, MS Project (PWA) for scheduling, TRNSPRT for estimates, and a custom suite of programs called iSYIP for data input and management
Washington	✓	Primavera P6 and Contract Management
Wyoming	✓	Primavera P6 for Engineering Design
Ontario	✓	Capital Improvement Delivery System - budget and forecasting of projects. Focus is on tracking contract letting dates and duration. Does not track project development.
Saskatchewan	✓	

APPENDIX VII: TRANSPORTATION DEPARTMENTS PERFORMING 42 PRSM FUNCTIONS

Table 13 tallies which of the 42 PRSM functions transportation departments are fulfilling using the software they use agency-wide. States or provinces that did not answer a question are not shown.

Table 16.1: Transportation Departments Performing 42 PRSM Functions

AK	CA	CO	DE	FL	GA	HA	IA	ID	KS	MI	MN	MT	NC	NJ	NY	OH	OK	ON	OR	PA	SC	SD	UT	VA	VT	WA	WY
Q9a. Do you track planned total person hours (in-house consultants etc.) by WBS?																											
	✓	✓			✓					✓	✓		✓		✓		✓			✓	✓						✓
Q9b. Do you track planned in-house person hours by WBS?																											
	✓	✓			✓					✓		✓	✓	✓	✓						✓						✓
Q9c. Do you track planned named individual's hours by WBS?																											
	✓	✓											✓														
Q9d. Do you track planned consultant hours by WBS?																											
	✓	✓			✓					✓			✓	✓	✓		✓			✓	✓						✓
Q9e. Do you track planned direct dollar costs by WBS?																											
	✓	✓			✓					✓			✓				✓			✓							
Q9f. Do you track planned indirect (overhead) dollar costs by WBS?																											
	✓	✓			✓					✓			✓							✓							
Q9g. Do you track actual total (in-house consultants etc.) person hours by WBS?																											
	✓				✓				✓	✓			✓							✓							
Q9h. Do you track actual in-house person hours by WBS?																											
	✓				✓				✓	✓		✓	✓								✓						
Q9i. Do you track actual named individual's hours by WBS?																											
	✓								✓				✓														
Q9j. Do you track actual consultants' hours by WBS?																											
	✓				✓								✓							✓	✓						
Q9k. Do you track actual direct dollar costs by WBS?																											
	✓				✓					✓			✓							✓							

Table 17.2: Transportation Departments Performing 42 PRSM Functions

AK	CA	CO	DE	FL	GA	HA	IA	ID	KS	MI	MN	MT	NC	NJ	NY	OH	OK	ON	OR	PA	SC	SD	UT	VA	VT	WA	WY
Q9l. Do you track actual indirect (overhead) dollar costs by WBS?																											
	✓				✓					✓			✓							✓							
Q9m. Do you track planned total person hours (in-house, consultants, etc.) by Phase?																											
	✓								✓	✓				✓	✓	✓				✓			✓			✓	
Q9n. Do you track planned in-house person hours by Phase?																											
✓	✓								✓	✓	✓	✓			✓	✓						✓	✓				
Q9o. Do you track planned named individual's hours by Phase?																											
	✓				✓				✓					✓									✓				
Q9p. Do you track planned consultant hours by Phase?																											
	✓								✓	✓	✓	✓			✓					✓			✓				
Q9q. Do you track planned direct dollar costs by Phase?																											
✓	✓		✓						✓	✓	✓	✓				✓		✓		✓			✓				
Q9r. Do you track planned indirect (overhead) dollar costs by Phase?																											
✓	✓		✓						✓	✓		✓		✓						✓			✓				
Q9s. Do you track actual total (in-house, consultants, etc.) person hours by Phase?																											
	✓	✓							✓	✓		✓		✓						✓			✓			✓	
Q9t. Do you track actual in-house person hours by Phase?																											
	✓	✓							✓	✓		✓		✓								✓	✓	✓			
Q9u. Do you track actual named individual's hours by Phase?																											
	✓	✓			✓				✓			✓		✓									✓				
Q9v. Do you track actual consultants' hours by Phase?																											
	✓	✓							✓	✓		✓		✓						✓			✓	✓			
Q9w. Do you track actual direct dollar costs by Phase?																											
✓	✓	✓							✓	✓		✓								✓			✓	✓			
Q9x. Do you track actual indirect (overhead) dollar costs by Phase?																											
✓	✓								✓	✓		✓		✓						✓			✓				
Q10. Do you track Estimate-To-Complete (ETC) data?																											
	✓	✓		✓					✓	✓	✓		✓			✓			✓	✓			✓	✓	✓	✓	
Q11a. Do you track Estimate-to-complete (ETC) person hours by WBS?																											
	✓								✓	✓	✓									✓							

Table 18.3: Transportation Departments Performing 42 PRSM Functions

AK	CA	CO	DE	FL	GA	HA	IA	ID	KS	MI	MN	MT	NC	NJ	NY	OH	OK	ON	OR	PA	SC	SD	UT	VA	VT	WA	WY
Q11b. Do you track ETC dollar costs by WBS?																											
	✓								✓	✓										✓							
Q11c. Do you track ETC indirect (overhead) dollar costs by WBS?																											
	✓								✓	✓										✓							
Q11d. Do you track Estimate-to-complete (ETC) person hours by Phase?																											
	✓								✓	✓						✓							✓				
Q11e. Do you track ETC dollar costs by Phase?																											
	✓			✓					✓	✓			✓			✓		✓		✓			✓	✓	✓	✓	
Q11f. Do you track ETC indirect (overhead) dollar costs by Phase?																											
	✓								✓	✓										✓			✓				
Q17. Do you calculate Earned Value?																											
	✓			✓									✓														
Q24a. Do you track planned milestone completion dates?																											
✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Q24b. Do you track actual milestone completion dates?																											
✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Q25. Do you conduct what-if analyses of multiple scheduling/budgeting scenarios?																											
	✓			✓		✓			✓	✓	✓		✓	✓	✓		✓					✓	✓	✓	✓	✓	✓
Q26a. Do you develop an initial project plan by copying an existing plan and making modifications?																											
✓	✓			✓	✓	✓		✓	✓	✓				✓	✓	✓	✓						✓	✓	✓	✓	✓
Q26b. Do you develop an initial project plan by selecting a pre-defined project template?																											
✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓						✓	✓	✓	✓	✓	✓
Q26c. Do you develop an initial project plan by creating a plan from a task database based on answers to posed questions?																											
	✓				✓					✓	✓													✓			
Q27. Does your software suite notify project team members (e.g., by sending email) if there are issues that they must address?																											
✓	✓		✓					✓	✓	✓		✓	✓							✓			✓	✓			
Q31. Is your system integrated with Timekeeping?																											
	✓						✓		✓	✓			✓														

Table 19.4: Transportation Departments Performing 42 PRSM Functions

AK	CA	CO	DE	FL	GA	HA	IA	ID	KS	MI	MN	MT	NC	NJ	NY	OH	OK	ON	OR	PA	SC	SD	UT	VA	VT	WA	WY
dQ33a. Does your software suite allow an electronic data interchange with Accounting?																											
✓	✓		✓	✓			✓					✓	✓			✓				✓					✓	✓	✓
Q33b. Does your software suite allow an electronic data interchange with Personnel?																											
	✓								✓	✓	✓		✓										✓	✓			✓
Total Yes																											
11	42	12	7	9	17	4	5	5	30	35	12	15	23	15	11	11	7	3	2	26	7	6	23	13	8	10	10
Project Management Software																											
	CA PPM	Microsoft Project Server	Oracle Primavera	Oracle Primavera	Oracle Primavera	Microsoft Access	In-house oracle database	Microsoft Project Server	in-house	Planisware	Oracle Primavera	Planisware	SAP	Oracle Primavera	Oracle Primavera	in-house application for capital	Hewlett Packard and Microsoft Project	Capital Improvement Delivery System	Microsoft Project Server	In-house oracle database	Oracle Primavera	Oracle Primavera	in-house	Microsoft Project Server	Artemis Projectview	Oracle Primavera	Oracle Primavera
AK	**CA**	**CO**	**DE**	**FL**	**GA**	**HA**	**IA**	**ID**	**KS**	**MI**	**MN**	**MT**	**NC**	**NJ**	**NY**	**OH**	**OK**	**ON**	**OR**	**PA**	**SC**	**SD**	**UT**	**VA**	**VT**	**WA**	**WY**

APPENDIX VIII: SOFTWARE INTERFACES WITH STATE PROJECT MANAGEMENT SYSTEMS

Table 14 tallies which of the functions a state fulfills has a software interface with that state's project management system.

Table 14: Software Interfaces with State Project Management Systems

State	AK	CA	DE	FL	IA	ID	KS	MI	MN	MT	NC	NY	OH	OR	PA	SD	UT	VA	VT	WA	WY
Q31 Is your system integrated with Timekeeping?																					
		✓			✓		✓	✓			✓										
Q33 Does your software suite allow an electronic data interchange with (check all that apply):																					
Accounting	✓	✓	✓	✓	✓		✓			✓	✓		✓		✓				✓	✓	✓
Personnel		✓					✓	✓	✓		✓						✓	✓			✓
Programming	✓		✓	✓		✓	✓	✓			✓	✓	✓		✓	✓	✓	✓	✓		
Budgeting	✓		✓	✓				✓		✓	✓		✓					✓	✓		✓
Environment Permit Data				✓				✓	✓		✓		✓		✓			✓	✓		
Right-of-Way Parcel Data					✓		✓		✓		✓							✓			
GIS				✓			✓										✓	✓	✓		
Personal Calendars																		✓			
CADD														✓							
Number of Interfaces	3	3	3	5	3	1	6	5	3	2	7	1	4	1	3	1	3	7	5	1	3
Number of like interfaces to PRSM	1	3	1	1	2	0	3	2	1	1	3	0	1	0	1	0	1	1	1	1	2
Number of like features to PRSM (max. 42)	11	42	7	9	5	5	30	35	12	15	23	11	11	2	26	6	23	13	8	10	10

APPENDIX IX: RESPONSES TO NARRATIVE QUESTIONS ON ESTIMATES TO COMPLETE

Table 15 summarizes the states' responses to narrative questions pertaining to estimates to complete. States or provinces that did not answer a question are not shown.

Table 205.1: Responses to Narrative Questions on Estimates-to-Complete

State	Q12. How are Estimate-to-complete (ETC) hours established in your software suite?	Q13. What methods do you use for estimating ETC hours?	Q15. How frequently do you update ETC hours?	Q16. Who updates ETC hours or percentages complete?
CA	ETC entered manually as numbers	Depends on the Function and Task	Monthly	Supervisor of team doing the work ("Task Manager")
CO				
FL	Only dollar amount	We do not track hours in Preliminary Design	Monthly	Project Manager
KS	Track by duration - not man-hours	Formulas or factors developed by your agency		Supervisor of team doing the work ("Task Manager")
MI	By Tasks Completed (relatively short tasks)	Remaining Hours	When Tasks Complete (short tasks)	Project Manager
MN	We start by using the percent remaining of any task but each district management team is offered the opportunity to make modifications to those hours	All of the above	Quarterly on a program level and every other week on active projects	Project Manager, Project Management Staff
NC	Percent complete entered and then ETC calculated using the formula % Complete = (Expended-hours-to-Date) / (Expended-hours-to-Date + Estimated-hours-to-Complete)	Data from prior projects	Monthly	Project Management Staff

Table 15.2: Responses to Narrative Questions on Estimates-to-Complete

State	Q12. How are Estimate-to-complete (ETC) hours established in your software suite?	Q13. What methods do you use for estimating ETC hours?	Q15. How frequently do you update ETC hours?	Q16. Who updates ETC hours or percentages complete?
OH	ETC entered manually as numbers	The opinion of an agency expert (e.g., estimator)	2 a year or as needed	Project Management Staff
ON	All designs done by consultants, track % complete against deliverables, do not track their hours.	The opinion of an agency expert (e.g., estimator)	Only during procurement phases for design services or contract administration services.	Project Management Staff
PA	ETC entered manually as numbers	System won't allow multiple so we use data from prior projects, opinion of district experts and a mutual gains guide	Monthly	Our ECMS system does when the consultant invoices the department
UT	We do not use hours in our schedules just start and end dates. Hours are only used in billing.	The opinion of an agency expert (e.g., estimator)	Every other week	Consultant. Not tracked on projects designed by UDOT staff.
VA	ETC entered manually as numbers	From scoping estimates	@ project milestone phases	Project Manager
VT				
WA	Percent complete entered and then ETC calculated using the formula % Complete = (Expended-hours-to-Date) / (Expended-hours-to-Date + Estimated-hours-to-Complete)	The opinion of an agency expert (e.g., estimator)	Monthly	Supervisor of team doing the work ("Task Manager")

APPENDIX X: STATE EMPLOYEE VS. CONSULTANT MIX IN STATE- AND PROVINCE TRANSPORTATION DEPARTMENTS

Table 16 presents data on expenditures pertaining to preliminary engineering and construction engineering work performed by state employees, consultant, local agencies, or others.

Table 16.1: State Employee vs. Consultant Mix in State- and Province Transportation Departments

State or Province	Q5. Focusing on preliminary engineering and construction engineering work done on your State highways, and looking back at the most recently completed fiscal year, approximately what percentage of the expenditures (in $) on this work was performed by:				With reference to dollar value, estimate what percentage of your capital projects that were awarded in the previous fiscal year were developed by consultants? (AASHTO 2005)	Apparent (computed) increase (+) or decrease (-) in use of consultants from 2005 to 2017
	State Employees	Consultants	Local Agencies	Other		
Alaska	40	55	5	0		
California	90	10	0	0	0 – 10%	0%
Colorado	50	40	10	0	30 – 40%	0%
Georgia	25	70	5	0	60 – 70%	0%
Hawaii	55	35	10	0	70 – 80%	-35%
Idaho	30	70	0	0	70 – 80%	0%
Indiana	20	80	0	0	> 90%	-10%
Iowa	50	50	0	0	40 – 50%	0%
Kansas	30	70	0	0	60 – 70%	0%
Michigan	40	60	0	0	50 – 60%	0%
Minnesota	55	40	5	0	30 – 40%	0%
New Jersey	20	80	0	0	80 – 90%	0%

Table 16.2: State Employee vs. Consultant Mix in State- and Province Transportation Departments

State or Province	Q5. Focusing on preliminary engineering and construction engineering work done on your State highways, and looking back at the most recently completed fiscal year, approximately what percentage of the expenditures (in $) on this work was performed by:				With reference to dollar value, estimate what percentage of your capital projects that were awarded in the previous fiscal year were developed by consultants? (AASHTO 2005)	Apparent (computed) increase (+) or decrease (-) in use of consultants from 2005 to 2017
	State Employees	Consultants	Local Agencies	Other		
New York	40	60	0	0	50 – 60%	0%
North Carolina	35	60	5	0	30 – 40%	+20%
Ohio	35	60	5	0	60 – 70%	0%
Oklahoma	50	45	5	0	40 – 50%	0%
Ontario	5	50	0	45		
Pennsylvania	30	65	5	0	80 – 90%	-15%
South Carolina	45	45	10	0	20 – 30%	+15%
South Dakota	80	20	0	0	10 – 20%	0%
Virginia	30	40	30	0	0 – 10%	+30%
Washington	95	4	1	0	20 – 30%	-16%
Wyoming	75	10	15	0	20 – 30%	-10%

APPENDIX XI: QUESTIONS FOR ENGINEERING DESIGN MANAGERS

The researchers conducted one-on-one telephone interviews with a select number of practitioners in private practice, working for architecture- and engineering-design companies. The interviews were semi-structured, based on the following 13 questions. Interviewees were emailed a copy of these questions before they were interviewed so they could prepare to discuss them. Subsection II.4 of this Report presents the take-aways from these interviews.

Questions for Engineering Design Firms (19 April 2017)

Respondent's name:
Respondent's firm:
Date and Time of interview:
Interviewer's name:

The California State Legislature has instructed the University of California to review the software system (called PRSM) that the California Department of Transportation (Caltrans) is using for agency-wide management of its portfolio of State highway projects.

As a comparison to Caltrans we would like to know how your firm manages public agency projects in California. As background, we understand the qualification based selection process, and how it is required for these projects.

1. At what level in your firm is the decision made to propose on a contract?
    - At the local office level?
    - At the level of a regional director with authority over several offices?
    - At the national level?
    - At the global headquarters level, with authority over the entire multi-nation firm?
2. Are there thresholds that limit the size of contract that a local office can propose on without approval from regional or national directors?
3. If a contract is too large for a local office to handle on its own, or needs skills not available in the local office, where do you look for additional resources?
4. Is there a sequence that you normally follow in looking for additional resources? (If this question appears to be misunderstood, or if one of the items below is not mentioned, ask): Would that be from areas such as:
    - Other offices within your firm?
    - Other firms in the area?
    - Additional employee hires?
    - Independent (one-person firm) sub-consultants?
    - Other?

Is there a sequence among these sources? That is, where do you look first (and where second, third, etc.)?

5. Understanding "portfolio management" to mean the centralized management of all the projects in an organization in order to optimize overall resource use, and "project management" to mean the one-by-one management of individual projects, would you characterize your firm's approach as mainly "portfolio management" or "project management"?

If the answer to Question 5 is "project management", skip to Question 7.

6. At what organizational level is the portfolio established? Is the organization across which the portfolio established:
    - A division of the local office?
    - The local office?
    - A multi-office region?
    - All the offices in the nation?
    - All the offices globally, throughout the multi-national firm?
    - Other?
7. Do you have a commercial software suite that you use as your system for project management on Architectural and Engineering (A&E) projects?

If the answer to Question 7 is "No", skip to Question 11.

8. Is the use of this project management system mandatory in your firm?

If the answer to Question 8 is "No", skip to Question 10.

9. How broad is the mandate within the firm? Is it mandated:
    - For a particular set of projects? (please explain)
    - Within a division of the local office?
    - Within the local office?
    - Within a multi-office region?
    - Throughout the nation?
    - Globally, throughout the multi-national firm?
    - Other?
10. What project management software suite do you use?
11. Do you have any questions for us?
12. In our report, may we name your firm or do you prefer to remain anonymous (e.g., Company A)?
13. If we have additional questions, may we contact you again?

Thank you for your time, we greatly appreciate your participation in this study.