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A Case Study of Enterprise Historic Resources Information Management in Large Transportation Agencies

MTI Report 09-06

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MTI Report 09-06

A CASE STUDY OF ENTERPRISE HISTORIC RESOURCES INFORMATION MANAGEMENT IN LARGE TRANSPORTATION AGENCIES

January 2010

Eric E. Ingbar

a publication of the
Mineta Transportation Institute
College of Business
San José State University
San José, CA 95192-0219
Created by Congress in 1991

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. CA-MTI-09-2502	**2. Government Accession No.**	**3. Recipients Catalog No.**
4. Title and Subtitle A Case Study of Enterprise Historic Resources Information Management In Large Transportation Agencies		**5. Report Date** January 2010 **6. Performing Organization Code**
7. Authors Eric E. Ingbar, M.A.		**8. Performing Organization Report No.** MTI Report 09-06
9. Performing Organization Name and Address Mineta Transportation Institute College of Business San José State University San Jose, CA 95192-0219		**10. Work Unit No.** **11. Contract or Grant No.** 65W136
12. Sponsoring Agency Name and Address California Department of Transportation Sacramento, CA 94273-0001	U.S. Department of Transportation Office of Research—MS42 Research & Special Programs Administration P.O. Box 942873 400 7th Street, SW Washington, D.C. 20590-0001	**13. Type of Report and Period Covered** Final Report **14. Sponsoring Agency Code**
15. Supplementary Notes		

16. Abstract

Historic resources are in some way managed by every transportation agency in the nation. Transportation agencies manage historic and prehistoric archaeological sites, buildings, structures, objects, routes, landscapes, and districts to prevent damage to such resources and to mitigate damage when it is unavoidable. In order to track known resources, transportation agencies often keep local files in a variety of forms, rely upon external sources of information (e.g., historic preservation agencies at the state level), and depend upon staff expertise gained by years of local work.

Starting in 1997, Caltrans started a series of surveys of rural rights of way in its district offices. This work, which is still on-going, created fairly similar sets of digital data within approximately half of the agency's district offices. The GIS datasets and relational database management systems are roughly similar between offices, but not identical.

The present study focuses on defining how the district office information systems for historic resources can (and cannot) be used to create an enterprise information management model specific to historic resources within Caltrans. Results of this study range from findings specific to Caltrans and its district offices to general findings that should apply to any transportation agency contemplating an enterprise-wide system for managing cultural resources.

17. Key Words Geographic information systems; History; Historic preservation; Native Americans	**18. Distribution Statement** No restrictions. This document is available to the public through The National Technical Information Service, Springfield, VA 22161		
19. Security Classif. (of this report) Unclassified	**20. Security Classifi. (of this page)** Unclassified	**21. No. of Pages** 52	**22. Price** $15.00

Form DOT F 1700.7 (8-72)

Library of Congress Catalog Card Number: 2009943708

To order this publication, please contact the following:
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ACKNOWLEDGMENTS

The work reported here would not have been possible without the help of many different individuals. Margaret Buss, Billy Silva, Anmarie Medin, and Glenn Gmoser at Caltrans headquarters in Sacramento have been ardent supporters of an enterprise approach to managing cultural resource information in their agency. Their assistance has been invaluable in tying the project into Caltrans practice overall. In the Caltrans District Offices, Russ Adamson of District 2 and Carie Montero of District 4 have been patient and helpful collaborators. Russ, in particular, assisted immensely in modeling the conversion of existing information tools to a more enterprise-like format.

Outside of Caltrans, the faculty at San José State University (SJSU) and the Mineta Transportation Institute have made working on this project relevant to a larger audience than just Caltrans. Stella D'Oro, a SJSU graduate student was instrumental in the Caltrans needs survey and in helping to set up the plan for assessing how the different district databases function. Dr. Mark McCoy and Dr. Marco Meniketti served as advisors to the project for SJSU.

Jerome King of Far Western Anthropological Research Group has been the ideal colleague throughout this research: consistently helpful, willing to share ideas, products, and information.

In my own office, Marybeth Grant has helped with writing, managing, and coordinating. Without her assistance, the project would never have finished. Sally Rubio has provided administrative help.

Four peer reviewers provided very useful comments and criticisms. I greatly appreciate their patience in reading this manuscript, thinking about it, and giving clear directions for its improvement.

While all of these great people have helped with this research, faults and errors are mine alone.

The authors also wish to thank MTI staff, including Research Director Dr. Karen Philbrick, Communications Director Donna Maurillo, Research Support Manager Meg Fitts, Student Publications Assistant Sahil Rahimi, Webmaster Ruchi Arya, Research Support Assistant Chris O'Dell, and Graphic Artists J.P. Flores and Vince Alindogan.

Final editing and proofreading services were provided by Catherine Frazier.

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EXECUTIVE SUMMARY

This study presents the results of a multi-year planning, assessment, and pilot data conversion study concerning digital information about historic resources. The study had as its goals recommendations concerning the most effective mechanisms for implementing enterprise-wide digital data systems for the inventory, assessment, management, and protection of cultural resources.

The study examined information use in Caltrans District Offices and the agency's headquarters. Also examined was how other agencies and participants in the cultural resource management process created and used such information, both on paper and (increasingly) in digital forms.

In order to examine how conversion of information from one system to another might affect adoption of an enterprise approach, a specific application and set of data was converted to a different, more widely used, application and data model.

During the course of the study, the agency itself changed its approach to system development. This was beneficial to this study, because it allowed examination of impediments within the organization that a simpler study, focused more on needs assessment, would not have uncovered.

INTRODUCTION

This research project focuses on the role of information technology in one particular aspect of transportation agency activities: cultural resource management. The explosion of information technology in all aspects of transportation organizations is nothing new to the cultural resource management divisions of most Departments of Transportation (DOTs). Cultural resource managers in DOTs have systematically collected maps, documents, and photographs since the 1930s. In digital technology, DOT cultural resource programs have been leaders since the 1970s. In most DOTs, the cultural resource staff have relied upon information management (on paper, a computer, or both) far longer than their other colleagues in related environmental disciplines.

Information management in transportation agency offices has been a long-standing work practice, but it has been, and largely still is, somewhat idiosyncratic at a national and even state level. Each office may have its own organization of paper and electronic records. Some offices rely upon external information sources entirely while others, even in the same state DOT, use only internal files. Where digital systems are used, the content and format may vary from one office to another, or even from one professional to another in the same office.

Enterprise information management systems eliminate variation and increase efficiency within an organization's data systems. Such systems address the collection or dissemination of information and operational needs for information across multiple departments, offices, and individuals within an organization. Within a given work specialization, enterprise information systems conform to operational requirements (i.e., business rules) and store or display information in operationally appropriate ways (i.e., domain-specific data and terms).

Enterprise systems are generally more efficient than individual office systems within the same organization for several reasons. First, the time and effort expended by people using the system can be minimized: training, procedures, and workflow follow a single model. Movement within the organization from one office to another does not necessitate re-training. Second, because information is stored and presented in consistent, appropriate ways, work itself is accomplished more efficiently. Unique pockets of information are made more widely available, and redundancy is eliminated. Third, software and hardware support time and costs can be less because a single infrastructure is maintained, rather than multiple isolated computer systems. Because of these benefits, enterprise approaches are common in information technology.

Drawbacks to enterprise information management systems also exist. Because the very nature of these systems is to make information more uniform, there may be a loss of locally valuable data. Individuals may feel that they are being forced to abandon tried and true work methods in order to conform to a computer system. Changing the system may become more difficult as software and procedures become larger and less easy to alter. Enterprise systems can be jeopardized if long-term support for them declines or is removed; this is especially hazardous to enterprise systems that appear to offer little operational benefit.

Cultural resource management is a fairly uniform process that relies upon an extensive information base. The processes used in every state are similar with some local variation to accommodate state and local laws and policies. The record of cultural resources is cumulative: decisions about project management and impacts to historical resources (sites, buildings, bridges, and other defined types) are almost always made in light of existing knowledge about those resources and others similar or nearby. Consequently, cultural resource management is an excellent candidate for an enterprise information management approach.

CALTRANS AS A STUDY SUBJECT

The work processes of cultural resource management staff in DOTs are fairly consistent at a national level. Because most transportation projects involve federal funding, DOT cultural resource specialists follow federal guidelines and procedures. Some states have state laws that also dictate additional procedures but these usually add on to the federal process rather than replacing it with something different. In short, while there has not been an enterprise model for cultural resources management information within DOTs, the domain is appropriate for the formulation of such a model.

Caltrans (the California Department of Transportation) is the nation's largest state transportation agency. Caltrans has twelve district offices (DOs) and a headquarters in Sacramento. The District Offices do the bulk of Caltrans project-driven construction and maintenance activities. Staff in the DOs perform planning, permitting, and compliance actions needed for such projects. Caltrans is therefore an excellent case study for an enterprise information approach: it has thirteen different offices, twelve of which share similar day to day needs, and a central office that must draw together information from all of the districts. Although each district has its own information content, the need to access, update, and share that information is the same in all of the offices.

California itself is a complicated landscape for information about cultural resources. Caltrans staff interact with regional archives where previous studies and information about known cultural resources are stored. This information is sometimes, but not always, redundant to records already on file in district offices. The need for an enterprise approach to information management is widely acknowledged by DOT staff. They are well aware that digital technology makes information sharing easier, but inconsistent information will hamper or even disable the use of shared information.

Study Goals

This study is an assessment intended to aid Caltrans, and similar agencies (especially DOTs), in implementing enterprise approaches to historic resources information management. The study addresses:

- What functions define an enterprise system for historic resources information?
- What architecture aids or hinders such a system?
- Which existing data models, if any, best suit such a system for Caltrans?
- How can one transition smaller data systems to a common model?
- What planning, permission, management and other processes should be used to implement an enterprise approach? What pitfalls should such an approach try to

avoid?

The study also undertook a specific case study, converting District 2's information management system to the District 4 application and data model. This conversion was done to determine whether the District 4 application and data model best fit Caltrans needs, and to determine what problems integrating other information (even from other agencies) such a model might present.

Study Methods

This study proceeded in several phases to accomplish the goal of assessing the value of an enterprise approach, designing the general characteristics of an enterprise system, and defining a pathway to move Caltrans toward such a system. The study began in late 2006, having first been proposed in 2003. It was completed in the second quarter of 2009.

The study proceeded in a series of general steps, some of which were concurrent or overlapping:

- Examination of existing general characteristics of cultural resource systems and earlier proposals for designs for these systems.[1]
- Collection of existing Caltrans cultural resource databases, including GIS datasets (when available), user manuals, and points of contact for further information.
- Collection of existing California-specific data models extraneous to Caltrans from other agencies, including information centers (regional archives), California Office of Historic Preservation, the Bureau of Land Management, the U.S. Forest Service, and the National Park Service.
- Assessment of Caltrans staff needs through an on-line questionnaire, telephone interviews, and meetings.
- Assessment of Caltrans overall information technology infrastructure from telephone interviews with information technology staff, meetings, and discussions with Caltrans Joint Application Development Team (JADT) for cultural resources.
- Examination in detail of District Office systems as candidate data models for an enterprise system. This examination comprised detailed dissection of data tables, composite data entities, geographic information system (GIS) dataset models, and study of the user interfaces present in each system.
- Evaluation of a candidate data model by actual conversion of an existing, functional, system (used in Caltrans District 2) to a candidate system (Caltrans District 4), followed by interviews with District 2 staff to evaluate how the newer system worked compared with the older one.
- Formulation of needs and requirements for an enterprise model and drafting of a preliminary model.

Study Presentation

The first section of the study is a brief summary of cultural resource management processes, so that those unfamiliar with the subject matter have enough knowledge to comprehend the rest of the report.

The study then examines information gathering and use within the context of cultural resource management. This general summary is elaborated upon by a summary of how Caltrans cultural resource managers gather, maintain, and use information in digital and paper forms at present.

Following this summary of the current status of information system development within Caltrans cultural resource management, a high-level data model for cultural resources information is presented. This model is elaborated upon in the context of “project-driven” needs like those of a transportation agency.

The study then turns to an examination of two existing data systems within Caltrans. In order to understand barriers to enterprise adoption, one of the systems was converted to a newer system. This substantial task (approximately 200 hours of effort), revealed a lot about the structure of the “small” data systems used in the agency. Using this experience, and knowledge gained through Caltrans staff interviews, meetings, and correspondence, the characteristics for an enterprise system are discussed.

The study concludes with both a retrospective on its course and a prospectus for the implementation of enterprise information management systems in transportation agencies generally and Caltrans specifically.

CULTURAL RESOURCES AND INFORMATION MANAGEMENT

The Cultural Resource Management Process

A general understanding of cultural resource management is necessary to understand the rest of this study. Cultural resources (also called heritage resources or historic resources) are the physical remains of prior human activities and also the locations of prior activities. In the western United States, the most numerous cultural resources are archaeological sites. Historic buildings are the next most common cultural resource, with structures (constructions not designed to have an interior for human occupancy) also quite frequent. Other types of cultural resources defined by the National Register program,[2] including historic districts (aggregations of cultural resources), objects (e.g., statues, monuments), landscapes (areas of historic or heritage value that retain characteristics of a sense of place and history), and traditional cultural properties (places or landscapes of value to Native Americans). In general, a fifty year cutoff is used to determine if a site, building, or object is of potential historical interest.

The Federal Highway Administration (FHWA) and state DOTs must all comply with the National Historic Preservation Act of 1966 (NHPA; Public Law 89-665; 16 U.S.C. 470 et seq.). Among other provisions, the NHPA requires that any federally funded or permitted project must evaluate the project's effect upon historic properties. A historic property is an instance of one of the property types above that has been deemed to be eligible for inclusion on the National Register of Historic Places (NRHP). The property need not actually be enrolled on the NRHP but must meet specific criteria that might justify its enrollment. A term of art used for such properties is that such a property possesses "significance."

Another important regulatory constraint is Section 4(f) of the Department of Transportation Act (DOT Act) of 1966. Regarding non-archaeological cultural resources e.g., buildings, structures), Section 4(f) requires that any (federalized) action affecting cultural resources must be both unavoidable (no feasible alternative) and minimize harm to significant cultural resources.[3]

Caltrans, the subject of this research, is also bound by state requirements, notably the California Environmental Quality Act (CEQA). CEQA mandates that any project requiring a discretionary permit be reviewed for the presence of significant cultural resources. State guidelines, fairly similar to those used in federal regulations, are used to determine significance.[4] Projects that will affect significant resources must be redesigned or, as a last resort, conduct excavation and analysis, or "data recovery."

The regulatory frameworks discussed above impose requirements concerning cultural resources on DOTs. Since these requirements are similar nationally, information systems for cultural resource management can be similar from one DOT to another. Again because the requirements are similar nationally, DOTs follow roughly the same cultural resources management processes when implementing a specific project (Figure 1). These processes determine the content and form of a cultural resource information system.

First, a DOT determines whether a proposed action or undertaking ("project") is even subject to review. Some kinds of actions have little potential to affect cultural resources and are therefore categorically excluded by agreement. Exemptions from review may be dictated by programmatic agreements between a DOT and one or more agencies. Usual parties to such an agreement include DOT, State Historic Preservation Office (SHPO) and, if the right of way lies on public lands, the land managing agency such as BLM. A review agency—almost always the State Historic Preservation Office (SHPO)—land managing/owning agency such as the federal Bureau of Land Management (in California). Programmatic agreements may specify excluded actions that are exempt from review in specific regions, settings, or times (e.g., in a formally declared emergency). Caltrans, for example, utilizes a programmatic agreement with FHWA, SHPO, and the federal Advisory Council on Historic Preservation (ACHP). The Caltrans agreement lists 29 situations in which proposed actions are exempted from review so long as specific screening procedures are followed.[5]

Second, if a proposed action is subject to cultural resources review, the next step is to identify who will participate with the DOT in the review process. Review almost always involves the SHPO and in the western United States it often involves federal agencies that actually "own" the land traversed by highways and their rights of way. Tribal Historic Preservation Offices (THPOs), representing sovereign tribal governments, may also be involved. The review parties may discuss changing the scope of an undertaking with the project proponent and lead agency, if appropriate. It is not uncommon for the review and consultation process to provoke some re-design to alter an undertaking's area of potential effect (APE).

Third, cultural resources within the undertaking's area of potential effect (APE) must then be identified and assessed as to their significance. Existing, known, cultural resources may be found through a search of records of previous cultural resource inventory. As well, fieldwork may be done specifically to identify new cultural resources or to reassess the significance of resources already known to be present in an APE.

DOT staff usually start by searching existing documents and studies. Many DOTs (and SHPOs) maintain map archives in which each known cultural resource is plotted on a map. Inventoried areas may also be plotted on maps. Since projects are inherently geographic in nature, maps are the preferred way to locate known cultural resources and previous cultural resource studies. Not surprisingly, geographic information systems (GIS) is becoming the dominant form of map information for this purpose. Once known resources and studies are identified, further work may involve gathering the standardized resource records (used in most states) and studies. These documents are still generally paper items.

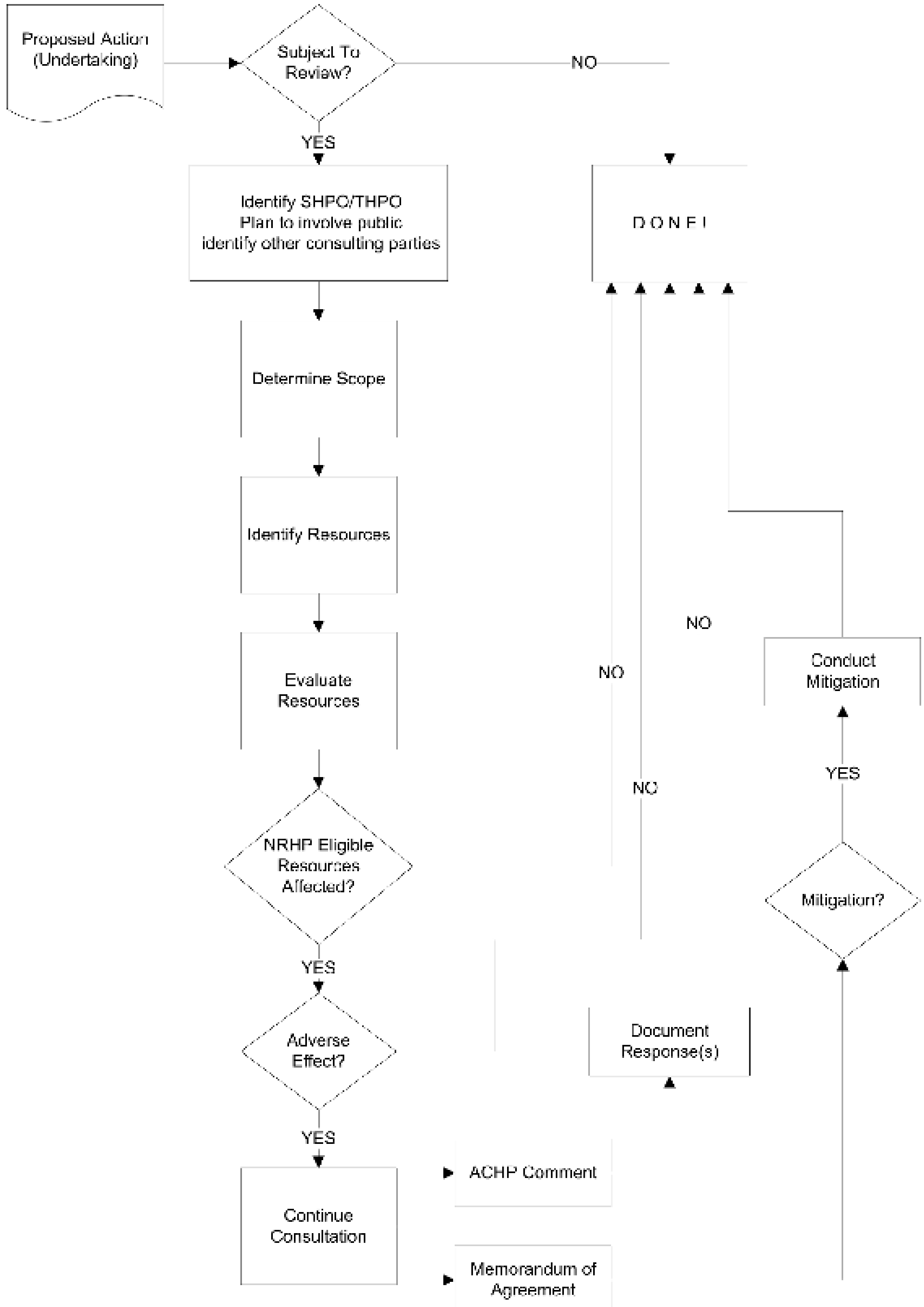

Figure 1 General Cultural Resource Management Process

Fourth, unless an APE has been inventoried recently, some fieldwork usually follows the records check phase. Fieldwork may visit only selected already known locales, or may systematically search for new resources. In the western U.S., new archaeological resources are usually found by surface inventory, seeking artifacts, traces of structures, or archaeological features. In the rest of the country, archaeological resources are usually found by a combination of surface inventory and subsurface probing to find buried or litter-covered traces. Buildings, structures, and objects are found by inspection alone. Landscape attributes, such as historic trail routes, may require a combination of seeking physical evidence and turning to historic documents to find probable locations.

Once found, new resources are recorded in state-determined formats and a narrative report is usually prepared. These documents become part of the archival record itself. Since cultural resources are non-renewable, each recording of a resource or collection of materials from it, is considered to have value forever.

Fifth, the cumulative knowledge of cultural resources is essential to the next stage in the cultural resource management process: the determination of each resource's significance. In brief, resources are significant if they are rare, are particularly characteristic of a time or event, are associated with important historical figures or events, or have a high potential to yield important scientific information. Obviously, these criteria rely upon knowledge of all other known cultural resources.

The reliance upon previous knowledge makes cultural resource management somewhat different from many other environmental regulatory programs in DOTs. For example, wetlands are regulated under federal and state laws—yet, assessing the significance of a wetland is done without reference to the regional population of known wetlands, relying instead upon the functional characteristics of the wetland itself. Cultural resources are generally evaluated for significance, rarity, and other qualities within a context of admittedly imperfect knowledge. Not all cultural resources are known prior to a specific evaluation event. Over time, as more knowledge is gained, the context itself changes. The closest analog to cultural resource management decision-making is threatened and endangered species considerations, in that the possible destruction of plants or animals must be considered in light of knowledge about each species as a whole. However, most environmental regulatory programs focus on contemporary knowledge only (e.g., wetland delineations use current fieldwork only, and are not required to consider earlier field examinations).

There is no single formula for evaluating the significance of cultural resources, nor is evaluation simply an art. Instead, a combination of expertise and information are used to make significance determinations. The problem is amenable to information technology solutions. Indeed the Transportation Research Board sponsored work that created two computer applications to assist in significance judgments.[6]

Sixth, if significant resources are present in the APE, and the proposed action will have an effect upon those resources, some form of mitigation of the adverse effects must be made. Sometimes the proposed action is changed either in extent or characteristics, so that no adverse effect impacts the resource. An adverse effect may also be mitigated through some other action, such as data recovery. The least preferred alternative is to allow an undertaking to proceed with an adverse effect to cultural resources. When this occurs, some form of agreement document is always created.

Information Collection in the Cultural Resource Management Process

A salient feature of the cultural resource management process is that it relies upon the timely collection of new information and the availability of existing information. Decisions are made, and information gathered at several junctures in the cultural resource management process. Fieldwork—discovery of historical resources—is an obvious information-gathering activity. The necessity to conduct field research is itself usually judged based on prior knowledge of an area. Cultural resources management decisions at almost every level—fieldwork, permitting, preservation, interpretation—depend upon the cumulative body of knowledge about the past.

Returning to Figure 1, one can distinguish moments in the process where new information is gathered for use or existing information is employed. Table 1 summarizes the kinds and forms of information gathered and used. Though cultural resource-specific information (sites, surveys, etc.) is essential, some other kinds of information used in the process are general. For instance, a list of common highway maintenance activities that are excluded by law or agreement from being subject to review is important to the process, even though it affects review actions outside of cultural resources too. An information management strategy for cultural resources should, if possible, recognize the existence of relevant non-cultural information.

Table 1 Information Gathered and Used During Cultural Resource Management Process and its Common or Potential Formats

Process Step	Information Gathered	Information Used	Format
Proposed Action	Proposed actions area of potential effect (APE)	May be informed by already known or suspected cultural resources (e.g., a predictive model of archaeological site presence)	Maps, plans, regional and long-term planning documents. Maps (or GIS) may be of highest value.
Subject To Review Decision	Whether subject to review	Information on policy, agreements, regulation relevant to nature of activity	Documents, lists of exemptions, categories of activities. Tables (non-spatial data) of highest value.
Identify Parties Involved	Names and contacts of relevant parties	Existing, known, parties (e.g., address and contact index)	Lists (tables in database systems).
Determine Scope	Modified area of potential effect (could be several iterations)	Area of potential effect. May be iterative process of definition	Maps and descriptions. GIS datasets in electronic systems.

Identify Resources	New fieldwork results—areas of inventory, new or re-recorded cultural resources. Presented as paper and possibly electronic records (GIS, tables).	Existing areas of inventory, known cultural resources. Paper archives and electronic data may both be used.	Paper maps, study documents, resource records. GIS and database records in electronic systems.
Evaluate Resource Status Decision	Characteristics of known resources	Characteristics, criteria for significance, population of similar resources and their geographic distribution.	Context documents that direct evaluation of different types of resources (tables, narrative). Maps of resource type distributions. GIS and tabular data in electronic systems.
Adverse Effect Decisions	Evaluation of impact of undertaking on each NRHP-eligible resource.	Most current NRHP status of resources.	Lists or tables, tabular data in electronic systems.
Agreements Documents	Characteristics of agreement (e.g., start date, end date, decision-making procedures, report requirements)		Typically retained as files of paper documents. Could be both GIS (agreement geography) and tabular data on characteristics along with document image.
Consultation and Documenting Responses	Respondents, response date, kind of response		Typically retained as letter files, could be tabular (list) and document image.
Mitigation Actions	New information about cultural resource, typically in written report.	Existing information about similar or even the same cultural resource.	Paper report, could be retained as document image. Association of mitigation with individual resource kept in list.
Done	Date that process was completed allowing action to go forward or not.		Note to file, or database table entry tracking history of undertaking.

A key feature of cultural resources information is that it has value in several different time frames and activity realms within transportation agencies and that information tends to get re-used in these different decision-making contexts. As the table above shows, in many DOT cultural resource management programs, the most common actions require some existing information to be available initially, and then the activity will generate new information of potential use in other iterations of the cultural resource management process.

Because DOTs are "project-driven," the major information collection and use points are mostly determined by planning, permitting, and construction needs. Typical components of DOT project cultural resources management (shown in Table 1) are:

- General planning: determining in general where cultural resource conflicts could impede DOT activities
- Project scoping inventory: determining where cultural resources occur within a specific proposed project footprint through record searches and (if needed) fieldwork
- Historic resource status assessment: determining the legal status of each resource within a specific proposed project footprint, and tracking whether its legal status has changed over time
- Mitigation of project effects: collection of records, information, and other activities intended to offset damage to significant resources

Some information is more useful, or valuable, than other kinds of information. An efficient information system must make this higher value information available, even at the expense of less useful information. Because so much of the cultural resource management process has been done on paper, it is pretty easy to define the high-value electronic information—it will be digital forms of the high-value paper documents.

Determining whether an APE has been inventoried is an important decision that relies upon accurate knowledge of previous work. Two kinds of information are needed to make this determination:

- Whether the APE is already systematically inventoried for cultural resources and if so, when, and whether the inventory was done to current standards.

- What cultural resources are known to be within and nearby the APE, no matter how they were found?

Maps, or GIS in the electronic realm, are obviously of very high value in this step of the management process. Note, however, that the attributes of the cultural resources or inventories are equally important. It is necessary to know where these things are, but not sufficient in itself, for one must also know the characteristics of inventories, the types of cultural resources, and the NRHP eligibility of each resource.

Once recorded, or known, the cultural resource management process requires evaluation of a resource's significance to history, science, ancestral groups, and the public in general. Significance evaluations can be made more than once over time, so they potentially vary. For the cultural resource management process, one needs to know the most current significance, either by making a new evaluation or by finding the most recent prior NRHP-status determination. Typically, tables of such information are very useful (as opposed to storing the information in resource-specific paper files).

The legal status (significance) of each cultural resource is mandatory to assess the effects of an undertaking on a cultural resource. Legal status decisions about National Register eligibility are largely framed in terms of how a particular historical resource adds to existing appreciation or knowledge of historical events. Making such a decision requires one know the constellation of resources already considered valuable for a particular historical or scientific context. So, while tables are the most useful way to track information about legal status of particular resources, a combination of maps and tables, or GIS and attributes of the electronic map features, is the most effective means for evaluating a single resource against the regional population of such resources.

Once the significant historical resources within a project are known (if any), an assessment of the effect of the project is made (and concordance sought with other regulatory authorities). Decisions ("determinations") of an undertaking's effect on significant resources can change during the course of project scoping and consultation. An undertaking may be re-scoped several times for intrinsic reasons or to avoid impacts to resources of many sorts (not just cultural resources). The final decision about project impact, or effect, is usually retained in the form of letters and, sometimes, plans for mitigating impacts.

Most of the data or information discussed above is integral to the work of cultural resource specialists, who use it internally to make yes or no decisions about plans, problems, and moving forward with a project. These decisions are then passed on to other parties (e.g., a project environmental manager). So, the "enterprise outcome" of the work done by cultural resource specialists may be a simple yes/no result—yes, all cultural resources concerns have been addressed or, no, they have not yet been addressed fully. This status value (yes/no) may itself be enterprise-level data, used by project planners, engineers, and other staff.

External non-cultural resource specialists also may use more detailed information about cultural resources. Several recent studies on transportation planning and cultural resources found that planning (and subsequent implementation) efforts benefit greatly by having cultural resources information as early as possible. Appropriate knowledge of cultural resources allows transportation construction to have the least potential to affect archaeological sites, buildings, and most other types of cultural resources.[7] Cultural resource inventories—knowing the population of cultural resources—is of highest value in the planning process.

Models of the probability of finding cultural resources—especially buried archaeological sites—are important planning tools too. The cost of archaeological inventory prevents many DOTs from doing "planning" surveys to locate archaeology within their areas of operations. Many environments cover archaeological sites so that they are not visible from surface inspection, and must be found by probing or are not found until construction is under way. Both of these situations—lack of inventory, and difficulty of finding buried materials—are in part handled through archaeological resource forecast models. These models may predict where sites are most likely to be found, to be buried (and thus a potentially unwanted surprise), or both. Planners use such models to find least risk areas in which to stage transportation projects.[8]

CALTRANS AND HISTORIC RESOURCE INFORMATION

Caltrans staff have a long-standing commitment to information management. In the past, staff used District Office-based archives of paper maps and records. During the past twenty years, Caltrans staff have moved toward digital indexing and storage of the primary phenomena of interest to cultural resource specialists: areas of inventory and known cultural resources.

Over time, Caltrans cultural resource staff have pretty much devised their own methods for archiving records and for keeping digital information. Until the past few years, each District Office organized its records as it pleased. Because there are many smart and inspired professionals working for Caltrans, uniformity occurred because good ideas were shared swiftly. Similarities between District Offices were due more to congruent interests than to strategic information planning.

None of this is to say that Caltrans cultural resources staff lack a keen interest or desire to move to some standardized technologies for information management. During the course of our staff survey (conducted in 2007), we found that most staff members were eager to have some kind of combined GIS and database management system. Indeed, one respondent summed up his office's view as "the sooner the better, it doesn't have to be perfect because anything will be a huge improvement for us."

This section summarizes how Caltrans, as a specific example of a transportation agency, generates and uses technology to manage cultural resource information. Obviously, Caltrans history will be different from that of other transportation agencies. Nevertheless, with twelve offices throughout a very large state, the range of variation within this one agency is probably typical of the national range.

Like many DOTs, Caltrans relies upon staff in its field offices (District Offices or DOs) to accomplish day-to-day project planning, scoping, and management. Cultural resource specialists in DOs are the agency's experts on these resources in formulating plans for construction and maintenance. As projects move from planning to actual scoping, the heritage resources staff in the twelve Caltrans District Offices are responsible for compliance with federal, state, and in some cases, local historic preservation laws and regulations. In each of the twelve offices, a designated Heritage Resource Coordinator (HRC) is the senior authority responsible for legal compliance. The HRC and other heritage resource experts are all located in environmental divisions or sections.

Prior to a series of projects funded by the federal Transportation Enhancement Act, Caltrans DOs kept records in whatever format was convenient. Common practices included the use of U.S. Geological Survey 1:24,000 scale quadrangles to plot cultural resources and surveys, retention of paper records in a variety of filing systems (by state number, by temporary number, by resource type, etc.), and libraries of reports of work filed (usually) by Caltrans project number (expenditure authorization, or EA). Documents were shared in a variety of ways. Most DOs had map libraries, some had shared document libraries, and others had idiosyncratic, essentially personal collections of information based upon the work of individual specialists.

Caltrans did (and does) participate in the statewide information network for cultural resources headed by the state's Office of Historic Preservation. The information center system, consisting of twelve independent entities that operate using uniform standards and procedures, cover the state. While these are discussed in further detail below, Caltrans District Offices have a long history of support and use of the centers. The centers are used by Caltrans and its contractors for records that fall outside of Caltrans record-keeping. This can be due to new work in areas where Caltrans has never dealt with cultural resources (e.g., a road extension) or because a particular District Office lacks some records (or thinks it does).

The Caltrans TEA Inventories and Information Collection at Caltrans

The somewhat haphazard methods used in offices began to change in 1997, when Caltrans District 2 (central coast area) and District 5 (northeastern California) began cultural resource inventories of rural rights-of-way. These inventories, funded by Transportation Enhancement Act (TEA) funds, covered approximately 800 and 1200 miles of rural highways, respectively. Due to their large scale, each inventory was accompanied by well-defined information management strategies. Protocols and standards were created for:

- Global Positioning System (GPS) field recording of map boundaries and other phenomena of cultural resources, including standardized data dictionaries used in field equipment
- GIS datasets
- Cartographic symbols
- Database tables to hold attributes and other observations about cultural resources and to produce state-mandated cultural resource recording forms
- Electronic storage of background documents and existing recording forms

The systems created in the first two DOs were slightly different, but achieved many of the same functions for Caltrans staff:

- GPS use became standard for cultural resource specialists through equipment acquisition, training, and procedure manuals
- Desktop GIS systems were put in place on at least one specialists desktop in each office with electronic maps of inventory results and previously known cultural resources
- Production of standard cultural resource recording forms was done through a database application
- Document library structures were defined for electronic files
- In each DO, one or more staff were trained in how to integrate the four major kinds of digital information (GPS, GIS, database, scanned documents)

The two data systems created in the initial TEA inventories were far more similar to each other than they were different. Specific differences are discussed further below; here, the important point is that although the data systems were similar in form and function, they were still considered "district-level" products that need not talk with each other or with any more centralized store of information.

The District 2 and District 5 TEA inventories were judged successful by Caltrans, and TEA-funded inventories of many other districts have followed. Districts 1, 3, 4, 6, and 10 have used a descendent system from the initial District 5 project. District 11 used a somewhat different variant based upon both District 5 and District 2 models and a pre-existing District 11 database and GIS.

CALTRANS TODAY

To this point, in 2009, Caltrans has created fairly comprehensive inventories of cultural properties in rural rights-of-way. The results of these inventories are stored in two similar information management systems that incorporate desktop databases and geographic information systems. These cover the network of highway rights-of-way subjected to inventory and are shared within District offices but not system-wide.

Because these systems are similar, but slightly different, Caltrans has not developed a single information management model and tool that can be utilized statewide. This hampers Caltrans environmental management in several significant ways:

- No global, statewide, view of Caltrans performance on environmental commitments or stewardship is possible without polling each district
- Each District that contemplates automating cultural resource information is tempted to build its own system, further hampering effective oversight and adding cost to automation
- The proliferation of independent information systems makes it difficult to come up with permit and construction management processes that are consistent, because such processes typically rely upon uniform, timely, data information (about cultural resources, about impacts, about other resources, etc.)
- Training agency staff in using electronic tools is more difficult and costly when each office has its own interfaces, applications, and conventions
- Interaction with external agencies is facilitated at the District Office level because of digital data, but for agencies that span multiple DOs, information exchange is more difficult because it is not uniform. Even slight differences in information format can require substantial GIS and database editing sessions. Eventually, external agencies conclude that digital data exchange is not worthwhile, and so the benefits in time and cost of sharing data are not realized.

California lacks a single coordinated information system for cultural resources. In some states, there are consistent, shared, statewide information systems for cultural resources. These are usually run by the state historic preservation offices. In California, a dozen different Information Centers (ICs) run in conjunction with the Office of Historic Preservation (California's state historic preservation office) are the archives for different counties within the state. Information Centers are self-supporting enterprises housed in California universities (although one IC is now hosted by a tribal government). ICs depend upon file search fees to pay their costs, which in turn depend upon the pace of economic development in the counties for which an IC is the archive.

The ICs and OHP have created uniform standards and procedures, but differences in revenues has historically caused differences in the ICs for archive users. Well-funded ICs tend to get records processed more swiftly, so it is easier to search for already known cultural resources. Until the past five to ten years, almost all IC files have been on paper, including maps, copies of narrative reports, resource recording forms, and photographs. Basically, to do background research, one has had to go to an Information Center and search paper maps, finding the “processed” records on those maps, and then search “unprocessed” records for additional phenomena. The latter are sometimes boxes of material lacking any geographic organization. Over the past dozen years, some information centers have digitized major parts of their records into GIS, index databases, and scanned document collections. This work is on-going. Most of the ICs furthest along in these efforts received substantial help from the TEA inventory projects. Caltrans turned over data from the background file search digitization and new fieldwork, or directly paid ICs to create background file search GIS. Interestingly, these Information Center and District Office combinations have not resulted in the creation of shared digital information systems for historic resources; each organization has its own similar (but different) set of applications, procedures, and data. As of this writing (2009), the ICs are still moving toward common standards and formats for data and for in-house data management tools, but have not yet arrived upon them.

Caltrans, directly and through its contractors, has been an important consumer of Information Center services. For many District Offices, Information Center fees are a significant part of the cultural resources program budget—accounting for perhaps as much as half of a full-time equivalent salary, if one considers the fees paid by Caltrans contractors as part of work done for the agency. As Caltrans develops its own information management resources, the ICs will probably see some decrease in revenue, since DOs will no longer routinely pay for searches at information centers.

A particular problem for Caltrans offices is that district boundaries are not concordant with Information Center boundaries. So, one district office may have to rely upon more than one information center for record searches. The TEA-initiated information systems have changed this somewhat, since District Offices are starting to control more comprehensive sets of their own records and thus rely less upon information centers. However, most Caltrans contracts still require private consultants to perform file searches at ICs. These costs are passed on to Caltrans by the consultants, so Caltrans is still paying to support the information centers indirectly. Again, if Caltrans changes how it works with records and has contractors perform searches using its internal system(s) only, information centers will see less business.

The lack of a single statewide system, shared between the major government agencies like Caltrans, has induced some costs to the agency. As well, the absence of a single set of digital information management standards has provoked semi-independent creation of information systems, with attendant costs in staff time, project delay, and duplications of effort.

- Caltrans experiences with database management, GIS, and GPS have been very effective, notwithstanding variation between the District Offices. In general, Caltrans offices use and routinely find good value in: GIS datasets of cultural resources

- GIS datasets of inventory areas
- Tables of cultural resource attributes stored in a relational database management system (RDBMS; Microsoft Access in most cases)
- Tables of inventory reports and associated descriptions stored in an RDBMS
- Tables of undertakings (Caltrans projects)
- Scanned resource recording forms (DPR523 forms)
- Use of the RDBMS to maintain relationships between these different sets of information.

The survey of Caltrans staff done for this study found that GIS datasets were considered to have the highest initial value. The respondents understood the need for tabular information, but day-to-day business was assisted most by accurate and up to date GIS.

Data quality is an interesting aspect of Caltrans use of information technology. Because Caltrans relies heavily upon the digital data that it created through the TEA inventories and other efforts, a high value is placed on accuracy and completeness. This is seen in Caltrans field standards for recording buildings, sites, and other historic resources—high quality GPS coordinates (with submeter error ellipses) are required. Consultants and agency staff are expected to create excellent electronic records. This emphasis will aid Caltrans when the time comes to combine data from different District Offices.

AN INFORMATION MODEL FOR HISTORIC RESOURCES

The introductory discussion pointed out the major nodes in the cultural resource management process where information is collected and could be retained in formal systems. In this section, a general information model is presented. It draws heavily upon data models created by a multi-agency working group in a USGS-sponsored study on cultural resources information standards.[9]

Figure 2 presents a data model for cultural resource information as a whole, drawn from Ingbar et al.[10] This model focuses on historic resources themselves, how they are recorded, and the resulting documentation of them. It distinguishes between individual historic resources, and resources that are themselves composed solely of aggregations of resources, such as Districts and Landscapes.

At the heart of the model are two essential entities: Resource and Investigation. A Resource is any single cultural resource (site, building, etc.). A Resource exists independent of any other entity in the model. For instance, an archaeological site at a particular place exists, whether anyone has ever seen it or not. An Investigation is any human action that systematically attempts to find or learn about one or more resources. The most common forms of investigations are fieldwork activities: inventories to discover and record historic resources, excavations at archaeological sites, documentation of historic buildings, structures, and objects, and other field activities. However, a study of museum collections from a particular archaeological site is a form of investigation, as is an interview with a tribal elder about a rock art locality. Examination of historic records of building plans and permits could be an investigation.

Although a Resource exists independently of any Investigation, we can only know about a Resource if some Investigation discovers or describes it. Each discovery or description comprises a Visit—an episode of observation of a particular resource. So, a Visit is observations made on a particular cultural resource in the course of a particular investigation. Visits are (theoretically) independent observations of the same resource. Of course, one hopes that one set of observations will not be too different from earlier sets. Cultural resources do change over time, though, and a given resource could appear different from one visit/investigation event to the next for many reasons:

- natural landscape processes (especially on archaeological sites)
- destruction or alteration by human action
- changes in recording procedure (e.g., no one collected charcoal for radiocarbon dating in the 1930s because the dating method did not exist)
- changes in general knowledge of the past (e.g., recognition that a particular kind of building was very important in colonial settlements)
- differences in the information sought in recording (e.g., a different recording form with different questions is used, different instructions are given)

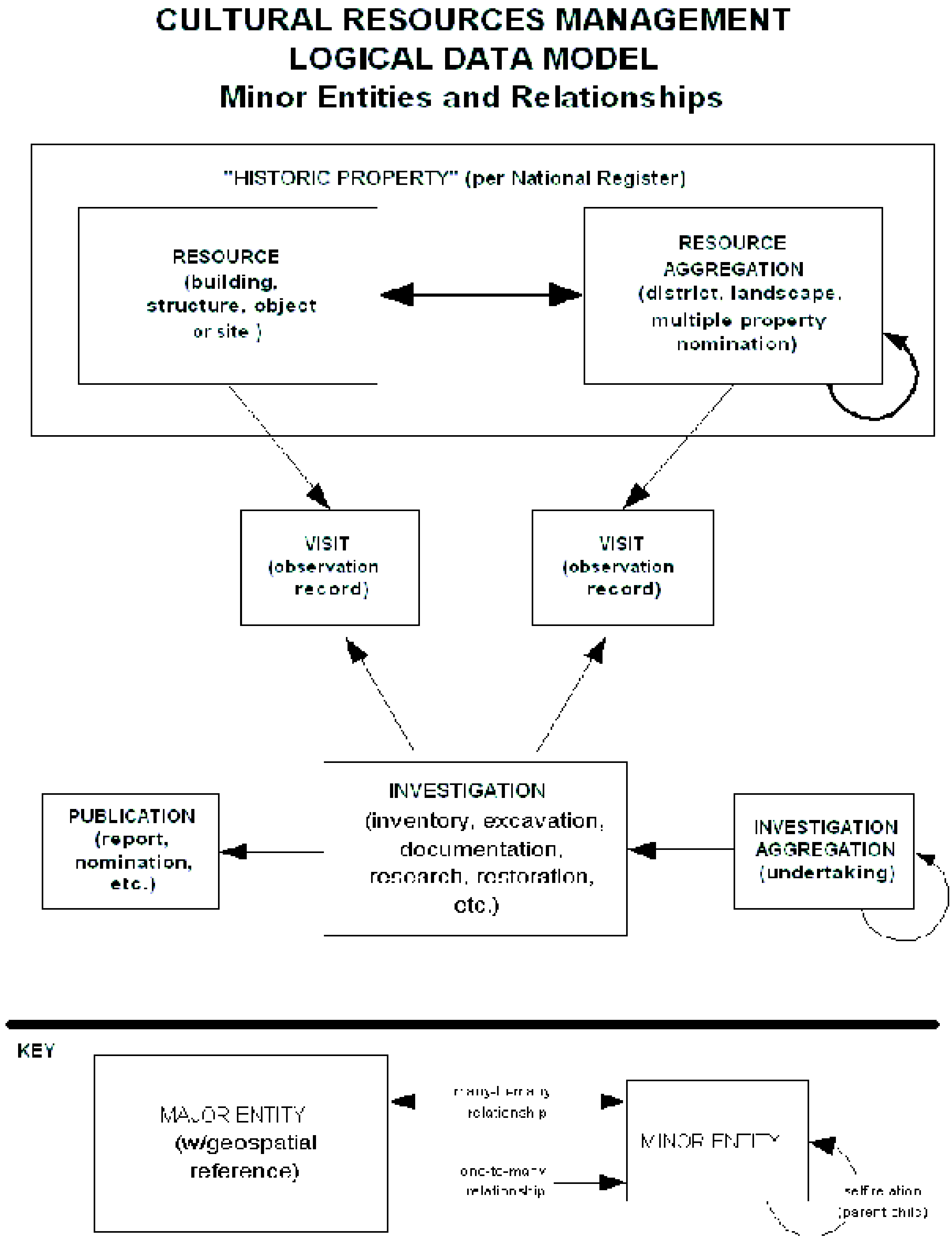

Figure 2 General Model of Historic Resources

Visits link together investigations and resources. One Visit may yield a resource recording form, such as a DPR523 form, for a resource. A subsequent Visit, may result in an update to that same form, or a new form, or may create some other documentation entirely.

A Resource can be aggregated to form composite types of resources described in the National Register standards. Historic districts, for instance, exist only because they contain individual resources. These are termed Resource Aggregations in Figure 2. They too are observed by an Investigation in a Visit.

Minor entities associated with Investigation include publications and investigation aggregations. Investigations themselves may generate documents (Publications, in Figure 2) that describe the methods, results, and observations (indeed the DPR523 resource recording form is a specialized document format, but is still an instance of a Publication in Figure 2). As discussed in the general section on cultural resource management, one may need to group together a number of distinct investigations to get a complete view of what has been inventoried within a given undertaking—an Investigation Aggregation.

The model in Figure 2 is a general logical model for cultural resources information collection. For DOTs, investigations are typically made to manage cultural resources during a particular DOT action, and thus follow a cultural resource management process. One of the minor entities in the general model, the “Investigation Aggregation,” thus becomes very important to DOTs, because to determine the effect of an undertaking on cultural resources one may have to group together one or more investigations.

For DOTs, a “project” (e.g., bridge replacement, roadway construction) may necessitate multiple investigations: an inventory, further intensive field examination of selected sites (testing) and buildings (architectural evaluation). Caltrans, like many DOTs, groups together all of these actions in a functional way, since they are all important to completion of a proposed undertaking. For Caltrans, the expenditure authorization, or EA, for the project is the usual identifier. Recognize, however, that an EA usually comprises multiple investigations (in the sense of Figure 2).

Figure 3 presents a more DOT-specific model of how historic resource information is created, and the major entities of interest to the cultural resource management process.

Figure 3 is a more accurate depiction of how information is thought of in day to day cultural resource management. The key information is the legal status of each resource and whether the qualities that make a resource legally significant will be affected by the proposed undertaking. Any single undertaking may rely upon multiple investigations to accomplish cultural resource management information needs. So, for instance, a highway project might use an existing inventory of buildings and a new field inventory of archaeological sites—two different investigations—to evaluate the historic resources that might be affected by the project.

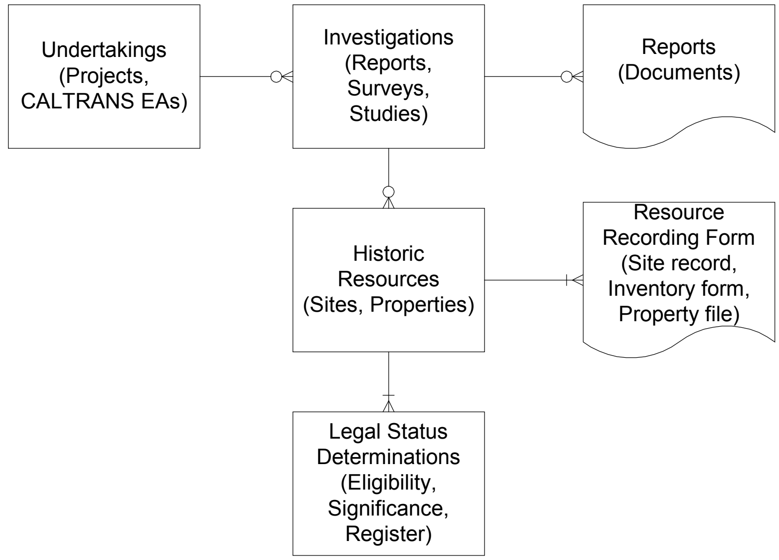

Figure 3 A General Model of Historic Resource Information in Project-Driven Settings

As in the general model shown in Figure 2, any specific historic resource may be visited (recorded) multiple times in different investigations. The same building may be reported (and recorded) multiple times in different investigations so there will be multiple resource recording documents such as forms, photos, etc. The same building may have multiple legal status statements made about it, perhaps because successive investigations change the knowledge of it. All of this information is used in the cultural resource management process, and thus all of it demands retention in some form.

Cumulative vs. Replacement Information Models

Figures 2 and 3 presented general models for historic resource information entities. The concept of a “visit” was introduced in discussing the general cultural resource information model and is an observation of a particular resource at a particular time. How “visits” are retained in information systems is an important part of the general model architecture for historic resources.

There are two prevalent information models for historic resources information (Figure 4). A cumulative information model is one in which information about a given subject is retained with each successive wave of new information. In contrast, in a replacement information model, each wave of new information about a given subject replaces the prior information. Both models are prevalent in historic resources information management.

The majority of the nation’s known, formally recorded, historic resources are described on paper records. These records are filed in record centers at state historic preservation offices, universities, historical societies, and (in California) at semi-independent information centers. Paper records are one form of information model, even if we don’t often think of them as such. In this model, information about historic resources accumulates over time. Each investigation that records more information about a particular resource adds to a paper file in some way. The paper files are almost always operated in a cumulative information model. In a cumulative information model, successive observations (notes, drawings, recording forms) of a phenomenon (a historic resource) add to the information store (i.e., a paper file folder) for that phenomenon.

Cumulative information models are efficient, generally, because they do not require any judgment about information value. Older information may be more valuable or less valuable than newer, but this is not a concern in the cumulative model. Assessment of information value falls to the user, not to the archivist. For example, an archaeologist opening a folder containing three different recordings of a shell mound might find the oldest information about its extent, depth, composition, etc. of greatest value because the site had been least affected by looting, earth moving actions, etc. Current observations of extent, depth, and composition might not reflect the original characteristics of the archaeological site. Nevertheless, the newest recording forms for the archaeological site might have the most accurate information on its location. In a cumulative model, information is simply available, and its value is left to the consumer.

Few, if any, paper archives operate using a replacement information model. In this model, each set of successive observations replaces the earlier, older, information. In general, there is an assumption that newer information is more valuable than older information. In a paper archive, this would mean that each time a historic resource is recorded again, all the earlier notes, photographs, recording forms, and such are cleaned out of that resource's file folder and only new documents are placed in it. Paper archives do not operate in this fashion for obvious reasons—potentially useful older information is lost.

Electronic information systems have to implement either a cumulative or replacement model too. Many of the heritage resource information systems in the United States use a replacement model, even though the paper archives in the same organization use a cumulative model. As Figure 4 shows, in a replacement model the database record for a given phenomenon (in this example, a historic resource's attributes) is replaced with each set of new information. In a cumulative model, the information about a phenomenon is added without replacing existing information.

Why is the replacement model more common in electronic data systems, even though it seems less natural for historic resources information than the cumulative information model? Interviews with information system managers at state historic preservation offices found that the use of the replacement model in their systems was based upon both a technical limitation and an assumption. The technical limitation is that many systems are keyed to having unique resource identifiers in the database table that stores the information (i.e., a row) for a historic resource. The key value is typically a human-friendly identifier, such as a trinomial code (e.g., 26CH5, the fifth site recorded in Churchill County, within the 26th state), a statewide inventory number, or even a name. So that duplicates are not unwittingly present in the table, this key value is constrained to be unique.

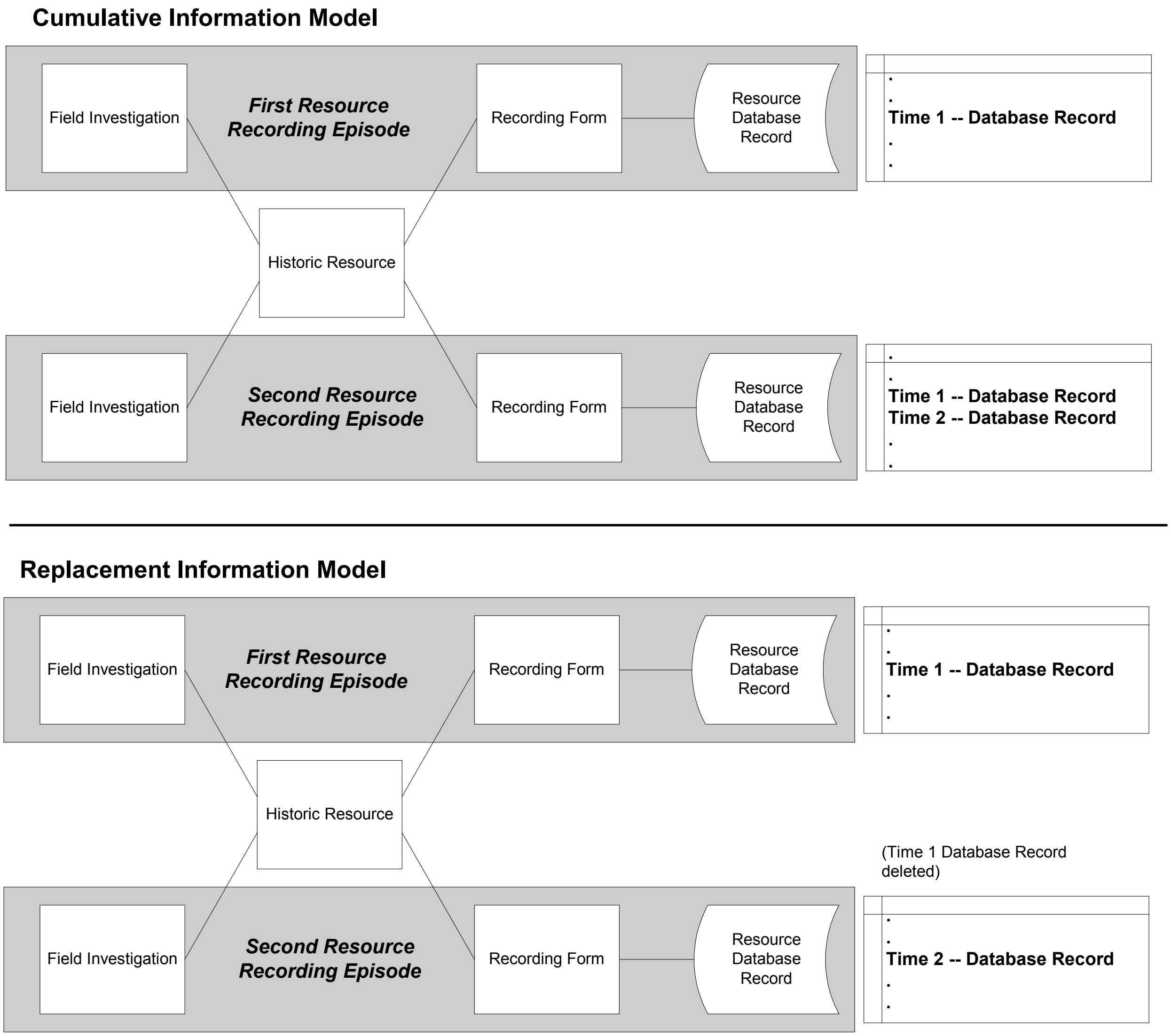

Figure 4 Cumulative and Replacement Information Models Using Historic Resource as an Example

Because historic resources information systems have mostly been designed ad hoc, this unique key idea has persisted in today's information systems. Relational databases are easily able to cope with one to many relationships, so that a replacement model of information is not required. Many of the older data systems in historic resource information management were not designed with a sound relational model, so they are constrained to have only a single row of information for each resource.

Another factor leading to the prevalence of information replacement models in historic resource databases is the opinion that knowledge generally advances, and newer observations should replace older ones. Informal interviews were conducted with archive managers in several western states (California information centers and OHP, Nevada, Utah, Wyoming, Arizona). Most managers of information archives thought that in many cases newer observations were more relevant than older ones. However, all managers said that there were exceptions to this general rule. These usually had more to do with who conducted the newer investigation, rather than the nature of the resource. For instance, one manager stated that she would prefer to rely upon a twenty-year old site record created by a university field school rather than a new site record created by an archaeologist working for an oil and gas exploration firm. She thought that the former was a more detailed, accurate, set of information than the latter, since the university crew spent a week at the site and the oil and gas archaeologist spent half of a day there. However, she also said that in the absence of any reason to rely upon older information, her staff would update existing database records (i.e., replace them) from newer resource recording forms.

One possible means for coping with the problem of information replacement is to retain all recording information (i.e., the results of all visits in Figure 2 terminology), and simply flag the most recent. This has several advantages: no information is lost, the information user can make up her or his own mind, and data entry need not rely upon expert opinions given from a desk rather than based on fieldwork.

Geospatial Components of an Enterprise Model

Five of the six entities in the cultural resource information system model (Figure 2) have spatial definition. The Publication entity is probably not relevant spatially except in light of its parent Investigation entity instances. In general, the two most "atomic" entities of Resources and Investigations share spatial characteristics:

- They have definable spatial boundaries ("edges") even if a particular entity instance boundary may be unknown
- A single entity instance may have multiple boundaries defined for it, perhaps because different observers record the boundary differently or the observable boundary changes through time
- A single entity instance may have different types of boundaries defined for it (e.g., a National Register boundary definition and a boundary defined by field observation)
- A single cultural resource or investigation may consist of multiple discrete spatial instances. For instance, a single cultural resource may occur in patches or segments that are not contiguous
- Resources may overlap spatially, as may Investigations
- Resources and Investigations occur in three spatial dimensions. If one chooses to implement a "visit"-based model of data, then Resources and Investigations occur in four dimensions because every observation is bound to a particular time
- The spatial extent entity itself is of interest, not the space that it occupies. That is, we seek to describe the entity as a geographic feature, not to describe the geographic space that contains the feature. The latter may be captured with reference to some other spatial data (e.g., a spatial dataset of hydrologic units might be used to describe the location of cultural resources.

Resource Aggregation instances and the minor entities of Visits and Investigation Aggregations inherit the boundary characteristics of the other two entities, so they share the characteristics described above.

A HISTORIC RESOURCES ENTERPRISE INFORMATION MODEL FOR CALTRANS

In order to understand Caltrans needs better, the principal investigator and Stella d'Oro, a San José State University graduate student, formulated a survey of information needs. The survey was placed on line for Caltrans staff to fill in. Unfortunately, only 10 responses were received from more than 120 historic resource specialists within the agency—too few to be very useful.

Despite the insufficient responses to the formal survey, the study continued to gather information through telephone interviews, meetings, and email correspondence with Caltrans staff. We were able to identify several key issues that any enterprise model for Caltrans must address:

- Lack of GIS data outside of TEA-inventory areas
- Continued reliance on Information Center archives due to uncertainty about record completeness in District Offices
- Confusing mechanisms for updating electronic datasets, when they do exist, relance upon the "office expert"
- No mechanism for going "fully digital" with all records in electronic form, including scanned documents

There are two major areas of interest in formulating an enterprise model: what data the system must contain, and what the enterprise information system must offer its users as functions and capabilities.

The logical data model, followed by the DOT-centric model, in the previous section addresses the latter, and is reiterated briefly below. The former is discussed extensively below, based upon the study and meetings with the Caltrans Joint Application Development Team (JADT), which was starting to develop a plan for funding an enterprise system for cultural resources.

For the sake of brevity, the future enterprise system concept is called the CCRMIS—the Caltrans Cultural Resource Management Information System. This title was adopted by the JADT as shorthand for an eventual Caltrans application and data system.

Data Requirements of an Enterprise System

Data requirements for the CCRMIS enterprise system are:

- Captures investigation and resource information entities appropriately
- Allows for resource recording events/visits to be retained in the history of investigations and in the history of individual resources
- Allows attachment of recording forms/tabular data/geospatial data for cultural resources
- Explicitly specifies either a cumulative or a replacement model

- Incorporates geospatial information
- Allows free association of investigations, visits (resource recordings), legal status statements, and other business information. In other words, implements many to many relationships between:
    - Resources/Resource Aggregations and Investigations (i.e., visits)
    - Investigations and Undertakings (i.e., investigation aggregations)
    - Undertakings and Resources (i.e., allows statements about effect of a specific undertaking on a specific resource to be retained as data)
    - Resources/Resource Aggregations and National Register Status statements (one resource may accumulate multiple status statements).
- Permits documents and images to be retained as data
- Uses data structures and conventions consistent with information centers, Office of Historic Preservation, and other major partners as much as possible.

Business Requirements of an Enterprise System

Business requirements are functions a system must provide that are external to its users (by and large). The requirements below are largely from the November, 2007 JADT discussion in which information technology and security issues were brought up that had not arisen in discussion with cultural resource specialists. As well, the list has been augmented from general knowledge about cultural resource and other regulatory information systems.

- Will implement security that meets DOI, Caltrans, SHPO, and other interested parties requirements (perceived or real)
- Data will be complete for Caltrans projects in some form or another
- All projects can be found by postmile, either by map or by data search or both
- Every part of cultural resource work in Caltrans has “status.” CCRMIS needs to reflect defined terms for status, such as “proposed,” “scoping phase,” “initiated,” “in progress,” “completed,” “cancelled.”
- The application can be supported by Caltrans IT at headquarters and in the Districts
- Need to access and incorporate electronic documents (e.g., site records, correspondence) in a timely fashion
- Content experts (CRM specialists) determine appropriate security levels overall and for individual records or documents
- Must offer appropriate security for records
- The CCRMIS will be user-friendly
- Must be technically maintainable by both Caltrans and common vendors. Thus, uses industry standards in programming, deployment, etc.
- Must support/be compatible with the general workflow laid out in CFR 800
- Must support/be compatible with the work requirements of CEQA, PRC 5024, and other state law
- Must support/be compatible with work requirements common to programmatic agreements, memoranda, and so on that alter CFR 800 and/or other regulatory processes
- Supports other cultural resource program needs through query, reporting, etc. of the data system

- Maintains current GIS functionality and allows use of appropriate GIS functions for common cultural resource program tasks
- The design of the data system makes possible interchange with data from other information systems/other organizations (n-tier, service-oriented)
- Contains agency and national metadata as appropriate
- Does not rely upon vendor-specific data models (e.g., particular geospatial logical formats or vendor-specific data constructs like instantiated views)

Functional Requirements

Functional requirements are those things that any effective system must accomplish for its users.

- Has user roles with different levels of access (thus, passwords)
- District Data Steward can override record status (visibility to others), but otherwise visibility to others is set by default functional process
- Creates reports (printed or print-like) output for information tracking system entry (future goal)
- Does NOT directly send data to other environmental tracking systems such as the Integrated Tracking System. This may be a long-term functional goal, but is not currently a need
- Has a disconnected editing mode in which a user can:
    - Create investigation, resource recording, and resource records in the database and the GIS when detached from the Caltrans network
    - Work with existing data segmented from the CCRMIS database (“pack and go” of both database and GIS data)
    - For Caltrans users when re-connected to the Caltrans network, automatically uploads new data to the system, runs quality control and conflict detection processes, flags records that need Data Steward review
    - for consultants and other non-Caltrans users, creates a package of data that a District Steward can review and they synchronize to the CCRMIS
- Displays appropriate metadata for GIS, GPS, and database records
- Performs transformations of geospatial data (different coordinate systems) without extensive user intervention (user specifies coordinate system of data only, system does the rest). CCRMIS saves this information for data sources so user does not have to re-specify it every time application is used
- Can import compatible data from Caltrans partners (e.g., BLM, OHP, USFS, SANDAG, other geospatial data management organizations, such as counties)
- Can integrate local geospatial data and network geospatial information on a temporary basis, including CAD data
- Allows attachment of other media files (images, PDF, text, audio, video)
- In urban areas, can link across to online GIS that may offer other capabilities (Microsoft Virtual Earth, Google Earth, Yahoo). Works only when an internet connection is processed
- Has a method for address lookup and uses standardized addressing fields. This is especially important for the built environment. Returns likelihood of address being correct (geocoding metadata) and displays result in GIS for further editing
- Uses standardized parcel and property numbering schema for land records (cf.

FGDC Cadastral Data Standard)
- Uses standardized street naming (recommend URISA standard)
- Allows street address and APN to be associated appropriately (one address = one APN, but one APN does not equal one street address)
- Tracks in a simple way curation and repositories used. Checkbox indicates collections from a resource, one can then enter repository (from list) and accession number(s) and date
- Generates PDFs with searchable text for DPR523 recording records
- Has searchable text in PDFs (for new, incoming PDF), but potentially for all
- Should DPR come up with some modification to the DPR series forms, can incorporate this new format in to the CCRMIS without completely re-engineering the application
- Compatible data formats for use with current GIS tools
- “Pack and Go” Requirements for quick creation of data to use in field
  - Can load and go in to field for particular project area
  - Common, readily adaptable field file formats
  - Appropriate background imagery for field GIS and GPS
- Forms are designed to be used on a standard dimension tablet in the field
- Analysis returns (via intersection) values from predictive models (potential for buried sites, etc.)
- Allows some data to be visible in different ways depending upon user security role. For example, areas of tribal concern can be shown to some users, and depending upon user role, may show only some (or all) of the information about the tribal concern area
- Stores all site boundaries recorded over time but displays only most current or “most authoritative” (cumulative, but acts like “replacement” to simplify use)
- Has a way to store and update resource status, tagged by date of observation. For example, can state that a resource is in “good condition” at time A, “destroyed” at time B, and so on
- Has appropriate values for resource status such as: destroyed, supposed to be destroyed, intact, unknown, partially destroyed, etc.
- When connected to Caltrans network at office, map screens and data screens are generated in 5 seconds or less (on average)
- Spell-check and other conveniences
- Has project list screen that shows all projects in a selected District
- Allows GIS to be used to select database records
- Allows database records (queries, filters) to be used to select GIS records
- Stores user selections from one sign-on to the next
- Implements a named selection system for users to save particular selection sets
- Is vendor-neutral on GIS and software requirements for external users and, if possible, internal users

Moving to Enterprise: DO 2 to DO 4 Assessment and Conversion

One way to examine data models and applications in detail is to compare them to each other by converting the data from one application to another. In the process, one can generally find areas where the target application is different from the source, and thus come to understand the capabilities of the target application more fully. This study converted the District 2 TEA inventory application suite to the newer District 4 application suite for exactly this purpose. The conversion helped illuminate potentially valuable aspects of both data models and applications. This is useful for this study.

The conversion was also directly useful to District 2 staff who can now inform the JADT about likes or dislikes concerning the current District 4 application suite. Since this suite is serving as a model for the JADT system planning, staff opinions will be very valuable.
Caltrans District 2 was one of the first two DOs to have a TEA-funded inventory of rural rights of way. Approximately 1,200 miles of highway verges were inventoried for archaeological sites, buildings, and associated features. The District 2 information system consists of a Microsoft Access database and an ESRI ArcView version 3 GIS containing:

- 12 GIS vector datasets of cultural resource and associated Caltrans information (e.g., highway centerlines, postmiles)
- Raster GIS datasets of USGS maps and aerial photography
- Data import application custom built in to ArcView for bringing GPS data in to the GIS from Trimble Pathfinder Office GIS exports
- Data management tools custom built in to ArcView for quality control flags of imported data, allowing manual and semi-automated quality checks
- A custom built analytical tool in which one specifies county, route, postmile segments and widths for a project, and the tool creates a GIS dataset of the analytical boundary and then uses the resulting GIS features to select and report upon all cultural resource phenomena within the analytical boundary

The District 2 information system Microsoft Access database (version 97, then 2000, and finally 2003) contains more extensive attributes of undertakings, investigations, documents, and resource records. Database records for investigations and resources link to their representations in GIS using a common key field, but linkage is a manual process necessitating knowing the key value in the database.

The District 2 database contains a complete set of forms for creating standard resource recording forms in California (known as DPR 523 series forms). From the database, one can enter all pertinent information, attach maps, photographs, and other figures, and then export the resulting database report as a full DPR 523 form set in PDF format.

The District 2 information system also contains a store of scanned documents, mostly archaeological site records. These are linked to the GIS application and to the database application.

District 2 also has a matched GPS field mapping protocol using a custom data dictionary. GPS and GIS integration is handled through a series of scripts, which in turn rely upon following file naming and transfer procedures documented in a formal manual.

The District 2 information system is easy to use for basic search, query, and basic data entry for DPR 523 forms. According to District staff, it is difficult to use for GIS integration with the database and selective import of GPS data. Initial training reflected these difficulties, with basic functions requiring a few days of training time for Caltrans staff, but more advanced data editing and integration taking another two weeks of instruction and mentoring.

In both District 2 and District 5, the initial information system development showed that each district office will likely need a cultural resources specialist who is adept at using the historic resource information system. This person, the data steward, may delegate some duties associated with the information system, but ultimately serves as the in-house expert and responsible party for data quality and support for “regular” information users.

Supporting the information system has sometimes been a challenge for District 2 staff. At various times, Microsoft Access (a core technology of the application) has been either not approved for use on Caltrans computers or available only in older non-compatible versions. Similarly, as GIS software versions evolved, no District 2 staff were available to make fairly minor, but technical, repairs to the custom applications.

When the District 2 and District 5 TEA inventories occurred, the resulting information systems were based on the same technologies. Later TEA inventories moved to newer software versions of the core GIS application. ESRI ArcView 3.1 was the initial GIS software. Applications were eventually migrated to ArcView 3.3 in District 2. Current TEA inventories use a very different GIS application—ESRI ArcGIS. The custom built tools for GPS integration, quality control, analysis, and cartography are now re-created by Caltrans contractors in ArcGIS. The most comprehensive inventory database to-date was created for Caltrans District 4. Aside from use of a contemporary GIS, this information system has all of the same functions as the older District 2, 5, 10 systems and other new features:

- Import and export of database subsets through database replication, making it possible to give portions of the database to different non-networked users for update and entry
- Integration with Caltrans master postmile and centerline information
- Improved search, selection, and export using GIS tools
- Better integration of bibliographic records
- Improved database search for resource records
- More flexible printing

In short, the nearly ten year evolution of Caltrans district office information systems has culminated in the District 4 information system. Is this an enterprise information system model for Caltrans, at least in terms of its functions? One hallmark of a successful information system is that internal users of it are satisfied with it and external users are also able to use whatever portions of the system they need to with satisfactory results.

To date, the District 4 model has proven successful (Montero, personal communication, 2008). The District 4 Caltrans Cultural Resource Database has been integrated in to daily work by Caltrans staff and by consultants working independently on Caltrans projects. The consultants then return information to the District. The data steward checks the information and then integrates it with the District data sets. This is an enterprise model writ small, as it were.

Underlying the success of the District 4 information system is a slightly different data model than that used in earlier data systems, especially District 2. Figure 5 shows the basic table models for the District 2 database. The GIS data model is very simple, relying on key values for investigations and resources to link attribute tables to the database, and so is not shown in this figure.

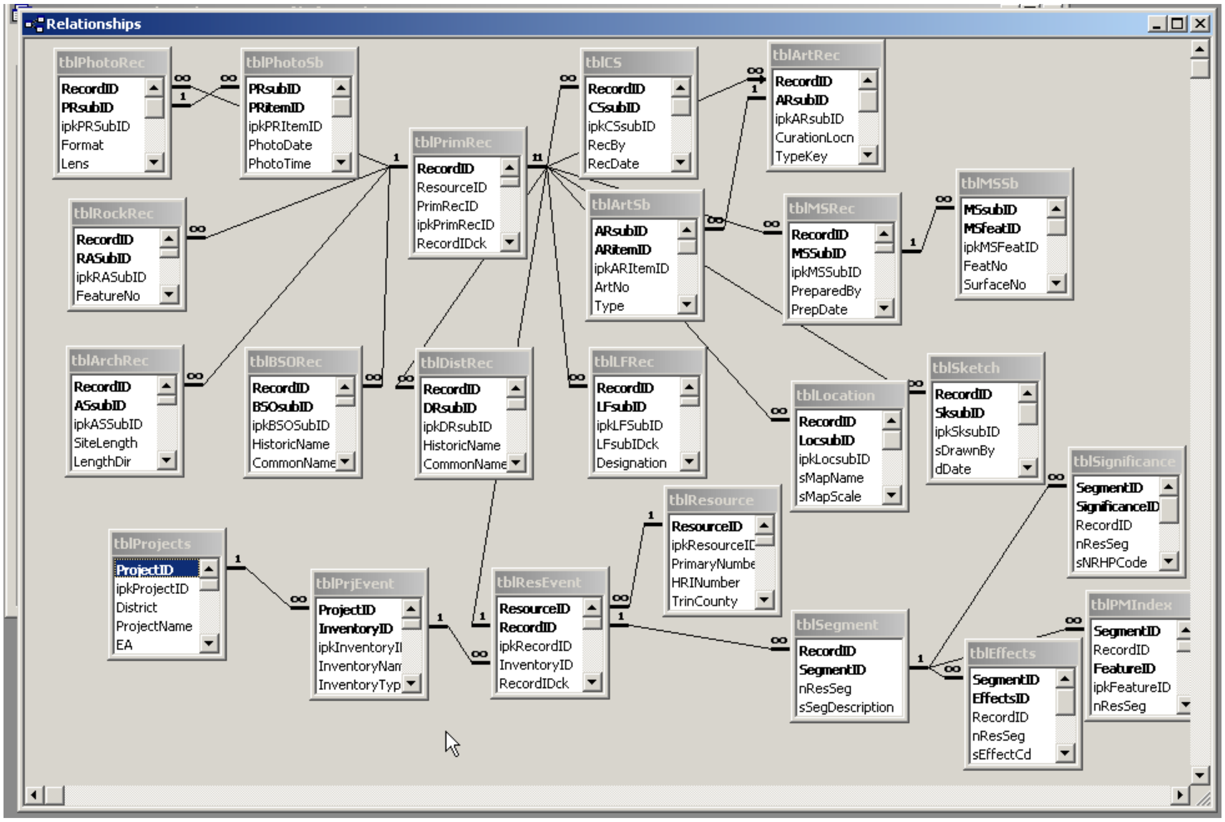

Figure 5 District 2 Database Model

The District 2 model is a cumulative information model. Resource recording "visits" are created in the context of a given undertaking (EA) during the course of a specific investigation with each resource visit/recording linked to a given fieldwork episode (a "project event" in the database.) Furthermore, each investigation ("project event") can have multiple visits to the same resource, generating more than one set of resource information. Because the information system is within a DOT, some rules of association are also enforced:

- Every investigation and resource must be associated with an undertaking of some sort; free-standing investigations and resources are associated with a default phony undertaking that serves as a placeholder
- Every resource must be associated with an investigation; as for undertakings a phony investigation is used as a placeholder
- Resource records are unique—each historic resource has a single table row that serves as its "master" record; as in the information replacement model, the most current values for legal status and site name are updated within this record;
- Visits (recording episodes) are a combination of a resource and an investigation.

- The DPR 523 form series (one "A" record with multiple add-on records) is available as a distinct "branch" of tables (stemming from tblPrimRec in the upper third of the figure); core, statewide, information is therefore preserved in a distinct, separable data submodel.

The District 4 information system uses a similar overall model (Figure 6), but there are some important differences in how information associated with resources are handled. In the lower center of Figure 6, the main resource table (one row per historic resource) is shown linking to multiple one-to-many indexing tables.

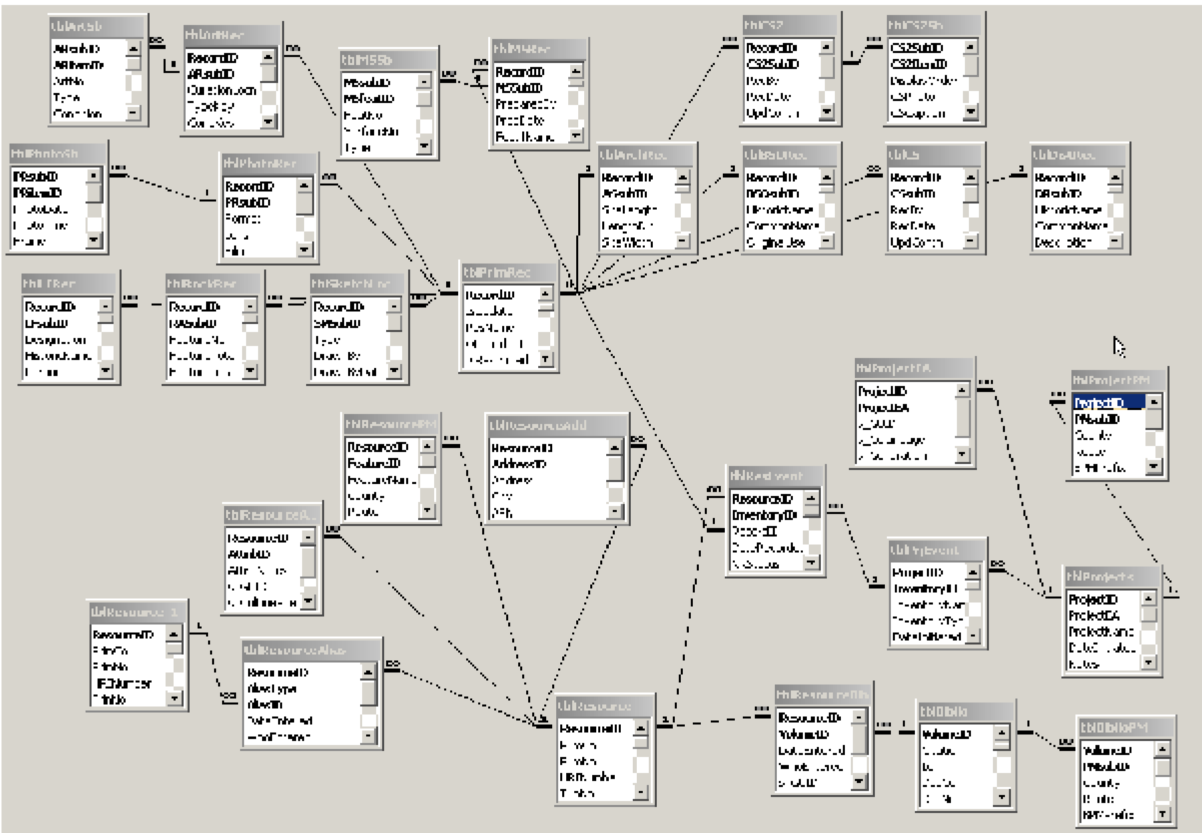

Figure 6 The District 4 Database Model

The one-to-many tables in the District 4 model allow retention and search of information on:

- Resource aliases: the concordance between different resource identifiers (names, state site numbers)
- Resource characteristics: are kept in an information replacement model in this table, whereas in District 2's database model, the same information is retained in a per-visit table (i.e., a cumulative model); District 4's design allows for easier searching
- Resource street addresses: these are buried in recording events and visit-specific tables in the District 2 model; locating them here makes them easier to search
- Resource postmile associations: these are kept in a per-visit table within the District 2 model; they are easier to search in this form.

- Undertaking (EA, project) postmile associations: these are modeled directly as a child table making them easier to search while allowing any number of postmile ranges for a project

The actual database applications are fairly similar, and both are well documented. As described above, the GIS functions in District 2's older application are all present in the District 2 GIS tools.

In order to test how difficult it would be to move Caltrans district office databases and GIS datasets to a single model, the District 4 information system was chosen as a proxy for an enterprise system. From a functional standpoint, the District 4 information system meets most of Caltrans needs; from an enterprise system standpoint, the same functions and architecture used in the "small" database of District 4 could scale up (with new code) to an enterprise database and GIS system. Preserving data relationships is especially important in this test, as it would be in a scale-up to an enterprise system,

Conversion of the District 2 database to the District 4 database was more of a tedious process than a difficult one. The most important changes had to do with differences in some small conventions about field names, and what some database columns contained. Usually, concatenation or simple manual edits solved these problems.

Four hundred and eighty undertakings (projects, EAs) were converted. The District 2 model allowed for duplicate names, so slight name changes were used to fix this in conversion.

Investigations ("project events," surveys, excavations, etc.) converted readily. Of the 1,525 records, only two had to be edited to shorten some text in a field.

More than 3,100 resource recording visits were converted, along with their linked recording information. These records had the greatest changes in conversion, because they required moving some attributes from the DPR 523 tables in to tables related directly to the main resource table (as discussed above).

The GIS data, comprising more than ten thousand rows of spatial information required the most changes. District 4 GIS records are held in a simpler GIS data model, in which fewer GIS datasets are present, but attributes within each GIS dataset separate different types of geographic features. For instance, in the District 2 GIS dataset, point features representing artifacts in archaeological sites and point features representing reference stakes (datums) implanted at historic resource locations are in two different GIS datasets. In District 4's model, all points associated with historic resources are in a single GIS dataset, with a "type" attribute that distinguishes them. Changes in the GIS application itself (from ArcView 3.x) make this a more efficient model. However, for conversion, each of the twelve GIS datasets had to be brought in to an appropriate District 4-format GIS dataset, keeping track of multiple key values, and verifying database linkage.

The District 4 Information System As An Enterprise Model

The District 4 information model is an excellent starting point for an enterprise Caltrans model. The details of tables, key structures, and integration have all been ironed out through more than ten years of district-level data systems. All the key entities of a DOT historic resource information system (and most others) are present: undertakings, investigations, resources. These are tightly linked together in a coherent, maintainable model. The data model is mutable in appropriate ways if, for instance, the state standard for recording forms changes. One could simply start a different table "tree" of recording information from the resource visit table.

It is important to separate the District 4 model from the District 4 implementation. District 4's model runs on desktop or workgroup level software, not enterprise platforms. The model can, however, scale up to enterprise relational databases (e.g., SQL Server, Oracle), to web-based GIS (ESRI ArcGIS Server, other platforms), and document management systems (e.g., Microsoft Sharepoint, EMC Webtops, Adobe LiveCycle).

Some gaps in the District 4 model have to do with retaining the results of consultation with other agencies and decisions about undertaking effects on resources. For instance, one cannot:

- Find all legally significant resources said to have been affected by a Caltrans project
- Determine how many undertakings were judged to have no effect on historic resources
- Find undertakings in which Native Americans were consulted

In fairness, these were never intended to be functions of the district-level information systems. These systems focus on inventory, bringing forward known historic resources quickly for planning and decision-making, and capturing results of new investigations. The TEA-funded inventories and their associated information systems were not intended to capture all the regulatory activity surrounding undertakings. These parts of an enterprise data model can be added around the sound core of the district data model to create a true enterprise system.

Implementation—Time, Money, and Partnerships

Enterprise information management systems require time, money, and partnerships in order to be created. Although these were not primary foci of this study, they did arise during the research. This section discusses each of these briefly.

Timing of enterprise system implementation is important. As stated in the introduction to this study, enterprise systems can require a lot of time to plan, design, and put in place. This is due to their nature—they have to integrate with a complicated IT environment and they have to be supported by IT.

For instance, the U.S. Forest Service (USFS) built a national system called INFRA-

HERITAGE (INFRA, for short). INFRA planning and design began in 1996 as a module within a larger agency-wide data system. Initial prototypes appeared in 2001, and actual use in the field began in 2004. INFRA has continued to evolve over time and cannot be said to be finished. One of the enterprise-level problems that INFRA faced was deriving a data model that was common to the application as a whole but still met the needs of fifty states in which the USFS collaborates. INFRA had to create resource recording forms appropriate for every state in the nation while still using common terms at the USFS desk level in the INFRA application itself.

Caltrans can implement much faster than the INFRA example by starting out with the existing TEA inventories, as discussed above.

Money and staff time (a different form of money) are clearly essential to an enterprise system implementation. Turning first to staff time, aside from programmers and other information developers, Caltrans will need to allot a considerable amount of cultural resource specialist staff time to aiding in the design and functional layout of the CCRMIS. Using the USFS effort as an example, 1.5 cultural resource staff years per year were allotted to the development effort. In the implementation phase, approximately 0.5 specialist years per year were allotted for a coordinator who served with an IT specialist as the management team for the system.

Costs for enterprise system development vary widely because enterprises start in different places. For instance, Caltrans may already have much of the transactional logic and workflow in place that links geospatial and tabular information appropriately (as defined above). This may be present both in the district TEA application suites, as a sort of miniature version of what the enterprise system must do, and in a full enterprise system in, perhaps, other environmental realms.

Is the cost likely to be worthwhile, when compared to systems based at the District Offices that are independent of each other? There is likely to be a gain in efficiency due to reduced training costs, better portability of staff between offices, and consolidation of data storage and application updates. However, enterprise systems are expensive to build, even if they become efficient once in place. Common ways to amortize the cost of enterprise development include:

- Enforce use of the system to ensure maximum gain from it
- Track actual costs and benefits realistically by designing performance measurement into it: for instance if the system is intended to save the time it takes to evaluate an undertaking, make sure CCRMIS tracks the time in staff hours and elapsed days
- Evaluate associated costs and track changes in them that are induced by the system; for instance, if fewer visits are made to Information Centers, make sure this cost is accounted as a benefit
- Likewise, the “hidden” costs of information technology should be tracked—time spent in supporting the CCRMIS, back up, problem-solving

Partnerships are usually part of an enterprise system, especially in government organizations. Caltrans cultural resources staff are not the sole masters of the cultural resource program for the agency. Within Caltrans, the environmental program as a whole bears responsibility for cultural resources compliance. Ensuring that staff from “parent” and “sibling” levels in Caltrans participate in the discussion about the enterprise implementation of CCRMIS will help make the system useful beyond just the heritage resources program itself.

External partnerships are key to Caltrans cultural resources endeavors. Caltrans consults daily with the California Office of Historic Preservation. This agency has overall responsibility for the protection of historic properties in the state and management of information about them. Collaborating with OHP on system design and development is essential to the success of both agencies. While they approach processes from somewhat different angles, there is complete overlap in the need to document basic investigations, reports, and cultural resources appropriately. Shared development with OHP, and perhaps other state agencies would be useful to Caltrans even if implementation is not shared between the agencies. In other words, the same design could be used in multiple agencies. This would greatly facilitate data exchange, which in turn saves elapsed time and redundant effort.

CONCLUSIONS AND RECOMMENDATIONS

This project came about because Caltrans could foresee that at some point, the combined presence of information systems at district offices would point out the opportunity and need to have an enterprise data system. The original study proposal was to design and create a prototype of just such a system. The project team of two SJSU faculty, a graduate student, and the principal investigator designed a survey to assess needs and evaluate how the enterprise system should differ from the existing district office information systems.

Unfortunately, events soon overtook us. Few of the potential respondents had time to work through the fairly short survey. Caltrans information technology staff began to take an interest in creating an enterprise system for historic resources. Caltrans procedures prevented our participation in the JADT, once that team turned to design, needs, and formal funding requests. So, just as our study was ready to re-address needs (through telephone interviews), we were asked not to approach Caltrans Staff.

Instead we concluded, with Caltrans, that an appropriate avenue to assist the agency and meet our study goals was to evaluate the general merits of the different district data systems and perform a detailed comparison of them. The latter was accomplished, at our suggestion, by converting the District 2 information system into its District 4-format equivalent. To date, users in District 2 have found the conversion worthwhile. Thus the study achieved two useful goals: evaluated the most up to date of the office system models and performed a useful conversion.

A key lesson learned about implementing free-standing studies like this one is that they must have strong sponsorship and interest from within the agency. Our first contact with agency information technology staff came as the project started. Our next contact with agency information technology staff was nearly two years later, at the JADT meeting. Free-standing studies can be a little too distant for anyone to feel they must participate in them; some measure of that independence may have hampered the start up to this study.

Caltrans is a key agency in historic resources management. It generates millions of dollars in historic resource studies and investigations annually (by its staff and its contractors). This is typical of DOTs throughout the nation. As discussed at the start of this study, DOTs have somewhat different agendas than other agencies. The construction and maintenance focus of DOTs makes them more like private sector developers, seeking to minimize impacts but not necessarily avoiding them. Information systems are helpful tools in this regard but are not justifiable in themselves—unless the system helps to get the project completed. For instance, maintaining an elaborate inventory of historic resources, in which every detail is encoded in a database, is searchable by fairly fine-grained and complicated attributes (window trim, paint color) has little or no value to DOTs. Instead, information systems that capture information of highest regulatory interest must be given precedence: Where is the archaeological site?; What is its legal status?; How sensitive is it to rubber-tired vehicle travel?. These kinds of questions are more important in the day to day of DOT cultural resources management.

With that said, DOTs have a great need to prove that they act as responsible stewards of the resources they touch, be they natural or cultural. Management information systems that track and account decision-making processes (e.g., permits and follow-through compliance) are of value to DOT cultural resource programs. In Caltrans, at least, these are handled at a higher level than just one specialty like historic resources, being instead dealt with at the department or whole agency through work tracking mechanisms. Yet, measuring accomplishments like the number of cultural resource impacts avoided would be useful to most DOT cultural resource management programs.

Because of their high volume of work, DOTs are especially suited to become data-sharing partners with other agencies. Potential partners include their state historic preservation offices. State historic preservation offices, charged under the National Historic Preservation Act with maintaining an inventory of historic properties, generally welcome such partnerships. DOTs and SHPOs share a keen interest in the basic documentary and inventory part of information management of historic resources. Investigations, resources, and publications are all sharable information entities. A conclusion of this study is that the needs of DOT agencies like Caltrans on the basic inventory databases (e.g., the district information systems) do not differ greatly from those of any cultural resource management agency. The inventory portion of a DOT enterprise system could be a shared component.

Caltrans and DOTs in general will succeed in creating enterprise information systems. The economics of having them are simply too compelling. Above, I have argued that such systems should be designed with two goals in mind: share information that everyone needs for decision purposes, such as resource databases, investigations, etc., through shared information systems; prove stewardship and responsible actions by integrating workflow tracking that is already in place. The tools are all present, it is simply a matter time and vision to build such systems.

ENDNOTES

1. Eric Ingbar, Mary Hopkins, and Tim Seaman, *Creating a Cultural Resources Metadata Standard for the Western United States*, report prepared for the Federal Geographic Data Committee of the United States Geological Survey (2000). (Cooperative Agreement #1434-HQ-97-AG-01904). This study lays out common information entities used in cultural resource management, especially those relevant to federal projects, including most transportation agency projects.

   A second study that examined how information systems are used in transportation agency decision-making was also consulted: Terry H. Klein, Lynne Sebastian, Samantha M. Ruscavage-Barz, Stephanie Ford, and Joe Watkins, *Managing Archaeological Investigations: A Synthesis of Highway Practice*. National Cooperative Highway Research Program Synthesis 347. (2005); Transportation Research Board, *Data Partnerships: Making Connections for Effective Transportation Planning*. (Transportation Research Circular, Number E-C061, 2003). This study examined how archaeology, specifically, depended upon prior information about sites, decisions about impacts and the importance of sites, and knowledge of regional scientific issues. The study summarizes processes used by DOTs (at that time) and examines variation within them.

   A third study of importance, following the 2005 study cited above, examined how decision-making in transportation agency cultural resource programs can be enhanced by better information management tools. Mark R. Edwards, Rebecca L. Peer, Emily Lindler, and Terry H. Klein, *Evaluating Cultural Resource Significance: Implementation Tools*. National Cooperative Highway Research, Report 542. (Washington DC; Transportation Research Board, 2005).

2. National Park Service, “How to Apply the National Register Criteria for Evaluation”. National Register Bulletins (2002). http://www.nps.gov/history/nr/publications/bulletins/nrb15 (accessed September 8, 2008).

3. U.S. Department of Transportation. Environmental Review Toolkit|Section 4(f)|Overview (2009) http://www.environment.fhwa.dot.gov/4f/index.asp (accessed March 3, 2009).

4. Lake County Archeology. http://www.wolfcreekarcheology.com/CEQALaw.htm (accessed March 3, 2009).

5. Caltrans. http://www.dot.ca.gov/hg/env/cultural/index.htm (accessed March 3, 2009).

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7. Terry H. Klein, Lynne Sebastian, Samantha M. Ruscavage-Barz, Stephanie Ford, and Joe Watkins, *Managing Archaeological Investigations: A Synthesis of Highway Practice*, National Cooperative Highway Research Program Synthesis 347, (2005); Transportation Research Board, *Data Partnerships: Making Connections for Effective Transportation Planning* (Transportation Research Circular, Number E-C061, 2003).

8. Minnesota Department of Transportation, http://www.mnmodel.dot.state.mn.us/, accessed March 3, 2009).

9. Eric Ingbar, Mary Hopkins, and Tim Seaman, *Creating a Cultural Resources Metadata Standard for the Western United States,* report prepared for the Federal Geographic Data Committee of the United States Geological Survey (2000) (Cooperative Agreement #1434-HQ-97-AG-01904).

10. Ibid., Figure 3, with modifications.

ABBREVIATIONS AND ACRONYMS

APE	Area of potential effect
APN	Assessor parcel number
BLM	Bureau of Land Management
CAD	Computer-aided design software FGDC
Caltrans	California Department of Transportation
CCRMIS	Caltrans Cultural Resource Management Information System
CEQA	California Environmental Quality Act
CFR800	Code of Federal Regulations, Section 800 (implementation of cultural resources laws)
DO	District office
DOI	United States Department of Interior
DOT	Department of Transportation
DRP523	Department of Parks and Recreation form 523 series forms, used for standard cultural resource recording in California
EA	Caltrans expenditure authorization, generally equivalent to a DOT project
FHWA	Federal Highway Administration
GIS	Geographic information system
GPS	Global positioning system
HRC	Heritage Resource Coordinator
IT	Information technology
JADT	Joint Application Development Team (Caltrans)
NHPA	National Historic Preservation Act of 1966 and later amendments
NRHP	National Register of Historic Places
OHP	California Office of Historic Preservation (State Historic Preservation Office)
SANDAG	San Diego Area Governments coalition of local governments
SHPO	State Historic Preservation Office
TEA	Transportation Enhancement Act
THPO	Tribal Historic Preservation Office
URISA	Urban and Regional Information Systems Association
USFS	United States Forest Service

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Eric E. Ingbar has been a professional archaeologist and cultural resource specialist for over 20 years. He is a founding principal of Gnomon, Inc., a business firm specializing in creating, implementing, and maintaining information systems for managing resources and infrastructure, including cultural resources, other natural resources, and proposed land uses. He manages projects, directs staff in the technical and professional arenas, and serves as a lead analyst on GIS projects. Ingbar and Gnomon, Inc. are primary IT consultants to many state historic preservation offices, creators of the successful large-scale pilot use of GPS and GIS within Caltrans, consultant to the Bureau of Land Management (BLM) for multi-agency data sharing and nationwide technical assistance, and recipients of multiple successful agency automation and study projects. He also serves as an advisor to two different Federal Highways projects pertaining to automation of cultural resources information and environmental streamlining.

Ingbar earned his B.A. in social anthropology from Swathmore College, graduating with honors in 1979, and his M.A. in anthropology from the University of New Mexico, also graduating with honors, in 1983.

PEER REVIEW

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