INFORMATION MODEL FOR DESIGN MANAGEMENT IN ROADWAY CONSTRUCTION PROJECTS

Kwanhee Cho[1], and Jongwon Seo[2]

[1] Graduate Student, Department of Civil Engineering, Hanyang University, Seoul, Korea
[2] Assistant Professor, Department of Civil Engineering, Hanyang University, Seoul, Korea
Correspond to jseo@hanyang.ac.kr

ABSTRACT : This paper describes an information model, devised to manage roadway design information and to improve the collaboration among the multidisciplinary design teams. An analysis concerning the workflow, the rules and the functions of current roadway design was conducted. A process model based on the result of the analysis was developed by utilizing IDEF0 methodology. The process model reflects the interdependencies among multidisciplinary design disciplines and is capable of managing communication processes. This paper also discusses the design information hierarchy and the component representation schemes for systematic design information management. It is anticipated that the proposed information model would be able to improve the overall process of design of roadway construction projects by managing design information and helping the participants communicate and share information of the project effectively.

Key words : Information Model, Roadway Design, Design Management, Process Modeling

1. INTRODUCTION

Designing a roadway system is a multi-disciplinary process as it is composed of sub-systems that are designed by engineers with different backgrounds. Five major sub-systems that constitute a roadway system design are: 1) Roadway geometry & pavement system, 2) Structure system, 3) Drainage system, 4) Traffic system (Traffic signal, signs and lighting) and 5) Environment system. Each individual sub-system designers, who are often geographically separated, make design decisions, with respect to their own disciplines. These decisions, however, are interdependent. The vertical clearance between the bridge and the roadway profile, the cover depth of storm drainage pipe and the roadway profile, and the traffic signal timing and the turn lane layout are good examples of the interdependency in roadway design. Usually, engineers from different disciplines have regular meetings and conference calls for design coordination. These processes are very time consuming and often ineffective as they are being done manually or in a very primitive way of automation, if any. The result is a poorly designed surface transportation system as a whole even with excellent individual design parties. Most of the problems are not even recognized until the construction starts eventually creating construction delays and cost overruns. Common types of errors are:

- Tight constraint on design time and cost
- Indefiniteness in design information
- Continuous changes of general design condition
- Mismatch between connected sub-systems
- Indefiniteness of work scope and responsibility between sub-systems
- Delay of unnecessary decision-making for important matters
- Absence of design database

Design changes or evolves over time because of its nature (recursive loop of 'design-analysis-design'). Other factors such as changes in the project specifications contribute to the design changes as well. A design change in a sub-system, in many cases, creates subsequent changes in other sub-systems as found from the above described inter-dependencies. Often the negotiation process is very difficult as it is difficult to find the best solution for the whole system or one design party is reluctant to change its original design.

Therefore, it is necessary to make sure that design process is coordinated so as to sustain compatibility among the various sub-systems and components. This paper describes an information model, which has been developed and implemented to support the roadway design coordination process. The proposed information model thus aims to improve the overall process of design of roadway construction projects by managing design information and helping the participants communicate and share information on the project effectively.

The development of the model starts a review of related research work. The analysis of the coordination process during design phase follows. Finally, the information model is proposed and discussed.

2. REVIEW OF RELATED RESEARCH WORK

Many attempts have been made to address the complexity and the interdependency of design processes by dividing the tasks that are assigned to different design groups.

Mokthtar(2000) proposed a web-based system for managing design changes, such as tracking design files, notifying users of file changes [2]. Hegazy(2001) also proposed and developed a collaborative system for building design, which is based on the representation of building data in a hierarchy(BPH) and a representation of design rationale [3].

In Korea, most of the research efforts are related to managing design information focused on features like tracking design files, linking external textual and geometric documents [7].

These efforts, however, are limited to building design or only consider general design communication features. Because a discipline specific design process and inter-dependencies must be investigated for a effective design management system, this paper proposes and information model for roadway design processes which has not been attempted yet.

Table 1. Recent developed systems related design management

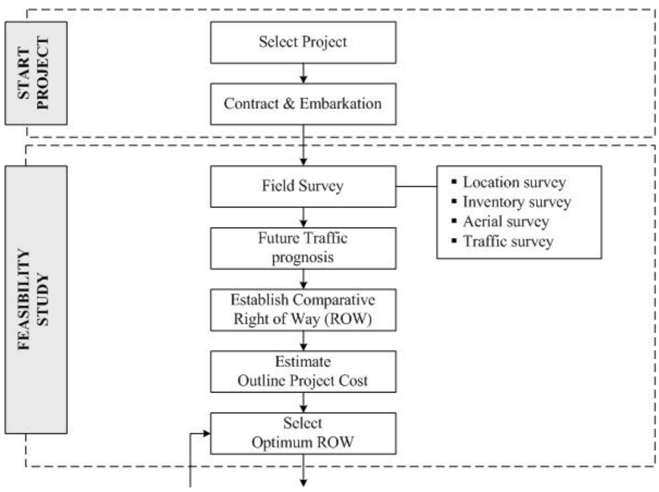
Name	Features
T. Hegazy (2000)	· Unify the storage and manipulation of building data · Documenting Design Rationale · Managing Design Changes
COMMIT	· Recording of the intent behind construction project decisions · Versioning, notification, object rights and ownership · Providing a complete project history
COWORK	· Collaboration of workgroup via Web · A central document repository · Index and search information · History of all activities over all workspace
ProjectWise	· Collaboration contents management · Optimizing for AEC workflows

3. ANALYSIS OF ROADWAY DESIGN TASKS

3.1 Workflow in Roadway Design

In general, the workflow of roadway design is composed of three main stages; Feasibility study, Planning & preliminary-design, and detailed design, which include inspection, discussion, and revision.

A description of the workflow is summarized in Figure 1.



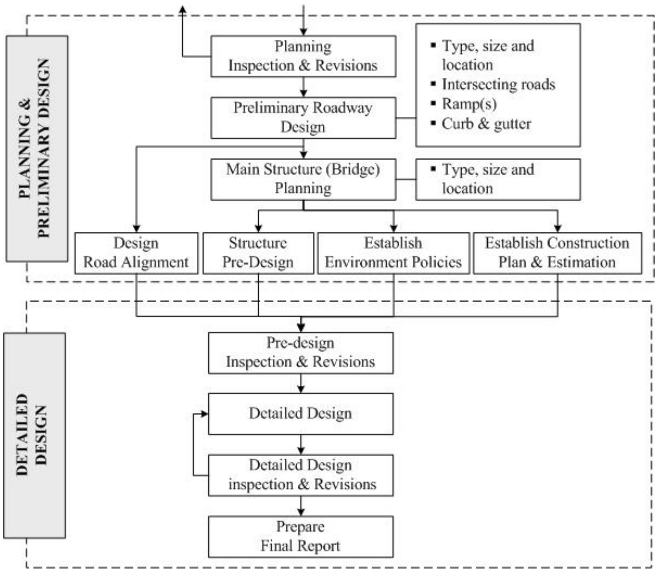
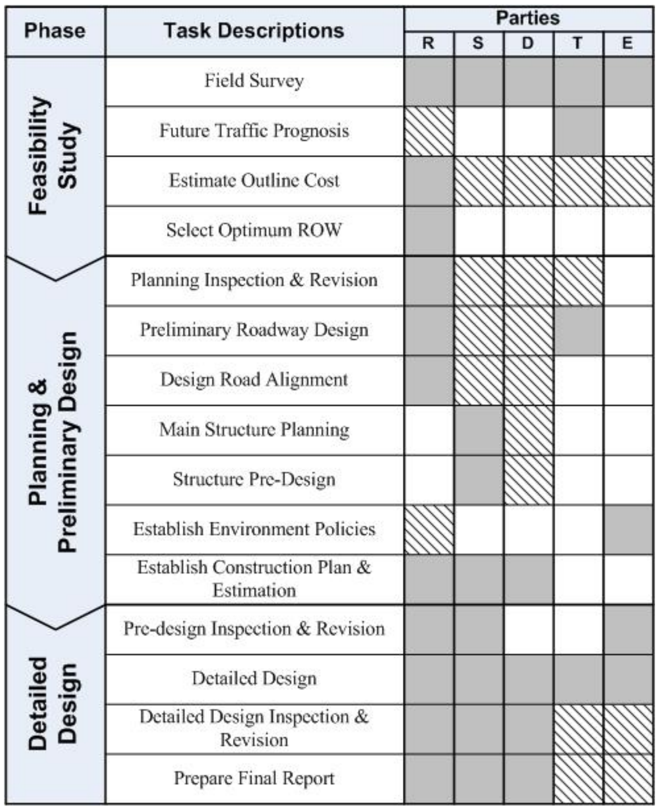


Figure 1. Workflow in Roadway Design

3.2 Interrelationship Analysis Concerning Rules and Functions of Current Roadway Design

The design participants identify important milestones throughout their designs at which they send or receive information to and from other sub-systems. The common interrelationships observed among the sub-systems throughout the roadway design process are represented in Figure 2, which shows the level of involvement of each design sub-system. Figure 2 can be used to identify the parties that are involved in design to be communicated. For example, the 'roadway geometry & pavement' design sub-system will affect the 'structure' design sub-system throughout 'road alignment design' task.



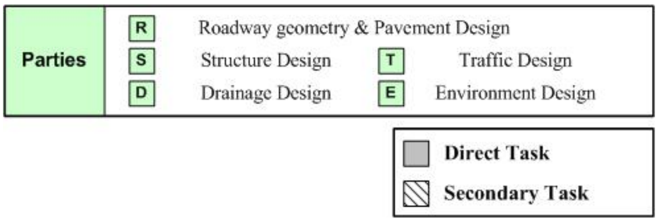


Figure 2. Phases, tasks and related design parties for roadway design

3.3 Interrelationship Analysis between Design Component

Design components, which are produced by the parties in roadway design, were identified and interrelationships between the design components were studied based on the interrelationship analysis of Section 3.2 (Figure 3).

The analyzed interrelationships can be used to manage design change processes. In other words, each interrelationship defines what design components are affected by a given change in any of the other component attributes.

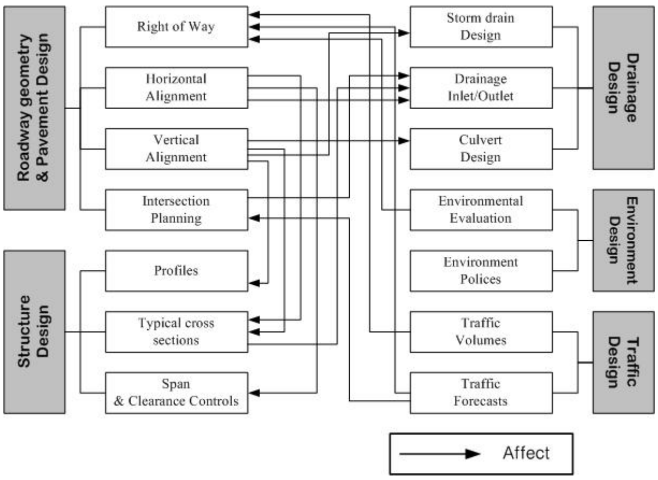


Figure 3. Interrelationships between design components

4. DESIGN PROCESS MODELING

4.1 Description of Modeling Methodology

The method of investigating the communication process in a roadway design environment is the IDEF0 methodology derived from system analysis technique known as structured analysis. This technique is primarily concerned with the development of the functional specifications for a design process. It is a well-known technique that is currently being used to develop information systems. The objective of the structured analysis technique is to provide the analyst with a step-by-step procedure for developing a structured specification for a design system [9].

The IDEF0 diagrams are composed of four basic elements described below.

1. **Input**– the data or objects acted upon by the operation
2. **Output** – output arrows mean results of operation.
3. **Control** – controls specify the conditions required for process to produce correct outputs.
4. **Mechanism**– mechanism arrows that indicate supporting means for performing the function

Figure 4presents a composition of the IDEF0 diagram that includes each of the four elements

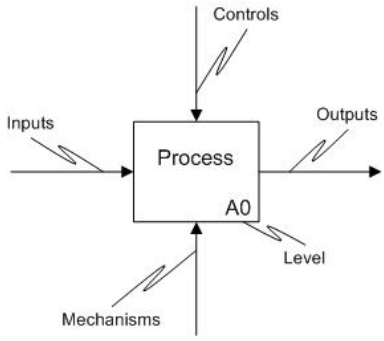


Figure 4. IDEF0 Diagram

4.2 Example IDEF0 Diagrams of Roadway Design

The planning and preliminary design phase of a roadway construction project was chosen as an example of IDEF0 diagram in this study. An example IDEF0 diagram for the planning and preliminary design phase is discussed in this paper to illustrate data flow between sub-systems. The data flow is illustrated from input and output arrows of the IDEF0 diagram. Control arrows are shows the conditions required for the function to produce correct outputs, such as specifications. Mechanism arrows represent the participants involved in relevant phase. All information of the IDEF0 diagrams are based on the analyzed contents analyzed in Section 3.

The IDEF0 modeling for the 'Planning and Preliminary design' phase begins with a A*4 diagram (Figure 5). The A*4 diagram is a second level of the entire model in the IDEF0 diagram.

As the lower level of A*4 diagram (or Child Diagram), 'A*43' IDEF0 model for 'Preliminary Road Alignment design' phase is shown in Figure 6. This diagram is the decomposition of 'Preliminary Road Alignment design' in A*4 diagram shown in Figure 4. All the other phases and the tasks described in Figure 2 were also modeled based on IDEF0 methodology, which abstracted the entire spectrum of the roadway design process.

4.3 Design Change Process

To allow for efficient management of design change, design components need to be active and the report changes made to the design values must be reported to related design parties automatically. This change report can included proposal of a change, the changes made to the component, and related components affected by changes (Figure 7). In addition to the component-related procedures described and modeled in Section 4.2 for design change management, other general procedures are needed as shown below and in Figure 7.

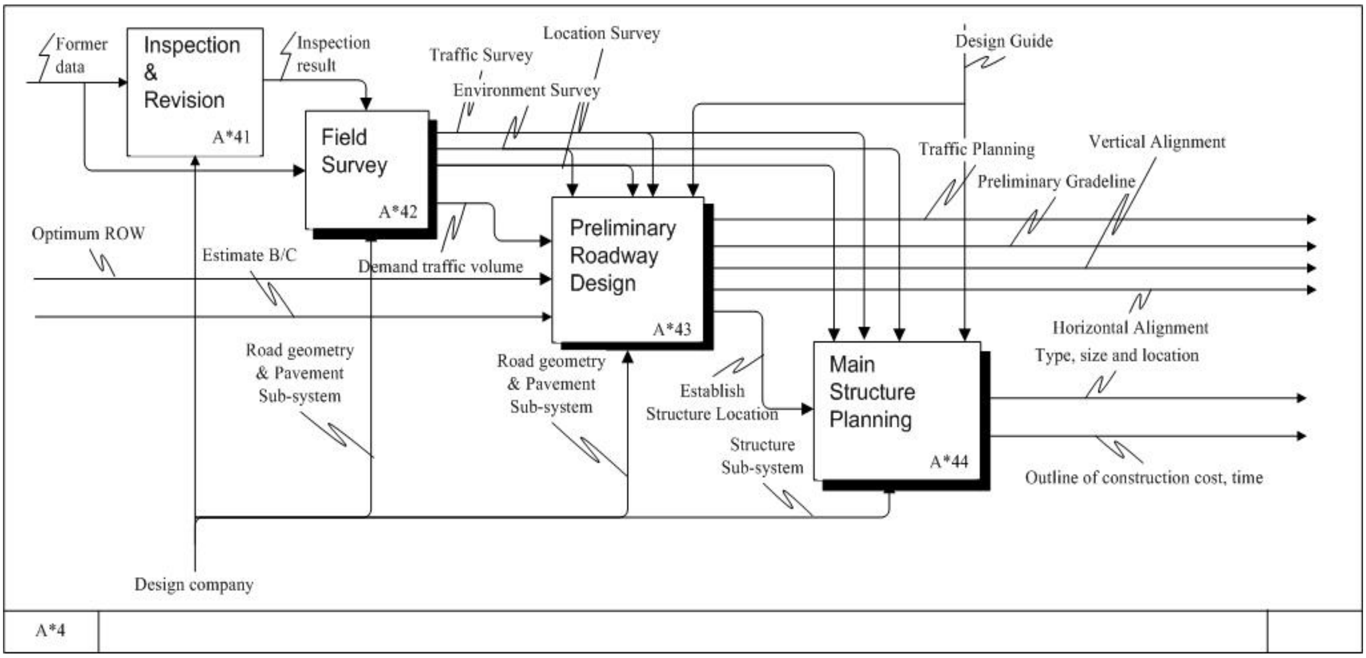


Figure 5.‘Planning and Preliminary design Phase’ IDEF0 Model (A*4)

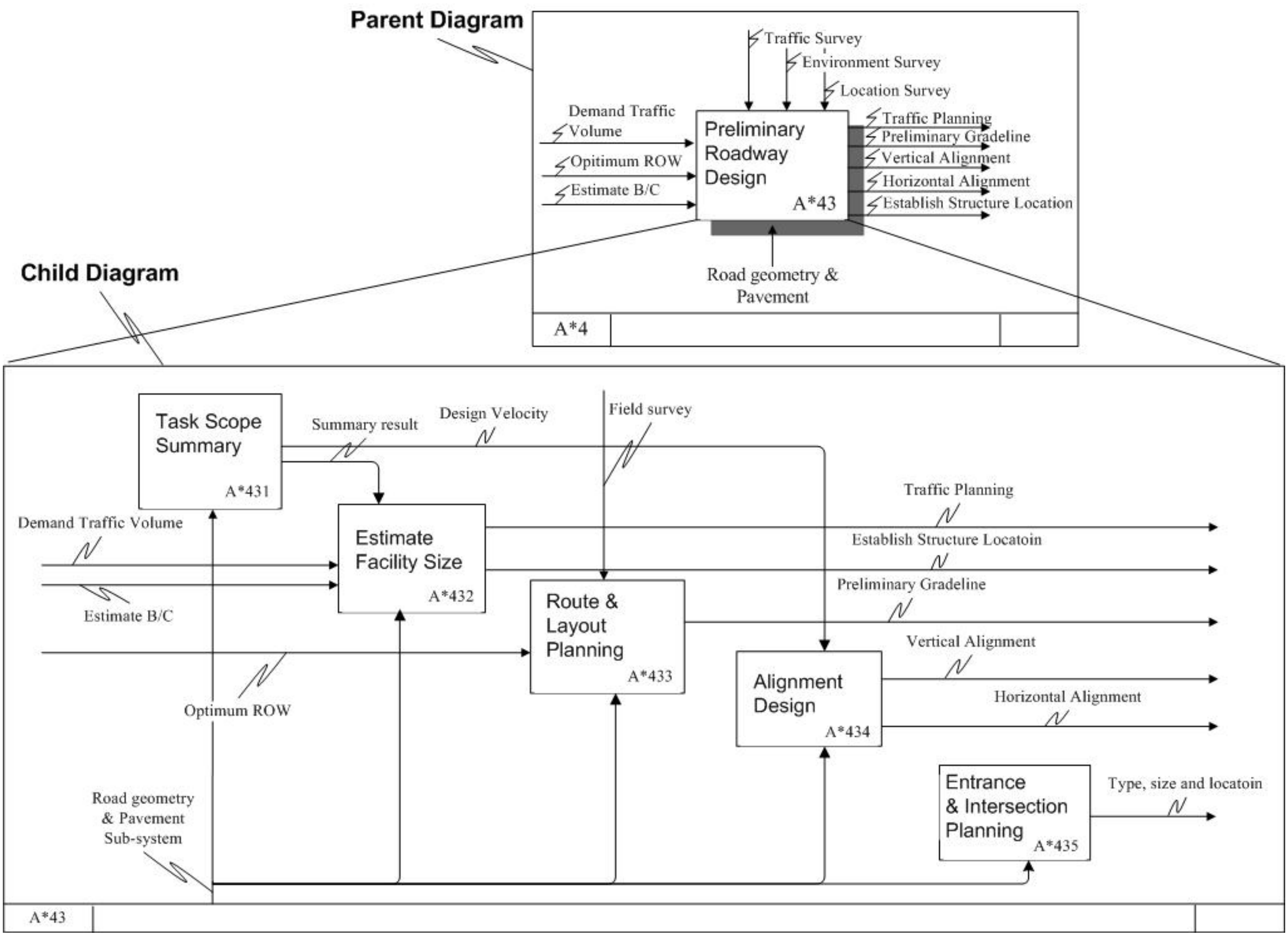


Figure 6. ‘Preliminary Roadway Alignment Design Phase’ IDEF0 Model (A*43)

(1) **Warning/Notice**: warn or notice design participants of the proposed changes and approved change proposals
(2) **Response**: respond to proposed and/or approved changes
(3) **Approval/Implement**: approve and implement approved change proposals
(4) **Reporting/Lessons Learned**: provide several reports that can be viewed by all disciplines, such as the history of all changes made throughout the design evolution, pending changes, changes affecting a certain design sub-system, and changes initiated by a certain design sub-system. These reports can be used to track responsibilities and to utilize them as lessons learned data.

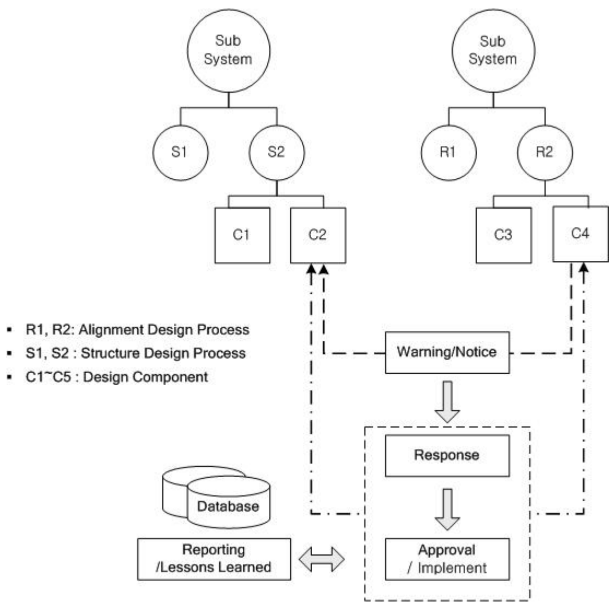


Figure 7. Design Change Process

5. DATA MODEL FOR DESIGN MANAGEMENT

5.1 Design Hierarchy

As a method for design data management, this paper is proposed design hierarchy to unify the storage and manipulation of design data and avoid redundancy. While participants in design team are working during each phase, the proposed design hierarchy can be used to store, group and classify design information. As shown in Figure 8, four levels are used in the proposed hierarchy:

(1) **Phase Level –** represent a progressed phase in design project, e.g. Planning & Preliminary Design.
(2) **Task Level –** can include allotted tasks in phase level, e.g. Design Road Alignment.
(3) **System Level**– described sub-systems that participated in Task level, e.g. Roadway geometry & Pavement.
(4) **Component Level -** can include more than one design component, which performed by sub-system, with attributes that include the entity information, design rationale, and related participants.

5.2 Data Components and Forms

Each component in the design hierarchy shown in Figure 8 is aware of its data and incorporates three types of information related to entity information, design rationale, and communication paths. The information can be numeric, textual, or can have links to external textual and geometric documents, e.g., specifications and CAD drawings, respectively. The component information is stored at a central repository of database, which will be described in Section 6.

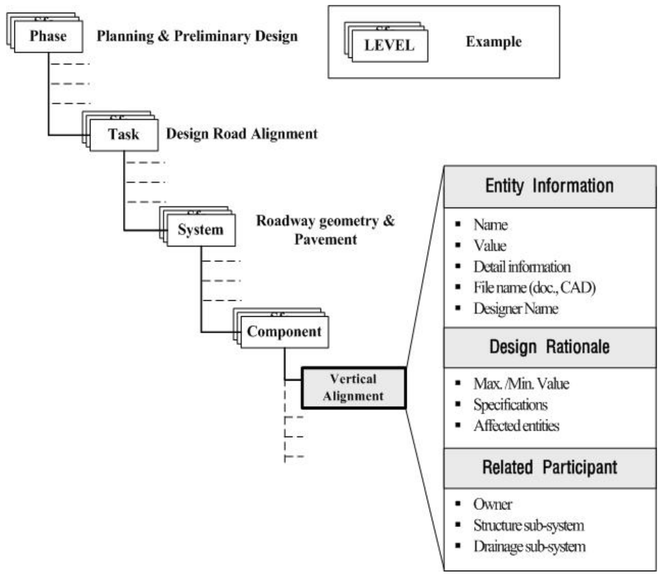


Figure 8. Design hierarchy and Data Component Form

6. DESIGN MANAGEMENT DATABASE

This paper is proposed a framework of design information database for consistency and efficiency of design (Figure 9)..

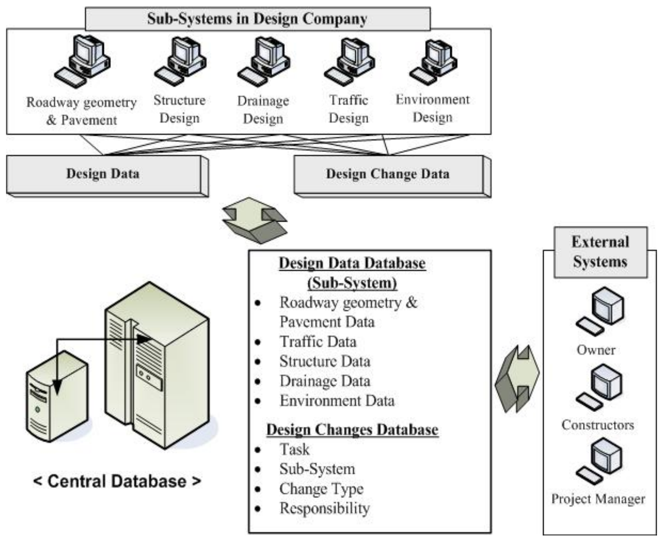


Figure 9. Schematic of Design Management Database

All databases for managing information are in a central repository. All sub-systems can activate and view the project's hierarchy but designers within sub-systems and external participants can only access and work on their related components. Accesses of any sub-systems to its own database gives full modify/use control while access to any other sub-system's database gives view-only control.
To allow flexibility in accepting or rejecting changes to the hierarchy, all disciplines work on a copy of their previously saved central databases, and at any time they can save their work to the original databases

7. CONCLUSIONS

In multidisciplinary environment, designing a roadway system require serious collaboration among design teams as the design from on discipline affects other disciplines. This paper has presented an information model, which to manage roadway design information and to improve the collaboration among the multidisciplinary design teams. Also, this paper discusses the design information hierarchy and component representation schemes for systematic design information model. It is anticipated that the proposed information model would be able to improve the horizontal communication or data transfer for the design of the roadway system. Details on implementing this model for design coordination will be dealt in a continuous study.

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