HIGHWAY INTERCHANGES:
CONSTRUCTION SCHEDULE AND TRAFFIC PLANNING
VISUALIZATION

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ABSTRACT

Highway Interchange projects present particularly complex and changing geometric configurations. Such configurations are hard to visualize and understand, and associated management, construction decisions, and traffic control strategies are difficult to optimize and communicate. This paper presents a computer-based system, which utilizes 3D and 4D CAD technology in order to: facilitate the communication of information regarding construction schedule and traffic control measures to all interested parties; allow consultants and contractor personnel to make better decisions with respect to a wide variety of issues. This new system was successfully employed during the planning and construction phases of a section of the 635/75 Interchange project in Dallas to visually display alternative schedule and traffic control strategies during the construction of the project.

KEYWORDS
Visualization, Traffic Planning, Construction Schedule, Highway Interchange, 4D Modeling
1. INTRODUCTION

Highway interchange projects are characterized by a high level of geometric complexity and are thus very hard to visualize and understand. For their construction, as with any construction project, project teams rely mostly on geometric information graphically communicated via 2D plans, and schedule related information organized in bar charts and network diagrams. However, 2D plans alone do not adequately communicate the 3D geometry of the structure. They also rarely provide the details necessary for the construction personnel to orchestrate the actual field installation of the various components indicated in the design and in the accompanying construction schedule. In fact, visualizing the sequence and duration of the construction process of highway interchange projects from 2D drawings and bar charts is difficult even for the most experienced contractors. Due to such difficulties in understanding and visualizing the different phases of the construction schedule, unexpected delays or conflicts often occur that undermine the success of the project.

In addition, during its construction, a highway interchange project is characterized by continuously changing geometric configurations that affect traffic planning decisions and complicate the overall project management. Without a good understanding of the changing 3D geometry of the structure during its construction, traffic control strategies are difficult to optimize and implement.

To facilitate decision making regarding both construction sequence and traffic planning, a visualization system is needed that will display the progression of construction over time and allow all project teams to visualize the 3D geometry of complex highway interchange projects and respective traffic regulations during each construction stage. A desired feature of the system is the ability to communicate the information on construction schedule and traffic regulations to all interested parties, including the traveling public. Basic features of 4D technology that were considered in the development of the system are described in the following section.

II. 4D TECHNOLOGY FOR CONSTRUCTION

3-D modeling as a graphical representation method is closer to the representation of the physical reality of a structure than 2D plans, and can, in principle, provide a better understanding of the aspects of a project that depend on spatial constraints. 4D CAD is a relatively recent technology that involves linking 3D digital models with construction activities. 4D technology is intended to be used by planners, designers, and engineers to analyze and visualize many aspects of a construction project, from design related considerations, to the sequence of construction, to the relationships among schedule, cost and resource availability data. In essence 4D can assist designers and planners in developing realistic and practical schedules and estimates (McKinney et al. 1998).

A significant component of 4D models is the method employed for animating and visualizing various project planning and construction operations. Snapshot animation is the most common method of visualizing a construction project. According to this a computer animation file is
automatically generated from the compilation of views of the 3D model that follow the time sequence defined in the project construction schedule.

Although the usefulness of visual 4D models has been tested in planning the construction of various large scale public and commercial projects, (Koo et al., 2000; Luiten G., Tolman and Fischer, 1998; Luiten. and Fischer, 1998), no application of 4D technology and associated visualization techniques in the planning and construction of highway projects has been encountered in literature. An effort to develop a new visualization system that makes an efficient use of 4D CAD technology and is able to integrate construction and traffic schedules is described in the following section.

II. VISUALIZATION SYSTEM: FEATURES AND CAPABILITIES

The basic features and performance requirements of the proposed system for the visualization of both construction schedule and traffic planning are as follows:

1. **Comprehensive 3D CAD Database Integration**

   The system should allow for the integration of a comprehensive 3D database of the geometric configuration of complex highway interchange structures. For the planning and construction of interchange project typically three distinct levels of geometric configuration are required: a) current as-built, b) intermediate planned/as-built (including temporary structures), and c) final as-designed.

   The structure of the database should allow for a flexible display of the 3D model geometry based on specific thematic organizational requirements. That is, the graphical entities that correspond only to demolition or construction planning, should be easily generated and displayed to improve communication of relevant information between project teams. (DOT personnel, contractors or sub-contractors, etc.)

2. **Schedule Integration**

   Construction schedule is primary project information that is typically visualized with the use of 4D CAD technology. Therefore a performance requirement of the new system, of critical importance for the planning and construction of highway interchange projects, is:

   To effectively communicate project planning and scheduling information and to allow for the visual evaluation of various schedule options during project planning.

3. **Traffic Planning Integration**

   A significant difference between construction scheduling for standard projects and highway interchange projects, is that the construction phasing of the latter is directly related to the traffic planning. According to this the new system should allow for the integration of traffic planning, and effectively communicate traffic control decisions. It should also allow for the visual evaluation of various traffic control options during project construction.
4. Visualization Capabilities

An additional performance requirement of the new system is to support various graphic output formats and to allow for the display of the geometry, schedule, and traffic controls in presentation formats that can be easily understood by all interested parties including the general public.

In this regard graphic output formats should allow for:
- Snapshot animations of a) Schedule, b) Traffic planning, c) Combined schedule and traffic planning.
- Multiple representations of static images such as rendered views, combined rendered and wire-frame views, perspective views from various angles, views with various levels of detail.
- Effective photo-matching methods for the communication of traffic control information to the public.

In addition the system should allow for the:
- Electronic transmission of all graphic output formats to project participants to be used in project review meetings
- Storing of all output formats together with schedules of project activities in Web pages for information to the public during construction.

For the integration of all the above project material and the development of the new computer based system the following software has been used:

a) Microstation TriForma. TriForma provides the necessary tools to design projects in 3D and at the same time keep track of materials, quantities, cost reports and specification texts, by linking graphical objects to non graphical databases.

b) Schedule Simulator. Schedule Simulator, that is based on the J Space object-oriented technology, allows for the integration of the 3-dimensional graphical model with project schedule data, developed using commercially available scheduling software (Primavera, Project Planner, Microsoft Project etc.) Schedule Simulator allows for linking graphical objects (piers, girders, etc) to corresponding schedule activities and enabled us to interactively create new groups of graphical objects or re-organize existing.

c) Enterprise Navigator. The Enterprise Navigator environment is required mainly for running Schedule Simulator. In other words, Schedule Simulator performs graphic simulations and animations of the construction process within Enterprise Navigator. Enterprise Navigator allows for 3D navigation while the simulation runs.

IV. COIT BRIDGE: CONSTRUCTION AND TRAFFIC PLANING VISUALIZATION

The usefulness of the new system has been tested in the construction of the first phase of the “Coit Bridge” in Dallas, Texas, the construction of which started on January 2002. The construction of Coit bridge represents one of the most complex sections of the new five layered 635/75 Interchange project, known as Dallas High Five. Traffic regulations during the Coit
Bridge construction have been and will continue to be of critical importance until the completion of the project.

Most notable stages in the development of the above mentioned systems to be used in the planning and construction of Coit bridge include:

**STAGE 1: Thorough 3D Database and Construction/Demolition Animations**

a) A complete and detailed 3D model of the Coit Bridge, based on hard copies and/or digital files of 2D plans and sections provided by HNTB and TXDOT, was developed. The geometric information was organized in levels and reference files according to construction phases and stages as was indicated on the provided plans. (Figure 1) Triforma was used for the development of 3D graphical modeling and the grouping of graphical objects. The development of the comprehensive database allowed us to retrieve and display model information in the form of both static images and animations, by demolition, construction plan, etc. More specifically the following have been developed:
b) Animation of the Coit Bridge demolition
c) Animation of the Coit Bridge construction (Figure 2)
d) Animation of the combined demolition and construction organized by phase(Figure 3)

At this stage of the project, the animations of demolition, construction, and combined demolition and construction were based on an initial schedule provided by TXDOT- at the time no descriptive schedule had been provided by the contractor.

**STAGE 2: Construction Schedule Animation based on Contractor’s Detailed Schedule**

A 4D CAD model has been generated by linking 3D graphical objects with construction schedule activities, times, resource allocations, etc. (Figure 4). This has been made possible with the use of Schedule Simulator and Enterprise Navigator software.

The system provided an effective feedback in terms of alternative schedules and allowed TXDOT personnel make better decisions with respect to a wide variety of issues. Indeed several meetings were held with TxDOT engineers and contractors at the TxDOT’s Dallas District office. After viewing the animated schedule, TxDOT engineers were able to identify potential problems in the schedule proposed by the contractors, and to make informed decisions regarding changes in the construction schedule. More specifically the early construction of an overpass was identified by TxDOT engineers as a potential problem. Several alternative schedules were generated during the meeting. The display and comparison of animated alternative schedules, running at the same time intervals, helped contractors and engineers agree on a most preferred schedule.

**STAGE 3: Integrated Construction Schedule/ Traffic Planning Animation**

At this stage, traffic planning is added to the system. Lane indications become graphical objects and are represented with activities added to the schedule. In this manner, the 4D model that was previously developed, displays combine traffic schedule and planning animations. (Figures 5, 6)
In summary, the most significant contributions of the schedule and traffic planning integration have been the following:
- Evaluation of the potential impact of unplanned occurrences during construction
- Identification and prompt solution of errors in the schedule
- Identification and prompt solution of errors in the traffic planning

Additional tasks that applied to all stages involved the development of:
1. Specialized functions, supplemental software and analysis procedures to automate user interaction. As an example a challenging issue was to determine the most appropriate and effective visualization method for the communication of traffic control decisions to the traveling public. A sample of an animation/rendering product that can be used for the information of the public on construction operations, closed traffic lanes etc. is shown in Figure 7.

2. A project WEB-page on which all relevant information can be uploaded.

V. CONCLUSIONS
The main objective of this work was to contribute to the collaborative decision-making about construction schedules and traffic planning for highway interchange projects. To this end an efficient system for the integration of a comprehensive 3D project database, construction schedule, and traffic planning has been developed. The system has allowed for the visualization of the progression of the construction over time and the display of traffic measures at respective stages of the construction. The system has been useful in the construction of the first phase of Coit Bridge, a section of the Dallas High Five Interchange project that is currently under construction. It has helped project engineers and contractors make collaborative decisions for both the construction schedule and traffic planning of the bridge.

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