A Communication-Based Paradigm for Construction Asset Management

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Summary

This paper describes a paradigm for the use of bidirectional real-time communication in Artificial Intelligence (AI) based construction asset management. A Logistics Management Center or LMC houses a nexus of artificial intelligence tools, knowledge bases, and communication facilities that serve to make up a Information Logistic Expert System or ILES. The LMC is in constant two-way communication with the field sites of the construction project, staging areas, equipment suppliers, manpower sources, traffic and meteorological monitoring station, and transportation infrastructure providers. The ILES has a predicate-calculus knowledge base that implements both predicative and corrective measures to keep the construction project on schedule by anticipating problems with resource logistics and optimizing the response to such problems. The basis of this system is the implementation of existing AI tools in a wireless-web environment.

Keywords: Asset Management, Wireless Web Technology, Construction Planning, Construction Logistics.

1. Introduction

Construction logistics is the movement and scheduling of personnel assets, material assets, and equipment assets for the purpose of supporting a construction project or projects. Five dynamic uncertainty factors affect construction logistics; weather, traffic patterns, personnel absences, equipment breakdowns, and unexpected technical issues in the construction itself. Any one of these problems can lead to catastrophic system-wide failures completely stopping useful work at a construction site. Due to the need to continue payment of salaries, utility and usage fees, interest on loans, and so forth these types of failures can easily bankrupt a small to mid size contracting company or public works agency and cause serious financial problems for even larger companies or public works agencies. Further, there are complex dynamic linkages between these uncertainties. For example, serious inclement weather causes traffic issues which delays personnel and materials in transit. Mild inclement weather makes climate sensitive tasks like concrete pouring and exterior painting impracticable. Time sensitive contracts make rescheduling of the needed personnel and materials even more problematic.

2. Review of Literature

The literature in this area of research is enormous and no claim is made of a comprehensive listing. Majidzadeh (2000) and McKim and coworkers (2000) have commented on the general aspects of computer/internet technology in the Construction Industry [1, 2]. Rosta (1999) has commented on the economic aspects of communications in the Construction Industry and Sawhney and coworkers (1997) have commented on techniques to plan for weather delays in construction projects [3, 4]. In more detailed discussions of the role of communications in construction, Unal and Grayson (1998) have described the implementation of real-time radio based communications in mining, and Thomas and coworkers (1998) have described the hierarchical nature of communications in construction projects [5, 6]. Phair contributed two articles in 1997 that described specific projects to standardize the communications/web based aspects of Construction Industry practices [7, 8]. Luiten and Tolman (1997) have described a communications automation paradigm that called STEP that will implement "...data transfer without human interaction..." [9]. Phair (1997) and Menzies (1994) have described the use of traditional communications links such as satellites and microwave-radio in construction projects [10, 11]. Menzies described an elaborate communications network called VENNET implemented by the Petroleum Industry in Venezuela that includes telephone, telex, video conferencing and e-mail links based on satellite and microwave-radio communications. Russel (1993) has described the use of computers as a site-level tool for data gathering in construction projects [12]. Teicholz and Fischer (1994) have proposed a CIC or Computer Integrated Construction paradigm based on the CIM or Computer Integrated Manufacturing paradigm already widely used in the Manufacturing Sector [13]. A number of papers have been contributed to the literature describing the application of Artificial Intelligence tools to construction projects including the work of Haidar and coworkers (1999) describing Genetic Algorithm based methods, Leu and coworkers (1999) describing Fuzzy-set based methods, Ersoz (1999) describing Neural Network based methods, and Lee and coworkers (1998) and Hosny and coworkers (1994) both describing Knowledge-Engineering based methods [14-18]. The work of Lee features a constraint-type system for optimizing apartment construction called FASTRAK-APT with a knowledge base implemented on the KAIST expert systems shell.

3. The Paradigm

The heart of this paradigm is the creation of an Information Logistic Expert System or ILES. The paradigm is depicted graphically as an information flow-chart in Figure 1. The ILES is one or more computers networked with wireless internet terminals in the field. The ILES is housed in a Logistics Management Center or LMC. The LMC receives information from other relevant real-time sources such as traffic monitoring systems, weather monitoring systems, and so forth. Although weather, traffic, absences, breakdowns, and technical issues are not rigorously predictable, information science tools are available to (a) predict possible problems and (b) enhance construction schedule recovery from such problems. The overall structure of this communications-based paradigm is as follows:

(1) Field personnel will be equipped with two-way communications interfaces to the ILES. This interface will take the form of palm-top computing devices with wireless internet access. Field personnel will enter relevant data on a regular basis throughout the workday to the ILES and will receive detailed updates to their tasks and schedules throughout the day from the ILES.

(2) The LMC will monitor existing information channels for weather and traffic problems and regularly input this data to the ILES.

(3) The ILES contains three major components:

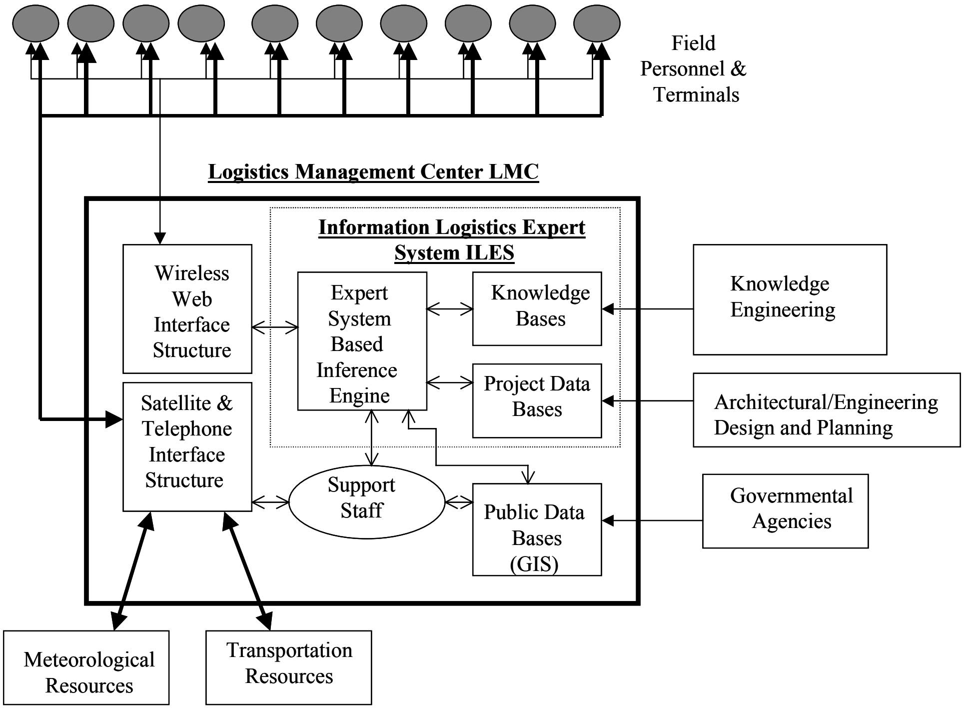

Figure 1. Flow Chart for the Paradigm.

(I) The ILES has an AI-shell programmed with a Predictive Knowledge Base. For example, traffic Engineers from experience know what intersections are most likely to be congested at certain times of the day. Experts in the construction trades know what tasks are most likely to result in injuries. Managers of construction equipment know what types of equipment are most likely to breakdown. This knowledge base will make predictions as to what problems are most likely to occur based on the data input by personnel from the field and other monitored sources such as weather forecasts, and on the existing construction schedule.

(II) The ILES has a Comprehensive Asset Database. Personnel assets are listed as to all possible job competencies. Material database contain stocking information from available suppliers. Equipment databases have information as to the status and location of all equipment. Engineering databases contain detailed information breaking down each separate task in the construction sequence as to the needed personnel, material, and equipment assets.

(III) The ILES has an AI-shell programmed with a Corrective Knowledge Base. For example, traffic Engineers know from experience what alternative routes are available. Personnel experts know the types of tasks most suited to be performed by temporary, non-expert workers, and know what types and numbers of such workers are likely to be available. Equipment experts know what types of repairs are needed for specific breakdowns and what time, parts, and cost factors are involved.

(4) The paradigm works as follows during normal operations. The ILES formulates the best asset management plan for the project on a short-term (daily), mid-term (weekly) and long-term (entire project) basis. The ILES receives data from field communications terminals and other sources. The ILES uses the Predictive Knowledge Base to update the short-term and mid-term asset management plans by using the generating likely problem scenarios. The Corrective Knowledge Base generates optimal responses to these scenarios and implements them through direct communications to managers and workers in the field. The Corrective Knowledge Base also updates the Comprehensive Asset Database with this information. The Predictive Knowledge Base updates and refines the mid-term and long-term asset management plans on a daily basis.

(5) In the event of a catastrophic failure, for example a major structural collapse, the managers at the LMC input the details of the situation to the ILES. Field workers and managers enter information about the status of affected assets using their wireless terminals. The managers at the LMC use the Corrective Knowledge Base to run what-if scenarios to formulate and refine recovery strategies for the construction project.

Although complex, this paradigm does not use any information technology tools not commonly available. The purpose of this paradigm is to integrate existing information technology tools with construction logistic asset management procedures to create a better system for predicting and recovering from disturbances to construction schedules and for automating and enhancing the management of construction assets on both a short-term and long-term basis. A number of scenarios are presented to illustrate the possible benefits of this paradigm to a construction project.

3.1 "Dead Heading" Truck Scenario

- Trucks used to transport construction materials (1) typically are owned or leased by a single vendor and (2) typically are returned empty after fulfilling their delivery schedule. The ILES can implement a far more efficient method of materials logistics:
- The trucks can be rented or shared by all vendors.
- The truck loads can consist of shipments from several vendors arranged in each truck in an optimal manner. For example, if a job requires materials from several vendors, the materials can be localized in one truck. If a load of materials needs to go to different sites, the materials can be loaded in an order that the entire truck need not be emptied to reach an item.
- The wasted "Dead Heading" trips can be eliminated. Empty trucks leaving the site can be loaded with refuse or rented equipment being returned to a vendor thus making use of a previously wasted resource.

3.2 Routine Weather Scenario

- Inclement weather is predicted by meteorological resources.
- The ILES's Predictive Knowledge Base restructures the short-term, mid-term, and long-term plans to bring weather insensitive tasks forward and push weather sensitive tasks backward wherever possible.
- The Comprehensive Assets Database is searched for the supplies, equipment, and personnel available.
- The Corrective Knowledge Base selects weather insensitive tasks to be performed based on the data stream from the Predicative Knowledge Base and Comprehensive Assets Database. Traffic and geographical data are used to shift orders to vendors least likely to be impacted by the weather scenario.

3.3 Routine Labor Shortage Scenario

The Predictive Knowledge Base includes expert knowledge gained from personnel managers. For example, these managers know that workers are likely to take vacation or personal time at certain periods such as Holidays. These managers also know that heavy construction tasks are more likely to result in injury than light tasks. The Predictive Knowledge Base incorporates these issues into its plans. The long-term plan includes a scheduling of labor intensive tasks away from Holidays and deliberately hires or places on call extra staff for injury-prone tasks.

3.4 Weather Catastrophe Scenario

- A catastrophic weather event is predicted by meteorological resources.
- The Predictive Knowledge Base has expert knowledge as to the likely consequences for this event. For example, weather might be so severe that work must cease and special precautions must be taken to protect the worksite and equipment.
- The Comprehensive Assets Database is consulted as to what supplies and personnel are available. The Predictive Knowledge Base formulates a site protection plan. In a less major case, the weather catastrophe might not directly affect the construction site but might close delivery routes for distant vendors.
- The Predictive Knowledge Base and the Comprehensive Assets Database are used to alter the short-term and medium-term plans to allow work not using these unavailable materials or equipment to continue. In either case, managers and workers in the field can enter weather information allowing the ILES to include extremely localized weather information into the planning process.

3.5 Construction Catastrophe Scenario

- If a major structural collapse occurs on the construction site, site managers can enter data on the personnel, materials, and equipment impacted.
- The Comprehensive Assets Database and the Predictive Knowledge Base are used to implement disaster recovery by reallocating resources and rescheduling jobs affected and not affected by the catastrophe.
- The ILES can generate detailed listing of personnel at the site and the vendors providing equipment and materials to that specific failed task for investigative purposes.
- Ultimately, a sufficiently sophisticated Predictive Knowledge Base should be able to foresee possible problems and offer pre-emptive solutions. For example, the personnel records of each worker would have a detailed listing of very specific job skills. The Predictive Knowledge Base would raise an alarm if the skills of the workers available for the task are not sufficient for the inherent danger and complexity of the task.

4. A Work in Progress based on this Paradigm

A project is underway to optimize the allocation of assets for the task of snow removal. This project is based on building a Knowledge Base on a commercial Expert System Shell. The Shell interfaces with GIS geographical databases and databases listing the personnel assets (snow plow drivers), equipment assets (snow plows), and material assets (salt, sand, and other snow removal materials). The Knowledge Base uses heuristic rules to optimize the implementation of the snow plowing task. Work is in the preliminary stages of adding real-time meteorological data to the system. Snow plows equipped with GPS (Global Positioning System) and two-way radio-based data communications capabilities are already in use in the State of Iowa and other places in the USA. Work is in the preliminary stages of using these real-time communications resources to help refine the optimization of the snow removal plan during the actual snow removal process.

5. Conclusions

Though complicated the paradigm presented in this study contains no technologies not already widely used and available in other industries. The heart of the paradigm is a parallel structure of communications and decision making based on human-human, human-computer, and computer-computer information flow. The availability of cheap and reliable computer devices like wireless-based internet terminals in the form of Personal Digital Assistants (PDA), palmtops, laptops, and internet-ready cellular telephones greatly facilitates the implementation of this communications structure. As highly localized weather forecasts in real-time internet form and real-time transportation information are both easily available, their incorporation should present a few technical challenges. The challenge of this paradigm lies in the creation of the Knowledge-Base through Knowledge-Engineering of the various trades and crafts involved in the Construction Industry. This is still a largely unexplored subject and will be the focus of the continuing research in this paradigm

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