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E-COORDINATING INFRASTRUCTURE DECISIONS

Tamer E. El-Diraby
Assistant Professor, Civil Engineering Department, University of Toronto, Canada

ABSTRACT
Infrastructure projects involve hundreds of participants, thousands of decisions and huge volumes of data. Centralized document-based project development schemes pose technical difficulties in addition to providing sub optimal outcomes. Distributed development environments provide an effective solution to the challenge of collaborative infrastructure development as has been successfully shown in other sectors of the economy. This article outlines a theoretical framework for a web-based system for coordinating infrastructure decision-making using component engineering. An infrastructure decision component encapsulates all necessary elements of a decision activity in a network-based entity that references all required decision ingredients: administrative procedures, decision criteria, decision-makers, and software involved in the decision activity.

KEYWORDS
Infrastructure, Decision making, Coordination

1. INTRODUCTION

The steady stream of infrastructure developments over the ages from towering bridges and the electrification of our cities to intelligent transportation systems and the Internet is a major human achievement and a fundamental component of our modern life. Yet, in spite of its importance, a coordinated approach to infrastructure development and renewal rarely exists. The decision powers and the knowledge needed to optimize them are scattered and incompatible. With the ongoing plethora of urban renewal projects, it is timely to initiate a coordinated approach for infrastructure decision making (IDM) to provision integrated infrastructure systems that promote sustainability, optimize the overall city-level infrastructure network, and enhance human economic activities, but not at the expense of social and environmental objectives (Petak and Schuler, 1998).

This paper presents a theoretical framework and a perspective for the use of component engineering and web services in coordinating infrastructure developments over the Net. Component engineering is a method to encapsulate human knowledge regarding certain process in reusable computer modules. A decision component, as defined here, combines four heterogeneous elements of a decision activity in an object-oriented format: administrative procedures, decision makers, decision criteria and decision software (PDCS). The utilization of such components will facilitate IDM data exchange in a decentralized network-based process.

Web services are Internet applications that fulfill a specific task or a set of tasks that work with many other web services in an interoperable manner to carry out their part of a complex workflow or a business transaction. Web services are poised to help decision makers combine compatible software modules to build on a real-time basis a decision making environment with seamless exchange of data.

2. NEW DEVELOPMENT PARADIGMS

Meeting the overwhelming challenges of urban renewal in North America will require reengineering the IDM process to create a new understanding of the relationships between sustainable community development and the demands for efficient use of resources and reduced social and environmental impacts. The process has to address a multitude of questions: Who should define and decide the level(s) of sustainable project objectives? How to coordinate IDM across organizational boundaries? How to address the complex relationships between the owner, developers, engineers, citizens, and governments? What performance measures should be established for project design, construction, operation, maintenance, and inevitable renewal? What balance should exist between project impacts on the environment and economic development? What are the impacts and benefits of IT tools and the emerging e-society (Ichioka, 2000) in coordinating urban renewal?

Three paradigms are proposed as the base for such reengineering:

- Integrating the IDM process through flatter organizational structures and better information exchange and coordination of IDM (Talvitie, 1996).
- Changing the decision criteria to reflect relevant aspects of sustainable development ranging from environmental to urban and social objectives.
- Broadening IDM stakeholders' panel through active involvement of the society and private sector in the decision process. Past experience has shown that public satisfaction and cooperation have a direct bearing on project maintainability and sustainability.

3. INFRASTRUCTURE DECISION COMPONENTS

Infrastructure is a web of heterogeneous engineering systems administered by a multitude of institutions and layers of government. Component engineering could be an effective mechanism to navigate this web and achieve collaborative IDM. The concept of infrastructure decision component (IDC) stems from a similar concept in software engineering where a software component is defined as: "self-contained, clearly identifiable, pre-defined entity that provides well-understood function and is intended to be used with other components to provide more complex functions (Norris et al., 2000)."

IDC can be defined as a self contained coherent segment of the IDM continuum that encapsulates all necessary elements of a decision activity in a network-based entity that references all required decision administrative procedures, decision criteria, decision makers, and software involved in the decision activity.
An IDC is inherently a computer object that references the PDCS of a certain decision through four proxy elements (a proxy is a reference to the network location and interface of the corresponding element):

- *Decision procedures proxy:* reference to all the administrative aspects of the decision under consideration like data to be collected and their analysis, permits required, entities claiming jurisdiction over the decision and their approval hierarchy, and decision documentation.
- *Decision makers' proxy:* identifies the contacts of the authorities responsible for administering the decision at various levels of responsibilities and weights (some could be an interim decision maker, another could be a consultant, and a third could be the final decision maker).
- *Decision criteria proxy:* reference to the definitions, evaluation methodologies and weights of criteria to be used in making the decision.
- *Decision software proxy:* reference to applicable software for analyzing the decision with specified input and output parameters, user interface and decision augmentation methodologies.

IDCs portray a network of entities representing different decision activities that can interact on a real-time basis. Each IDC will make itself available to all users registered on its decision makers' list. It will display relevant information to all of them based on their "security clearance". The procedure proxy will list the required procedures needed to certify a decision along with contacts to the authorities administering such procedures. For example, a service provider could document a certain permitting cycle into a for-rent sub-component that can be used to contact different jurisdictions and prompt their systems with the required documents (or drawings) for permitting. The sub-component could then receive their approval and update the client IDC to proceed to the next step. Such for-rent

service software are already available in other industries and are emerging in the construction industry (Han et al., 1998). The IDC then identifies and prompts a decision maker to proceed to the next step. Each IDC will have a comprehensive definition and reference to applicable decision criteria along with "help menu" about their evaluation (which could be on a different server). At some point a decision maker may request using a software to evaluate certain criteria. The IDC could invoke such software through its proxy which will locate the required software (at a certain server provider), prepare and send proper input and receive, configure and direct results to the next step.
Every related IDC could make note of the proceedings of other IDCs and make decisions accordingly. Meta components could be established to coordinate the timing of decisions and component interdependency. The Meta components could also handle citywide coordination among various infrastructure systems. Outside entities like bankers, investors, contractors could be informed with the ongoing component performance and decisions and could adjust their plans accordingly.

4. MIRROR WORLDS

As the information culture evolves in the infrastructure development community, specialized companies and brokers could provide "web services" and solutions over the Internet. More advanced than traditional Electronic Data Interchange, web services are poised to become the main approach for facilitating "e-infrastructure". They enable just-in-time application integration where web applications can be dynamically changed by the creation of new web services. Various applications that are available on the Internet can be accessed and invoked at run time without prior knowledge and programming requirements to enable business processes and decision-making at Web speeds.

The Universal Discovery Description & Integration (UDDI) project creates a platform-independent, open framework for describing services, discovering businesses, and integrating business services using the Internet. The UDDI project takes advantage of World Wide Web Consortium (W3C) and Internet Engineering Task Force (IETF) standards such as XML, and HTTP and Domain Name System (DNS) protocols and Simple Object Access Protocol (SOAP). The UDDI protocol is the building block that will enable businesses to dynamically find and transact with one another using their preferred applications.

Developing IDM web services will require a deliberate level of cooperation and research into the creation of a vibrant information supply chain—which includes:

- Content creation: creation of original multimedia content such as data, photograph, audio and video. These products cover current and future development, productivity data, labour statistics, resource usage information, material pricing, technology briefs, industry best practice, lessons learned, etc.
- Content packaging: modeling, digitization and manipulation of original content into suitable format. i.e. the development of proper means to express construction information in a compatible way (software, components, web services, process modules) that can provide the end-user with a needed service (analysis of one design aspect, communication between different parties, etc.)
- Market creation: developing and managing existing and new markets for information services. i.e. identifying, influencing and satisfying users through awareness and developing end-user oriented software and information commodities.
- Interface and system: establishing a means for the exchange of products among producers and users and between different users through communication protocols, date exchange standards, and directories of services, security regulations, etc.
- Customer support: developing interaction systems to solicit and respond to customer needs and requirements both in the software format or the hardware.

The major impact of such a supply chain is the creation of an environment conducive of network-based project development. Virtual dynamic organizations will evolve in the infrastructure development domain providing for more smooth collaboration. For the development of this condition, research will be needed into the following areas:

- Interaction and integration of business and technical factors relating to, for example, selection of components and suppliers, cost/functionality/quality/ availability/confidence trade-offs, future proofing, managing change, payment models, integration of business and technical processes.
- Implementation strategies and migration paths in user organizations that will facilitate the adoption of component/web service in infrastructure development.

- Creating the required user mass through studying and influencing user awareness and needs and establishing marketing strategies and means for collaboration.
- Studying the impact of component/web services and the establishment of industry organizations and forums to support the needed development efforts and encourage entrepreneurship the market.
- Study the economy of web services in infrastructure development through analysis of trends and economic performance of web-based development enterprises.

The proliferation of web services in the infrastructure marketplace will provide organizations with complete and immediate information about ongoing developments, best industry practice, and services to build their decision-making and business transactions through standardized web applications.

Still, full standardization of data and web services protocols of various industries involved in the infrastructure development may be not achieved. While it is easy to enable wider collaboration through data and web services standardization, static standards are inefficient and will be short lived. It is easy to alienate other participating industries (banking, insurance, Auto, etc.) due to the lack of standardization harmony. This leads to the need to develop dynamic standardization schemes that adapt to change and support inter-standards communications (in the same way OMG initiated the IIOP to connect various ORB standards). Essentially, we need to create modular self-describing standardization schemes where the component or web service holds within itself reference to its standards. This will require creating standardization-parsing meta-components that can dynamically resolve the conflict and exchange information among different standards. Therefore further research will be conducted into:

- Developing languages and protocols based on UDDI to facilitate interaction between different vendor web services.
- Creating proper taxonomy for dynamic virtual enterprise transactions that will provide for faster more harmonious exchange of products over the network.

5. REFERENCES

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