INTEGRATION OF PLANNING & CONTROL ACTIVITIES FOR BUILDING AND CONSTRUCTION: EXPERIENCING STANDARDS

Experiencing standards integrating data for B&C

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Abstract

The effective exchange of information regarding the planning and control activities (schedules, resources, materials, cost, cash flow) between the different parties involved in building and construction projects is a critical success factor to avoid projects' time and costs overrun and to insure better quality. However, current applications and research and development efforts on electronic exchange of information are usually restricted to the exchange of technical design information, particularly CAD exchange amongst designers and between these and contractors; and of business data (purchase orders, invoices, remittance advice, etc.), between contractors and builders, merchants and suppliers. This paper will review current practitioners' approach to the exchange of planning and control information, and discuss the business need to the seamless flow of scheduling, resource, materials, and cost information between firms. Different technical solutions available to address the subject will be described. Through the description of the experience in this area of two European projects, RoadRobot and SUMMIT, the paper will also describe the state-of-the-art regarding the development of international standards for the exchange of planning and control information, particularly at the EDIFACT, STEP and IAI levels. RoadRobot – Operator Assisted Mobile Road Robot for Heavy Duty Civil Engineering Applications, was a project devoted to implement a general standard-based architecture to support the information management for road construction environments, covering from the road design to road construction, embracing the site, cell, machine and tool levels. SUMMIT – Supply Chain Management In Construction Industry, is an end-user driven project which envisages the creation, implementation, test and evaluation of an EDI, STEP and IAI/IFC based communication infrastructure on a specific project of building prefabricated houses, connecting project manager, contractor and suppliers. This paper shows that international standards for planning and control information in B&C are not yet enough developed and that further developments are required.

Keywords: Integration, interoperability, modelling, planning & control, standards

1 Introduction

The integration of Information Technology (IT) into the Building and Construction (B&C) industry has not achieved yet a satisfactory degree of research and development work. No special amendments have been paid to this industrial sector, including the major areas of the building industry, suchlike the outdoor construction of dams, roads, airfields and other large projects.

Regarding the state-of-the-art in integration of new technologies into building industry, including IT, the results are still very poor. Most established developments are concentrated on the Computer-Aided Design (CAD), drafting, scheduling control of tasks, and automation of certain pre-fabrication processes.

Nowadays, no special attention has been given to the automatic data flow of planning and control information, or advocating about the business needs to the seamless flow of scheduling, resource, materials, and cost information between firms. For practitioners in these industrial environments, very often time and material planning are done in a manual process at the construction site in a standalone basis, most of the times assisted by data received on phone calls or paper support (Pimentão et al. 1994).

Up to now, only little research work has been undertaken into the development of overall control architectures for building sites, whereas the development of such control architectures for other industrial sectors has advanced significantly during the last years. The question is now, whether the results of the past developments can be transferred to the demands of the building and construction industry. The evaluation and improvement of architectures and modules coming from other industrial areas (Camarinha-Matos and Osório 1992) seem to be necessary.

For that reason, to learn from existing architectures and modules from other industrial areas, according the special requirements of the building industry, can help to find new ways towards fully or partly automated and integrated construction processes (Sousa.1998; Jardim-Gonçalves et al 1997).

Future developments have to focus at the integration of IT into the building industry (Bradley 1991). Besides the low-level automation of overall planning and control systems, the task-level programming of complete building sites has to be achieved. The main interest of future works lies in the development and elaboration of a generic architecture for standardised integrated indoor and outdoor construction sites. Therefore, further work should also be concentrated on the automation of specific heavy-duty machines (Ulrich 1991; Leidinger 1991) in order to obtain a manpower reduced building site, with computer integrated time scheduling and material planning possibilities. Also the integration with the commercial aspects related with the Building and Construction business should be considered, towards a complete and automated data flow among the internal (construction) and external (business) actors performing in this industrial sector.

The adoption of standards in modeling, using a specific data protocol to support the integration and flow of information using a unique data exchange format, to be adopted by the various activities in B&C environments is, for sure, a key factor where proposals are now starting coming out. Examples are the work being developed by STEP within ISO TC184/SC4 Building and Construction Working Group (STEP 1999), by International Alliance for Interoperability throughout its Industrial Foundation Classes (IAI/IFC 1999), and UN/EDIFACT

(UN/EDIFACT 1999) and its related adaptations.

2 Experiencing ISO 10303 - STEP in road construction

The purpose of the European ESPRIT 6660 RoadRobot (Operator assisted Mobile Road Robot for Heavy Duty Civil Engineering Applications) (Pimentão et al 1994) project was the definition of a flexible control architecture suitable for outdoor heavy-duty construction applications, towards an automated construction site involving mobile equipment, concerning the building industry requirements.

Recognising the low level of IT in building industry, the focus point of interest was to develop information technology for the specific requirements of this sector. Therefore, the knowledge and experience brought in by the building industry, the manufacturers of heavy-duty building machines, companies with special IT expertise, and the R&D institutes, was very important.

After system's analysis phase with road construction companies, it was realised that applications used by most companies were spreadsheet-based, and these were applied just for some of the planning and scheduling tasks. Therefore the development of some specific applications was required in order to complete the construction process cycle.

Since the purpose was to produce a flexible architecture, the consortium agreed on the use of standards. This would provide the flexibility of the solution and they provided a reliable way to produce an open architecture where new software tools could be added without restrictions on vendor's specific data formats.

The development status of STEP (ISO Part1 1992) by that time (1992) and the previous experience of UNINOVA on its application for the furniture industry (Jardim-Gonçalves et al 1993, Jardim-Gonçalves et al; 1994), led to the adoption of this standard for the data modelling within RoadRobot (Jardim-Gonçalves et al 1996). The data was modelled using the EXPRESS language (ISO Part11 1991), while for data representation the Part21 of STEP (ISO Part21 1992) was adopted.

2.1 Architecture of RoadRobot

The first problem to be addressed was "how to model a road throughout its life cycle?" (Jardim-Gonçalves et al 1995). Aware of the "Road Model Kernel" (RMK) developed by TNO and the Dutch ministry of Public Works, the consortium adapted and improved it, since the status of RMK model in those days lacked features that were needed for road construction, such topological and geological data for excavating.

Other models were also developed to represent the road construction process at the various levels of the architecture, such resource models, task models, planning information and scheduling information (Pimentao et al 1994).

The architecture of RoadRobot devised for the project has four logical levels: (1) Site, (2) Cell, (3) Machine and (4) Tool (Pimentão et al 1993), as depicted in Figure 1 where level 3 and 4 are represented together. In this case, production of information starts loading into the RoadRobot Information System (IS) the information produced by a CAE system (in this case the InRoads package from Intergraph), using a tool that we called "Project Development". After that, the information is decomposed and processed in order to produce the tasks. Task decomposition is performed in a semi-automatic way with the aid of a Decision Support System (DSS). Regarding the road construction section, the DSS looks at the geometrical and geological information and, based on a set of rules supplied by the experts (e.g. two-lane road produce a task per lane), and on equipment restrictions such as excavator arm length, to produce the tasks.

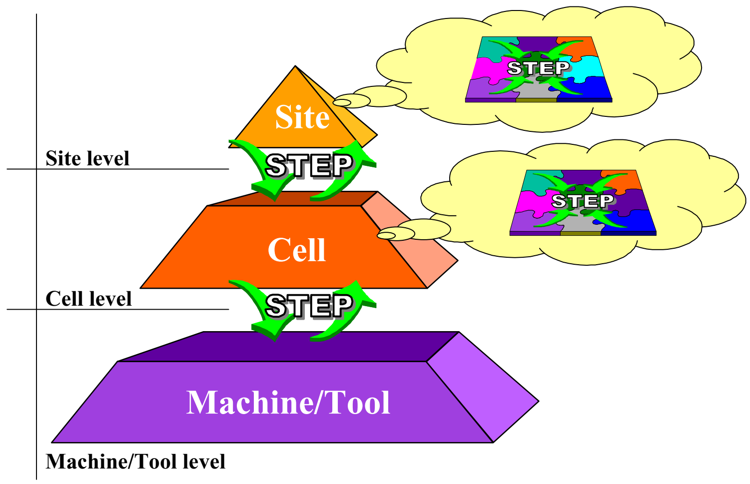

Fig. 1: RoadRobot's architecture. Integration within and with logical levels

Each task is then assigned to a given construction cell-type. Cell types are based on the characteristics of the set of equipment that composes it (e.g. paving cell). Task sequencing is performed with the help of a planner and task scheduling follows it with the assignment of existing equipment to each cell and effective time scheduling. At due time, the Site Operator is supplied with the information needed for setting up the given Cell, and once the Cell reports its operational status, it is fed with the task information. Machines, tools, operators and workers are also fed in an identical way.

Within RoadRobot's architecture, STEP is not only used for the modelling of the data to be transferred among applications within a given controller (e.g., Site/Cell), but also for the modelling of the information passed among controllers, like tasks, commands and responses. Therefore, all information flows within RoadRobot were modelled using STEP, including data and control flows, the last based on a specific model for controlling messages.

3 SUMMIT project

The ESPRIT 25559 Project Supply Chain Management in Construction Industry – SUMMIT, is to create, implement, test and evaluate an EDI-based communication infrastructure between the various partners involved in the manufacturing and construction of prefabricated houses (SUMMIT 1998). This infrastructure is to automate the tendering, ordering, delivery, invoicing and payment processes of house systems, equipment and services in its supply chain, whose members have different levels regarding Information and Communication Technologies (ICT).

SUMMIT is dedicated to the exploitation of potentials of both EDIFACT and STEP approaches to product and process data communication, by a concept of combining the complementary nature (business versus technical data) of both approaches. This, together with an EDI system based on an inter-organizational workflow system, will enable a better co-ordination between the companies on the supply chain, from the client's representative (project manager), to the contractor, and suppliers. Major results envisaged by SUMMIT are:

- A procurement process model exploiting the potential of pure digital data exchange and system interoperability
- EDIFACT messages sub-sets for the procurement of house systems and equipment
- STEP/IFC product model enabling the representation of project management data for houses
- An EDI communication infrastructure featuring secure and compatible information exchange for the entire production process
- A distributed information flow component based on EDI and inter-organizational workflow infrastructure supporting process definition and process execution the boundaries of autonomous organizations
- Two prototype implementations of business chains scenarios in a real world environment with realistic test data among a project manager (client's representative), a prefab house manufacturer, and its suppliers and subcontractors.

SUMMIT project started in December 1997 and results should be ready by October 1999. In the meantime, developments so far are partly described below.

3.1 SUMMIT developments in EDIFACT

Many groups of firms, within different industries, industrial sectors, associations, and different countries have defined proprietary formats for the exchange of administrative data. However, some years ago the United Nations started an initiative to define system neutral messages for administrative business processes. Nowadays, there are about 200 UN/EDIFACT (United Nations Electronic Data Interchange for Administration, Commerce and Transport) internationally agreed messages available at various stages of development. The trend is for old proprietary, idiosyncratic EDI systems to migrate towards EDIFACT, and new developments to be based on this standard (Jayachandra, 1994; Commission of European Community, 1998).

EDIFACT standards themselves do not lead necessarily to a plug and play solution for inter-organizational EDI connections, particularly in construction. The message content, the meaning of data within the message structure, has to be agreed by the interacting partners. SUMMIT will detail the content of the most important EDIFACT messages for the supply chain for prefab house systems, connecting the project manager (or other client's representative), the contractor / manufacturer, and suppliers/subcontractors. Thus, construction firms aiming to implement an EDI-based information flow will only be required to specify concrete instances of the detailed defined messages. The messages analyzed in SUMMIT are depicted in Figure 2. Further description of SUMMIT results regarding EDI and EDIFACT can be found elsewhere (Almeida et al 1998; Rabe et al 1998).

SUMMIT will also analyze the portfolio of commercially available EDI software and evaluate them against the requirements of the detailed EDI messages and their price range.

Table 1: EDIFACT Messages analyzed in SUMMIT

Business Transaction			
CONNIT	*Invitation to tender*	CONEST	*Establishment of contract*
CONTEN	*Tender*		
Materials Management			
PRICAT	*Price/sales catalogue*	REQUOTE	*Request for quote*
PARTIN	*Party information*	QUOTE	*Quote*
PRODAT	*Product data*	ORDERS	*Purchase order*
QUALITY	*Quality data*	ORDRSP	*Purchase order response*
ORDCHG	*Purchase order change*	DESADV	*Dispatch advice*
DELFOR	*Delivery schedule*	RECADV	*Receiving advice*
DELJIT	*Delivery Just In Time*	INVOICE	*Invoice*
Finance/Accountancy			
CREADV	*Credit advice*	FINCAN	*Financial cancellation*
PAYORD	*Payment order*	FINSTA	*Financial statement*
DEBADV	*Debit advice*		
Other fields			
PROTAP	*Project tasks planning*	CONDRO	*Drawing organization*
CONAPW	*Advice on pending works*	CONDRA	*Drawing administration*

3.2 SUMMIT developments in project management data

EDIFACT does not provide the solution to the whole spectrum of information exchange between heterogeneous IT applications within the supply chain. Most technical and managerial information exchanges will require other neutral format standards, particularly referring to product and process data.

In SUMMIT, it was perceived by the users, in this particular construction situation, the importance of complementing commercial and administrative data with project management data. Although there was an EDIFACT message specific for project scheduling and resources data exchange – PROTAP, it was decided that EDIFACT structure is not adequate to support the exchange of this type of data. Thus, the proposed solution was to apply developments in the Standard for the Exchange of Product Model Data – STEP, in AP225 and AP228, and particularly regarding the developments in the Building Construction Core Model (BCCM). The idea was to complement EDIFACT files with product/process data in standard format, i.e. embed the EDIFACT data structure with STEP structure. However, the analysis into this standardization area demonstrated that very few developments were made regarding project management data, and that current state-of-the-art would not support a pragmatic approach, a requisite for the user-driven type of project. RoadRobot was an exception in the standardization process, but little work had been developed afterwards. Moreover, it was also concluded that developments in STEP were moving slowly, and particularly developments in the BCCM had stopped, and thus little contribution could be made in this area.

In order to overcome the problem with project management data interchange between heterogeneous applications, SUMMIT envisages to use the developments made so far in the International Foundation Classes (IFC) version 1.5, of the International Alliance for Interoperability, to be actively involved in existing IFC

3.0 projects in the Project Management AEC domain, and contribute to the definition of Project Management IFC 4.0 requirements. In particular, SUMMIT will focus on the processes of construction scheduling.

According to the IFC Specifications (IFC, 1997a), the construction scheduling process creates a construction schedule using the objects across the IFC Model. In general, construction schedules will be developed through the analysis of the Task objects and Resource Use objects created when developing the Cost Estimating, and aggregating them into Construction tasks at the appropriate level for scheduling. However, this process must consider the size and complexity of the model. In situations where there is no cost estimating, the construction scheduling process will be different, implying a query to the shared project model. The objects found will be used as the basis for developing construction tasks. In both situations, time duration of the tasks will be estimated and construction sequences will be identified. The construction schedule is then created and analyzed, and after completion of the schedule, dates will be embedded in the IFC Model.

SUMMIT will not cover the full development cycle of the IFC (IFC 1997b). Indeed, due to time and resources constrains, only certain stages are covered. Thus, SUMMIT is working together with other existing projects in order to advance the Stage 2 – Specification, of the development cycle, regarding construction scheduling, on IFC 3.0. It will contribute to:

1. Enhance the usage scenario of construction scheduling, bringing specific requirements of the process of project management of prefab houses;
2. Detail the process model for the construction scheduling process;
3. Define the scope of the construction scheduling process;
4. Specify and enhance the IFC Object Model for construction scheduling;
5. Specify and detail Type definitions and Attributions;
6. Define Exchange classes related with construction scheduling classes.

SUMMIT will also contribute to Stage 1 of IFC 4.0 in the same domain. In this process, SUMMIT will suggest and propose new processes related to project management domain to be developed in the IFC 4.0 release.

4 Conclusions and acknowledgements

Building and construction industry should also concentrate on other areas of information integration rather than design, specially on those related with the automatic data flow of planning, control, scheduling, resources, materials, costs or general business and management information between firms. In an open market as we find today, integration of data has proved to be a requirement for substituting and improving with reliability and performance the manual or repetitive procedures.

The use of standards in the modelling process can help to proceed towards automated and integrated construction sites, integrating the actors in the different levels of participation in the manufacturing and business processes, both exchanging data among applications and sending messages for control of the process. Standards like STEP, IAI/IFC and UN/EDIFACT are examples of those that can contribute positively for the intent. The results achieved during the RoadRobot and SUMMIT projects stress these conclusions, based on experiences executed under real conditions. However, whether these systems are implemented in the real world is not just a technological problem (Grilo 1998).

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