INDUSTRY FOUNDATION CLASS MODELING FOR ESTIMATING AND SCHEDULING

Industry foundation class modelling

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Abstract

Industry Foundation Classes (IFCs) developed by the International Alliance for Interoperability (IAI) are general models of a building project that support project information sharing and exchange among different types of computer applications used in the project. The IFCs are developed based on the information requirements from industry processes. The Project Management Domain Committee of IAI's North America Chapter has developed process models of cost estimating, scheduling, and their integration for the purpose of generating the IFCs to support data sharing throughout estimating and scheduling applications. The goal of this paper is to present the models relevant to estimating and scheduling in the IFCs. The paper discusses various modelling issues covering subjects such as costs, construction processes, resources, products, and project documents for work plans and cost estimates.

Keywords: Cost Estimating, Data Modelling, IFC, IAI, Project Models, Scheduling.

1 Introduction

We believe that the evolution of information technology and computing for the architecture, engineering, construction, and facilities management fields (AEC/FM) will inevitably lead towards tools that collaborate through shared collections of information (i.e, models) about AEC/FM projects. A key technology required to enable such systems is high-level standards for representing and communicating project information. Many efforts are underway to develop such standards and establish them as for use throughout various industry segments. Within the building construction industry segment, the largest current effort is by the Industry Alliance for Interoperability (IAI), an international industry-based organisation that is developing data standards for AEC/FM projects called the Industry Foundation Classes (IFCs). Release 1.5.1 of the IFCs has now been distributed and is beginning to be supported by commercial software developers while releases 2.0 and 3.0 are currently under development. Although much of the initial focus of the IFCs has been on representing the physical components of buildings themselves (i.e, the product models), the scope of the IFCs also includes non-physical project data such as documents, costs, organisational aspects, schedules, construction resources, and other types of information. This paper focuses on project management aspects of construction projects and the ways that they are being treated within the IFCs. In particular, the paper examines typical project management processes that have been developed in IAI projects: cost estimating, construction scheduling, and their integration. The paper provides a brief overview of the IAI and IFCs. It then discusses the estimating and scheduling processes that have provided information requirements for the IFCs, followed by an examination of the information modelling approaches that have been developed in the IFCs for these applications. The paper concludes with brief comments on other related efforts. Most of the diagrams in this paper are simplified IFC model diagrams in EXPRESS-G (ISO 1991) notation. Most of them are partial or conceptual models where many details have been omitted.

2 Overview of IAI

The IAI is a global, industry-based consortium for the architecture, engineering, construction and facilities management (AEC/FM) industry (IAI 1996, IAI 1998). Their mission is to enable interoperability among industry processes of all different professional domains in AEC/FM projects by allowing the computer applications used by all project participants to share and exchange project information. The IAI's scope is the entire lifecycle of a building project from strategic planning, design and engineering, construction, to building operation. The IAI's goals are to define, publish and promote a specification—named the Industry Foundation Classes (IFCs)—for sharing data throughout the project lifecycle, globally, across disciplines and technical applications (IAI 1998). The IFCs are used to assemble a project model in a neutral computer language that describes building project objects and represents information requirements common to all the industry processes.

IAI members come from AEC/FM industry firms, software vendors, research institutes and universities, professional organisations, and government agencies. The IAI is organised into different regional chapters overseen by an International Co-ordination Council. Current IAI chapters include North America, German-speaking countries, United Kingdom, France, Singapore, Nordic countries, Japan, and Austral-Asian, with more than 700 members around the world. Based on the interest and initiative of the IAI members, a series of domains committees are established within each chapter to represent specialised industry sectors and to provide information requirements for the IFCs from these sectors' perspective. Domain committees include architecture, structures, codes and standards, building services, HVAC, project management, facilities management, etc.

2.1 IFC Architecture and development methodology

The IFCs architecture (Wix and Liebich 1997) is based on layers containing model schemas. The layers include: a resource layer that describes distinct underlying concepts (e.g, geometry, units and measures, etc.); a core layer that defines a kernel meta-model and core extensions to define the basic AEC/FM objects (e.g, projects, products, processes, resources, etc.); an interoperability layer that defines data that is used across multiple domain areas (e.g., building elements, structural components, etc.); and a domain layer that defines detailed data used within specific application areas (e.g, space layout, power and lighting system design, property management, etc.).

Instances of the IFCs are initialised, linked, and assembled by AEC software to create an object model of the building project. In the simplest form of interoperability, the project model is communicated from one software package to another in a data file (e.g, using ISO 10303 Part 21 format) (ISO 1992). Upon receipt of the data file, the software will re-create the project model for further processing and design additions. Currently, there are over 33 commercial software packages that have demonstrated interoperability using the IFC standards (Release 1.5), and several software companies are beginning to offer IFC exchange capabilities within their products.

The IFC standards are developed through IAI projects targeted at specific IFC releases (IFC Release 1.5.1 was finalised in late 1998 and major releases are expected approximately every year). IAI projects are carried out by IAI members who represent two basic roles: domain experts—who contribute their domain expertise and define the information requirements for the industry processes—and technical experts—who provide software engineering skills in information process analysis and modelling. Domain experts are organised into domain groups that meet regularly. IAI projects development follows a process-oriented methodology, which involves the following major steps (Yu, Froese, and Grobler 1998):

- *Processes selection* identifies projects for development based on many criteria relating to industry demand and impact and available resources.
- *Usage scenarios* are developed to define the basic requirements and illustrate their use in real-world examples.
- *Process definitions* determine the specific tasks followed to complete the process and the information flows associated with the tasks.
- *Information analysis* carries out the preliminary information modeling to support the processes.
- *Information modeling and validation* finalizes the information modeling in the context of the entire IFCs and carries out validation of the models, largely through implementation by member software vendors.

3 Process models of estimating and scheduling

Several IFC projects undertaken by different regional domain committees focus on project management related aspects of the IFCs. These include the North American Project Management Committee's Cost Estimating project (Project ES-1 for IFC Release 2.0) (Cole et al. 1998a) and Construction Scheduling Project (PM-1 for IFC Release 3.0) (Grobler. et al. 1998). The PM-1 project includes not only the construction scheduling process, but also the process of initializing a schedule from a cost estimate. Processes to examine extensive estimate and schedule integration, and generic scheduling, have been deferred to future projects, yet all of these efforts are being developed with an eye towards integration and a uniform approach to information. Other construction-related projects are mentioned later in this paper.

3.1 Scope and scenario

The intended scope for both the estimating and scheduling projects ranges from high-level preliminary conceptual estimates and schedules to very detailed planning. For example, the estimating process identifies the components of the project to be priced out, and then optionally supports detailed work method and resource planning. The scope also includes the task of editing and refining existing estimates and schedules to add detail and incorporate changes as the project progresses. The scope for the process of initializing a schedule from an existing estimate addresses a scenario in which an estimate has been prepared, including work method and resource planning, and this information is used to define an initial set of schedule activities upon which to base construction scheduling.

3.2 Process models

The process models developed to describe estimating and scheduling were discussed in Froese, Grobler, and Yu 1998. Fig. 1 illustrates a conceptual process model for the integration of estimating and schedule, involving four basics steps (Cole et al. 1998b):

1. *Retrieve Cost & Scheduling Work Tasks*: retrieves work tasks and all their related information regarding resources, logic and duration, etc, generated by both estimating and scheduling process.
2. *Compare Work Tasks*: compares estimating work tasks with scheduling activities (or vice versa) to identify their commonalities and differences.
3. *Identify Work Task Mappings*: identifies work task mapping points, i.e. where a work task identified from estimating should be mapped to one or more work tasks from the scheduling process (or vice versa).
4. *Identify Additional Work Tasks*: After the work tasks are compared and the mappings are identified, additional activities can be identified and created by breaking down a high level task into more detailed ones or inserting a task from one process to the other.

4 IFC Support for estimating and scheduling

The information requirements from the process analysis provide the inputs for IFC modeling. This section discusses relevant portions of the IFCs as they are currently being developed in Release 2.0. (Note that IFC development is on-going, most of the models described in this paper are proposals at the time of writing and final IFC versions may differ).

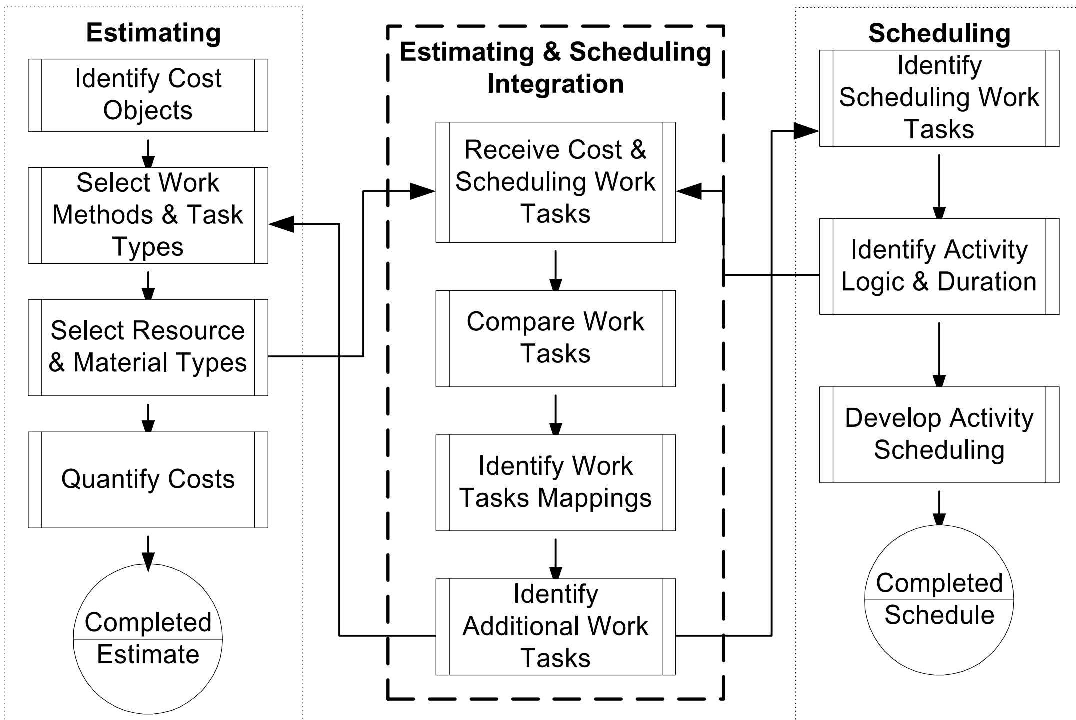

Fig. 1: Process for estimating and scheduling integration (abridged process)

4.1 Construction processes and planning documents

An important aspect of the project management portions of the IFCs is the explicit representation of work processes. While cost estimate items and schedule activities can be associated with work processes, the processes themselves are a distinct element that can be independently described and represented in project models. There are two major entities in the IFCs to support construction processes: IfcProcess and IfcWorkTask (see Fig. 2). The former represents any general actions taking place in completing a work of design, engineering, construction, or facilities management. IfcWorkTask, a subtype of IfcProcess, is intended to describe the work processes that make up construction operations. Information such as construction work methods, schedule dates and duration is defined at the IfcWorkTask level.

4.1.1 Work plans

Any collection of IfcWorkTask instances makes up a plan, represented by the entity IfcWorkPlan. Tasks can be organized in different ways to make up different

IfcWorkPlan instances (see Fig. 2). For example, tasks may be organized into a nested hierarchy according to the type of work required to define a plan that supports cost estimating, then the same tasks can be organized into another nested hierarchy according to work locations, possibly with additional work tasks added to expand certain details, to define a plan that supports work scheduling.

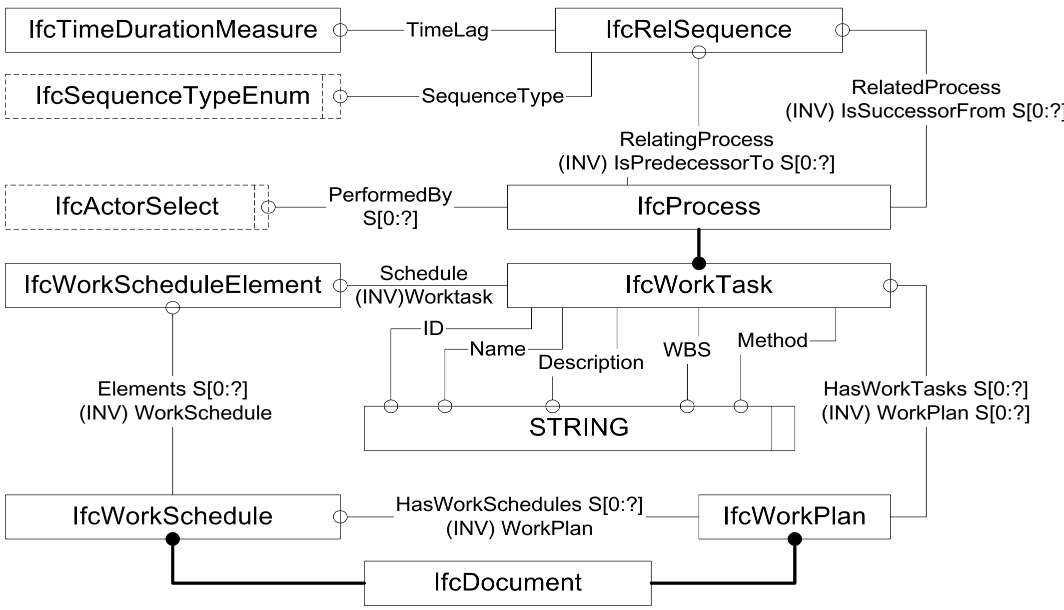

Fig. 2: IFC Process and work plan model

4.1.2 Work schedules

Time scheduling information can be assigned to work plans and work tasks by associating them with related work scheduling objects (see Fig. 2). Specifically, an instance of the entity IfcWorkScheduleElement, which holds time scheduling information such as start dates, end dates, float times, etc, can be associated with an IfcWorkTask instance to represent all the date and duration information for the work task (i.e, the combination of an IfcWorkTask and associated IfcWorkScheduleElement provides the equivalent of a traditional scheduling activity). All IfcWorkScheduleElement instances for a work schedule are grouped into an IfcWorkSchedule instance. One or more IfcWorkSchedule instances can be associated with any IfcWorkPlan. Thus, the related instances of IfcWorkPlan and IfcWorkSchedule comprise a subset of basic planning documents for a project (see Section 4.3 for estimating documents).

4.1.3 Process nesting

Work tasks can represent a process at any level of detail, from broad project phases to very detailed tasks. All levels have the same data structure rather than defining different entities for different levels of activities. For example, an overall project, its development phases, work packages, activities, work tasks, and operations can all be represented as instances of IfcWorkTask. A key requirement for the estimating and scheduling integration process is the nesting capability of work tasks. That is, a work task can be broken down into sub-tasks, but it still remains the same work task itself. In the IFCs, the entity IfcRelNestsProcesses is used to establish the nesting relationship between work tasks (see Fig. 3).

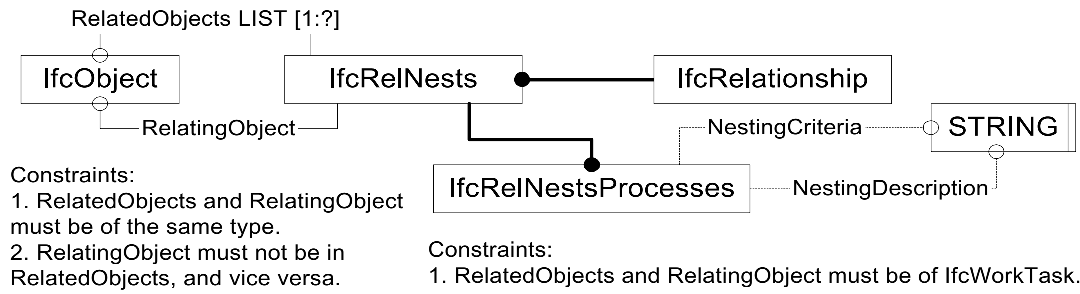

Fig. 3: IFC Process nesting model

4.1.4 Process sequence

The sequence of processes is defined as an objectified relationship between IfcProcess instances, as represented by the entity IfcRelSequence (see Fig. 2). This entity establishes the link between a successor and a predecessor process, providing a time lag and sequence type (e.g., start-to-start or start-to-finish sequence, etc.).

4.1.5 Linkages with products

One of the central relationships in modeling construction processes is the association between processes and the products upon which they operate. The IFC approach to this is to use an objectified relationship entity named IfcRelProcessesProducts between IfcProduct and IfcProcess indicating the operation type such as install, transfer, operation on, construct, remove, erect, and so on (see Fig. 4).

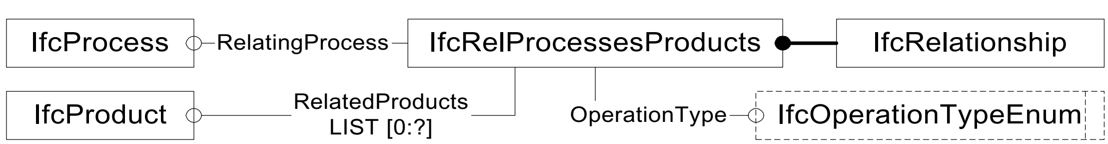

Fig. 4: IFC Model for process and product association

4.2 Construction resources

Construction resources are things that are used to carry out construction processes. The entity IfcResource can be used to represent either types of resources or individual occurrences of resources needed to aid in a construction process. The

IFCs currently support five different resource types: subcontractor, construction equipment, construction material, labor, crew, and product resources (see Fig. 5). A crew is a collection of resources (typically a collection of labor resources with some associated equipment and materials). A product resource is used in the situation where a product that results from a work task is used as a resource in another process.

Although it is common to model things such as construction equipment, materials, and labor as resources, it presents a problem in that all of these are things that might also play different roles on a project. For example, a crane might be represented as a temporary constructed product, materials might be represented as design properties or as the basic components in a materials management application, and labor might be represented as part of the organizational information for a project. Further, the characterization of these things as resources, products, etc, can be very dependent upon the perspective of the user of the information. Generally, things should be modeled as "what they are" rather than as "a role they play". Yet the concept of "resources" represents a role that certain things play on a construction projects, and it is difficult to design representational structures that satisfy all these different perspectives. Thus, a subtle but important change being proposed for the IFC Release 2.0 is that IfcResource is interpreted as representing “the use of a thing in the role of a construction resource,” rather than representing the thing itself. If only basic resource information such as the names, quantities, and prices is of interest to users of a project model, then IfcResource objects alone are sufficient to represent the information. However, if further information is required about the things that are being used as resources, then the IfcResource instances can be associated to other instances that represent those things (i.e., IfcProductRes and IfcMaterialRes can be associated to IfcProduct objects, IfcLaborRes can be associated with IfcActor instances, etc, see Fig. 5).

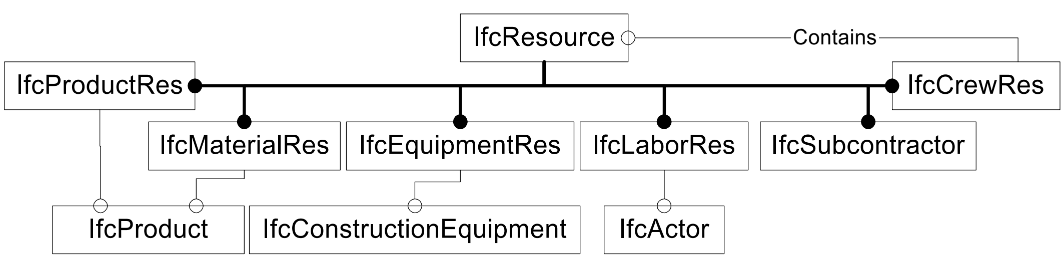

Fig. 5: IFC Construction resource model

4.2.1 Resource and process relationship

Processes use resources. This resource-use relationship is modeled by IfcRelUsesResource as an objectified entity carrying information such as resource use duration, quantity, waste factor, and costs (see Fig. 6).

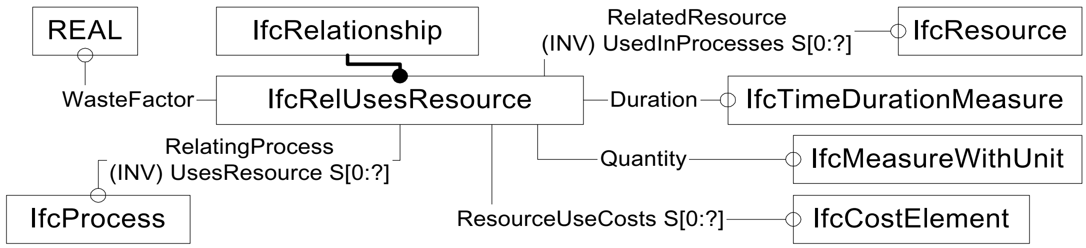

Fig. 6: Resource usage

4.3 Object costs

For cost estimating, different types of costs are assigned to objects such as work tasks or products. This section explains how the IFCs currently handle costs (see **Fig. 7**).

Costs assigned to objects can only provide meaningful information if the context of the cost values is known. For example, information about whether the unit price of a work task includes material purchases, transportation, material use wastes, equipment uses (operational or rental costs), labor costs, taxes, general contractor mark-up, etc. must be provided along with the numerical cost value. The IFC entity IfcCostElement addresses this by providing cost information, relating to the object being costed, and relating to a cost schedule document (IfcCostSchedule) that describes the context of a list of cost elements. IfcCostSchedule can be used to represent any form of cost list, such as an estimate, a budget, or a unit price table. An IfcCostElement instance can be associated with the objects being costed (e.g, a product, a resource, a process, etc.), through the objectified relationship IfcRelCostsObjects. An IfcCostElement can also be used to group related sub-costs using an IfcRelNestsCostElements relationship.

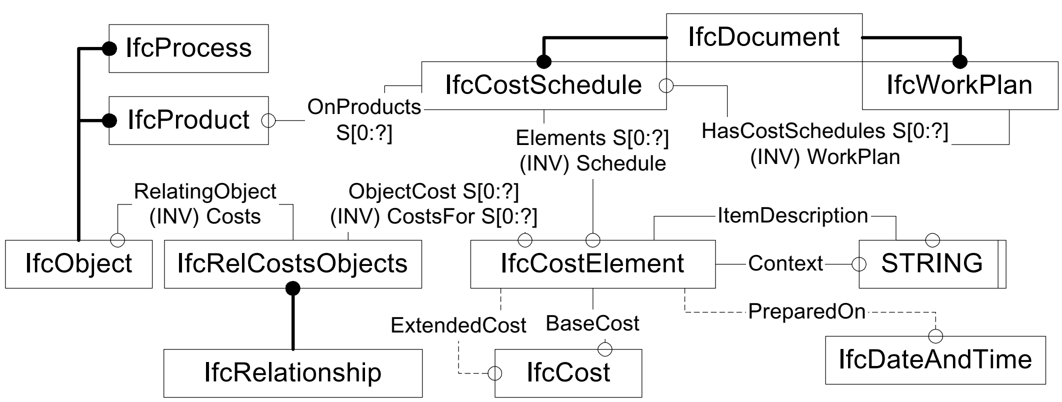

Fig. 7: IFC Object cost model

5 Related issues

The modeling constructs presented in this paper show only a few of the core elements of the project-management-related portions of the IFCs. Many other issues—such as multiple views of work schedules, classification of work tasks, references to external libraries of work types, etc.—are also being addressed. Other IAI projects are also examining other project management applications, including document management, preliminary cost planning, and planning of temporary facilities. Related work is also ongoing outside of the IAI effort, such as the ISO STEP (ISO 1994) and MANDATE (ISO 1998) projects. Finally, portions of the IAI cost model have already been implemented in a demonstration product by one major software vendor (Timberline Software), and others have expressed interest in implementing other portions of the project-management-related models.

6 Conclusions

This paper has outlined current efforts underway within the International Alliance for Interoperability to develop project-management-related portions of the Industry Foundation Classes, an emerging standard for the exchange of high-level project information. The main focus has been on representing work plans, resources, cost and schedule information. We anticipate that the IFCs will soon have sufficient core functionality within this topic area to support real industry data exchange between project management applications, and that significant changes to the way that computing tools are used to support the project management process will follow.

7 References

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