A CONSTRUCTION PROCESS MODEL BY USING DESIGN/IDEF

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Abstract

There are a few ways to model the construction process, which is an essential step when it comes to Computer-Integrated-Construction (CIC). IDEF0 together with NIAM, IDEF1X and EXPRESS or EXPRESS-G, the graphical presentation techniques used within ISO 10303 (ISO TC184/SC4/WG PMA Part 1), are the basic and popular modeling tools and languages in both manufacturing and construction projects. This paper presents a model which is an attempt to combine many aspects of the construction process description into a single comprehensive picture using IDEF0 representation. Based on the analysis of information generated in a construction project life span, including classification, evolution and exchange of information, first an information classification system is established, in which information for a construction project can be classified as project_dependent_information, project _independent_information, standards and codes, etc.. Second, a construction process business model is set up using the IDEF0 modeling technology. Software Design/IDEF version 2.5 is used for the realization of the graphics. At last an IDEF1X conceptual model is presented to illustrate the relationship between the entities of this construction process model.

1 BACKGROUND

Construction project modeling is a fundamental step for the purpose of Computer-Integrated-Construction. This construction project modeling has to adopt conceptual modeling methodology, which is the activity of formally describing some aspects of the physical and social world or the real world around us for the purpose of improving our understanding and communication (Loucopoulos, Zicari, ed. 1992). Conceptual modeling often known as *conceptual schema* is a single integrated definition of the data within an enterprise which is unbiased toward any single application of data and is independent of how the data is physically stored or accessed, i.e. it takes a neutral view of the real world.

1.1 CONSTRUCTION PROCESS MODEL

A construction project model is made up of two parts: 1) construction product model, and 2) construction process model.

Construction product model: it describes and models the building elements, such as doors, windows, floors, beams, columns, etc..

Construction process model: it describes and models the construction activities occurring during the whole construction process and the participants, information and materials associated with these activities.

There are many methodologies to model and describe the construction process, such as flow charts, tables, and textual descriptions, etc.. In this paper the construction process is modeled using IDEF0 and IDEF1X graphic modeling methodologies, which together with NIAM and EXPRESS or EXPRESS-G are used within ISO 10303. These are briefly described below.

1.2 STEP AND IDEF0

1.2.1 STEP

STEP stands for **ST**andard for the **E**xchange of **P**roduct Model Data. More accurately it is ISO 10303, the standard for *Industrial automation systems and integration - Product data representation and exchange*. It is a standard developed by Sub-committee 4 (Industrial data and global manufacturing programming languages) of ISO Technical Committee 184 (Industrial automation systems and integration) in order to meet the requirements for comprehensive and reliable information exchange mechanism to effectively integrate computer-aided (CAx) systems and evolving information technologies from the industry and the government. It provides a mechanism that is capable of describing product data throughout the life cycle of a product, independent of any particular system. The nature of this description makes it suitable for file exchange and for implementing, sharing and archiving product databases.

A fundamental concept of STEP is the definition of application protocols (APs) as the mechanism for specifying information requirements and for ensuring reliable communication.

Application protocols employ three types of models: an application activity model (AAM), an application reference model (ARM) and an application interpreted model (AIM).

- Application activity model (AAM): a model that describes the activities and processes that use and produce product data in a specific application context. The AAM is defined in IDEF0.

- Application reference model (ARM): a model that specifies conceptual structures and constraints used to describe the information requirements of an application. The ARM is documented in a formalized modeling language, such as EXPRESS, IDEF1X, or NIAM , as suggested by ISO.

- Application interpreted model (AIM): a model of selected integrated resources which are constrained, specialized or completed to satisfy the information requirements of the ARM. The AIM is defined in EXPRESS and EXPRESS-G.

1.2.2 IDEF technology and IDEF0

IDEF stands for Integrated Computer-Aided Manufacturing (CAM) **DEF**inition Language. It consists of IDEF0, IDEF2, IDEF3 and IDEF1/IDEF1X. They are designed to deal with and capture different aspects of process and information modeling. Generally IDEF modeling technology is based upon the Structural Analysis and Design Technique proposed by Douglas T. Ross of SoftTech. This was further refined and developed by the US Air Force ICAM program into a methodology known as IDEF technology. It incorporates four different but related viewpoints for complete understanding of a system. These four viewpoints are Function, Data, Dynamics and Knowledge of a system.

IDEF0 is one part of IDEF technology. It is a top-down hierarchical method which provides a description of functions and processes in a system. It is required to be a formalized modeling language in application activity model (AAM) when developing a STEP application protocol (AP).

2 THE CONSTRUCTION PROCESS MODEL IN IDEF0

A construction process model using IDEF0 is presented below. Before using IDEF0 methodology, an analysis of information classification, evolution and exchange during the construction project life cycle is necessary.

2.1 THE CLASSIFICATION OF CONSTRUCTION INFORMATION

Information generated in the construction project life cycle have different forms, types, life spans etc. They can be included into one of the following categories:

1) Design development and co-ordination information, such as client's instructions, feasibility study report, preliminary engineering drawings and detailed drawings for feedback, etc.

2) Planning approval data, such as schematic drawings, sent for planning approval, etc..

3) Regulatory data, such as requesting and receiving the local building regulations, technical information for building control and standards information, etc..

4) General product information, such as general information on product range, catalogues, drawings showing contractor's requirements, etc..

5) Specific product information, such as enquiry on specific product & response, details of specific product or service, etc..

6) Product technical information, such as product technical sheets, standard graphic elements, etc..

7) Product price information, such as priced leaflets on product ranges, price enquires and response on particular products, etc..

8) Tender information, such as invitation to tender to contractors, returned priced tenders fro subcontractors, etc..

9) Instructions to build, such as contract documents prepared by client's representative, drawings and specification, architect instructions, etc..

10) Statutory requirements, such as drawings for seeking approval, statutory reporting for accidents, abnormal loads, etc..

11) Progress information, such as outline program in the early design stage, progress information against baseline during construction, etc..

12) Cost information, such as quantity and cost data at design stage, cash flow including tables and graphics, progress payment, final account, cost control data from design and build contractors, etc..

13) Variations, such as variation drawings and specification, etc..

14) Quality control/test data, such as quality assurance documents, test data, etc..

15) As built/handover information, such as built drawings and handover documents.

The information used in a project can be classified into four categories: project_dependent_information, project_independent_information, standards and codes, and other industry information depending on how it is related to every individual project. There definitions are as given below.

Project_dependent_information: it arises during four stages, i.e. the initial stage, the design stage; the tender stage and the site operation stage, which is directly related to one project and excludes general industry information. They are client's instructions, feasibility study report, outline sketches and drawings, outline specification, etc..

Project_independent_information: it covers all information flows related to products or product ranges, such as general information on product range, catalogues, product technical sheets, standard graphic elements, price leaflets on product ranges, climatic data, etc. It is permanently and generally available within the construction industry or in the company's internal library.

Standards and codes: it refers to the information flows created by the use of certain standards, for example British Standards (BS) and Codes of Practice (CP). These documents are major reference sources which establish minimum standards for products and processes within the industry.

Other industry information: it represents building regulations, national building specifications, etc..

Among the fifteen information flows listed above (HMSO, 1988), flows 1, 2, 8, 11, 12, 13, 14, 15 and part of 9 are project_dependent_information. Flows 4, 5, 6 and 7 are product_independent_information. Certainly flow 3 is the standards and codes information.

In the following context, the effect of these information on the construction process will be discussed. In this model we mainly deal with project_dependent_information, project_independent_information, standards and codes.

2.2 THE DESCRIPTION OF CONSTRUCTION PROCESS

To model the construction process using IDEF0 technology, every construction stage or activity will be represented by boxes, and the actors will be the controllers. Input and output, including information as well as materials (physical product), will be the linking arrows between boxes.

At the most global level, the construction process can be described as shown in Fig.1..

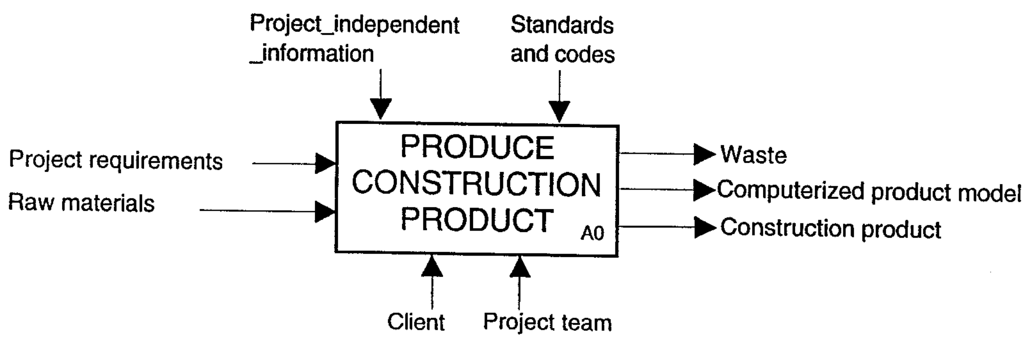

Fig.1. The Most Global Level of Construction Process

There are many ways to break down the construction project process. Based on the analysis of a few models (Walker 1989, Bohms 1993, Ofori 1990, HMSO 1988), here construction project process is broken into four first immediate sub-levels as follows:

- the initial phase of a project;
- the design phase of a project;
- the tendering phase of a project;
- the realization or site construction phase of a project.

Fig.2. shows the input and output among the first immediate sub-levels of construction project process.

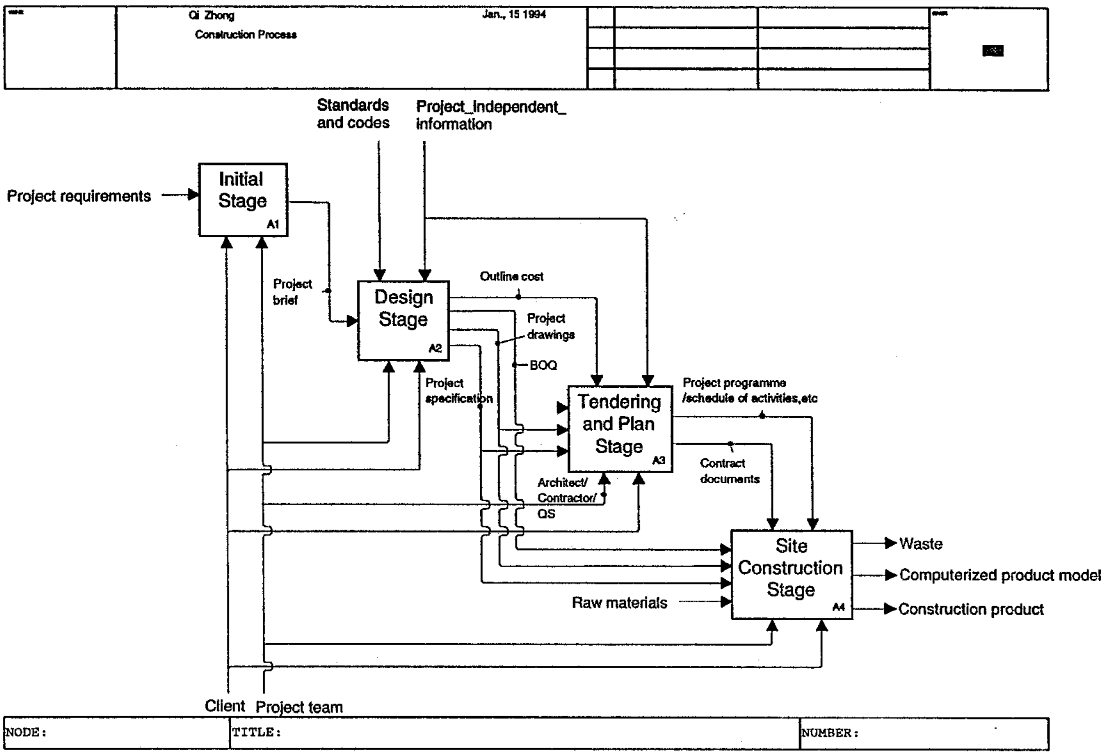

Fig.2. The Four First Immediate Sub-levels of Construction Process

There are many participants in the whole construction process. Some are only involved in part of the process. Others may be involved in the entire process. Many terms are being used to refer to the parties in a project. Here "actor" is adopted to refer the participants in a project. Generally, the actors most involved in a creation of the construction project:

- building authority or statutory bodies
- client
- project manager
- architect
- other consultants, including structural engineer, HVAC engineer, electrical engineer, building services engineer, energy engineer
- quantity surveyor
- construction supervisor
- main contractor
- sub-contractor
- suppliers

2.2.1 The initial phase of construction process

Here information at the first feasibility stage (A_1) is analyzed. The prime purpose at this initial stage is to set the project brief, especially the financial budget of project. If the project adopts some novel technologies, technical feasibility should also be taken into account. Output of this initial phase is the initial basic project requirements or project brief, among which the financial feasibility is a main concern. The constraints are financial availability and the competition in the market.

This initial phase can be approximately divided into two sub-stages (Fig.3.):

- Inception
- Feasibility study

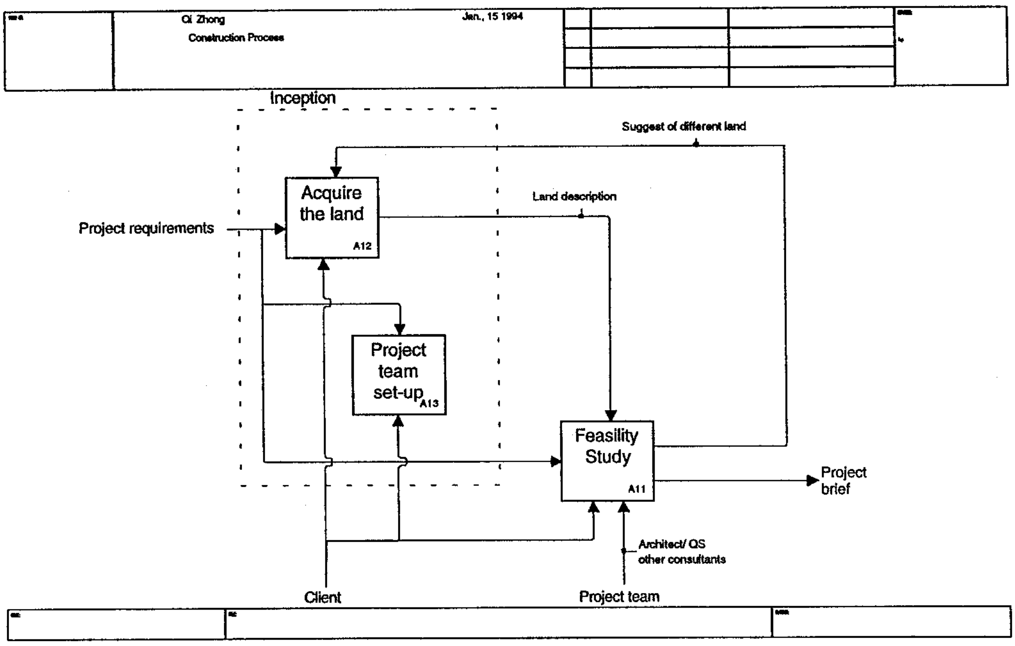

Fig.3. The Initial Phase

At the inception sub-stage, a need for a project arises from a potential client out of its need for survival in a competitive environment. Generally the stimuli for a construction project also may be economical, technological and sociological. As defined by Walker (1989), the start point of the construction process is the recognition by the potential client of the need or opportunity to achieve a particular objective for his organization. Client views the basic requirements of the project, acquires land and sets up the project team according to the previous experiences and market situation. (See the broken-lined box in Fig.3.)

At the end of the initial phase, the characteristics of the project, i.e. the project brief, have been worked out, i.e. client's instructions, feasibility study report, etc.. They will be the main information input to the design phase.

2.2.2 The design phase of construction process

The information at the design phase (A2) is now presented. The design phase can be further divided into three stages. They are design management, sketch plan and detailed design. Project_dependent_information and project_independent _information are mainly formed at this stage. At the first deign management (or briefing stage) and sketch plan stages, information is often in the form of ideas. Later, at the detailed design stage, the information is more structured and detailed. The design phase provides the later phase with very important information, like outline cost, Bill of Quantity (BOQ), project drawings and project specification (see Fig.4.).

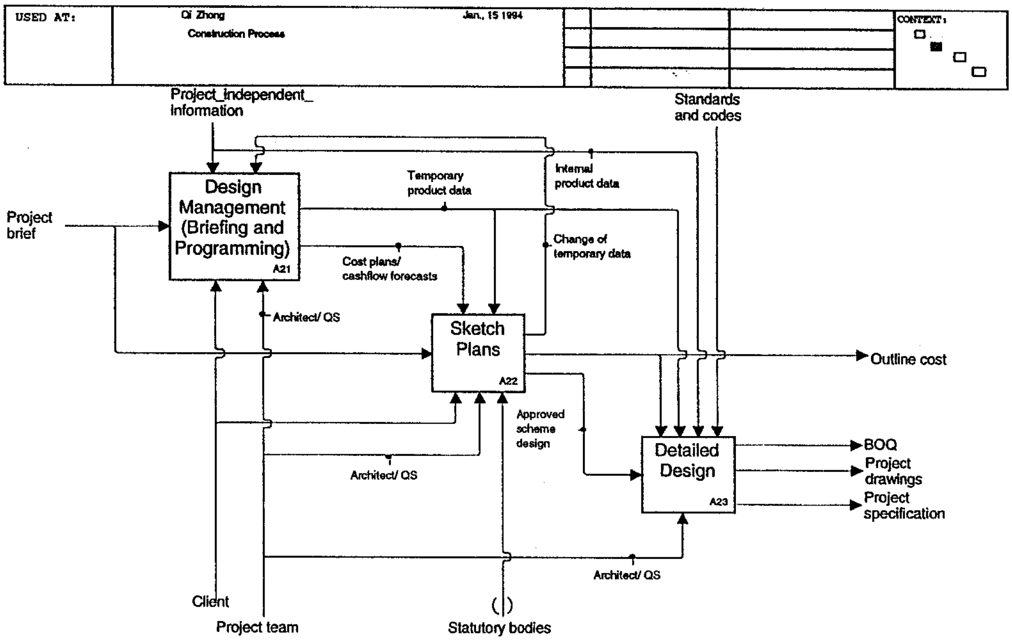

Fig.4. The Design Phase of the Construction Process

At the design management (briefing and programming) stage, the client working together with QS have to select suitable products to satisfy the client's requirements (here is the project brief); details of products being obtained either from the internal library or directly from outside sources. Cost plans and cashflow forecasts are also worked out at this stage. At this moment, since products have not been decided finally, this initial product data is filed temporarily and kept until the products are chosen. (see Fig.5.)

All this temporary product data and cost plans as well as cashflow forecasts will be passed to the sketch plans stage. Client together with QS and architect will work out the scheme design and outline cost based on the cost plans and the temporary product data from previous stage. Before this scheme design and outline cost are transferred to the detailed design stage, they have to be checked with other consultants and should be approved by the statutory bodies. This process can be very time consuming(Fig.6.). Here since statutory bodies are only involved in at this sub-level, so the tunneled arrow of one IDEF0's representation is used.

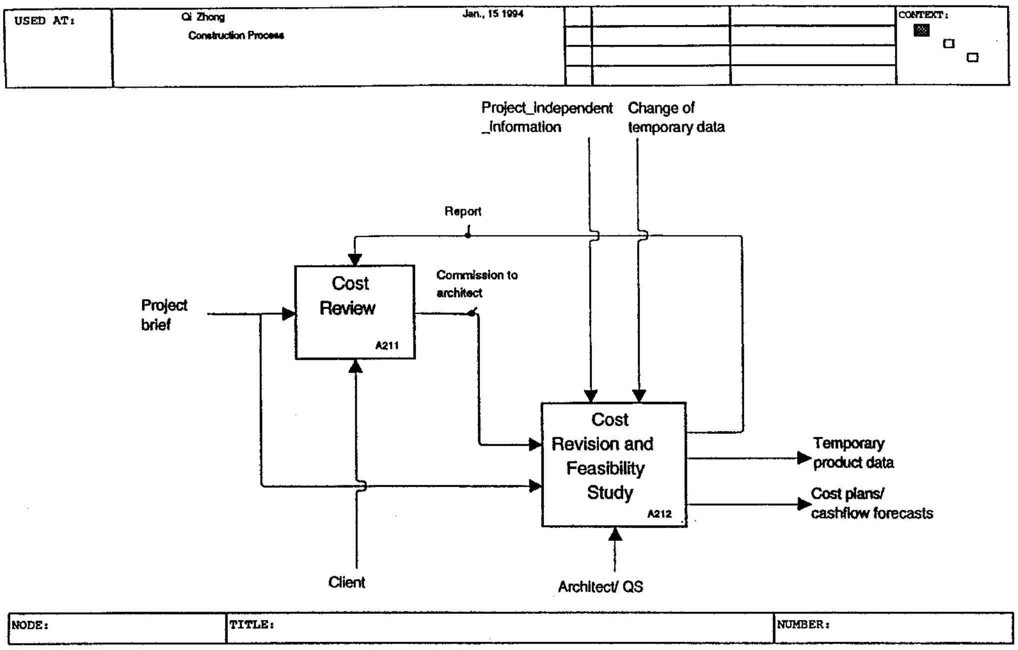

Fig.5. Design Management (Briefing and Programming) in the Design Phase

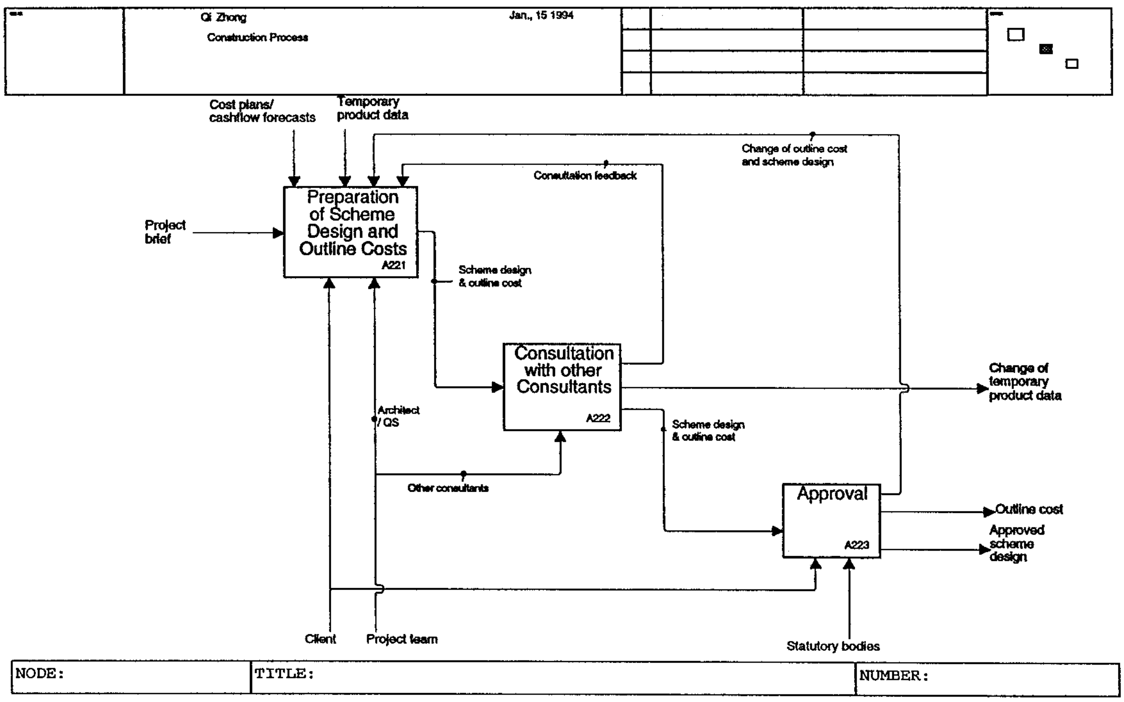

Fig.6. The Sketch Plans in Design Phase

Once the scheme design upon the consensus of other consultants have been approved by the statutory bodies, this scheme design and outline cost will be passed to the architect and QS for producing project drawings, project specification and Bill of Quantity (BOQ). (See Fig.7.)

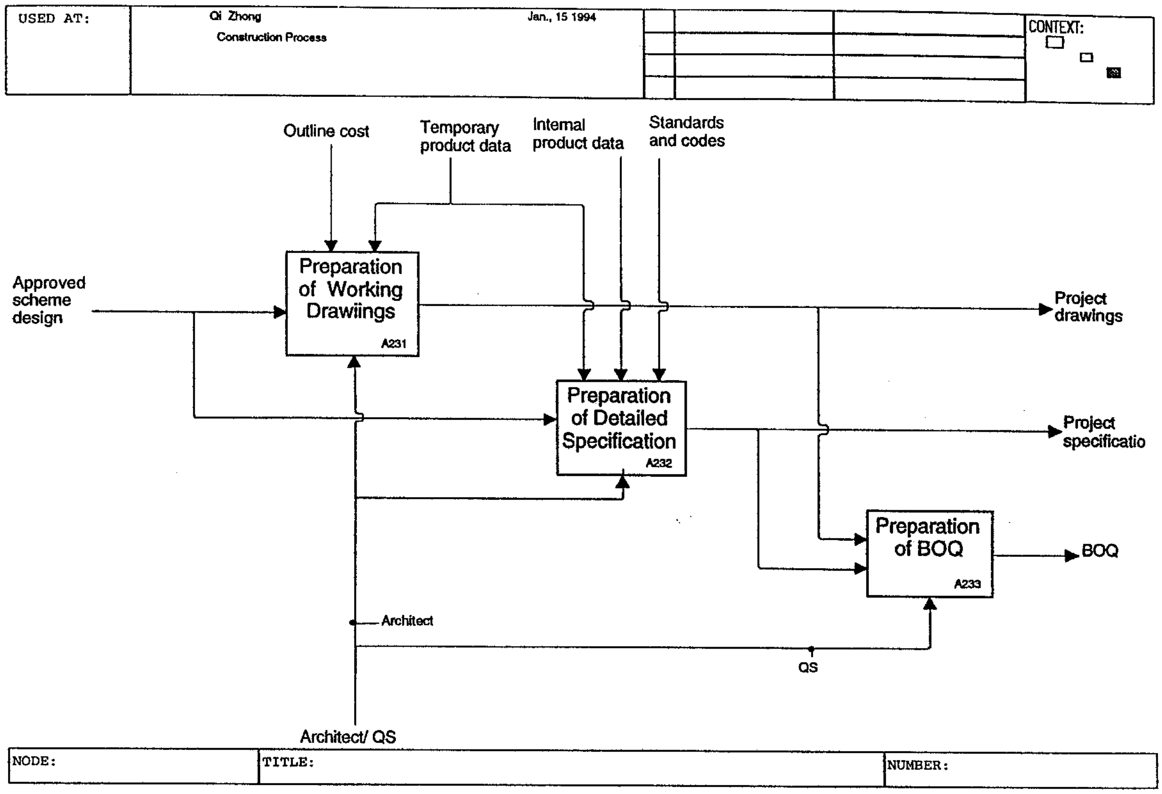

Fig.7. The Detailed Design in Design Phase

2.2.3 The tendering phase of construction process

The tendering phase (A3), can be further divided into four stages. These are: assemble the invitation to tender, price the tender documents by contractor, prepare tender report and select contractor and project planning. Firstly, QS usually handles tender procedures for the client. The QS assembles BOQ, project drawings and project specification together as a tender package and issues a copy to contractors. After the contractor prices the tender package and sends it back to QS. The QS prepares tender report based on the priced tender and passes them to client. They will select the successful contractor together. Then contract documents, which is largely a repeat of tender package, will be delivered to the contractor, based on which project program and schedule of activities can be set down by the architect. (See Fig.8.)

2.2.4 The site construction phase of construction process

The last phase of the construction process is the site construction (A4). All of the manpower information and materials are put together to form the final construction product. Although the site construction is very fragmented and complicated, it can be broken down into three main activities, viz. project financial control, management reporting and project supervision as well as technical control. There are a lot of feedback, and several revisions of the design. In the project financial control, contractors have to report monthly valuations to QS based on the tender rates from the BOQ. All of reports of financial status, construction status, together with contract documents, project program, etc. will aid contractor's management decisions, which should be reported to the client's representative, that is the project manager, regarding any design change or site instruction, etc.. Client may ask for some revision of the original design, and issue site instructions. All the physical construction activities are happening in the project supervision and technical control. (See Fig.9.)

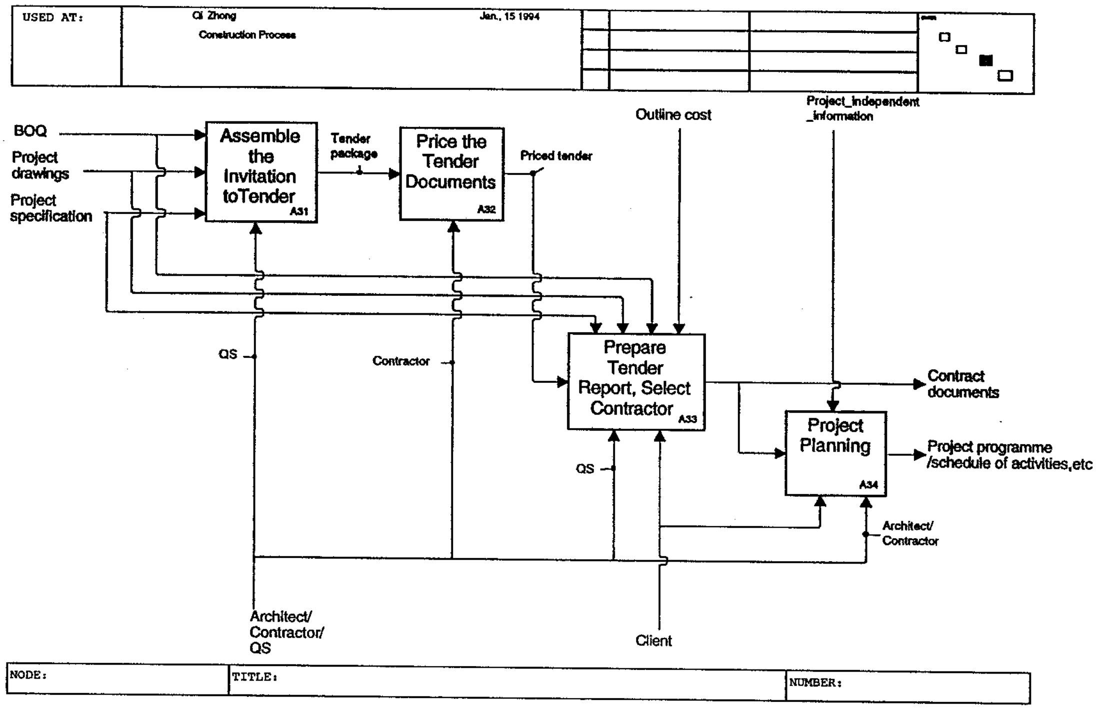

Fig.8. The Tendering Phase of Construction Process

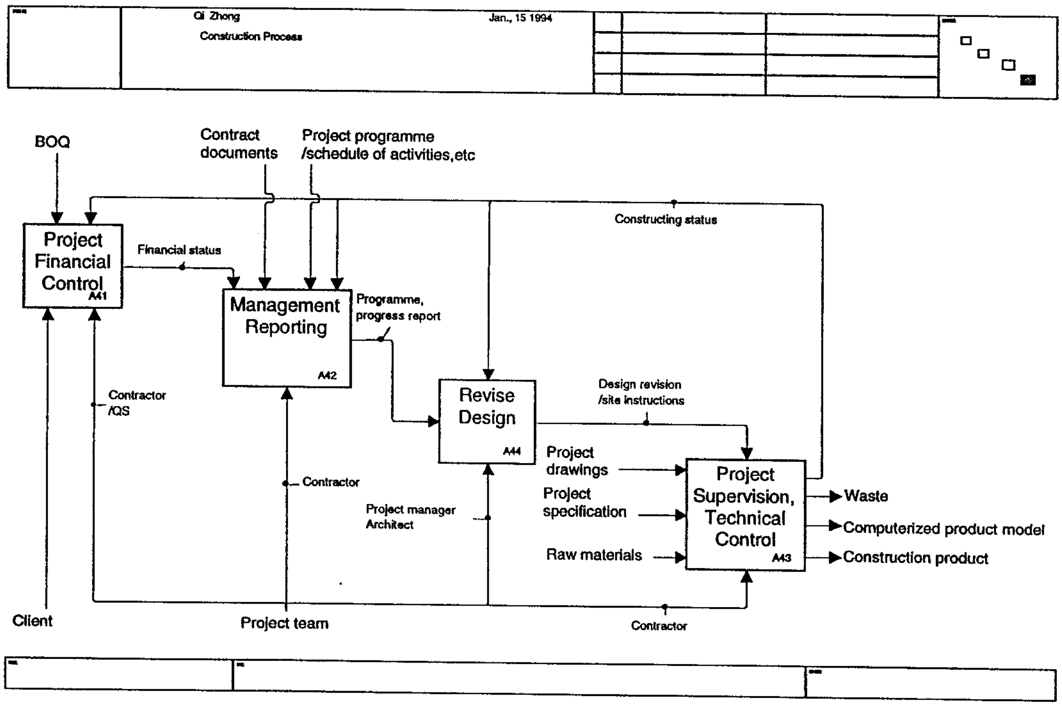

Fig.9. The Site Construction Phase of Construction Process.

3 THE CONCEPTUAL MODEL OF CONSTRUCTION PROCESS USING IDEF1X

In the following context, a construction process conceptual model is presented based on the previous IDEF0 activity model. Now IDEF1X is adopted as the modeling language.

3.1 ENTITY CLASSES IN CONSTRUCTION PROCESS MODEL

This conceptual construction process model describes the relationships between the entities. The entity classes in construction process model can have a few aspects, such as the overall relationships between the main entities, relationships between sub-entities, and relationships between certain specific entities which are involved in certain activities, like design, planning, cost estimating, etc.. There can be further detailed descriptions of the relationships between sub-entities once coming to a deeper layer of process model since this construction process conceptual model is conceived as a layered model.

The Entity Pool

The entity pool given here is a result which is derived from the previous IDEF0 model and also from other construction project conceptual models, like IRMA and GARM.

Process Entity Class:

- Process stage entity
    - Initial phase
    - Design phase
    - Tendering phase
    - Site_Construction phase

- Process actor entity
    - Client
    - Project Manager
    - Project_team
        - Architect
        - QS
        - Other consultants, e.g. structural engineers, HVAC engineers, etc.
        - Contractor
            - Main contractor
            - Sub contractors
        - Suppliers

    etc.

- Outcome entity
    - Physical product entity
    - Project-independent document entity
    - Project-dependent document entity

- Activity entity
    - Design entity
    - Cost_Control and Project_Documentation entity
    - Tendering entity
    - Planning entity
    - Site_Construction entity

    etc.

- Resource entity
    - Capital entity
    - Work force entity
    - Material entity
    - Equipment entity

    etc.

- Constraint entity
    - Time_Constraint entity
    - Budget_Constraint entity
    - Quality_Constraint entity
    - Regulation_Constraint entity
    - Site_Condition entity

    etc.

3.2 IDEF1X METHODOLOGY

The IDEF1X is a conceptual modeling technique. It was developed to meet the following requirements:

- Support the development of conceptual modeling: the IDEF1X syntax supports the semantic constructs necessary in the development of conceptual modeling.

- Be a coherent language: IDEF1X has a simple, clean, and consistent structure with distinct semantic concepts.

In IDEF1X, two main types of specific relationship can be defined, namely, *connection relationship* and *categorization relationship.*

A connection relationship (also referred to as a "parent-child" relationship) is a connection between entities in which each instance of one entity, referred to as the parent entity, is associated with zero, one, or more instances of the second entity, referred to as the child entity, and each instance of the child entity is associated with exactly one instance of the parent entity.

A "complete categorization relationship" is a relationship between two or more entities, in which each instance of one entity, referred to as the generic entity, is associated with exactly one instance of one and only one of the other entities, referred to as category entities. When an instance of the generic entity is not associated with any of the category entities, then the relationship is defined as an "incomplete categorization relationship" (see Fig.10.)

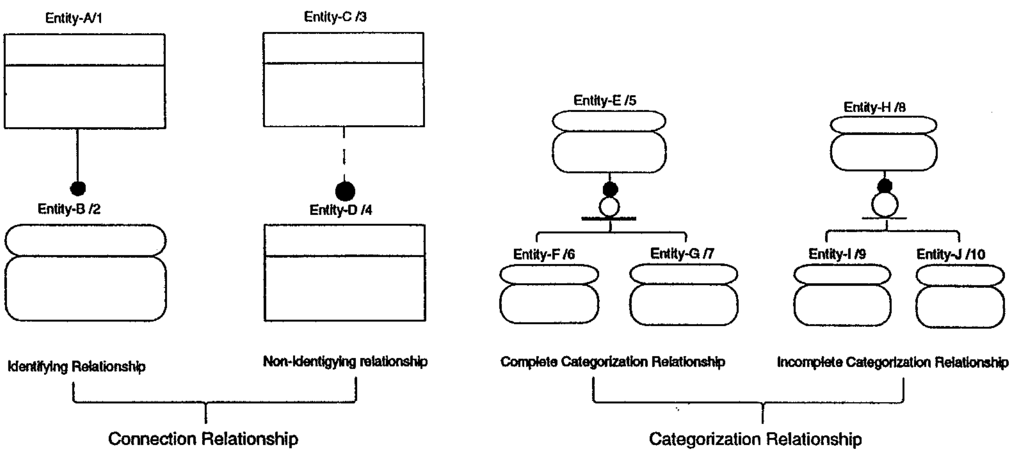

Fig.10. The Syntax in IDEF1X

3.3 THE CONCEPTUAL MODEL IN IDEF1X

At the top most global level, the relationships between the entities can be illustrated in Fig.11.

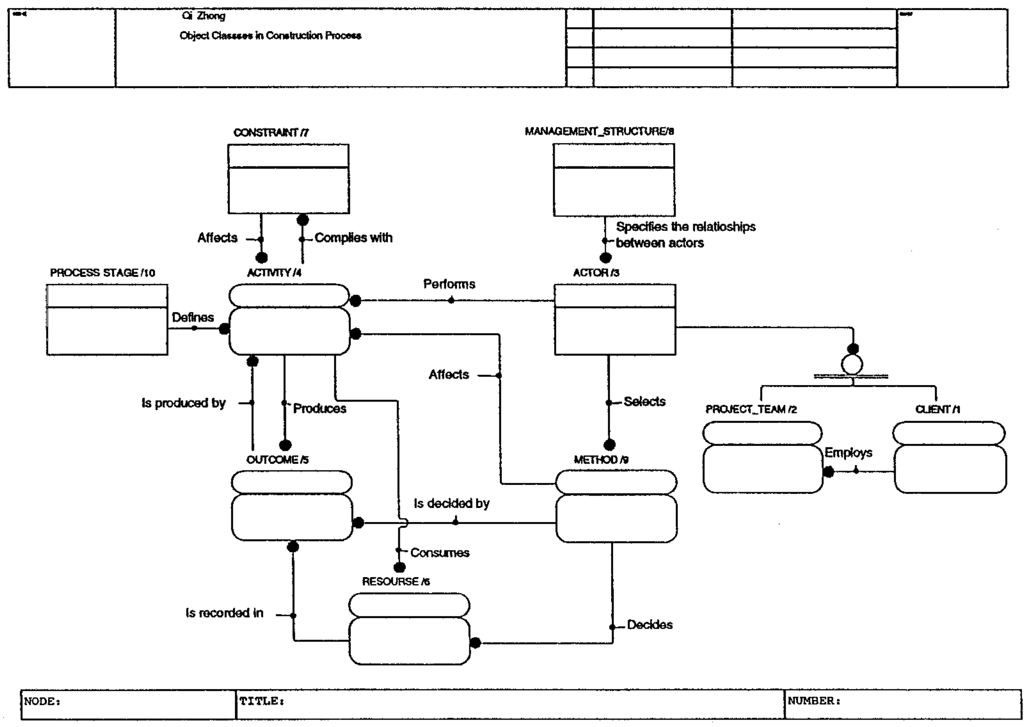

Fig.11. The Most Generic Entities Class of the Construction Process Conceptual Model

All these generic entities classes have category relationship to other entities, of which some important ones are listed in Fig.12, 13, 14, 15, 16.

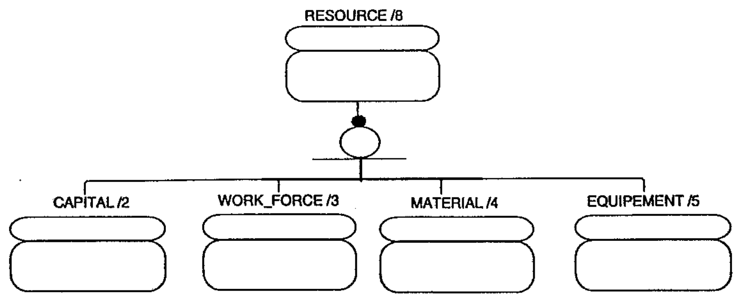

Fig.12. The Resource Entity Classes

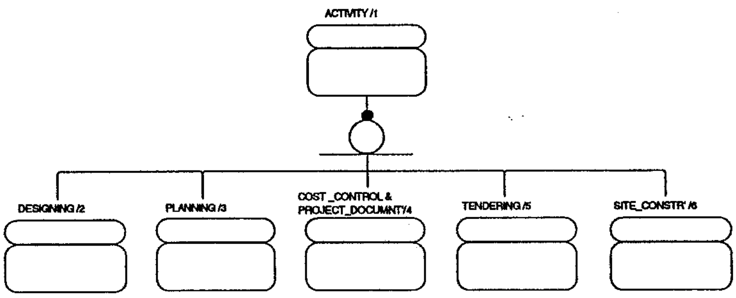

Fig.13. The Activity Entity Classes

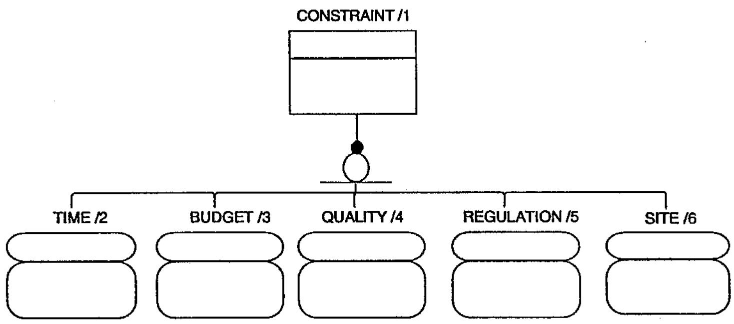

Fig.14. The Constraint Entity Classes

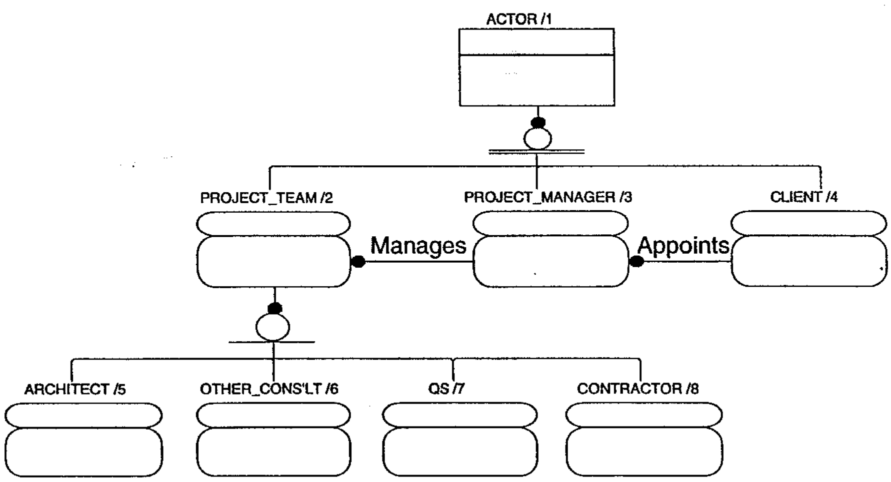

Fig.15. The Actor Entity Classes

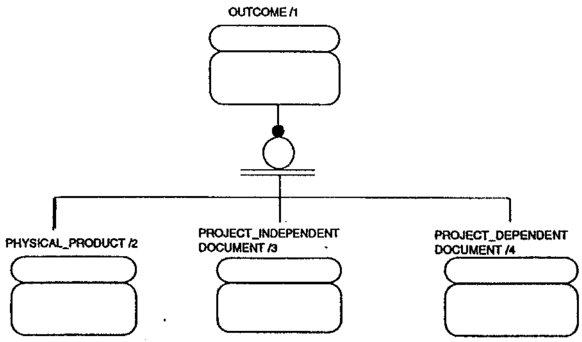

Fig.16. The Outcome Entity Class

Therefore, this conceptual model can be further presented as below (Fig.17.).

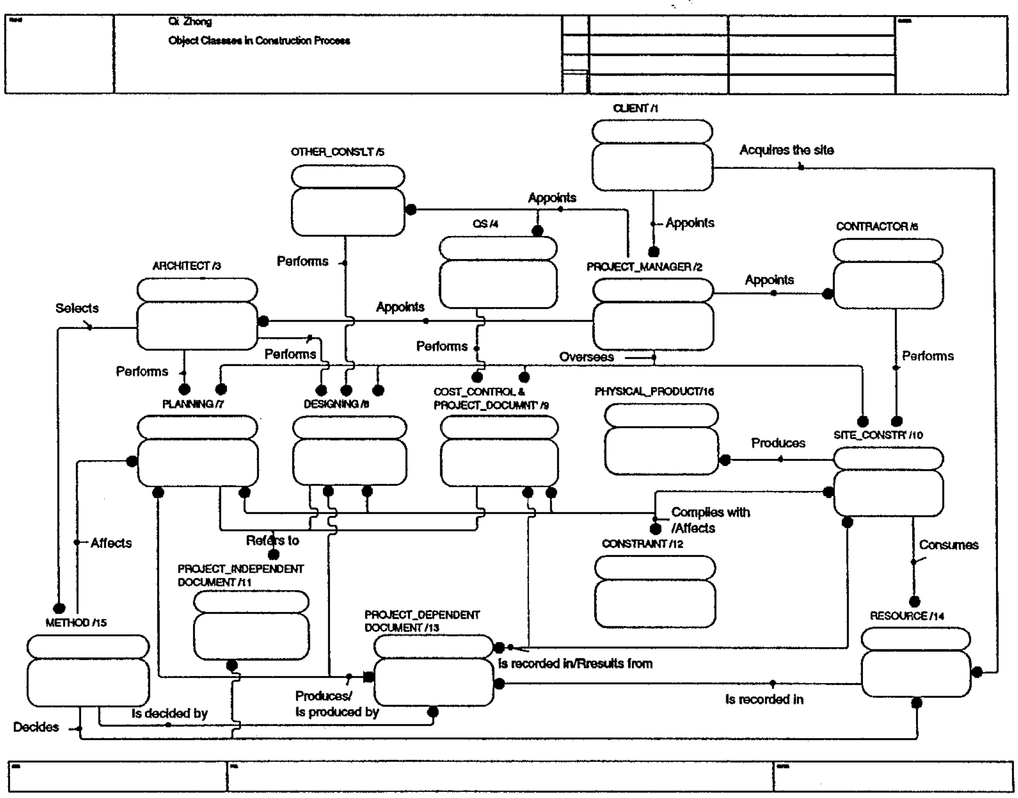

Fig.17. The Breakdown of the Construction Process Conceptual Model

4 THE CONCLUSION

Since the STEP methodology is still fairly new to the construction industry, the model proposed in this paper using IDEF0 and IDEF1X is a first attempt and thus tentative. It needs further testing and development. The framework established in this model can be further applied for other purposes, such as Architect's activity, Structural Engineer's activity, Planner's activity, etc.. The model has only focused on the very generic level of the construction process; definitely it can be further broken down to more detailed level according to the respective requirements.

The system proposed here, provides the part of the system architecture. The rest will be an intelligent scheduling and control model to be developed in the STEP format. When complete, the total system will hopefully be a generic architecture to model the construction process, which then can be applied to any other aspect of the construction process at any level of aggregation.

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