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Gunalan. G.J.

November 2001.

DECLARATION

I hereby declare that this submission is my own work and that, it contains no material previously published or written by another person nor material which, to a substantial extent, has been accepted for the award of any other degree or diploma of a university or other institute of higher learning, except where an acknowledgement is made in the text.

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Gunalan. G.J.
November 2001

ABSTRACT

Computer Integrated Construction (CIC) and Concurrent Engineering for Architecture, Engineering and Construction (AEC) require data standards or common Information Models through which computer systems can exchange project information. Information Modelling has received a lot of attention in the last decade and is now growing into a successful means to support design and production process, also in the area of building and construction. Collaboration through data exchange and model integration are coming within the reach of for all participants in the building process. This study identifies various types of Information Models and their purposes. Moreover, It describes Information Models developed with an intention of identifying the functions of a system by exploiting the techniques of System Analysis. Further, an activity or a process model, developed using the flowcharting technique to reveal the sequence of activities of that system is also presented. Though this study was confined only to system building suppliers, it can be applicable widely across the construction industry with necessary modifications.

Keywords: *Information, Information Modelling, System Buildings, System Analysis*

ABBREVIATIONS

A/C	- **A**ir **C**onditioning
AEC	- **A**rchitectural **E**ngineering and **C**onstruction
BOI	- **B**oard **O**f **I**nvestment
BPM	- **B**uilding **P**roduct **M**odel
BPR	-**B**usiness **P**rocess **R**eengineering
CAD	- **C**omputer **A**ided **D**rafting/ **D**rawing
CASE	- **C**omputer **A**ided **S**ystem/ **S**oftware **E**ngineering
CIM	- **C**omputer **I**ntegrated **M**anufacturing
DFD	- **D**ata **F**low **D**iagrams
HVAC	- **H**eating **V**entilating and **A**ir **C**onditioning
IBDS	- **I**ntegrated **B**uilding **D**esign **S**ystems
ICON	- **I**nformation/ **I**ntegration in **CON**struction
ICT	- **I**nformation and **C**ommunication **T**echniques
NPD	- **N**ew **P**roduct **D**evelopment
SBS	- **S**teel **B**uilding **S**uppliers
SER	- **S**tructural **E**ngineer of **R**ecord
SSDAM	- **S**tructured **S**ystem **A**nalysis and **D**esign **M**ethodologies
STEP	- **ST**andard for the **E**xchange of **P**roduct Model Data

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1 INTRODUCTION

1.1 Background

A representation of a thing, that resembles the represented thing in some way, is in everyday language called a model. A model concerns a specific member or group of members of a domain and is based on either a framework or a theory (Bjork, 1992). A concrete model is a thing that physically resembles the modelled thing, while a conceptual model is a mental representation of a thing, made up of concepts that represent the real thing. A computer-based model is a concrete model built into a computer, generally with the help of modelling software. A concrete model, be it in a computer or in clay, is a representation of a mental model, it is not a direct "footprint" or mould of reality. We don not model things directly as they are but as we see them in everyday praxis, expressed in a scientific theory, or in an artists vision. It is important to note the fact that the term model is often used both for models, frameworks and theories gives rise to an ambiguity in terminology.

In the context of computer-based information handling a conceptual model is also called an Information Model (Schenck & Wilson, 1994). Referring to computer-based models, e.g., product models, we normally mean the Information Model and not a concrete representation in the computer.

Modelling of information has become more and more important in developing information systems (Martin, 2000). Databases, as well as knowledge management systems are growing day by day. Modelling helps to understand, explain, predict, and reason on information, as well as the role and functions of components of systems. It can be performed with many different purposes in mind, at different levels, and by using different notions and different background theories. It can be made by emphasising users' conceptual understanding of information, or on a domain level on which the application domain is described, on algorithmic level, or on several representation levels. On each level the objects are different, and different rules govern the behaviour of them. Therefore the notions, rules, languages, and methods for modelling are also different. The approaches and background theories for modelling in application areas may differ considerably, too.

It is widely recognised that modelling construction information is complex task. (Aouad, 2001). Traditional Information Modelling revolves around producing conceptual data and process models that can be mapped into visual models that allow the rapid prototyping of buildings/products. These models, he further explains, can be used by novice users and clients to quickly assess and evaluate their requirements. The conceptual models describe the information infrastructure of the product under development. These models will be useful to developers rather than users. It has to be said that unlike the other industries such as defence, banking and manufacturing, the construction industry has yet to appreciate the importance of conceptual Information Modelling as well as visual modelling. In construction industry, Information Modelling is being undertaken on an ad-hoc basis without context or framework. This leads to the development of unreliable Information Models, which become unusable overtime. Thus, efforts and resources are wasted. In addition, the construction industry is divided for historical rather than logical reasons. These divisions reflect the roles performed by the disciplines not the information requirements of these areas. This leads to many problems in terms of Information Modelling and integration.

In this scenario, it is apparent that the construction industry could be benefited more than many other industries in adopting the techniques of Information Modelling. Therefore, System Building too, as part of the construction industry, should be benefited accordingly if it accepted the usage of Information Modelling. Many other industries have realised and accepted the importance of Information Modelling. Presently, it is almost unknown whether the industry has adopted any such practices. How the industry would be benefited by adopting the techniques of it is yet to be explored and the current practice, if available, of it has also to be unearthed and that will be of paramount importance if any further studies or researches are to be carried out.

1.2 Aim of the Study

The main aim of this study was to develop an Information Model for System Buildings Suppliers in Sri Lanka.

1.3 Objectives of the study

The main objectives of the study are as follows;

1. Enhancement of knowledge in System Buildings
2. Investigation on the current practice of Information Modelling
3. Identifying the importance of Information Modelling in construction
4. Identifying various techniques that can be used for Information Modelling

1.4 Methodology

Case studies will be carried out with come of the selected system-building suppliers to develop an initial Information Model. The model so developed will be cross-checked with the rest of the suppliers for confirmation.

In order to achieve the above-mentioned objectives a detailed literature survey will be conducted which will provide the theoretical background to the study.

A review of the present practise of Information Modelling in construction will also be clearly studied to do this dissertation to a required standard.

1.5 Scope of the study

The study will include all System Building suppliers in Sri Lanka, as there are only a few System Building suppliers in the market.

2 INFORMATION MODELLING

2.1 Introduction

This chapter seeks to identify the Information Modelling issues. It explores the views and concepts of Information Modelling. Further, the modelling process and the mechanisms are also viewed. Techniques of Information Modelling are another issue being focused in this chapter.

2.2 Background

An information model is an agreement on the meaning of data. Information Modelling (also known as data analysis/modelling) has long been an important technique for software architects and developers. In the form of entity-relationship modelling, it was a central part of such methods as Information Engineering and Structured System Analysis and Design Methodologies (SSADM). (Veyrad, 2001).

According to Veyrad, 2001, Information Modelling has been invented many times in the history of computing. Various line and box diagram started to appear from the mid 1970s, showing entities and the relationship between them. Notation wars broke out, some camps favouring crowsfeet tridents instead of arrows, some camps favouring rounded corners on the boxes, as if it mattered. Lots of complicated and confusing convents were invented to show interdependencies between relationships, dotted and half dotted lines, dotted and half-dotted arcs. In the 1980s and early 1990s, Information Modelling was a key component of a number of systems development methods, including Information Engineering. A number of modelling tools were developed, either stand alone or part of an integrated Computer Aided System/ Software Engineering (CASE) suite.

There are two reasons why Information Modelling remains important today. One is that many ideas of Information Modelling are valid in the object world, with many of the same patterns and frameworks. The second is that there are many system development tasks that require a proper understanding of information and data structure, from the design of persistent data storage, to the design of interfaces and schemas for information exchange across different platforms.

2.3 Definitions

Information is defined as the knowledge that is exchangeable amongst users in a given universe of discourse (Genilloud, 1997). In this context, information may be seen as the knowledge necessary to make use of a system or part of a system. An Information Model specifies thus what a user must know about a system, to make a proper use of it. A user may be a person or a other system. In this case, the users of the Information Model are people who specify, design or implement that other system.

Modern Engineering is based on the application of Information and Communication Techniques (ICT) to support single tasks as well as the co-operation and the working processes between the involved experts in engineering projects. The development of supporting software systems require a modelling of the relevant parts of the real world as well as a computer oriented preparation of the knowledge and experience in the relevant fields. Modelling means the abstract description of all-relevant properties and relationships in a formal way. Properties are parametric data and functional methods. Parametric data properties describe the state of the modelled world domain. Functional method properties describe the behaviour of the modelled domain as a functional relationship between the parametric data properties. The description of the properties is done by data and functions. They represent together with their meaning (semantic) information. So one of the main tasks for the development and application of computer software solution is Information Modelling.

Information Modelling is vital for a broad range of software projects, from simple data storage to large complex data warehouse, and from new application developments to complex system migration and integration projects. An information model addresses the underlying meaning of data regardless of technology. A model describes meaning through structure and correctness constraints. It does not specify encoding techniques for data values. When two parties agree upon an information model, they can map the model into a particular exchange technology.

2.4 General modelling terms

The term modelling is used with several meanings and different aims in all scientific and engineering disciplines. Examples are process modelling, construction modelling, economic and business modelling, geometrical modelling and experimental modelling. (Leeuwen, 1999). It is nearly impossible to give an overview over modelling in engineering disciplines or a definition of common modelling terms. But some general terms and principles can be extracted and summarised from the literature.

2.5 Abstraction

The real world is complex, not completely perceptible for humans. A complete modelling of the complex world or world domain is not possible. This means that not all properties of the relevant world domain can be considered. Aim of engineering is to find technical solutions under economical and ecological conditions for a defined specific task. Therefore the corresponding modelling focus on specific aspects (e.g. technical) of a world domain. The properties of the relevant world domain have to be reduced by abstraction.

There are two general forms of abstraction namely the coarseness and idealisation.

Coarseness substitutes an amount of properties with a smaller amount of properties. It reduces the size of a model. Example is the 2D integrated shallow water equation with integrated velocity.

Idealisation substitutes complex properties with simplified properties. It reduces the complexity of a model. Example is the physical behaviour description of concrete. Using a liner/constant stress strain function the complexity of the relationship between stress and strain is reduced to a simple mathematic description (Hendricx, 2000).

2.6 Modelling Process

The process to develop a model is called modelling process. The modelling process has usually four main steps

2.6.1 Analysis

The target of the analysis is the specification of the boundaries and the prerequisite for the model application and the definition of the core units and processes of the abstract model. The analysis include the general description of the states and process of the relevant world domain, case studies, definition of scenarios as well as the specification of a prototype.

2.6.2 Design

This contains the complete definition of the model type with a suitable modelling scheme/ language independent from the implementation but based of the results of the analysis. It starts with a coarse specification of the core model type elements and their relationships and is done in an iterative process of refinement up to a complete definition of all necessary details.

2.6.3 Implementation

The implementation transfers the design into software, including suitable model editors. The implementation is done using programming language, libraries and interfaces as well as defining of model schemes in database.

2.6.4 Application

In this step the application of the implemented software supports the working process in engineering projects. The application contains the process to create, edit and analyse models of the engineering project relevant parts of the world.

2.7 Types of models

There are many different types of Information Models and the intended role of any model is not always clear (Froese, 1994). The type models are models that they define the data representation constructs to be used for capturing information about some domain. These models are created using a modelling language (E.g., EXPRESS) and are used as the data type declarations by systems that store actual project information (Instance or occurrence models, or simply database).

According to Froese, 1994, many of the sample models are core models or reference models, rather than application models. Core models are intended to be high level models that provide a unifying reference model for more detailed application models that will be constructed on top of them. Unlike application models, core models are generally not intended to be instantiated for representing actual data (though they can be used for exchanging information between different application areas). While some of the sample models are intended to directly support actual implementations (such as ICON[1] models), even these can be described as model segments that they play “core” roles for other, more specified sections of the models.

Most of the sample models are also conceptual models, rather than aspect models or classification models, for example conceptual models provide formal definitions of the basic entities and relationships required to represent information about some domain. Architectural, Engineering and Construction (AEC) projects in this case. Aspect or property models are more detailed since they provide all of the specific attribute definitions required to fully represent the actual domain information. The sample model that are intended to support specific implementations tend to provide the attribute definitions, while those intended to act only as references for other modelling projects do not.

In contrast, classification models adopt some simple conceptual model for representing entities and use this to develop extensive categorisation or classification breakdowns of domains for the purpose of providing classification systems or enumerating all of the specific elements of the domain.

2.8 Modelling Principles

The quality or usefulness of Information Models derives, in part, from the modelling principles or styles followed in their creation (Froese, 1995). Some principles that are likely to lead to more useable models are sometimes not closely followed in the sample models.

[1] Further explanations regarding ICON models are given in Chapter 4

One such principle is that entities represent and be named after their underlying nature rather than the role that they play in a particular context. For example, both controls and resources may represent the roles played by things, which are more fundamentally described as simply different types of physical and/or information objects. An exception to this principle is that when characteristics relate to an entity's role in some context rather than to the fundamental nature of the entity itself, a role entity could be defined as a secondary superclass. For example, an entity to represent a wrench might be a subtype of physical entities, from which it inherits its physical properties, but also a subtype of a resource role entity from which it inherits a relationship to the processes that use it as a resource.

According to Froese, 1995, another principle is that all associations among physical or logical objects should be represented as entities rather than simple as relationships among the objects. Activities, resources, and resource use should all be represented as entities, for example, rather than just activities and resources.

Entities used to represent actual data are based on several different conceptual breakdowns. For example, a carpenter is defined in terms of his role as a person, an employee, a resource used in some activity, a physical object with a unique location, a member of a crew, an entity that exists in some current state with relationships to past and future, intended or planned states, and so on. Each of these distinct classifications can be expressed using a primitive object while the overall entity that combines all of the characteristics of these constituent primitives is called composite object. Given this perspective, it becomes an intractable problem for conceptual models to pre define all possible combinations and permutations of all primitive breakdowns. Rather, conceptual models should identify the primitive objects breakdowns and the actual composite objects can be derived from these within the context of specific applications.

Veyrad, 2001, summarises the principles of Information Modelling as follows:

1. A model is a communication of structure and properties. It usually presents itself as representing something, either in the 'real' world, or in the intentions of people (Managers or Engineers, planners or designers). Sometimes a model merely represents itself.

2. A model always has a scope, purpose and perspective. Sometimes there are stated explicitly. Often they are implicit or assumed.

3. Formal models are expressed in a strict modelling language or notation. The vocabulary and grammar of this modelling language may themselves be expressed as a model, which software engineers usually call a Metamodel. Such models are used for building support tools, such as diagramming tools and repositories.

4. For many purposes, informal models are as good as formal models, indeed, sometimes better.

5. All models leave things out. This is precisely what makes them useful, as long as you leave out the right things.

2.9 Modelling Mechanisms

Many of the Information Modelling challenges that must be addressed in creating models are widely applicable across domains (Froese, 1995). Solutions to the challenges, then, can be equally as widely applicable. These general modelling constructs make up a meta model, or a set of definitions and modelling solutions upon which to base specific domain models. Some of the sample models include extensive descriptions of proposed modelling mechanisms, others rely on even more generic modelling kernels to define these mechanisms, and still others avoid these issues altogether. Several of these mechanisms are introduced below.

Top level entities and entity subjects: West (1993) describes five subjects of entities as materials (objects that have a specific physical form such as a car), tokens (logical objects or concepts, such as an organisation or cost account), processes, associations (relationships among materials, tokens, or processes), and characteristics (descriptive information about entities).

Identification: Each entity requires a unique identification. The specific mechanism used to identify entities may vary with different types of implementation.

Classification: classification is used to represent the common characteristics of a collection of like objects.

Composition: Composition or aggregation, the identification of the sub parts that make up aggregate assemblies, is common in current project management software.

Connectivity: since many objects are represented as sub components of higher level assemblies, an explicit description of how components fit together is required. Connectivity has been modelled in some of the sample models by showing that entities are interfaced through ports, and a port on one entity interfaces with a port on another entity. In order to represent connectivity among objects represented at different levels of compositions granularity, the ports for an object described at one level can have a hierarchical equivalence relationship with the ports of objects higher or lower in a composition hierarchy.

Versioning: this is used when base representations of entities can have multiple variations or derivative versions, or when successive versions of an entity can be represented.

Extensibility: a current concern of product and process modelling technologies is that they define static models, the multi-year life of a project in ways that cannot be accurately predicted. Not only the database, then, but even the conceptual data model must be dynamic or extensible.

Representations: Several different representations of any entity can exist. A steel beam, for example, could be represented within a system using a set of characteristics parameters describing its location, shape, cost account codes, etc.

Characterisation: characteristics are properties of entities. While many of the sample models simply define attributes of entities to describe their properties, other models, explicitly define a generalised characterisation mechanism for relating entities and their characteristics.

2.10 Modelling techniques

Several Information Modelling techniques have been developed, introduced and applied over the last thirty years. These modelling techniques can be classified in dependence of the dominance of parametric or functional properties.

2.10.1 Data Oriented Modelling

Frequently used modelling techniques are data oriented modelling technique. These techniques can be used to describe parametric properties of world domain with abstract data structure and their relationship. These models are based on mathematical theories like set theory or predicate logic. This technique is mainly used in domains with a dominance of data. E.g. rational data model.

2.10.2 Functional Oriented Modelling

Functional oriented modelling techniques are used to describe world domains which are dominated by functional properties. Parametric data are handled in local data structures inside functions. The specified functions are arranged in a function structure. The data flow between functions is realised by function parameters and return values. These techniques are mainly used for the description of behaviour and processes.

2.10.3 Object Oriented Modelling

Object oriented modelling techniques are based on consistent semantic units with encapsulated parametric and functional properties. Theses units are called objects. With this approach object oriented modelling can be used to model in a balanced way states as well as behaviour of relevant world domain. Main principles of object oriented modelling techniques are encapsulation, generalisation and specialisation, standardisation, association, aggregation and composition. These techniques are used for complex modelling domains. Application examples can be found in documentation modelling, enterprise modelling or construction modelling.

2.11 Summing up

In this chapter various types of Information Models and their purposes have been analysed. Various techniques available to develop a model have also been focused. Further using this literature, a vital conclusion can be drawn up that the successfulness of the model would depend on the identification of the purpose of the model, type of the model and the techniques used to develop it. All these factors strongly influence the usefulness of the model.

3 SYSTEM BUILDINGS

3.1 Introduction

This chapter revolves around System Buildings. It explores the definitions of System Buildings and the advantages of having it in a particular situation over the other types of Building. The types of System Buildings are explored. Further it underlines the most common mistakes people make when buying a System Building.

3.2 Definitions

A System Building is a complete integrated set of mutually dependent components and assemblies that form a building. It includes the primary and secondary framing, covering, and accessories, all of which are manufactured to permit inspection on site prior to assembly or erection. (Source: http://www.mbma.org/)

A Steel Building System (SBS) is a building system in which steel structural and cladding components plus applicable appurtenances are engineered to facilitate mass production and to permit assembly in various combinations. The SBS can take the form of framed buildings (i.e. rigid frame structures) or frame-less buildings (i.e. stressed skinned structures). (Source: http://www.apegn.nf.ca/steel.htm)

In simpler term, it is a steel frame building that typically consists of Roof sheeting, Wall sheeting, Purlins, Girts, Frames (Including side wall column), Columns, End-wall Beams and columns, Flange bracing, Connections, Screws and bolts, Other non structural parts. When assembled, all of the parts form the shell of a complete structure. All components are typically designed, fabricated, and furnished by a single manufacturer based on owner identified requirements. They are delivered to the job site where they are assembled by a structural steel erector. The general contractor, erection contractor, building supplier, or other agreed upon party may act as the erector. Erection normally uses field bolted connections with little or no field welding. Primary components, such as columns, beams, and girders, are typically fabricated from plates, are shop welded, and are optimised for the specified loading conditions.

3.3 Why choose a Metal Building System?

The metal building[2] industry has increased its share of the low rise, non-residential market to an all-time high. It is growing at a much faster rate than the market in general because of the ever-increasing variety of applications for this type of construction.

The traditional advantages of metal building systems have been their design flexibility (particularly large column free floor areas), consistent quality, speed of construction, and predictability of costs and completion schedules. These features remain as valid today, as they were when the industry was in its infancy, over fifty years ago. Increasingly, architects, design professionals, and owners have realised the efficiency they gain in working with these systems. And architects lose none of their creative freedom in combining aesthetically attractive and functional metal systems with conventional building materials.

The result has been the growth of metal building systems into a limitless variety of end use applications to provide functional and comfortable spaces for offices, factories, education, recreation, commerce, industry, and other special purposes.

3.4 Advantages of System Buildings

3.4.1 More Economical

1. Lower initial cost
2. Little maintenance
3. Foundation is less expensive
4. Roofs have longer life
5. Faster tax amortisation

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[2] The terms metal building and steel building are used interchangeably instead of system building in some western countries

6. Easy insulation of building lowers initial and operating costs of heating and air conditioning

3.4.2 Earlier Occupancy

1. Faster delivery and erection
2. No job site processing before erection

3.4.3 Adaptability

1. Wide range of sizes
2. Non-standard sizes are standard
3. Expansion with minimum material loss
4. Can be dismantled and re-erected
5. Adaptable to overhead cranes and monorails

3.4.4 Attractive Appearance

1. Modern low profile
2. Attractive Multi-Rib panels with baked on colours

3.4.5 Quality

1. Computer-designed for best engineered construction
2. In-Plant fabrication with constant inspection
3. Production-Line fabrication produces more dimensionally accurate standard parts

3.4.6 Features

1. Favourable financing commitments
2. Economical clear spans and heights that are easily insulated

3. Fire resistant
4. Inexpensive sky lighting and adaptable to masonry and other wall materials. (Source: http://www.aviationbuildingsystem.com/)

3.5 Types of System Buildings

3.5.1 Quonset Hut Steel Building

These types of buildings are generally available in two different styles. First is the old-fashioned full arch steel building and, second, is the newer modified Quonset, which has perfectly straight walls and then a curved roof.

3.5.2 Steel I-Beam Buildings

This is the most common type of construction for steel buildings. It is so named because the profile of the steel beam looks likes a capital letter "I"", forged out of steel like a railroad tie. This system may also be called a rigid frame steel building or a red iron building. Most of the commercial type buildings fall in this type. Some are pre-engineered kits, and others are custom designed structures that are fabricated on site.

3.5.3 Hybrid steel/ Wood Combination Buildings

This style of building employs a mainframe open web steel truss placed every 10-16 feet apart. Each truss is composed of four pieces: two sidewall sections and two roof sections. Each section is bolted at the peak and at the eve. Trusses are usually assembled on the ground and then pulled up on to the anchor bolts, which have been set in the concrete foundation. On the outside edge (some designs have the clips internally placed) of each steel truss, running up the side and the roofline, are "C" clips every 24 to 48 inches apart. The clips are designed to hold the wood Purlins and Girts. (Source: www.steelbuildings.org/Building_Descriptions.html)

3.6 Structural Engineer of Record (SER)

The professional engineer who produces and is responsible for the structural design documents which are issued for construction. (Source: http://www.apegn.nf.ca/steel.htm)

3.7 Responsibilities of the SER

Some of the duties of that the Structural Engineer of Record (SER) may be professionally responsible for, on behalf of the owner, include:

1. The preparation of the structural design specifications for the SBS
2. The review of the SBS shop-approval/erection drawings for conformance with the design specifications
3. Review of the SBS construction to determine conformance with the design specifications

3.8 Common mistakes people make when buying a steel building:

Some of mistakes people commonly make when buying a system building are given below. (Source: http://www.steelbuildings.org/7_mistakes.html)

1. Buying the wrong type of building for the needs
2. Not figuring out the total cost
3. Trying to buy the cheapest building
4. Buying on the spur of the moment
5. Not checking references
6. No building experience
7. Not getting proper permits before deciding

3.9 Summing up

The selection of a System Building will depend on various vital factors like the client's requirements. If the client wants a building to be completed within a short period, he may opt out the other types of buildings and would prefer to have a System Building. The client should be aware or made aware of the advantages of having a System Building in a situation over the others. Therefore in the later case, it is the responsibility of the supplier to educate the client as to what the suitable option is and it should not be confined to the time period alone as far as this example is concerned.

4 INFORMATION MODELLING IN CONSTRUCTION

4.1 Introduction

Many types of Information Models were developed and used for the construction industry viz. product models, functional models, process/ activity model etc. This chapter reveals some of information models developed by various researchers, their features and uses in a particular situation. It also compares the construction industry with that of the manufacturing industry in the purview of Information Modelling. Furthermore, the usage of Information Modelling for the Integrated Building design System is also focused in this chapter.

4.2 Background

Process and process information are fundamental to manufacturing, but also to construction (Schlenoff C, Michel J, Cutting Decelle, 1998). In the last decade, there has been an increase in the number and types of software applications which attempt to capture the essence of process. Theses range from tools that simply portray processes graphically to tools that enable simulation, analysis and /or control of processes. As industrial (Manufacturing or construction) companies move toward an increasing integration, there is a growing need to share process information. For example, project management software will use process data from workflow applications. All this is leading to the conclusion that as more and more process are modelled, analysed, monitored and controlled, the probability is increasing of having these process expressed in different and incompatible ways. On the other hand, as more and more of these automated applications are implemented and integrated, the need is increasing in a unified way.

4.3 Information Models for Manufacturing System

The variability of the manufacturing system can be expressed through the features of the Information Model describing the system. This model will have to include the functional intent of product and processes encompassing product definitions, process definitions (process planning, execution and production engineering) and production operation and control (scheduling and building instructions). Model of the manufacturing system must be able to give everyone access to current data and share the up dated information instantaneously as the product evolves from one stage to another. As such, it encourages the use of common database, eliminating potentials for wasted or duplicated efforts in traditional data recreation and reformatting. These models should also provide a precise description of the activities, data connectivity and communication network of an enterprise. Through the acts of flowcharting, the model will capture the information flows through the units involved in the design and development of the product, since it reflects the information needs of both the manual and automated units of an enterprise.

4.4 Information Models in Construction

Information handled during the construction process can, from different point of view, be divided into several categories (Schlenoff C, Michel J, Cutting Decelle, 1998).

Accordingly, the first point of view, information can first of all state facts. This category of information is what design documents, which are the results of design decisions, primarily concern. Information that needs to be transferred between computing system in the construction process is mostly of this type. E.g., the colour of the surface “x” is of wall “y” is green. This context of the information is not specific to construction. Secondly, information has to define goals and requirements which a particular project must fulfil. E.g., the building may not have more that 5 floors. This kind of information could be called requirement, or constraint. The third category of information state rules which restrict facts, but which apply in general and are not tied to a particular project, such as the following “rule”; ‘a beam, which is directly or indirectly structurally supported by a column cannot be erected before the column’. These three categories of information can be called ‘facts’, ‘constraints’, and ‘knowledge’.

The second semantic point of view divides information into project specific and more general information. Facts can be both projects specific and general. Constraints are mainly project specific and knowledge is usually general in nature.

Third point of view concerns presentation and categorises the type of documents used to present the information for human interpretation. Some typical presentations formats used in construction are drawings, schemas, realistic visualisations, written specifications, calculations results, bills of materials, contracts, orders and various tendering documents.

4.4.1 Information Reference Model

The information reference model for AEC was developed at a workshop in 1992. While the model was intended more as a reference and comparison tool than an end product, it has served as a useful vehicle for further conceptual development (Froese, 1995). The model identifies the central objects in AEC projects. These are shown in Figure 4-1 while the more refined process model is shown in Figure 4-2.

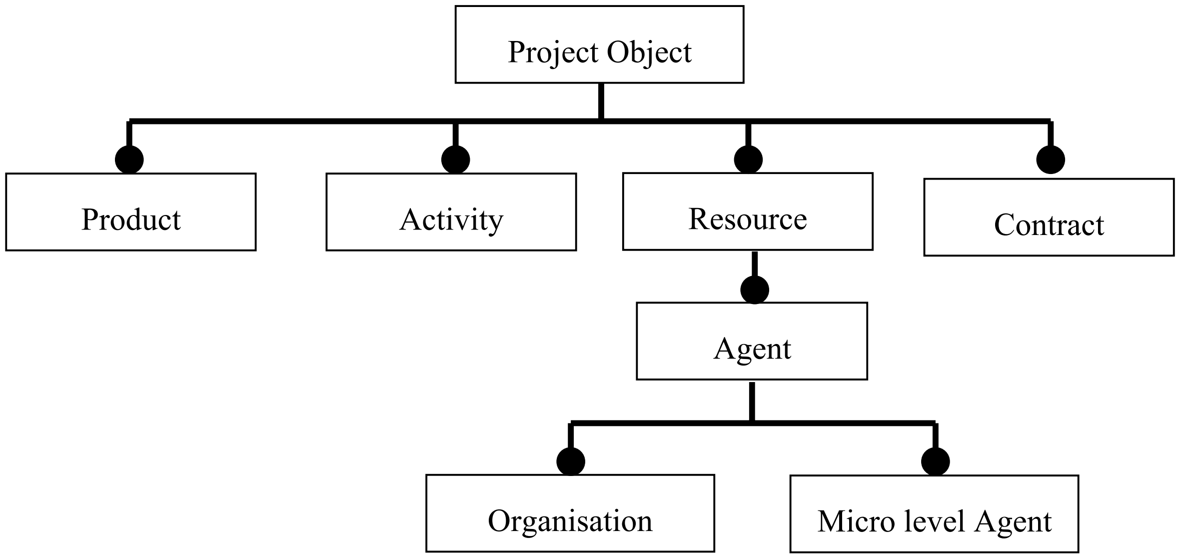


Figure 4-1 Hierarchy of the Information Reference Model for AEC

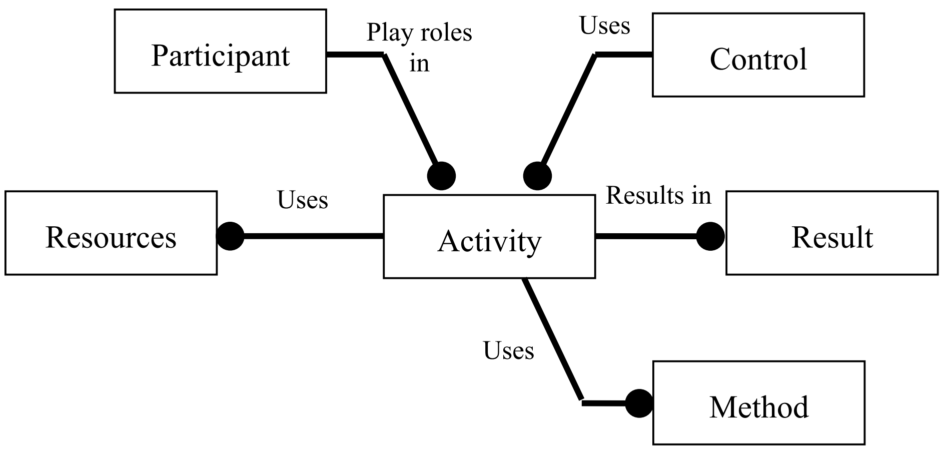


Figure 4-2 An AEC process view model

4.4.2 Building Project Model

This BPM was developed with the intention of providing a conceptual model that integrates product, activity and resource information (Luiten et al, 1993). The model focuses on two main abstractions namely the relationship between products and activities as illustrated in Figure 4-3.

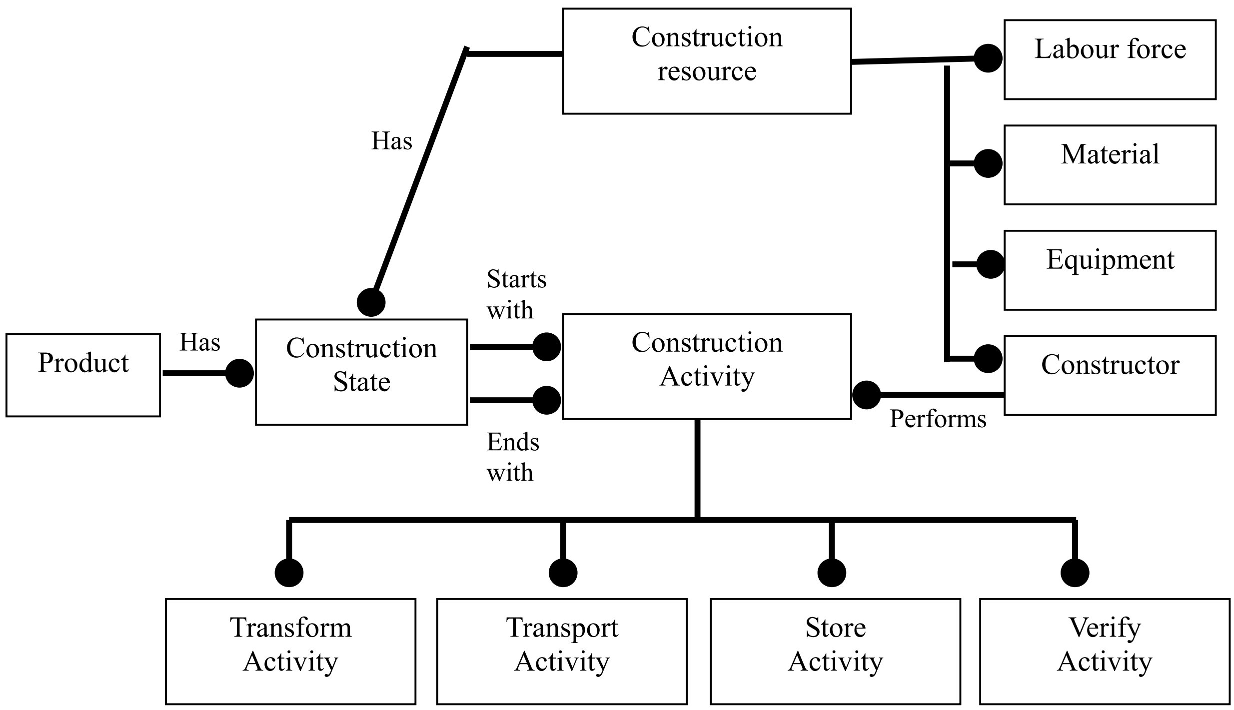


Figure 4-3 A Portion of the Building Project Model

4.4.3 ICON

The Information/ Integration for Construction Model is aimed at investigating the feasibility of establishing a framework for integrating information systems in the construction industry (Froese, 1995). It applied through information technology techniques such as the Information Engineering method, object-oriented analysis and design, and CASE. Figure 4-4 shows a portion of the ICON model.

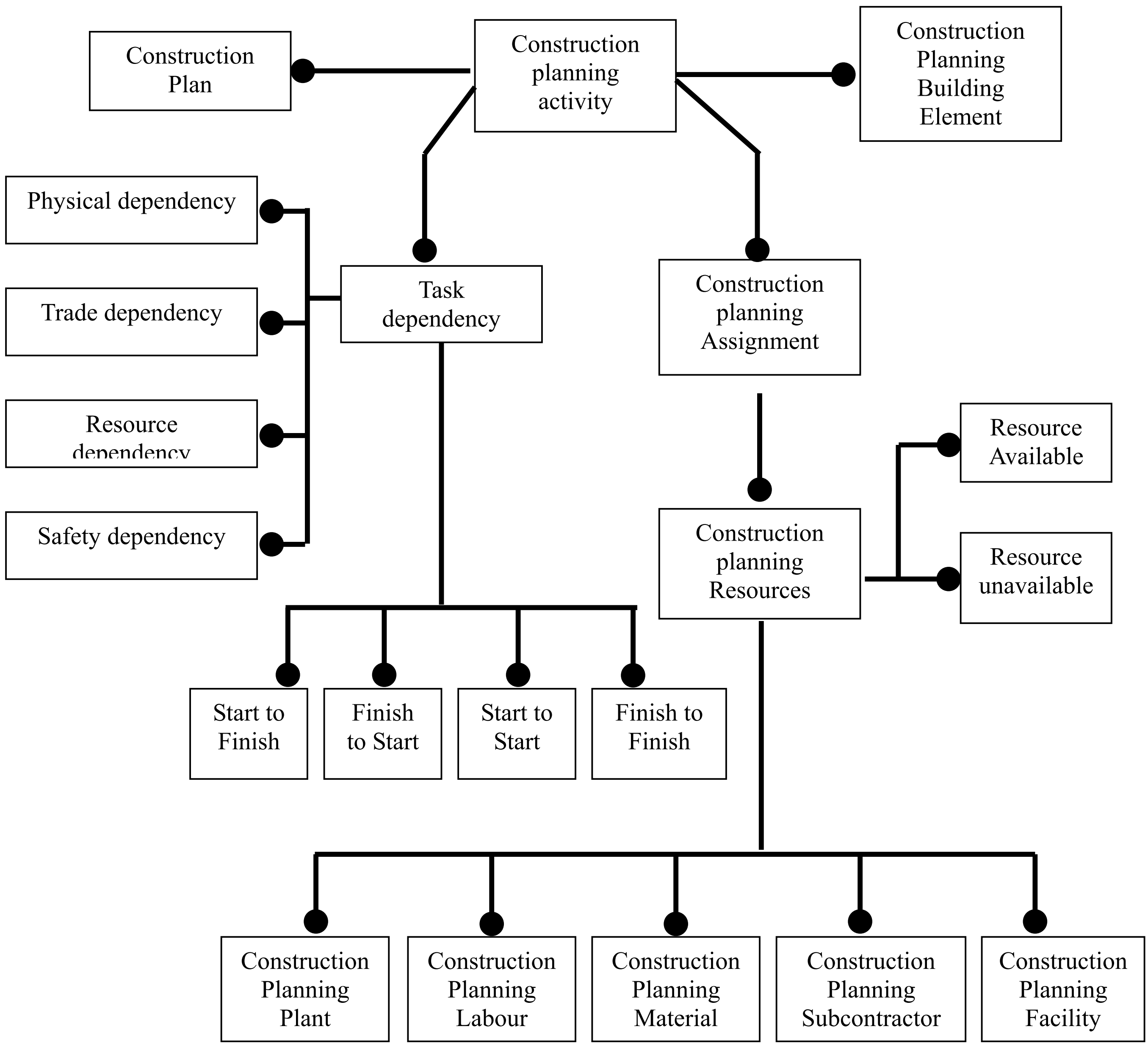


Figure 4-4 A portion of the ICON Construction Planning Object Model

4.5 Similarities and differences between manufacturing industry and construction

A number of lessons can be learned from the manufacturing sector with regards to the implementation and practical use of process view within the construction industry. The are within the manufacturing sector that relates to construction and building works is often called 'new product development'. It concentrates on the development of an idea, need or client requirement to the final commercialisation of the product (building or car}. A number of similarities can be found between the two industries with regards to the activities used for developing new products. They include;

1. The start of a project can be initiated internally or by direct and/ or indirect contact with the customers.
2. The development of the product requires the participation of a number of specialists and functions such as designers, surveyors, marketing, stress analysis, etc.
3. The successful construction or manufacture of a building and or product can only be achieved if all external and internal resources are utilised and co-ordinated effectively.
4. The building or product is handed over to the customer/ client and provisions are made for future support.

However, there are a number of distinct differences, the most important which is that in the manufacturing industry all NPD activities are co-ordinated, managed and controlled using a common framework which is the NPD process. The construction industry mainly uses ad hoc methods for achieving the later and therefore reducing repeatedly of process execution, resulting in the same mistakes occurring time after time. The shift into the establishment of a consistent process for the construction industry requires a new way of thinking entailing a change of culture and working practices. Further more, it will require,

1. A good understanding of current practices and future trends
2. Effective communication mechanisms of such processes, such as modelling
3. Agreement of participating parties.

4.6 Re-engineering the design process using Information technology

A prototype integrated design system that can be used to improve the information flow between the various stages of construction and to 're-engineer' the process so that designs that put emphasis on constructability and cost as well as structural adequacy can be more easily produced. This is done by the effective integration of the downstream activities within IT tools used for the conceptual design. There are four main aspects to the system:

Integration of design activities: This has mainly involved the association of the design of connections with the design of structures. The system uses a single data model hence, having modelled a structure, a change is one aspect (say resizing of a member) is reflected in the analysis model, member design and most importantly the connection. There are many benefits to this approach since the effects of member sizes on the adequacy of the connection are instantly recognised. Designers can easily identify failing joints and 'tune' member sizes to achieve safe structures and appropriately detailed connections (un-stiffened and standardised). The other main benefit to this is that the same analysis model, with its assumptions and resulting forces, are used for the design of the connection. The ease at which the two main design tasks can be carried out simultaneously will have a larger implication on avoiding what is often a contentious and confrontational issue at the design-fabrication interface.

Cost modelling and appraisal: The same data model above is also used to provide a measure of economic appraisal of the various design options. With the provision of 'basic cost' databases for material (sections, plates, bolts, welds) and fabrication and erection operations (welding, cutting, drilling, fixing bolts, lifting and coating), indicative costs of material and construction are instantly available for inspection. These can be inspected at various levels: whole structure, individual members, and individual joints and can also be split into material and construction costs and further itemised into basic cost items such as welding, cutting, coating, etc. The intended use of the estimated costs is to obtain indication relative costs of various design options and not absolute cost of construction. Economic appraisal of the whole structure or part of it can be carried out by comparing total cost or specific costs of various design options and therefore aid in the choosing of options that take into account the overall construction process.

Provision of advice: a 'knowledge-based expert system' style of programming has been used to embed an advice mechanism into the system. Again using the same data model, rules of thumb relating to constructability issues are used to provide guidance relating to design detailing of joints and taking into account the Design for Manufacture guidelines.

In summary the integrated system allows for the tackling of all design tasks at a single stage. Thus the effects of one on the others are clear. Adding to this, designers can make informed decisions based on the knowledge of the consequences of these on whole process. This is facilitated through the use of the economical appraisal and guidance aspects of the system. This is not to mention the implication of practising such an approach to design on the way the industry operates and its future organisation especially with respect to the interface between consultant designers and fabricators.

4.7 Modelling in Integrated Building Design System.

Under the broad concept of building design, there are many smaller tasks, such as building layout design, product specification, cost estimation, structural analysis, lighting design (Sun & Lockley, 1999). Traditionally most computer based design tools were developed addressing a single task of the design problem and were intended to be used by experts who have the domain knowledge. The effectiveness of those tools was limited by the communication constrains between members of a design team, and by the ability of each designer to relate the design tool to the design problem. As a result, those tools are often under used in design practice. Integrated building design system (IBDS) are aimed at providing supports to designers in an integral design context. For this purpose, an integrated building design system must have the following features;

1. To support multiple design tasks by including multiple tools in the system
2. To provide effective support throughout the design process
3. To automate data exchange between different tasks in the system
4. To facilitate the communication between design tools to support wider integration through the whole building life cycle
5. To provide certain degree of intelligent design support in a design context

According to different emphasis and system and system structure, these systems can be classified into three categories, database centred, executive centred, and product model centred.

In the product model centred approach, a system is centred around the design object or the building. An essential component is a product model of a building. The model is usually expressed in a neutral application tools, it is a description of what the building is rather than how it is used. Obviously, it will always need to be an ‘open model’, since it is difficult, if possible at all, to define a complete building model in the short term. Therefore the “concept model” is introduced for the product model approach. An “aspect model” is a partial view of the building object from the viewpoint of one or a set of application tools. Views of different aspect models are integrated, not simply aggregated, in the central “product model”.

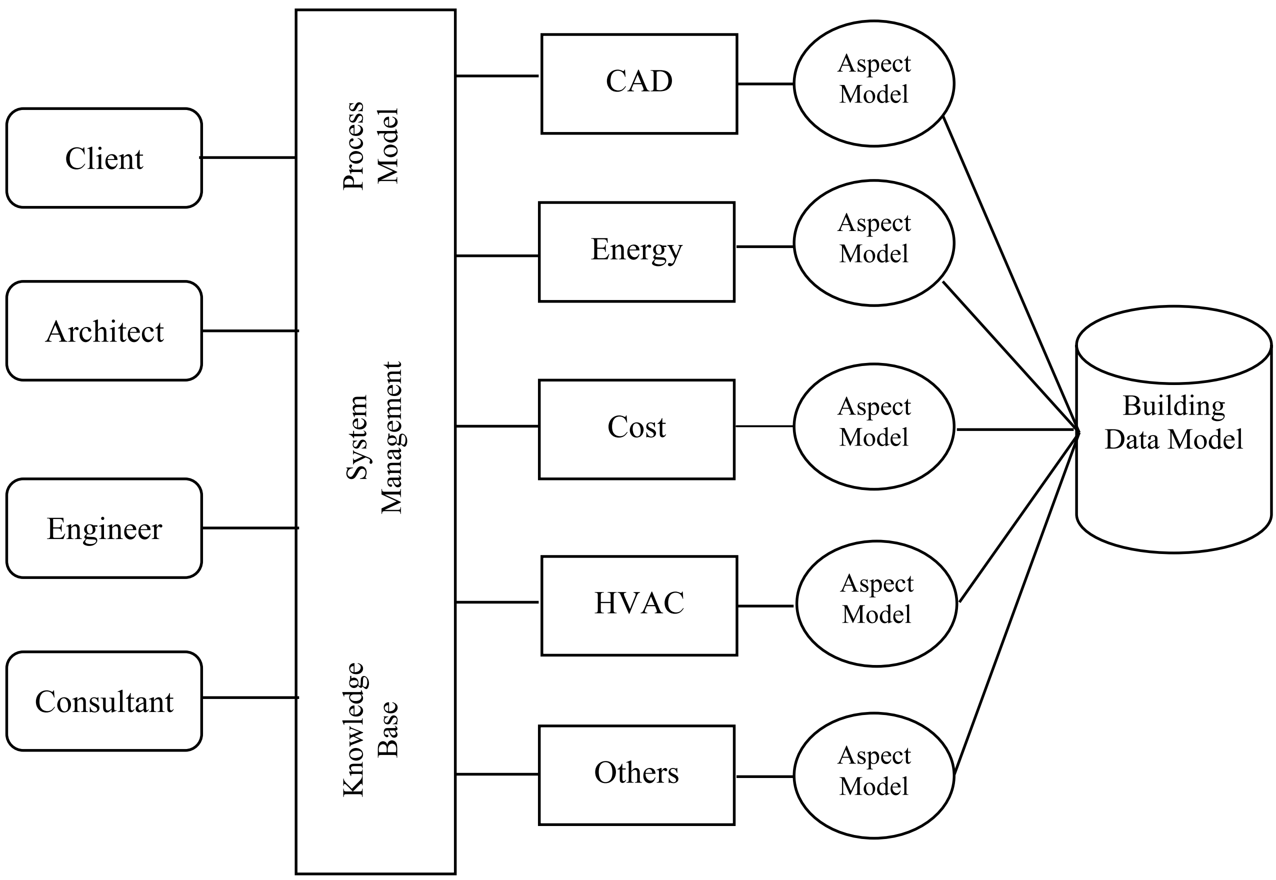


Figure 4-5 Integrated Building Design System

Sun & Lockley, 1999, describes an IBDS will include a number of tools for different design tasks, e.g., CAD drawings, energy auditing, cost calculation, HVAC design, etc. Each of these tools has a particular view of the building represented by their aspect model. All these views are unified into an integrated building data model. The conceptual data models define the data frame of data exchange for real building design projects. In addition, there will be a layer in the system that consists of system management modules, design process model information and knowledge base of climate data, material, product components, regulation, etc (As shown in Figure 4-5). Such an IBDS will enable clients, architects, engineers and consultants to work together as a synchronised team. It will also be able to provide intelligent support during the design decision process. However, this goal can only be achieved progressively. Three stages can be identified on the integration scale until a full integration namely the data exchange, data integration, process integration as shown in the Figure 4-6.

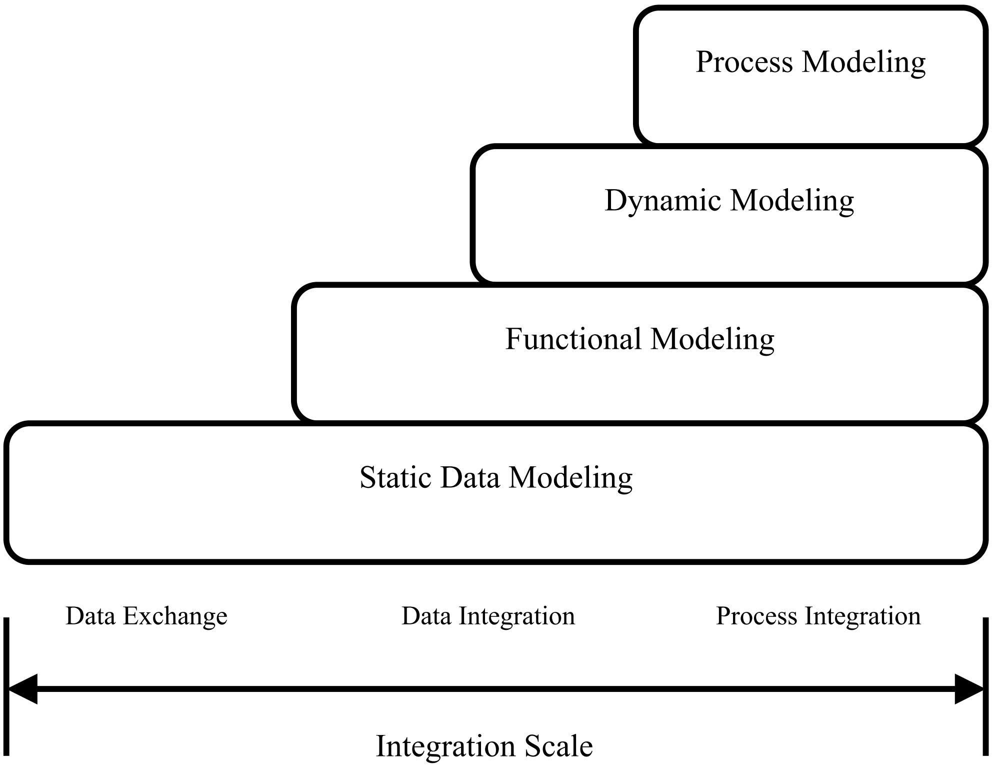


Figure 4-6 Integration and modelling requirements

4.7.1 CIM Project

The computer integrated manufacturing (CIM) models were developed by the CIM steel partners. This work started in the early days of CIM steel with the development of activity models. Using these formal representations to better understand industry requirements, work began on the development of a product model to capture the engineering information needed throughout the life cycle of a steelwork frame. The purpose of a product model is to define how engineering information relating to a product should be structured for data exchange (Weston, 1997). Figure 4-7 uses a different subset to show how information is related throughout the product's life cycle.

The CIS are open specification for implementing the exchange, sharing and management of engineering information relating to steel frames, and are applicable throughout a frame's life cycle.

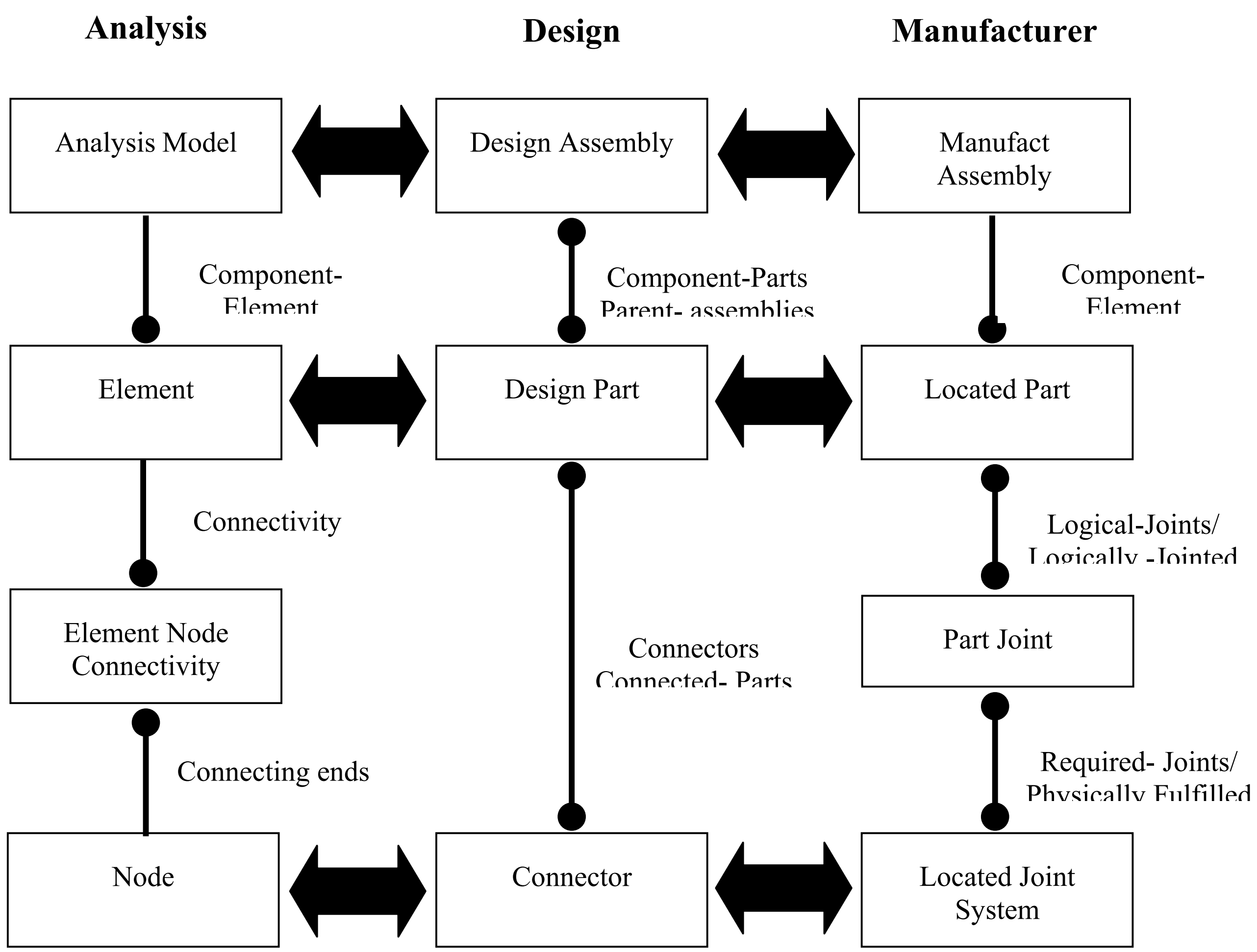


Figure 4-7 Relating information throughout the product life cycle

4.8 Activity /Process Modelling

The activities performed within a construction project can be modelled using techniques such as hierarchy, data flows, and flowcharts (Aouad, 2001). These techniques describe the information flows between processes. This is useful in understanding how information is communicated between processes.

4.8.1 The purpose of Process Modelling

The main purpose with process modelling is to gain knowledge of the existing process and to serve as a model for the future implementation. Some argue that a detailed model of the existing process is unnecessary and may take a long time to do. It should suffice with a simple model of the existing "as-is" process and then a more detailed of the future "to-be" process. However, understanding the current process is important for a number of reasons. (Svensson et al, 1999)

4.8.1.1 Facilitate Common Understanding

The process models are an important learning tool. In order to get valuable input of how the process could be improved, it is important that everybody understands the existing state, especially those who are not used to think of their work in terms of a process.

4.8.1.2 Understanding the Task

For many complex processes it is very difficult to estimate the magnitude of the change and the efforts required to implement the new process without knowledge of the existing state.

4.8.1.3 Avoid Repeating Problems

The recognition of problems in existing processes is important in order to avoid repeating the problems in the new process.

4.8.1.4 Value of Improvement

An understanding of the existing process makes it easier to estimate the value of improving the process. If it is not possible to show the benefits of the change, although the benefits might be obvious to those with good knowledge of the existing process, it might be hard to motive those supporting and participating in the project.

4.9 Summing up

Many people have developed various types of Information Models for construction industry. These models are found very useful for the users. They serve the novice users in an amicable and ample way. These models give a clear picture, for example, as to how the parties interact in a processes and how the activities are taking place in a sequence. These models can be used for various other purposes as well.

5 FUNCTIONAL ANALYSIS OF THE SYSTEM BUILDING SUPPLIERS

5.1 Introduction

This chapter focuses on the functions of the System Building suppliers and the sequence of activities of erecting a System Building form the inception to completion. The functions and activities are modelled using the Information Modelling techniques discussed in the previous chapters such as System analysis software and flowcharting. This chapter further highlights the parties involved in the process and the contractual relationships among them.

5.2 Aims of the Analysis

Main aim of the analysis is to identify the functions of the System Building Suppliers and to develop a model for the identified functions. Another aim of the analysis is to identify the main activities in the process of procuring and erection of building and to develop a model for the sequence of identified activities.

5.3 Method of Analysis

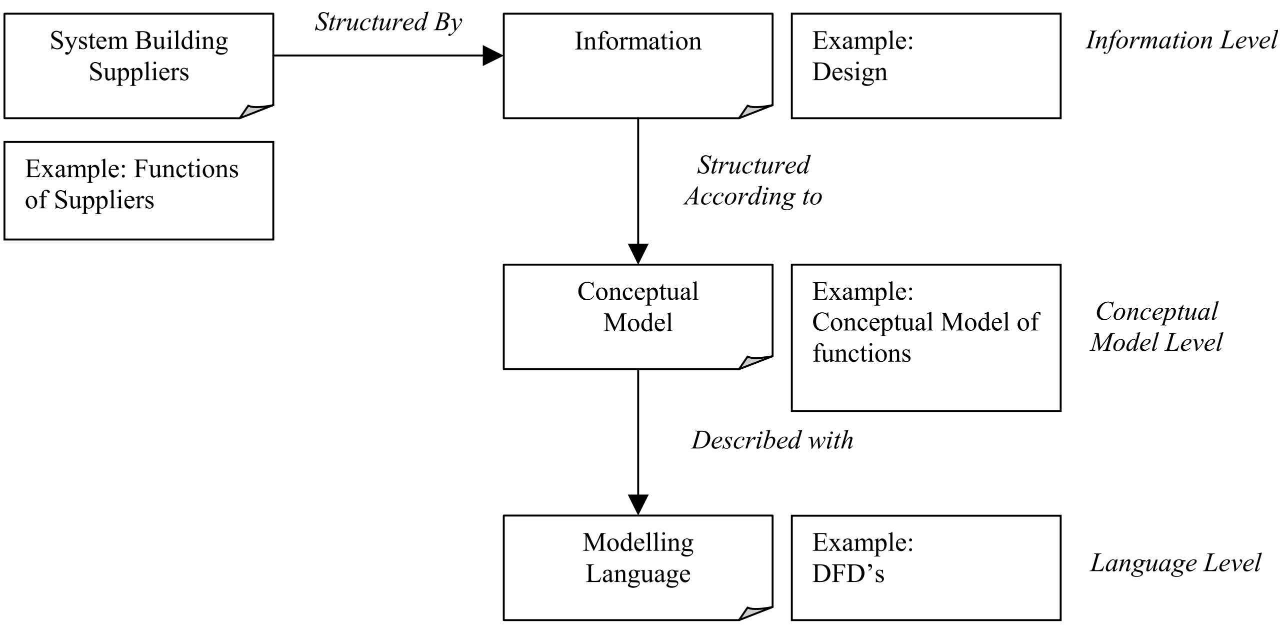


Figure 5-1 Method of analysis

5.4 Approach to Analysis of the Main Functions

The functions of the System Building suppliers have been analysed through interviews and case studies. A recently completed project by a supplier was selected and the functions of that particular supplier towards that project were critically analysed and this has been the main approach to this study. The functions of suppliers were mainly categorised under the following three categories.

1. Procuring the job
2. Design
3. Erection

5.4.1 Procuring the Job

Of the Six suppliers selected, four suppliers, who are all foreign based, responded that they prefer to undertake projects which are approved by the Board of Investments (BOI). Since the BOI approved projects are not taxable projects, nearly 63% of the contract sum[3] otherwise payable as tax on the building components that are imported is now saved. This is a huge relief for the client as far as the cost of the building is concerned and they are willing to accept the proposals that are made by suppliers.

On the request made to the BOI these suppliers get the lists of BOI approved projects in a year and approach the respective clients and make their proposals. On the other hand, some commercial clients who know the capabilities of a particular supplier directly approach the supplier and tell their requirements.

Most of the suppliers have their own certified builders locally. These builders also play a major role in procuring the job for the suppliers.

[3] See appendix C for further clarifications

5.4.2 Design

5.4.2.1 Configuration

All suppliers said that they could configure the building exactly as the clients require it. However, whether the client could afford for the project would be a big question when he wants to configure the building as such. Because designs fall under the categories, which are set out by the suppliers, are said to be cost efficient building or most economical buildings.

5.4.2.2 Technology Used in the Design

The interviewers said that the skilled structural engineers familiar with the state of the art technology are part of their design team. They further elaborated that they use the very latest in computerised engineering design and drafting systems, permitting the selection of the most economical and efficient framing system as well as accurate design and drawings. Other skilled technicians also use computerised systems to estimation, inventory control, job tracking, scheduling and accounting applications. Courtesy of the computer, quotations are provided in just a few days for even the more complex projects.

5.4.2.3 Standards

According to the interviewers, the American standards are being used in designing the buildings. The reason for this is because the British standards are very expensive when compare to the American standards. However, if the client prefers British or any other standards, they said, they could adopt that for the design purposes.

5.4.3 Erection

Most of the suppliers have their own certified builders and they work in collaboration with them. These highly trained builders work closely with supplier to offer the client efficient and economical construction services. Many are capable of offering complete turnkey construction services.

Erection process can be categorises as follows.

5.4.3.1 Substructure

The builder holds the responsibility of designing the foundation. The information needed to design the foundation such as the fraction forces, total load of the structure to be transferred on to the foundation, are given by the supplier when structural designs are completed. The builder is further expected to do so many other works in relation to this task such ass site clearance, the soil test etc.

5.4.3.2 Superstructure

The details of how the building should be erected are given in a step by step instruction in drawings. The building components are marked as to how and where it should placed. The suppliers' representative will assist the builder whenever necessity arises during the erection process. Further more, the suppliers said that they would provide full assistance from earliest consultations through engineering development and finally during erection.

5.4.3.3 Finishes and other works

Interviewers responded that they could supply the whole building furnished by the finishes and sanitary appliances that are manufactured by their group of companies. However clients do not prefer to go for this option since there is a lot of cost involvement and they prefer or are compelled to use locally available products.

5.5 Functions of the Suppliers

System Building Suppliers often interact with the environment to perform their various activities. The important parties with whom they interact are the clients, erector, contractor, sub contractors, client's professional advisors etc., as shown in the Figure 5-2. The main functions of these suppliers are to Design and construction of the building. Since most of the building projects of this type fall in the category of turnkey projects, the suppliers are capable to meet the demand of doing so by undertaking the task of both designing and construction. The information flows of these main functions are shown in Figure 5-3. While the designing part is divided in to two main sub tasks viz. the architectural and the structural designing, the construction part is analysed as the functions of the domestic and nominated sub contractors. Once the client agreed on the architectural design prepared by the either the Supplier or by any other party, the structural design of the building begins.

In the context of the Sri Lanka System Building construction, most of the buildings are erected by the certified erector or by other contractors. In many cases the civil, services and electrical works are done by sub contractors. The sub contractors are either nominated by the client or selected through the competitive bidding process. Further diagrams to illustrate the whole process are attached in the appendix.

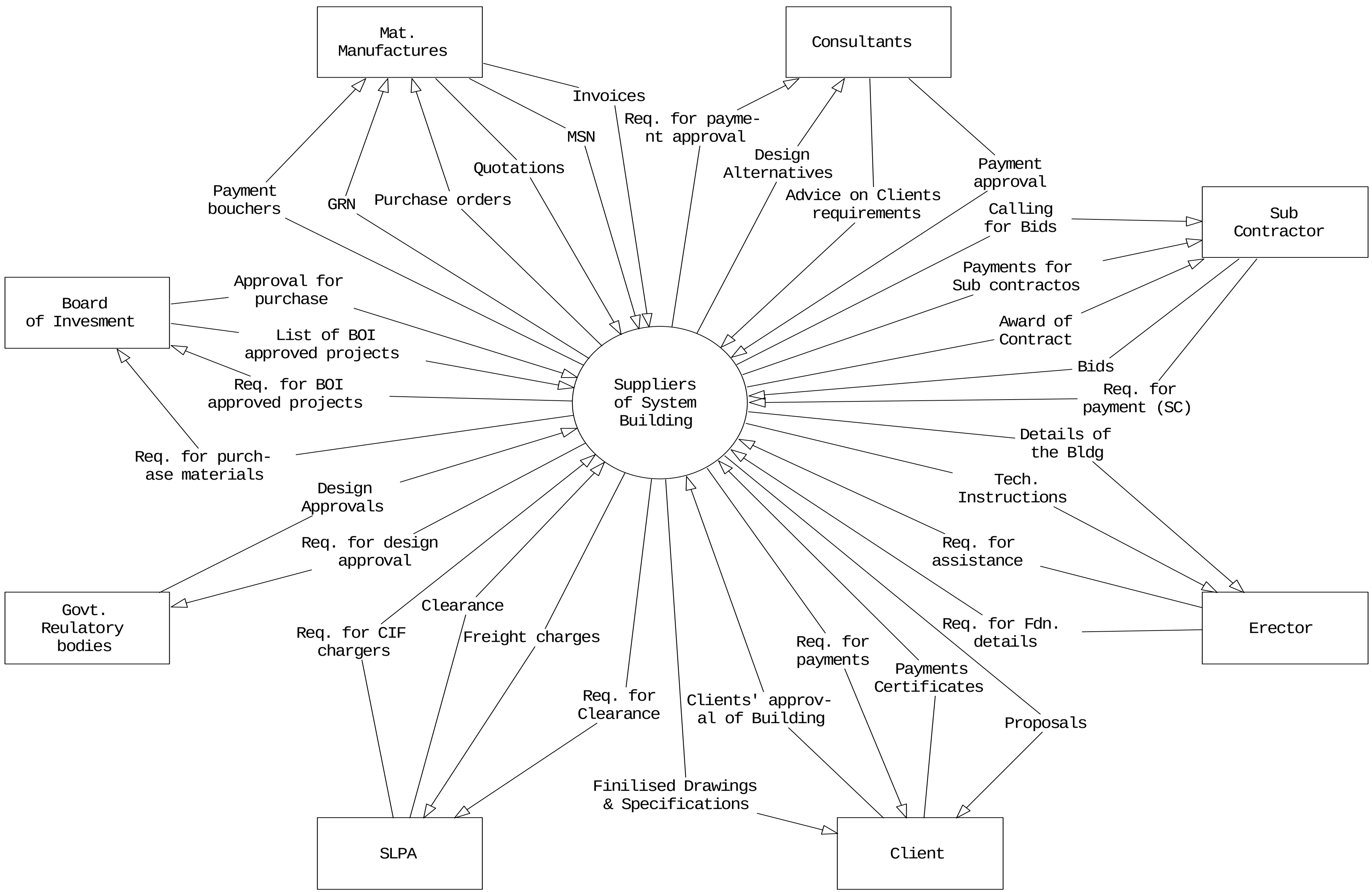


Figure 5-2 Functional Analysis of the Suppliers

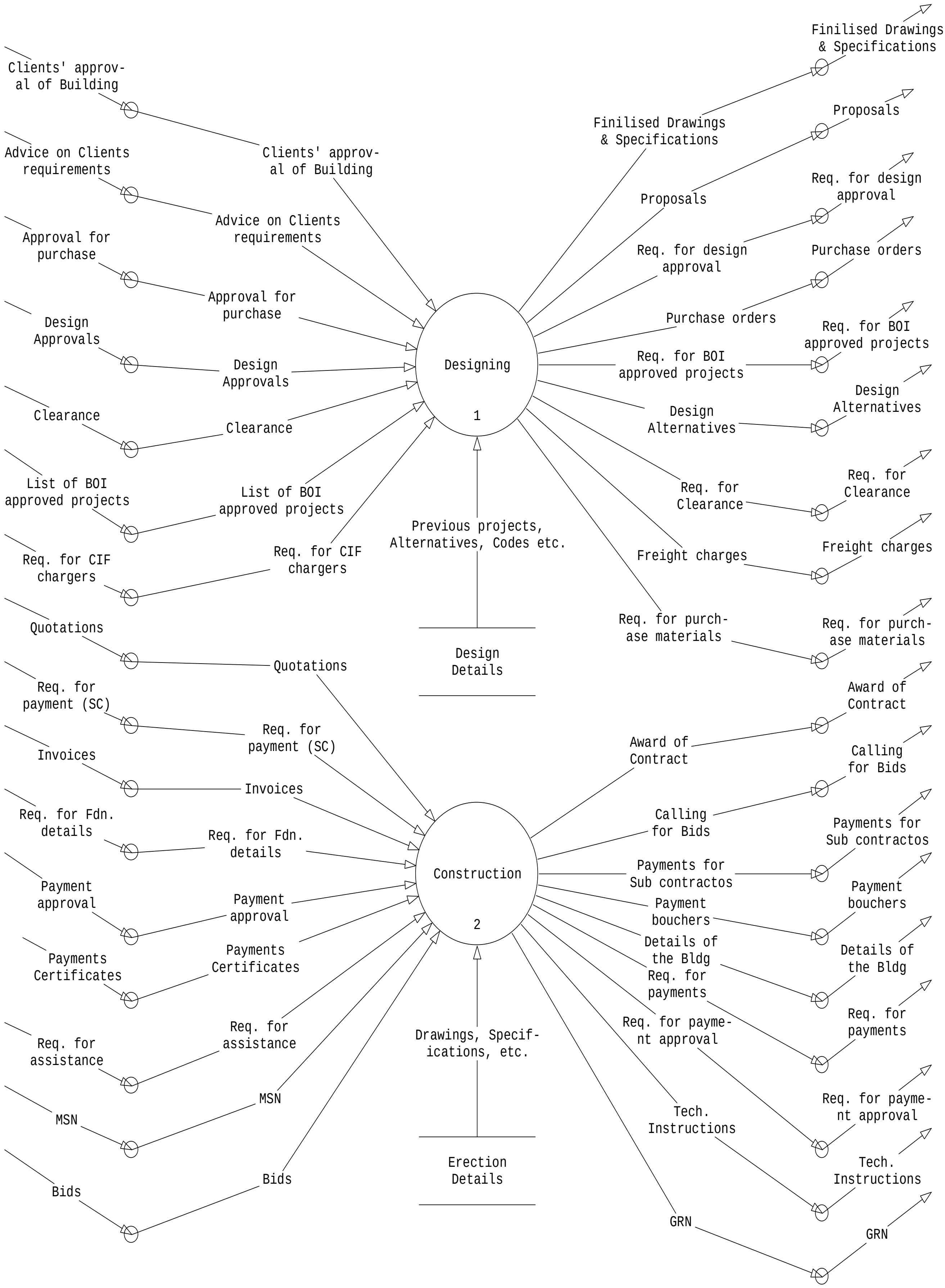


Figure 5-3 the main functions of the System Builders

5.6 Process Analysis

The main identified processes of the System Building construction are modelled using flowcharting technique. This model describes the whole processes since procuring the job until handing over the project in logical order. Figure 5-4, Figure 5-5, Figure 5-6 show the sequence of activities during the whole process of System Building construction.

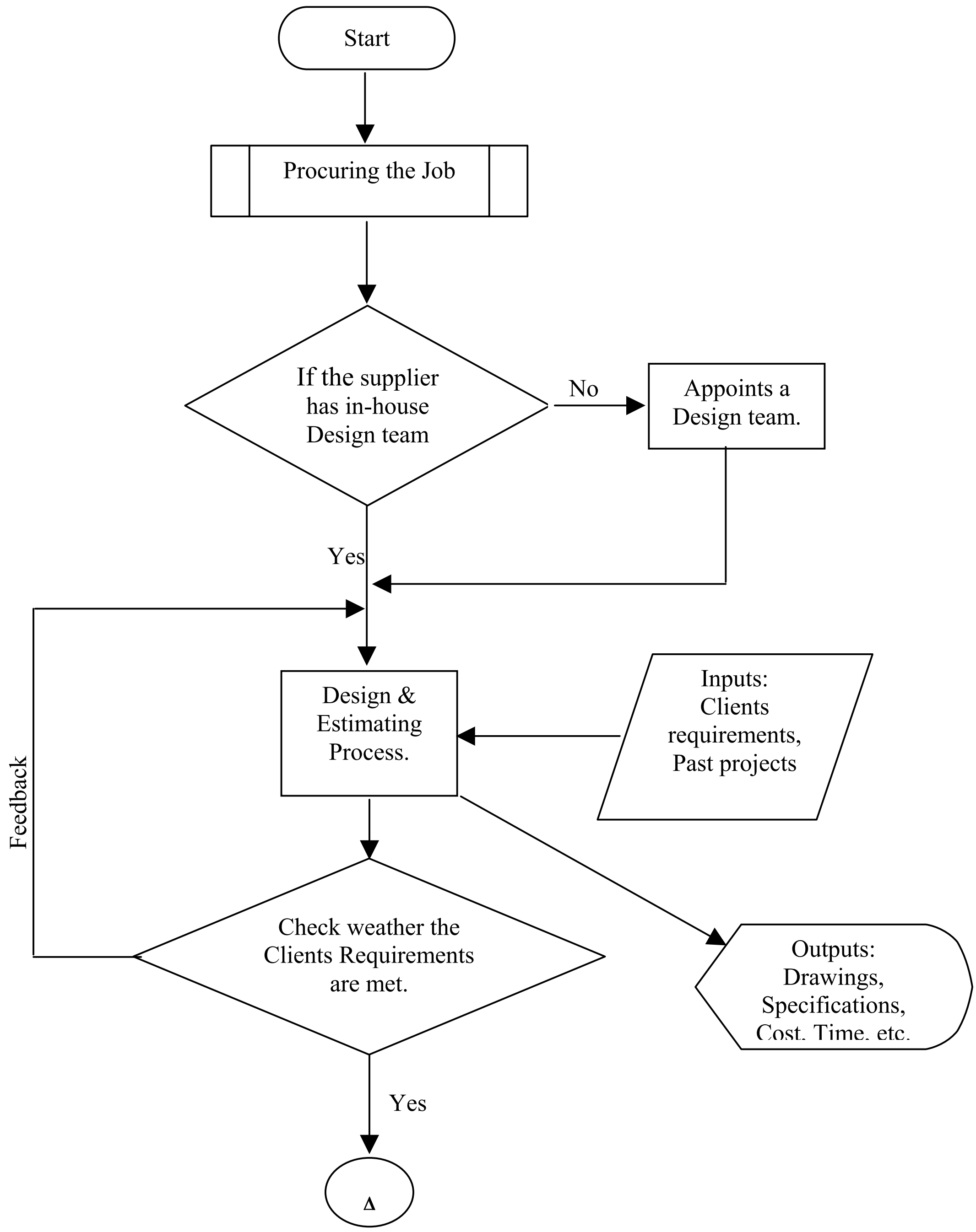


Figure 5-4 Process Analysis

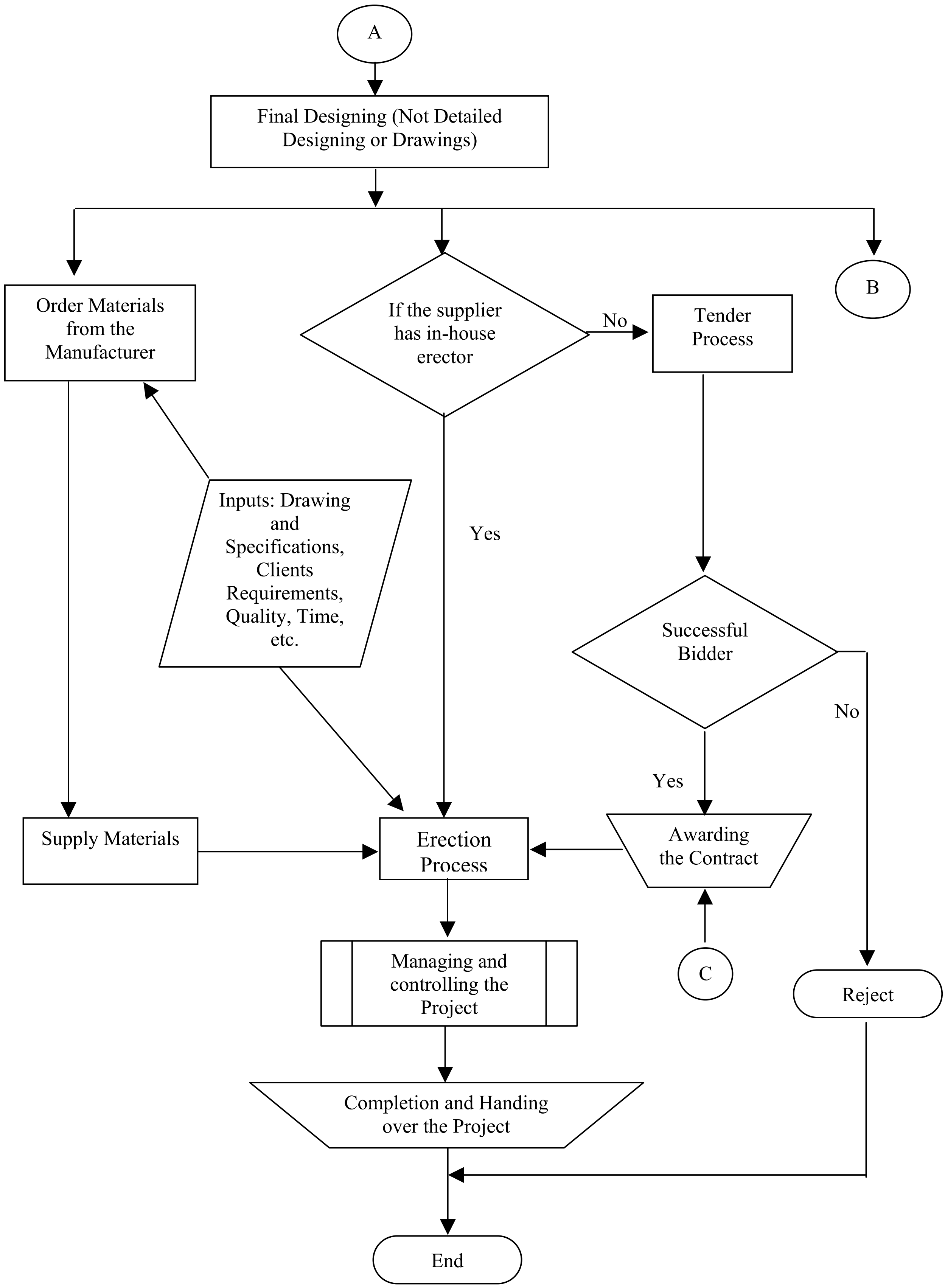


Figure 5-5 Process Analysis (Cont....)

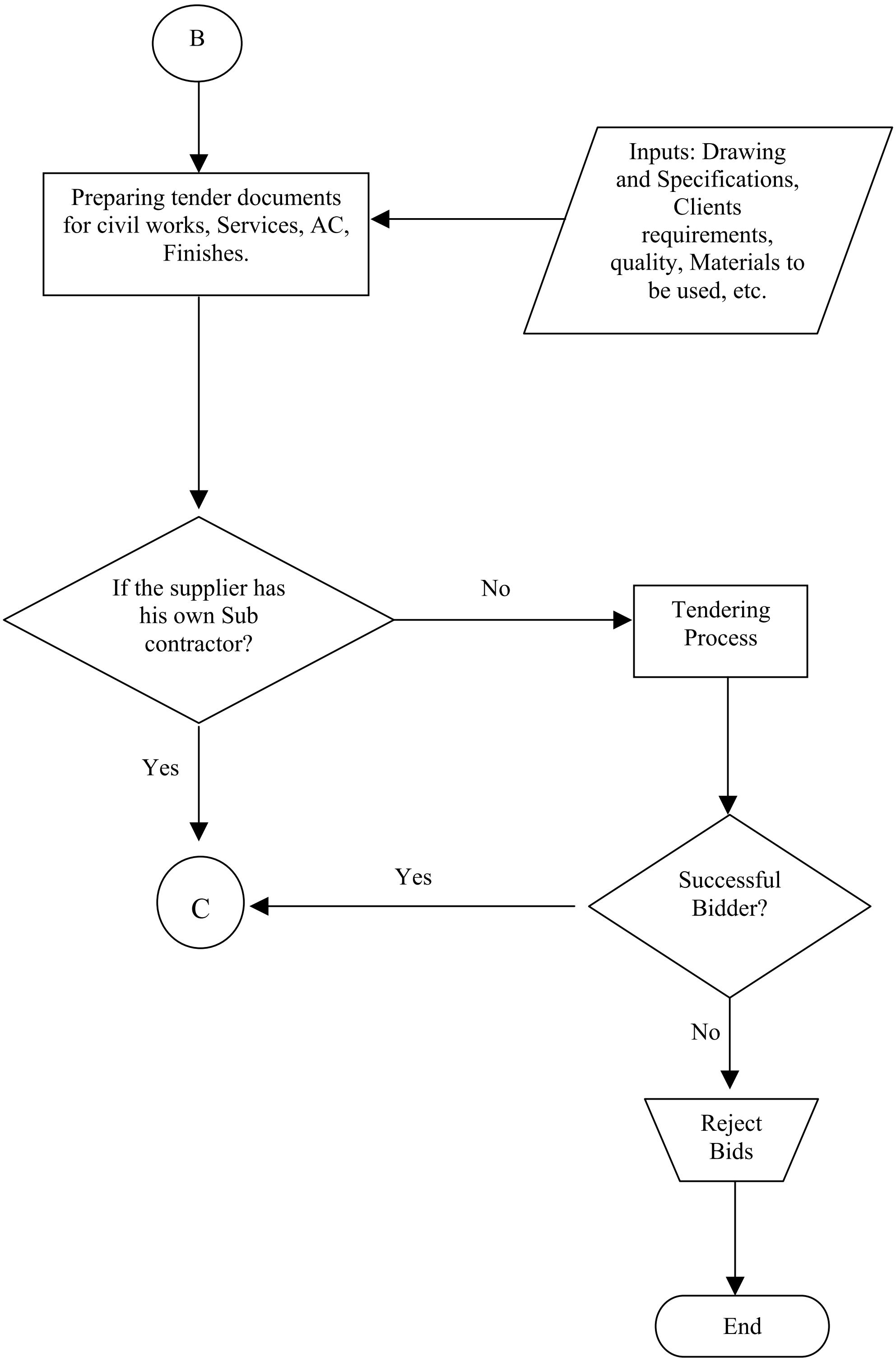
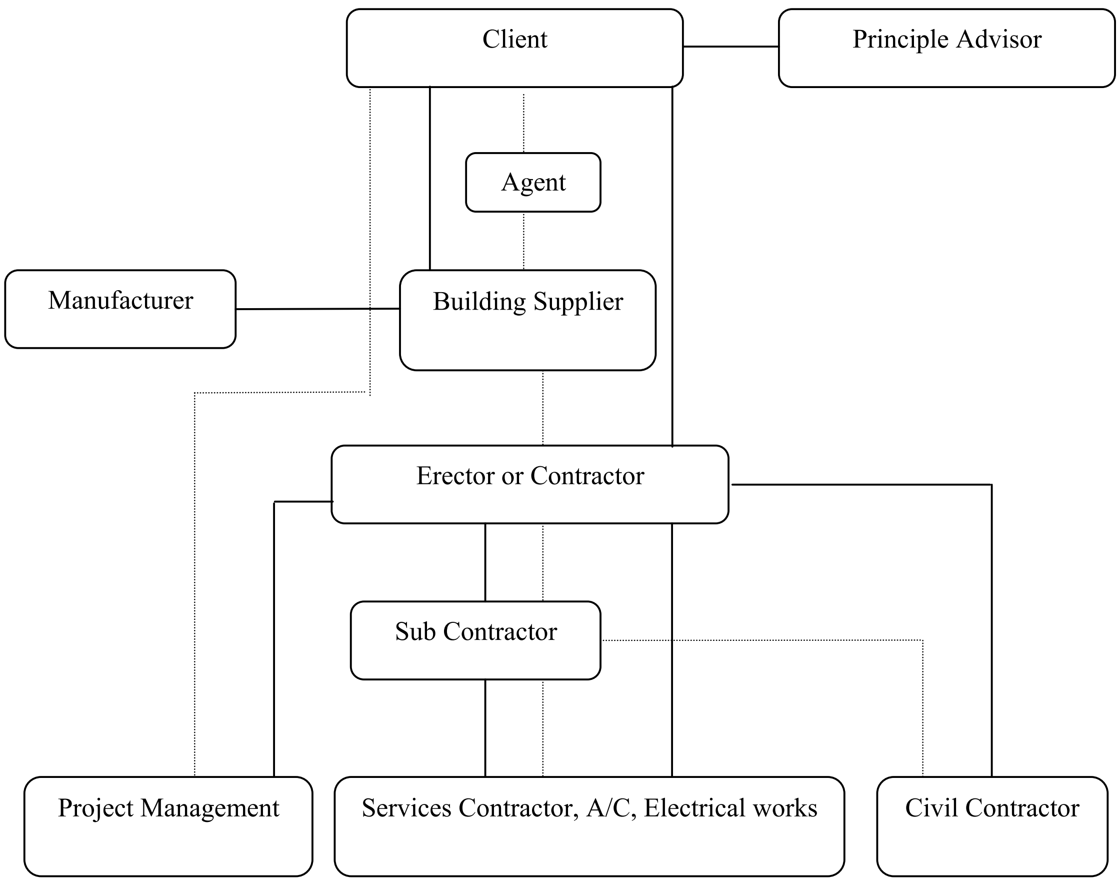


Figure 5-6 Process Analysis (Cont........)

5.7 Contractual Relationships

The client enters into the contract with builder and not with the supplier. A surety or Bank guarantees the payment to be made to the supplier by the client. Sub contractors and nominated subcontractors, if involved, either enter into a contract with the builder or with the client as client's wish. The supplier's involvement during the erection process continues in the form of technical assistance, project management etc., until the project is completed and handed over to the client. There are no contractual relations or whatsoever between the supplier and the erector or with sub contractor. But all the parties involved in this process unanimously agree to extend their fullest support to achieve the common interest of the successful project completion. Figure 5-7 shows the contractual relationships between the parties involved in the process.



Contractual Relations

Alternative Relationships

Figure 5-7 Contractual Relationships

5.8 Summing up

A comprehensive study of the functions of the System Building suppliers was carried out in this part of the dissertation. The external entities of suppliers and the interaction with the same also identified. The parities involved in the process and their contractual relationships are another significant finding of this chapter.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Information Modelling is a technique being used to represent a thing. This technique can be used to model, for example, the construction process information, product information and functional information etc.

The Construction Industry, obviously, would be benefited more than many other industries by incorporating the practices of Information Modelling. Specially, the functions and processes, if modelled, would lead to reap many advantages. For instance, Modelling the functions will lead to the automation of the system that will eventually lead to the Business Process Reengineering (BPR) while the process modelling would enable the forecasting of future activities and to make necessary preparations before hand such as resources allocation. Construction companies have during the past decades focussed more and more on their business in the belief that improved processes will lead to lower costs, decreased lead times and increased product quality. Information technology would be an enabler for business reengineering, offering opportunities such as process automation, improved information capture and data distribution.

The study identifies the current stages of the Information Modelling practices in the Construction Industry. It has to be said that the industry has to go for a long way to achieve the fruitful results of the practice. However, fruitful practical results have failed to emerge so far in the practice of Information Modelling because of the complex structure of the industry and because Information Technology has not been exploited properly. The Information Technology and the techniques of Information Modelling have to be fully exploited for the betterment of the industry.

In the Sri Lankan context, the System Building Industry, as a sub set of the Construction Industry can first practice the techniques of Information Modelling. The lesser complexity of the sub system when compared to the construction industry at large, makes it easy for it to adopt first. The greater similarity of the functions, activities etc., will lead to the easier adaptation of the practice by the whole construction industry.

6.2 Recommendations

The study includes all leading System Building suppliers operating in Sri Lanka. Interviews with top level management of each and every organisation has led to the gathering of reliable information. Hence, the reliable information derived from the whole sector of the industry paved the way for the development of realistic Information Models.

The functions of the suppliers were critically analysed. The Information Models so developed were based on the outcomes of the interviews and the findings of the functions of all these System Building suppliers. Therefore, it could be said that these models would be more reliable since they describe the behaviour of the modelled world domain. It is applicable widely across the sector of the industry.

The functions of the suppliers towards a particular project were analysed through case studies. Initial study was intended to develop a model based on the outcomes of the analysis of the selected few suppliers. Later the developed model was cross-checked with the rest of the suppliers. After being checked, the model is be made available for the users. It has to be accepted that this process of developing the model further strengthens the reliability of the model.

6.3 Limitations

In order to minimise the complexity of the model, certain information flows have been compiled and some are omitted. System Analysis is a study that analyses the system thoroughly, should be able to provide sufficient information, for example, for automation of a system, which requires all information of that system. Insufficiency of the information provided would lead to the implementation of an improper system.

6.4 Further Research

The developed functional model clearly depicts how the system of System Building suppliers interacts with the outside entities. Often system analysis paves the way forward in automation of functions of that system. The model clearly shows the information inflows and outflows of the system with that of the stakeholders. In this context, further research may be carried out as to how the functions of the System Building suppliers could be automated and the advantages and disadvantages of the automation over the existing practice.

The process model shows the sequence of activities performed during the pre and post construction period. If a cost data could be linked to these processes, one can find out the cost of the building. Therefore, as an expansion of this research, a software or a Process Based Cost Model (PBCM) can be developed that estimates or forecasts the cost of a particular building.

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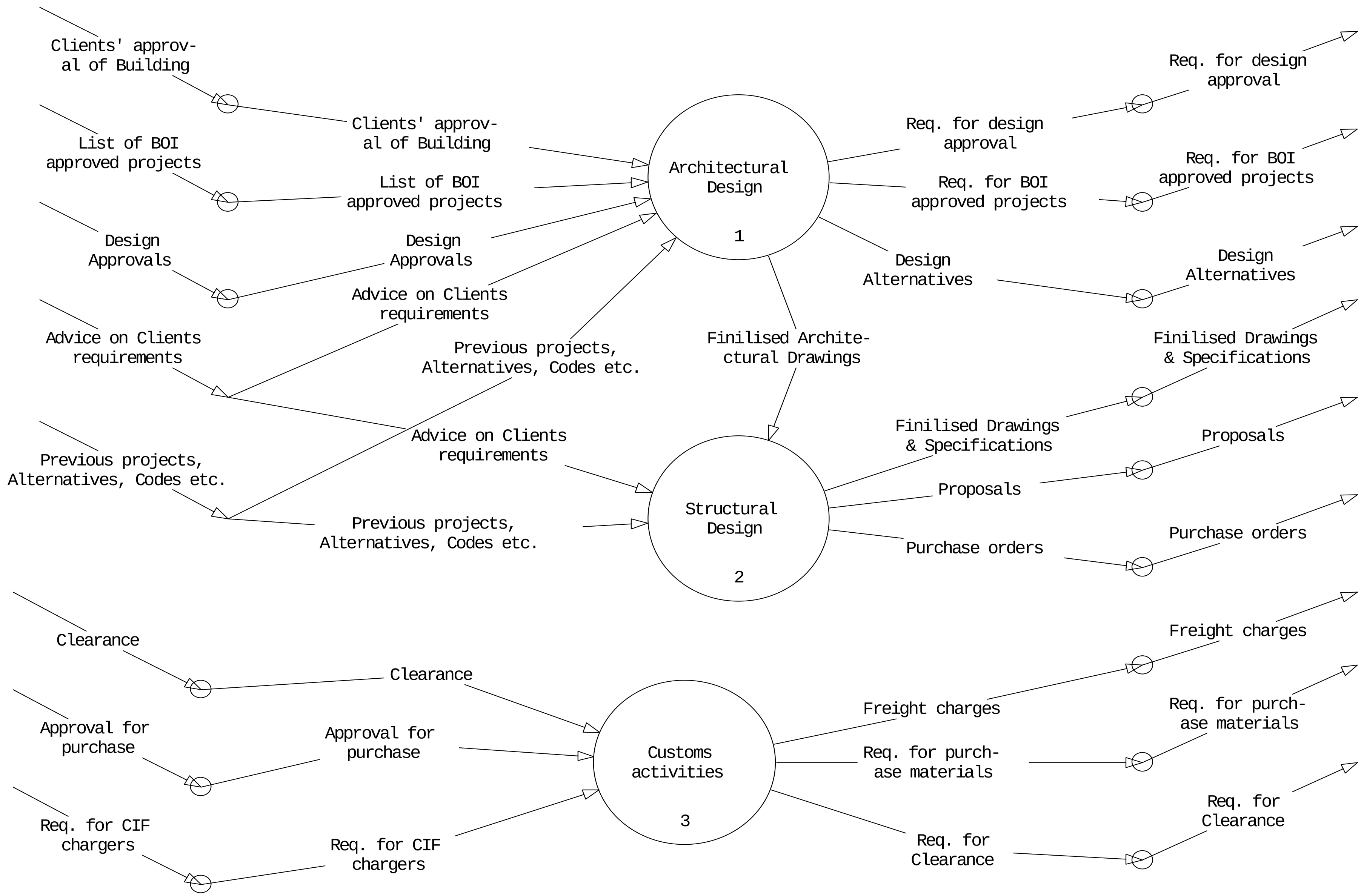
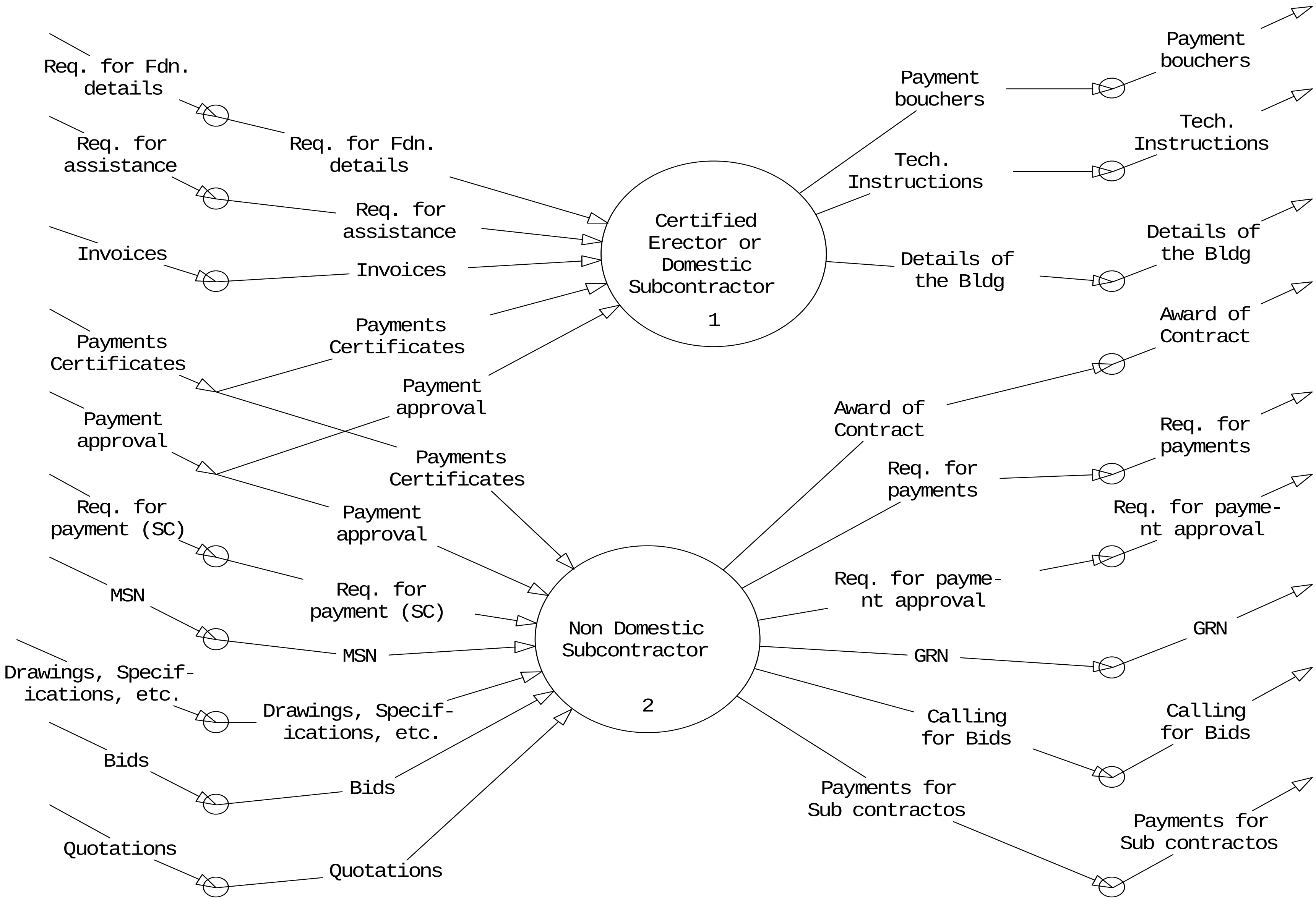
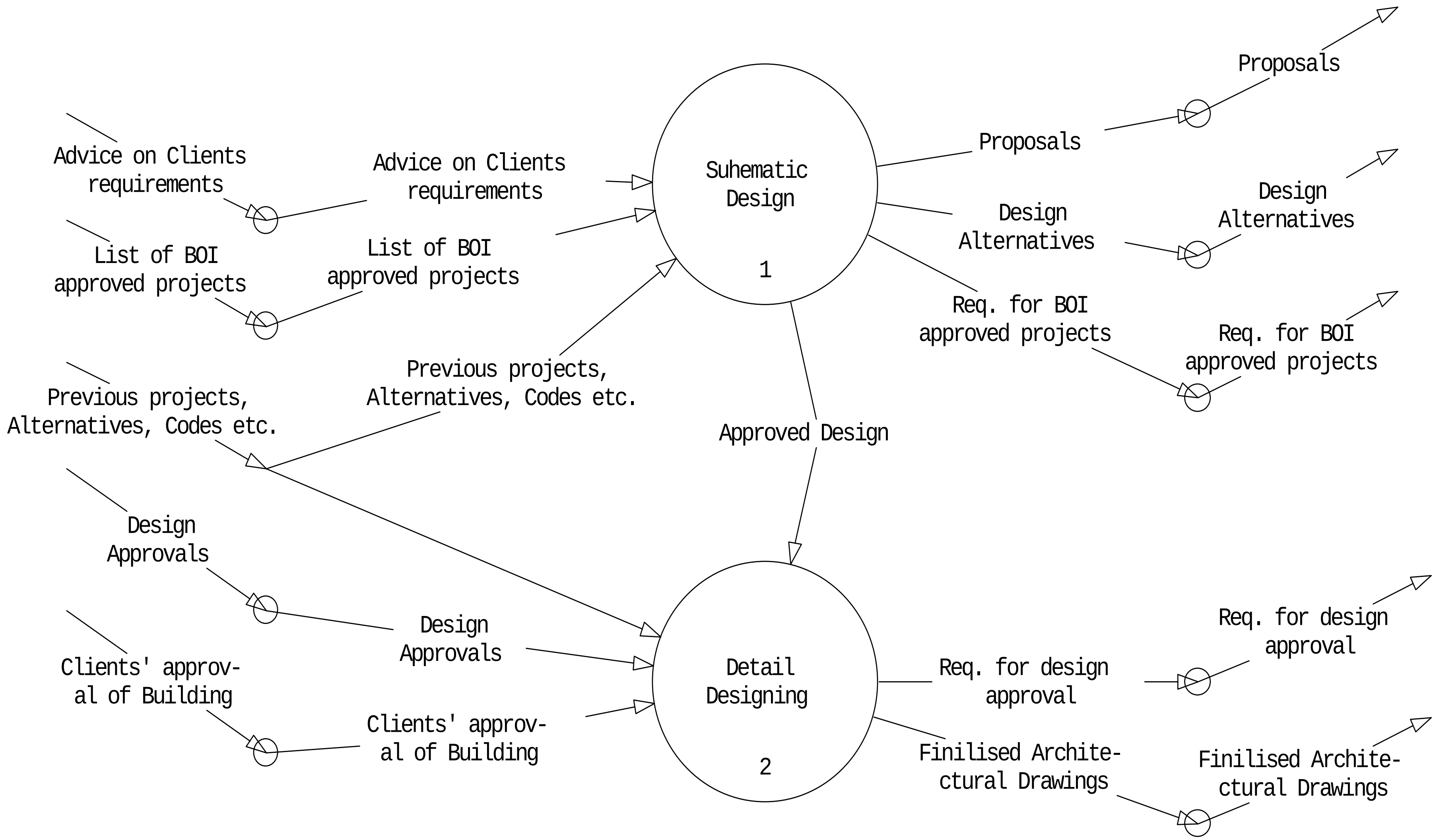
9. Steel Buildings, Americam Society of Civil Engineering (http://www.pubs.asce.org/BOOKbrowsesu.cgi?420)



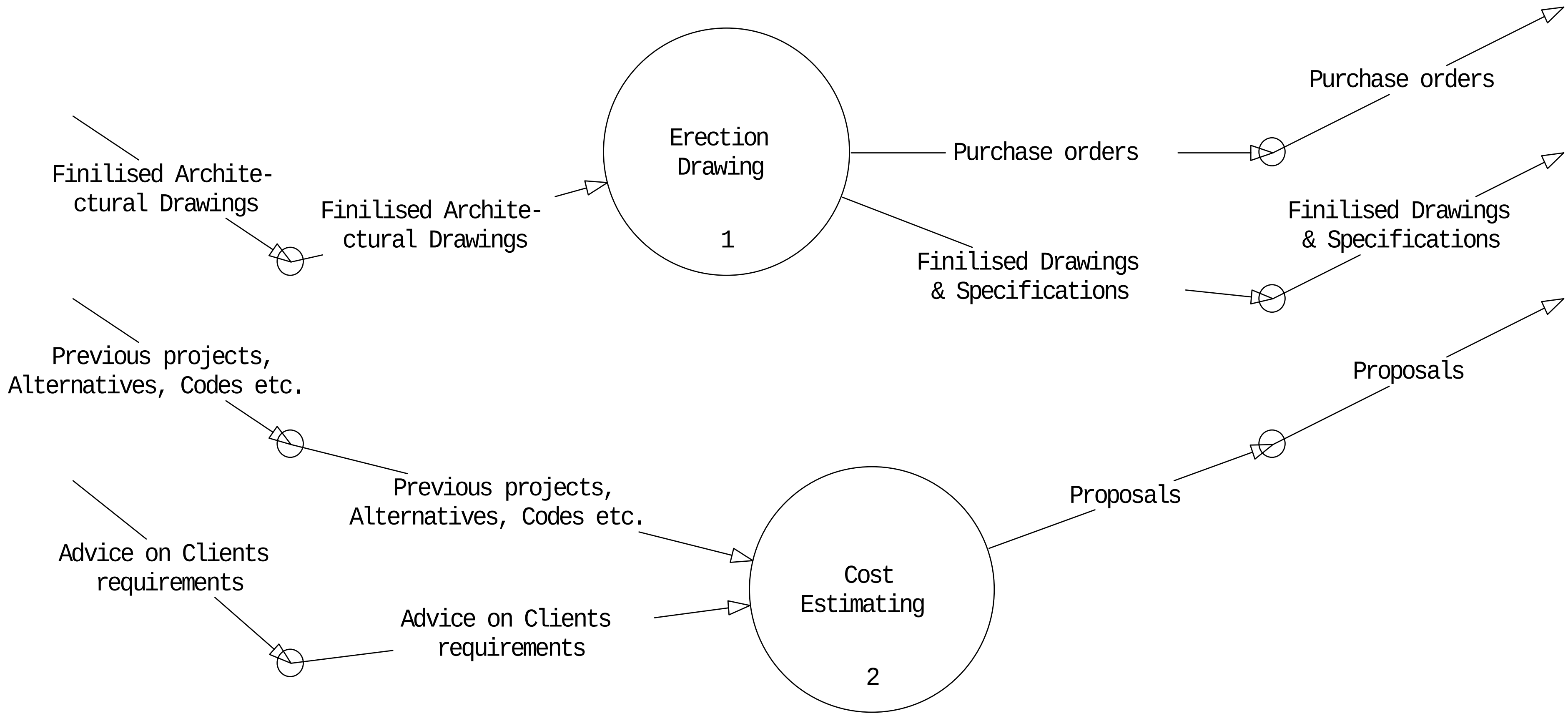
1.0 Designing [Dataflow.DFD]



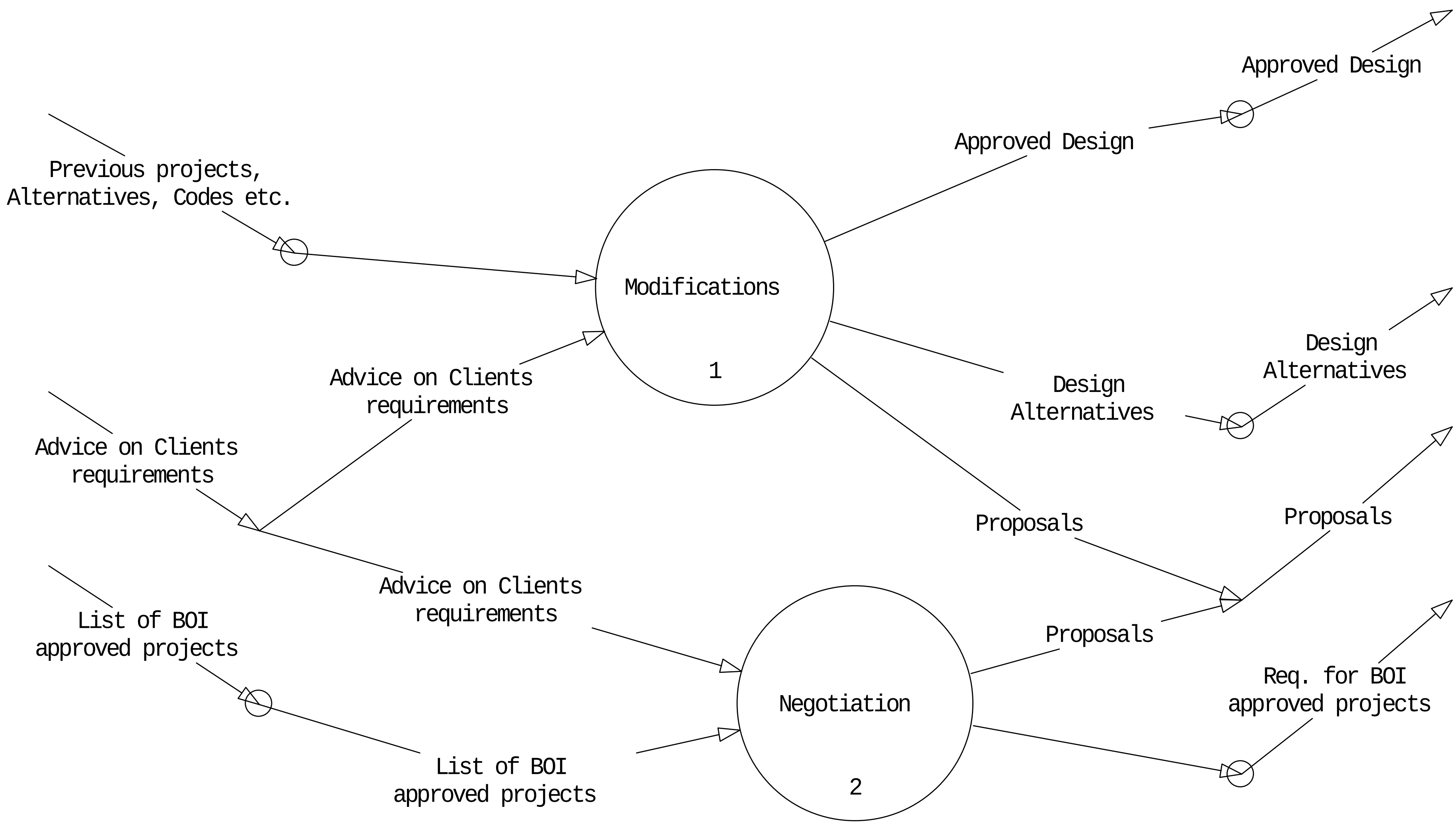
2.0 Construction [Dataflow.DFD]



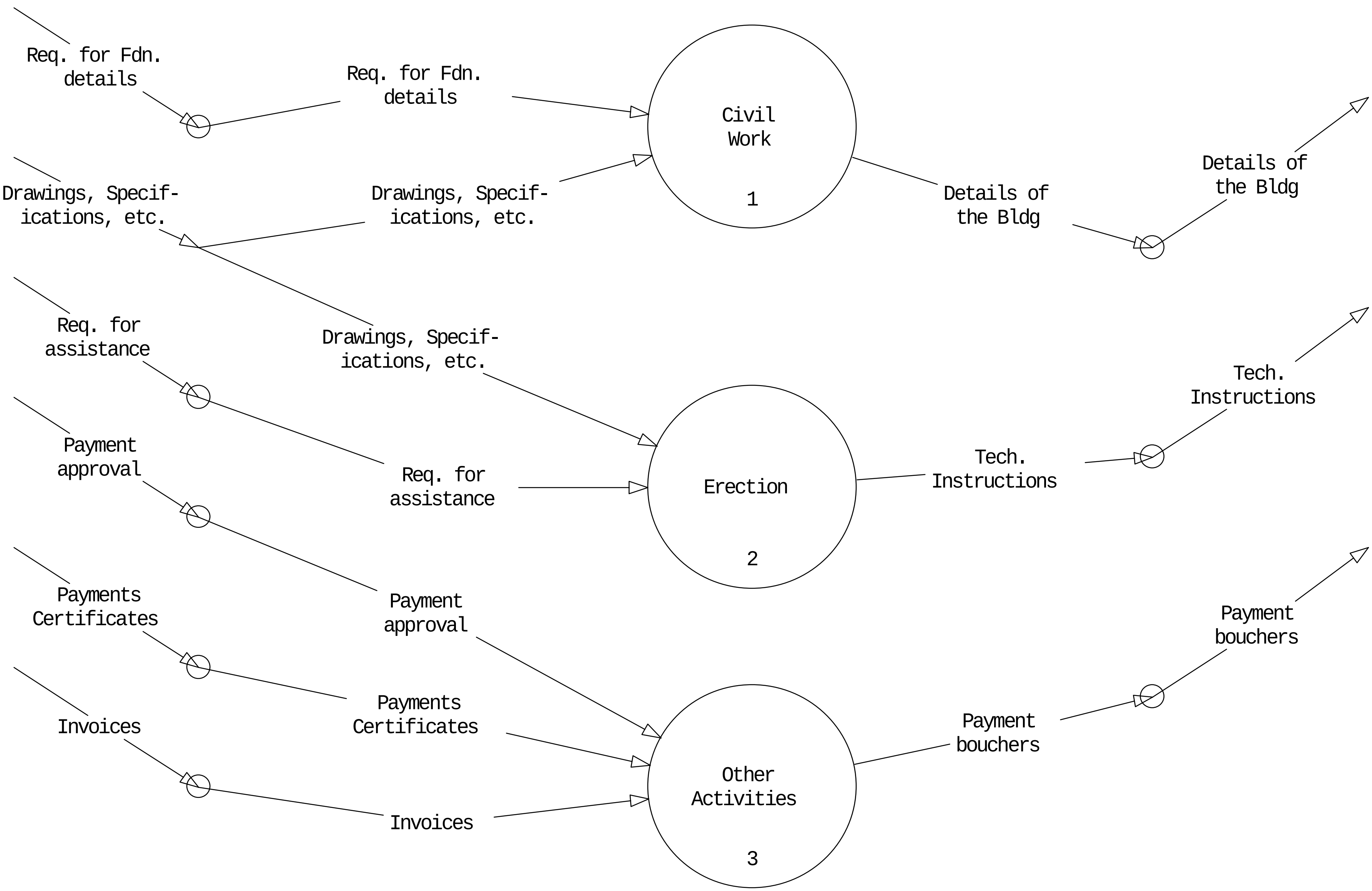
1.1 Architectural Design [Dataflow. DFD]



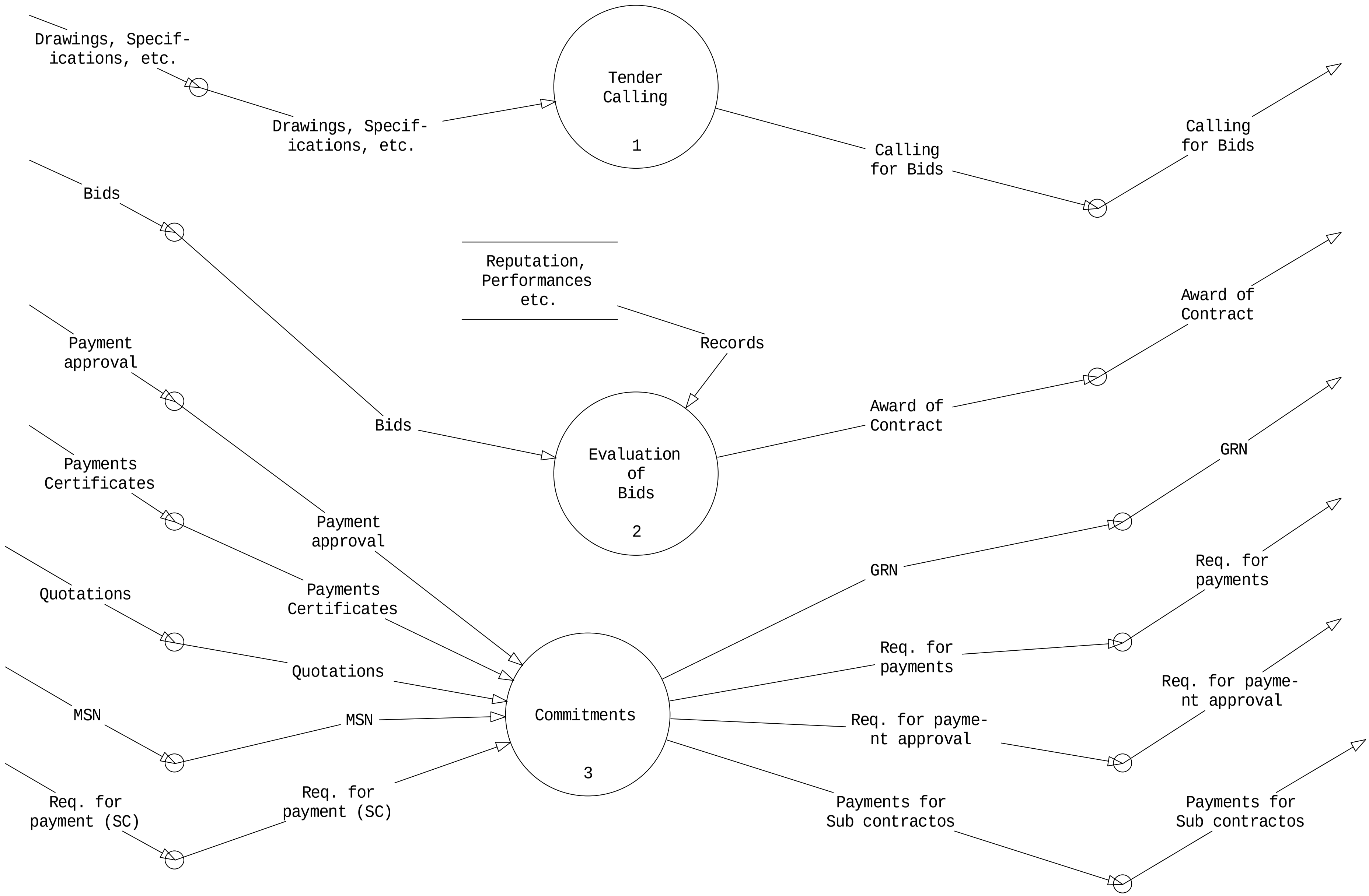
1.2 Structural Design [Dataflow.DFD]



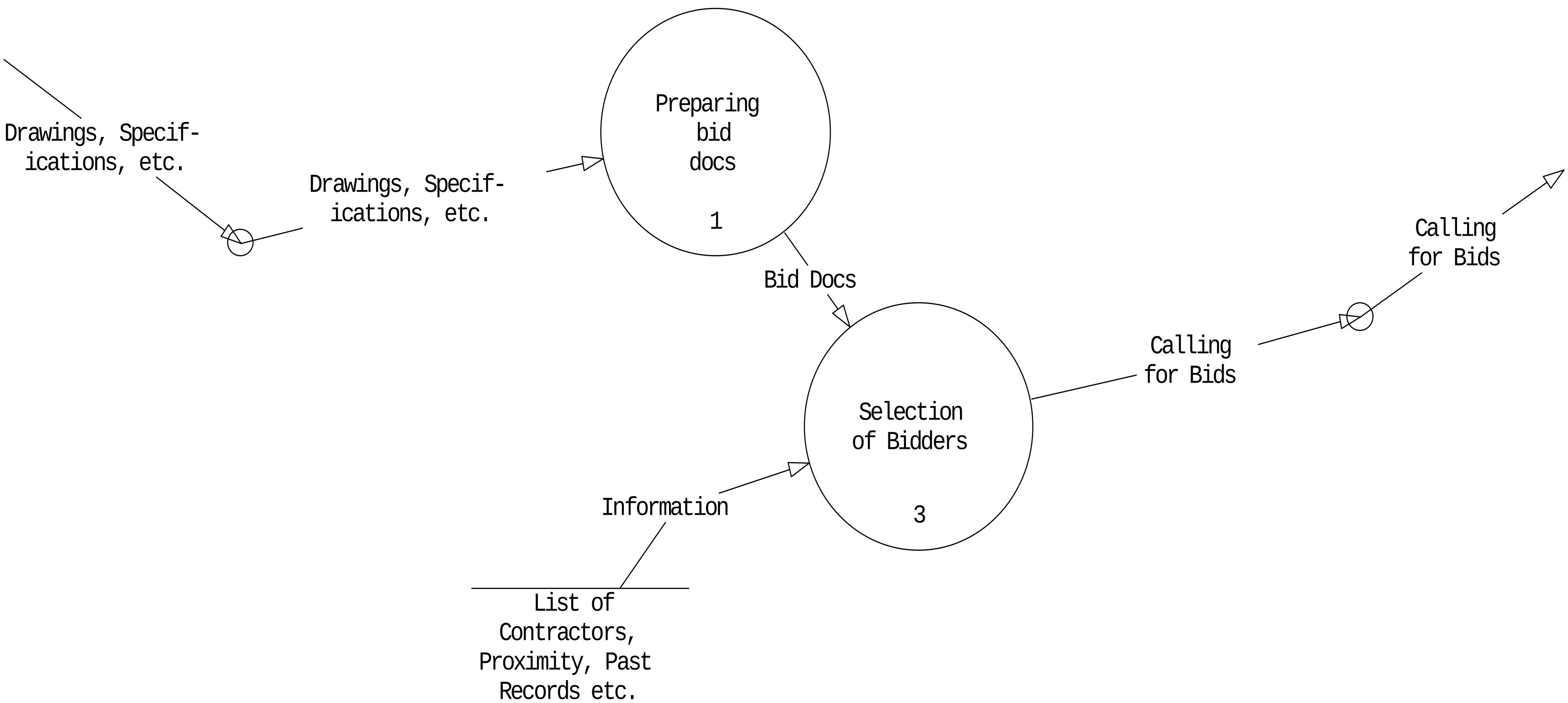
1.1.1 Schematic designing [Dataflow.DFD]



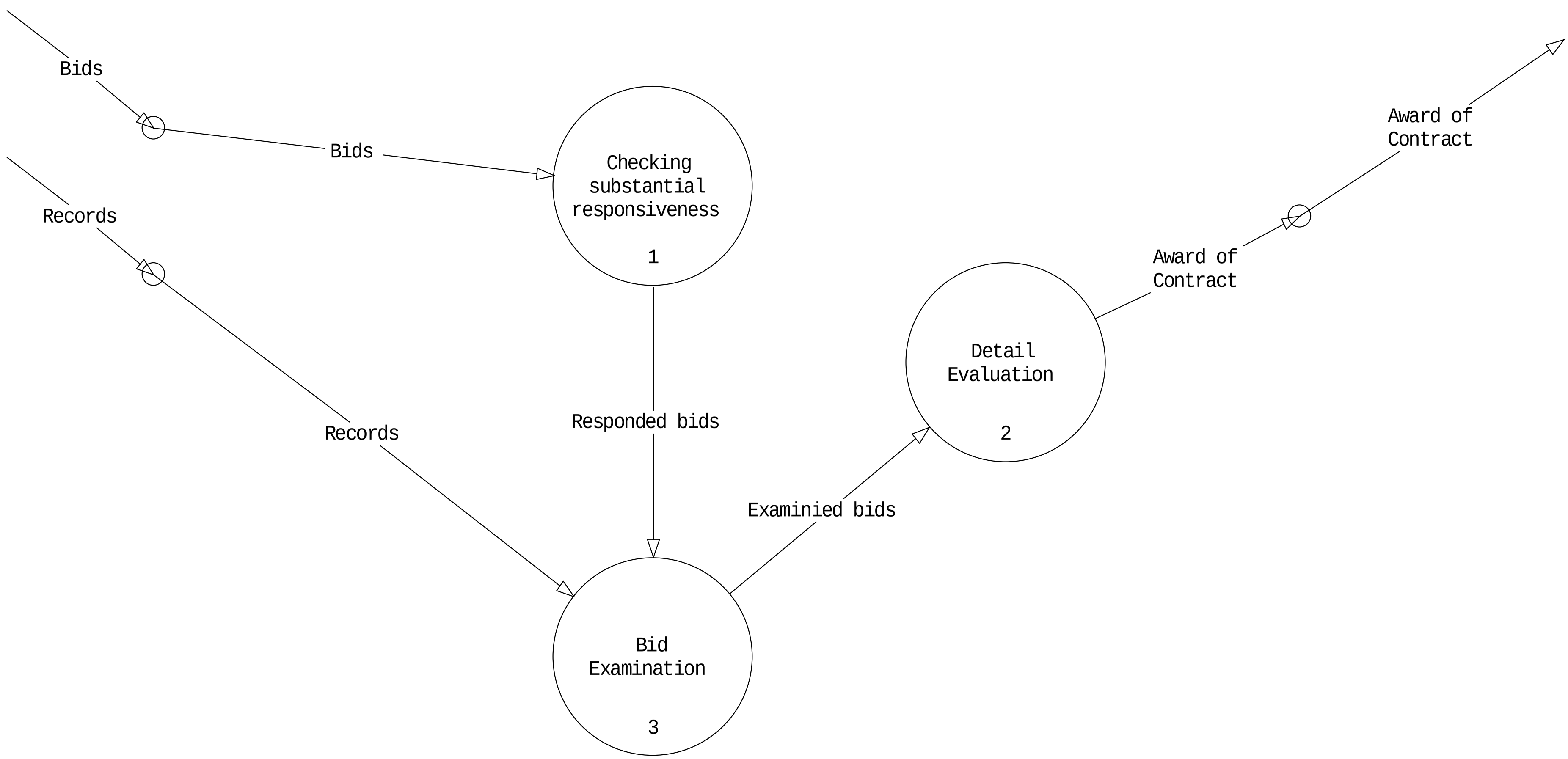
2.1 Certified Erector or Domestic Sub Contractor [Dataflow.DFD]



2.2 Non Domestic Sub Contractor [Dataflow.DFD]



2.2.1 Tender Calling [Dataflow.DFD]



2.2.2 Evaluation of Bids [Dataflow.DFD]

Project: C:\DISSER\
Title: Sys. Building Suppliers
Date: 21-Nov-101 Time: 10:51

Report: Object Interface

This report identifies the interface,(inputs/outputs), for data dictionary objects.
The format of the report is:
NAME, [TYPE]:
Inputs
NAME, [TYPE]
Outputs
NAME, [TYPE]

Architectural Design, [Process]:
Inputs
Advice on Clients requirements, [Discrete flow]
Design Approvals, [Discrete flow]
List of BOI approved projects, [Discrete flow]
Previous projects, Alternatives, Codes etc., [Discrete flow]
Clients' approval of Building, [Discrete flow]
Outputs
Req. for design approval, [Discrete flow]
Design Alternatives, [Discrete flow]
Req. for BOI approved projects, [Discrete flow]
Finalised Architectural Drawings, [Discrete flow]

Board of Investment, [Terminator]:
Inputs
Req. for BOI approved projects, [Discrete flow]
Req. for purchase materials, [Discrete flow]
Outputs
List of BOI approved projects, [Discrete flow]
Approval for purchase, [Discrete flow]

Civil Work, [Process]:
Inputs
Req. for Fdn. details, [Discrete flow]
Drawings, Specifications, etc., [Discrete flow]
Outputs
Details of the Bldg, [Discrete flow]

Client, [Terminator]:
Inputs
Proposals, [Discrete flow]
Req. for payments, [Discrete flow]
Finalised Drawings & Specifications, [Discrete flow]
Outputs
Payments Certificates, [Discrete flow]
Clients' approval of Building, [Discrete flow]

Commitments, [Process]:
Inputs
Req. for payment (SC), [Discrete flow]
Payment approval, [Discrete flow]
Payments Certificates, [Discrete flow]
Quotations, [Discrete flow]
MSN, [Discrete flow]
Outputs
Req. for payment approval, [Discrete flow]
Req. for payments, [Discrete flow]
Payments for Sub contractors, [Discrete flow]
GRN, [Discrete flow]

Construction, [Process]:
Inputs
Req. for assistance, [Discrete flow]
Req. for payment (SC), [Discrete flow]
Payment approval, [Discrete flow]
Payments Certificates, [Discrete flow]
Invoices, [Discrete flow]
Req. for Fdn. details, [Discrete flow]
MSN, [Discrete flow]
Drawings, Specifications, etc., [Discrete flow]
Bids, [Discrete flow]
Quotations, [Discrete flow]
Outputs
Tech. Instructions, [Discrete flow]
Payments for Sub contractors, [Discrete flow]
Details of the Bldg, [Discrete flow]
Payment Boucher, [Discrete flow]
Req. for payments, [Discrete flow]
Req. for payment approval, [Discrete flow]
GRN, [Discrete flow]
Calling for Bids, [Discrete flow]
Award of Contract, [Discrete flow]

Consultants, [Terminator]:
Inputs
Design Alternatives, [Discrete flow]
Req. for payment approval, [Discrete flow]
Outputs
Advice on Clients requirements, [Discrete flow]
Payment approval, [Discrete flow]

Cost Estimation, [Process]:
Inputs
Previous projects, Alternatives, Codes etc., [Discrete flow]
Advice on Clients requirements, [Discrete flow]
Outputs
Proposals, [Discrete flow]

Customs activities, [Process]:
Inputs
Clearance, [Discrete flow]
Approval for purchase, [Discrete flow]
Req. for CIF chargers, [Discrete flow]
Outputs
Req. for Clearance, [Discrete flow]
Req. for purchase materials, [Discrete flow]
Freight charges, [Discrete flow]

Design Details, [Store]:
Inputs
None
Outputs
Previous projects, Alternatives, Codes etc., [Discrete flow]

Designing, [Process]:
Inputs
Advice on Clients requirements, [Discrete flow]
Design Approvals, [Discrete flow]
List of BOI approved projects, [Discrete flow]
Clearance, [Discrete flow]
Approval for purchase, [Discrete flow]
Req. for CIF chargers, [Discrete flow]
Previous projects, Alternatives, Codes etc., [Discrete flow]
Clients' approval of Building, [Discrete flow]
Outputs
Proposals, [Discrete flow]
Req. for design approval, [Discrete flow]
Purchase orders, [Discrete flow]
Req. for BOI approved projects, [Discrete flow]
Design Alternatives, [Discrete flow]
Freight charges, [Discrete flow]
Req. for purchase materials, [Discrete flow]
Req. for Clearance, [Discrete flow]
Finalised Drawings & Specifications, [Discrete flow]

Detail Designing, [Process]:
Inputs
Design Approvals, [Discrete flow]
Previous projects, Alternatives, Codes etc., [Discrete flow]
Approved Design, [Discrete flow]
Clients' approval of Building, [Discrete flow]
Outputs
Req. for design approval, [Discrete flow]
Finalised Architectural Drawings, [Discrete flow]

Domestic Subcontractor, [Process]:
Inputs
Invoices, [Discrete flow]
Req. for assistance, [Discrete flow]
Payment approval, [Discrete flow]
Payments Certificates, [Discrete flow]
Req. for Fdn. details, [Discrete flow]
Outputs
Tech. Instructions, [Discrete flow]
Payment Boucher, [Discrete flow]
Details of the Bldg, [Discrete flow]

Erection, [Process]:
Inputs
Req. for assistance, [Discrete flow]
Drawings, Specifications, etc., [Discrete flow]
Outputs
Tech. Instructions, [Discrete flow]

Erection Details, [Store]:
Inputs
None
Outputs
Drawings, Specifications, etc., [Discrete flow]

Erection Drawing, [Process]:
Inputs
Finalised Architectural Drawings, [Discrete flow]
Outputs
Purchase orders, [Discrete flow]
Finalised Drawings & Specifications, [Discrete flow]

Erector, [Terminator] :
Inputs
Tech. Instructions, [Discrete flow]
Details of the Bldg, [Discrete flow]
Outputs
Req. for assistance, [Discrete flow]
Req. for Fdn. details, [Discrete flow]

Evaluation of Bids, [Process]:
Inputs
Records, [Discrete flow]
Bids, [Discrete flow]
Outputs
Award of Contract, [Discrete flow]

Govt. Regulatory bodies, [Terminator] :
Inputs
Req. for design approval, [Discrete flow]
Outputs
Design Approvals, [Discrete flow]

List of Contractors, Proximity, Past Records etc., [Store]:
Inputs
None
Outputs
Information, [Discrete flow]

Mat. Manufactures, [Terminator]:
Inputs
Purchase orders, [Discrete flow]
GRN, [Discrete flow]
Payment Boucher, [Discrete flow]
Outputs
Quotations, [Discrete flow]
MSN, [Discrete flow]
Invoices, [Discrete flow]

Modifications, [Process]:
Inputs
Previous projects, Alternatives, Codes etc., [Discrete flow]
Advice on Clients requirements, [Discrete flow]
Outputs
Design Alternatives, [Discrete flow]
Proposals, [Discrete flow]
Approved Design, [Discrete flow]

Negotiation, [Process]:
Inputs
List of BOI approved projects, [Discrete flow]
Advice on Clients requirements, [Discrete flow]
Outputs
Req. for BOI approved projects, [Discrete flow]
Proposals, [Discrete flow]

Non Domestic Subcontractor, [Process]:
Inputs
Bids, [Discrete flow]
MSN, [Discrete flow]
Req. for payment (SC), [Discrete flow]
Payment approval, [Discrete flow]
Payments Certificates, [Discrete flow]
Quotations, [Discrete flow]
Drawings, Specifications, etc., [Discrete flow]
Outputs
Calling for Bids, [Discrete flow]
GRN, [Discrete flow]
Req. for payment approval, [Discrete flow]
Req. for payments, [Discrete flow]
Award of Contract, [Discrete flow]
Payments for Sub contractors, [Discrete flow]

Other Activities, [Process]:
Inputs
Payments Certificates, [Discrete flow]
Payment approval, [Discrete flow]
Invoices, [Discrete flow]
Outputs
Payment Boucher, [Discrete flow]

Preparing bid docs, [Process]:
Inputs
Drawings, Specifications, etc., [Discrete flow]
Outputs
Bid Docs, [Discrete flow]

Reputation, Performances etc., [Store] :
Inputs
None
Outputs
Records, [Discrete flow]

Selection of Bidders, [Process]:
Inputs
Information, [Discrete flow]
Bid Docs, [Discrete flow]
Outputs
Calling for Bids, [Discrete flow]

SLPA, [Terminator]:
Inputs
Req. for Clearance, [Discrete flow]
Freight charges, [Discrete flow]
Outputs
Req. for CIF chargers, [Discrete flow]
Clearance, [Discrete flow]

Structural Design, [Process]:
Inputs
Previous projects, Alternatives, Codes etc., [Discrete flow]
Finalised Architectural Drawings, [Discrete flow]
Advice on Clients requirements, [Discrete flow]
Outputs
Purchase orders, [Discrete flow]
Proposals, [Discrete flow]
Finalised Drawings & Specifications, [Discrete flow]

Sub Contractor, [Terminator]:
Inputs
Calling for Bids, [Discrete flow]
Award of Contract, [Discrete flow]
Payments for Sub contractors, [Discrete flow]
Outputs
Bids, [Discrete flow]
Req. for payment (SC), [Discrete flow]

Schematic Design, [Process]:
Inputs
Advice on Clients requirements, [Discrete flow]
List of BOI approved projects, [Discrete flow]
Previous projects, Alternatives, Codes etc., [Discrete flow]
Outputs
Req. for BOI approved projects, [Discrete flow]
Design Alternatives, [Discrete flow]
Proposals, [Discrete flow]
Approved Design, [Discrete flow]

Suppliers of System Building, [Context node]:
Inputs
Advice on Clients requirements, [Discrete flow]
Design Approvals, [Discrete flow]
Quotations, [Discrete flow]
MSN, [Discrete flow]
List of BOI approved projects, [Discrete flow]
Req. for assistance, [Discrete flow]
Bids, [Discrete flow]
Req. for payment (SC), [Discrete flow]
Invoices, [Discrete flow]
Req. for Fdn. details, [Discrete flow]
Payment approval, [Discrete flow]
Payments Certificates, [Discrete flow]
Approval for purchase, [Discrete flow]
Req. for CIF chargers, [Discrete flow]
Clearance, [Discrete flow]
Clients' approval of Building, [Discrete flow]
Outputs
Proposals, [Discrete flow]
Req. for design approval, [Discrete flow]
Purchase orders, [Discrete flow]
GRN, [Discrete flow]
Req. for BOI approved projects, [Discrete flow]
Design Alternatives, [Discrete flow]
Tech. Instructions, [Discrete flow]
Calling for Bids, [Discrete flow]
Award of Contract, [Discrete flow]
Payments for Sub contractors, [Discrete flow]
Payment Boucher, [Discrete flow]
Details of the Bldg, [Discrete flow]
Req. for payments, [Discrete flow]
Req. for payment approval, [Discrete flow]
Req. for purchase materials, [Discrete flow]
Req. for Clearance, [Discrete flow]
Freight charges, [Discrete flow]
Finalised Drawings & Specifications, [Discrete flow]

Tender Calling, [Process]:
Inputs
Drawings, Specifications, etc., [Discrete flow]
Outputs
Calling for Bids, [Discrete flow]

Additional Amount Payable for Non BOI Approved Projects.

C.I.F 5 Cost 1 Insurance 1 Freight

Where,

Insurance 5 0.2275 of cost (Approximately)

Freight 5 1000 dollars for a 40 feet container (Approximately)

C.I.F Value 3 25% 5 Duty ………………….(1)

Duty 3 40% 5 Surcharge …..…..………….(2)

Goods & Service Tax

(Duty + Surcharge) 3 12.5% = G.S.T ……………… ….(3)

National Security Levy

[(C.I.F 3 12.5%) + Duty] 3 7.5% = N.S.L …………...…….(4)

Total of (1) + (2) +(3) +(4) = (Cost of Government Tax on Building)

Total tax on Building is say about 63% of the total cost of the building

(Souces: Kirby Building Systems, 2001)

<u>Building Description of a System Building</u>

Building (A) consists of (2) areas

Building (A) Area (1)

Quantity	: One (1)
Usage	: -
Frame type	: Rigid Frame "Clear Span"
Width	: 18.0M O/O of Steel Lines
Length	: 108.0M O/O of Steel Lines
Eave Height	: 11.0M
Bay Spacing	: 14@7.714m
Main and End Frame	: Post and Beam at both ends
Roof Slope	: 1:10
Roof Covering	: IBSF 26GA (0.50mm thick) rib pre-painted panels
Wall Covering	: IBSF 26GA (0.50mm thick) pre painted panels
Roof and Wall Covering	: X-rod bracing is allowed wherever is required by design
Wall Condition	: All walls are fully open up to 3.0m high above F.F.L., while the remaining 0.60m high are fully open for grills by others except common side wall with Area (2) which is fully open for block walls by others.

N.B. Both end wall gables will be sheeted.

INTERVIEW GUIDELINES

A system building system is defined as "***a complete integrated set of mutually dependant components and assemblies that form a building. It includes the primary and secondary framing, covering, and accessories, all of which are manufactured to permit inspection on site prior to assembly or erection***". - *Metal Building Manufacturers Association of USA.*

General

1. How do you procure the jobs?

2. What is the common type of client?

3. Is the trend of constructing system building increasing?

4. Parties' viz. general contractor, erection contractor, building supplier, or other agreed upon party may act as the erector. What is the situation in your organisation?

5. All components of the system buildings are typically designed, fabricated, and furnished by a single manufacturer. Do you supply any materials, components, or any other parts from any other manufacturers?

6. Who are the parties to the contract other than the client and you?

Design Criteria.

1. What are the basic information you require that the client should furnish or provide you to design the building?

2. What are the information that the manufacturer of the system building should be provided by you?

3. Have you established any design manual in your own for the purpose of designing or do you follow any standard and commercial practices for metal buildings, which were established by someone else?

4. Do you establish a budget for the project at the initial stage? (Cost Limit)

5. How do you ensure that the cost target is met? (Cost Controlling)

6. Who does these jobs?

Foundation

1. Usually metal building manufacturers do not design foundations. Do you design foundations or is it performed by a separate contractor?

2. Who does the civil works of these system buildings? Do you sub contract?

3. Who does the services works of these system buildings?

Specification Issues

Quality Certification

1. Do you check whether the design is strictly adhered to the design code of practices if you have prepared any or to the standard design and commercial practices for metal building as mentioned in the design criteria?

2. If a building is completed by you, does that completed building have to undergo any certification program by any professional of recognized body?

Building Configuration

1. What is the extent of customer requirements taken into account when designing the building?

2. "The appearances of these system buildings could be enhanced by the use of other cladding material such as pre-cast panels and reinforced masonry etc". What are the types of finishes you are using?

3. Do you sub contract another person for this purpose?

Drawings

1. In drawings excessive detailing should be avoided since the advantage of using a metal building systems is lost if the manufacturer is forced to use details other than those which have made standard for its product.

2. Do you agree with the above statement?

3. What are your practices of providing details in drawings?

4. Do you prepare drawings? Who does this job?

Design requirements

1. The Designer/ Specifier must be familiar with all referenced design standards and codes, especially when specifying large complicated structures, so that the specification contains the appropriate choice for the structure being produced

2. If you are using any standards, what are they?

Erection

1. Do you subcontract another person for the purpose of erecting the Building?

2. Do you appoint another person for the purpose of managing the Project? (Project Management)

3. Who are the parties involved in the process of erecting the Building?