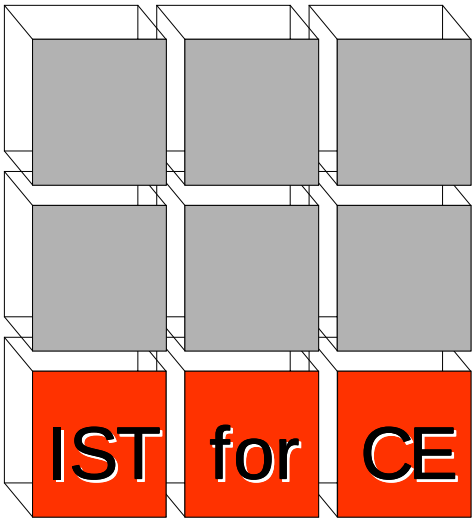
Intelligent Service Tools for Concurrent Engineering



INFORMATION FLOW SCENARIO

WORKPACKAGE:	*1*
DOCUMENT NO.:	*D 4*
AVAILABILITY:	*PUBLIC*
PARTNERS INVOLVED:	*AEC, CER, CST, FID, GEO, OPB, TUD*
DATE:	**5 JANUARY 2001**

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LIST OF ABBREVIATIONS

ISTforCE Partners

AEC = AEC3 Ltd., Berkshire, United Kingdom

API = Aplicaciones de Ingeniería y formación, Madrid, Spain

CER = ervenka Consulting, Prague, Czech Republic

CIN = Communicación Interactiva, Madrid, Spain

CST = Centre Scientifique et Technique du Bâtiment, Sophia Antipolis Cedex, France

FID = FIDES DV-Partner GmbH, Munich, Germany

GEO = Geodeco S.p.A. Consulting Engineers, Bogliasco (Genoa), Italy

OPB = OBERMEYER PLANEN + BERATEN, Munich, Germany

TUD = University of Technology Dresden - Computeranwendung im Bauwesen, Germany

ULJ = University of Ljubljana –Structural & Earthquake Engineering, Slovenia

Other Abbreviations

AEC = Architecture, Engineering and Construction

API = Application Programming Interface

B&C = Building & Construction

CE = Concurrent Engineering

CEE = Concurrent Engineering Environment

DM = Document Model[ling]

E&D = Exploitation and Dissemination

FM = Facility Management

PM = Product Model[ling]

R&D = Research and Development

WP = Work package

PP = Project Programme

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1 Introduction

When we mean to build,
We first survey the plot, then draw the model,
And when we see the figure of the house,
Then must we rate the cost of the erection,
Which if we find outweighs ability,
What do we do then but redraw anew the model
In fewer offices, or at least desist
To build at all?

William Shakespeare, *King Henry IV* [KHIV2]

This report presents the publicly available sections of the work to define an Information Flow Scenario within the EU funded ISTforCE project.It provides the process based background information upon which the end-user requirements for the project are developed. In its process centric view the deliverable concentrates on:

- review of existing process definition and modelling methods and recommendation for the most appropriate usage of such method in the building construction industries,
- review of previous work done in process definition and modelling and how it can be applied within building construction,
- proposal of a process architecture - a combined approach to utilise different methods appropriate to the scope and level of detail of processes in building construction,

Based on input from industry organisations, mainly from the Generic Process Protocol, a detailed information flow matrix is developed and published as an appendix to this deliverable. The information flow matrix identifies the process breakdown within the whole project chain in building and construction and relates it to the involved parties within the building construction processes. The methodologies used for the information flow matrix are introduced in the report.;

- General process protocol,
- Matrix analysis,
- Interface analysis

1.1 Technical Approach

The technical approach adopted for the development of an understanding of process concentrates on the following principal requirements:

- the overall processes of building construction by developing a more extensive information flow description than is currently available;
- the communication of information between the different roles in a project during the different processes including an understanding of who needs to send and who needs to receive the information;
- the format in which the communication is most likely to take place;
- the gaps that exist in current information models that should be addressed in the short term;
- creation of new models and extension of existing models in the specific areas of interest defined for the project.

In developing these requirements, this report contains:

- Development of general processes and identification of gaps in existing models

The methodologies adopted for the work are outlined below. The need to extend existing data models to address the data and interoperability requirements unveiled during the process descriptions is acknowledged in this deliverable.

Information models developed within STEP and IAI initiatives are regarded as the applicable base models to be extended by the requirements from the processes within the ISTforCE project window. Research done during the development of the detailed processes strongly emphasizes the need to base the required information model extensions on the latest Industry Foundation Classes (IFC) Version, IFC2x, published by the International Alliance for Interoperability in October 2000.

1.2 General Process Development Methodology

Preliminary work focussed on an understanding of work done in the development of process approaches within building construction. There are two elements to this stage:

1. A study of process model development carried out in previous projects. For this element, there is a substantial literature dating back over a long period of time. The major sources of information identified for study were:
   - Deliverables from previous EU funded projects that have a strong process model content
   - National research projects
   - Usage scenarios developed by the various domain projects undertaken within the International Alliance for Interoperability.
2. A series of discussions with organisations in the building construction industry. Each organisation has been selected for its awareness of process model development (either implicitly through its documented procedures or explicitly through its development of process models in formal notation). Each discussion concentrated on a particular part of the model where the knowledge of the organisation was valuable in filling gaps that were found in the results of the prior study.

From the study and discussions, an information type classification was defined that considered the level of detail required for process model development and suggests approaches (notations) for development at the different levels of detail.

A series of information flow matrices were then defined. Each matrix considers one stage of a project development and group's information according to definitions discovered from the information type classification.

From the architecture and the matrices, an analysis is undertaken that considers three fundamental issues:
1. information representing project model needs;
2. information representing e-Commerce services;
3. A suggested roadmap for future information model development for building construction (taking account of known current information developments).

Gaps in current model developments are then considered and Use Cases defined for further model development in the short/medium term. These are formed into a 'Road Map' for extension of the capabilities of existing models to much better meet the information exchange/sharing needs of industry.

2 Process Model Notations

In this section, a brief review is presented of the process notations that have been used in the development of process and activity models for the building construction industry. The objective is not to provide a complete description of the notation, but simply to recognise their use and how they have been used.

Whilst the notations identified have been used in building construction process model development, it is rare that they have been used fully due to the diversity of the industry and the difficulty in establishing a fully formalised process.

2.1 CRUD Matrix

The CRUD Matrix is an information requirements approach used within the ICON project [ICON1] that allows an activity being performed to be set against the information required to support it. Each activity is analysed to determine whether it will Create, Read, Update or Delete information that is associated.

Actor →	***Architect***	***Structural Engineer***	***Services Engineer***	***Contractor***
Activity 1	C	R	R	
Activity 2	R	C	R	
Activity 3	C	C	C	R
Activity 4		U	U	R

Table 1: CRUD Matrix

When fully developed, the CRUD matrix can be a powerful tool that can provide significant value in the development of process. In a simplified form, it is used in this report to provide a broad overview of major processes in building construction.

2.2 IDEF0

IDEF0 [FPS183] is the most widely used notation for the creation of process models in building construction being used within the ISO STEP standard, IFC development and in many R&D projects. It allows the identification of processes/activities, input and output information, controls that act on the process and mechanisms and process performers that assist completion of the process.

Figure 1 shows an IDEF0 diagram in which the various elements of the notation are identified.

2.2.1 Decomposition

Decomposition allows a process to be described initially in a broad manner, e.g. Move People and Equipment and then decomposed into sub-processes e.g. Plan Move, Design Move, Bid Move and Implement Move. As required, sub-processes may be further decomposed until further decomposition is not possible or necessary.

Process identification is normally developed by progressively adding a numeric character to the end of the identifier of the parent process e.g. A2 → (decomposes into) → A21, A22, A23; A22 → (decomposes into) → A221, A222, A223 etc.

2.2.2 Call Arrow

A Call Arrow is a special type of mechanism that allows processes in a different part of the process model or in a different process model to be ‘called’.

A call to a process within the same process model is labelled using the node number of the sheet on which the called process is located followed by the identifier of the process called. If the call is to a different model, the identifier is prefixed by the name of the model in which the called process is located.

When a process is called, only the parent process is identified. All child processes are the automatically called.

2.2.3 Tunnelling

Elements that are used for all processes in a child model can be omitted by identifying the fact that this is the case at the parent process. This is done by using a tunnel marking at the end of the arrow that connects *INTO* the parent process box. By using a 'tunnel' in this way, the author is stating that the arrow is a page boundary arrow that does not correspond to arrows on the child model.

Similarly, it is possible to omit elements at the parent process that are exposed in the child model. This is appropriate if the extent of detail at the parent process becomes too great. This procedure is again achieved by using tunnelled arrows but for this purpose the tunnel is placed at the unconnected end of the arrow.

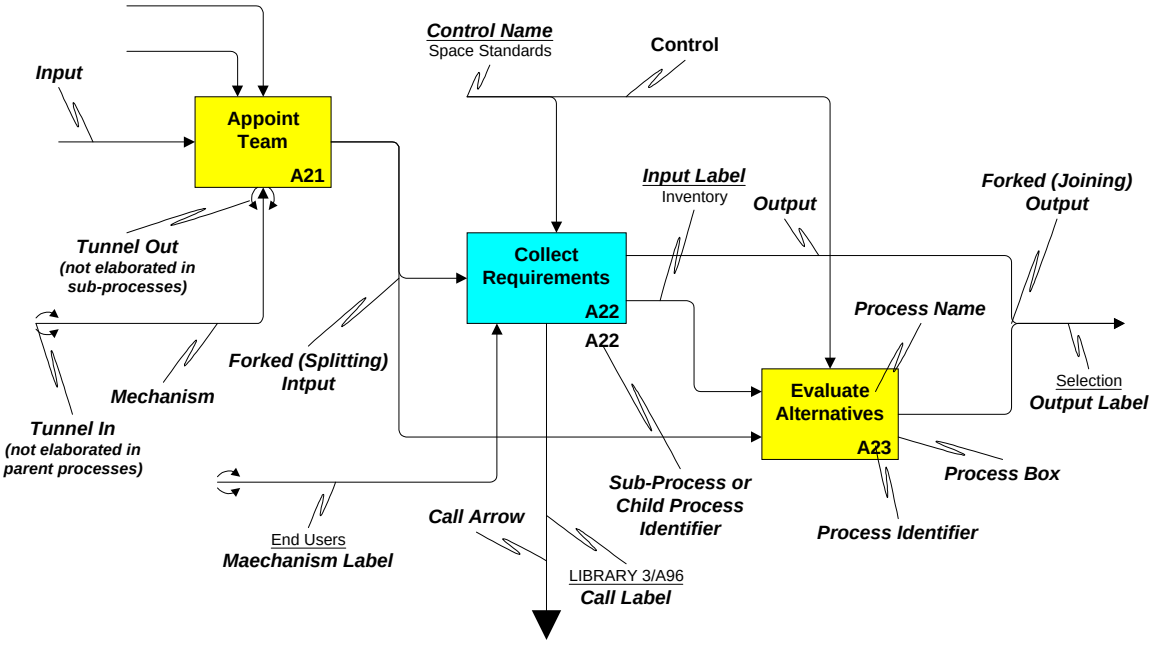


Figure 1 : IDEF0 Model

2.2.4 Strengths and Weaknesses of IDEF0

IDEF0 provides a powerful capability to break down a known process into its fundamental activities or functions. Generally however, in building construction, the depth of the IDEF0 model is limited and this state is never reached. Therefore, the connection supposedly existing between a process model and the information model that it is intended to inform is broken. Reasons for this may be seen as either the scope of the process model is defined too broadly or the analysis required to fully develop the model is not undertaken

Practically, these may be seen as the same problem since too large a scope is likely to leave insufficient resource available for detail.

However, for the purpose of developing an overall road map, IDEF0 can also be seen to be weak in that it is essentially linear. By providing a focus on an individual process, it lacks the strength to easily define communications between multiple processes.

2.3 UML Use Cases

The Unified Modeling Language (UML) is used to specify, visualise and document the artefacts of an object oriented (O-O) system under development [VISMOD]. It represents the unification of several prior methodologies and diagramming notations and is intended to provide a basis for O-O analysis and design.

UML comprises a number of separate but integrated approaches that reflect the requirements of different stages in the O-O development process. Amongst these is a diagramming approach that deals with the identification of process. This is termed 'Use Cases' (there are other approaches in UML that also deal with process but they are not considered here).

A Use Case documents the functionality of a system under development. Its most important role is to define communication.

There are three principal elements in the definition of Use Cases, namely Actors, the Use Cases themselves, and the Flow of Events for each Use Case.

Actors are defined as anyone or anything that interacts with the system under development. An Actor may be a person or an organisation or a software application or database from which information is taken or to which it is delivered.

Actors are not part of the system being developed but represent the environment with which the system must communicate. An actor may:

- Provide information to the system (input)
- Receive information from the system (output)
- Provide information to and receive output from the system (input and output)

Use Cases describe the capabilities that will be provided to an Actor by the system being developed. A complete collection of Use Cases for a system constitutes all the defined ways that the system may be used[1].

Relations in a Use Case diagram are shown by lines that may have arrows at one or both ends (depending on the direction of communication).

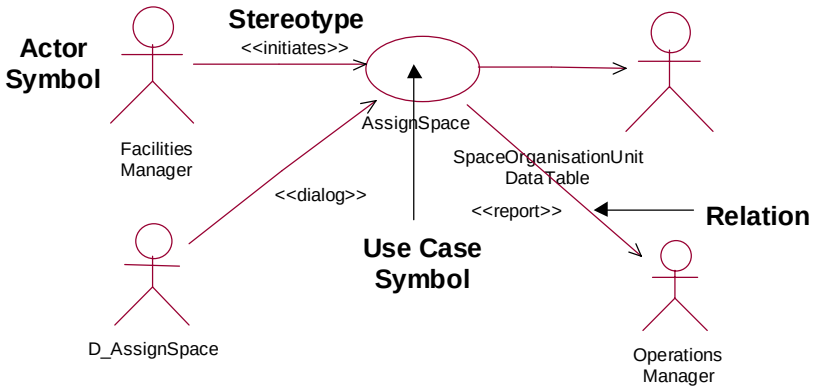


Figure 2 : Example Use Case Diagram

Everything included in a UML diagram of whatever type may conform to a stereotype[2]. A stereotype may be indicated in the diagram by enclosing its name in <<guillemets>>. In a Use Case diagram, the default stereotype for a relationship is <<communicates>> indicating that a communication is taking place between an Actor and a Use Case or between Use Cases.

Stereotypes can also be defined that represent additional subclasses of relationship. For the purposes of expressing the sharing of information, such stereotypes could be used to define not only that communication takes place but also the form that the communication takes. For instance, in the Use Case diagram below, the Facilities Manager is seen to initiate the AssignSpace Use Case. The D_AssignSpace Actor provides the dialogue(s) through which data may be provided to the Use Case whilst the Operations Manager receives a report as output from the Use Case. Strictly, this is not a normal way of using stereotypes but it is allowed by UML and is useful for defining forms of communication.

[1] The formal definition for a Use Case is: 'A Use Case is a sequence of transactions performed by a system that yields a measurable result of values for a particular Actor'.

[2] A stereotype represents the sub-classification of a model element. It represents a class within the UML meta-model itself (i.e., a type of modelling element).

2.3.1 Flow of Events

The flow of events for a Use Case describes the events that must be undertaken in sequence to achieve the required behaviour of the Use Case. It is defined in terms of what a system should do as opposed to how the system should do it. That is, it may be seen as a specification of requirements rather than a specification of intentions.

The fowing describes the information to be contained within a Use Case definition:

Overview	Provides a description or scope statement for the Use Case concerned.
Preconditions	Identifies any requirements that must be fulfilled prior to enactment of the Use Case.
Main Flow	Specifies the principal events within the Use Case and their sequence (typically, each event is numbered).
Subflows	Specifies subsidiary flows of events that occur within the Use Case. Typically, a subflow will identify an operation that may be global or within the scope of one or more classes identified by the Use Case.
Post Conditions	Describes the state of parameters following enactment of the Use Case.
Exceptions	Specifies exceptions that may occur during the enactment of a Use Case. An exception may be cnsidered to be an error condition, the statement of exceptions identifying actions that occur and recovery from the exception.
Required GUI	For a complete system design, the graphical user interface supporting the Use Case (in terms of menus, toolbars, diague boxes etc.) may be specified.

2.3.2 Strengths and Weaknesses of Use Cases

As with all aspects of the UML, Use Cases are specifically intended to assist with analysis and design of systems and are particularly adept at defining communications between elements of a system. They are not designed to deal with aspects of communication between different systems.

Generally, the level of granularity of process that is dealt with by a Use Case is quite fine. That is, they are designed to deal in detail with relatively small and tightly defined processes. Thus, they would not deal well with a broadly defined process such as ‘Design System’ but would handle a narrow process definition such as ‘Calculate Authority of Control Valve’.

However, at the most detailed level of process definition, the behaviour of individual functional elements becomes much more important than at the levels of aggregated processes. In this circumstance, the expressive power of the Use Case notation may be used to more accurately determine the actors that are involved in communication.

By applying stereotypes to relationships, the expressive power of Use Case notation can be further extended so that the form of communication can be defined. This is not generally available with other process model development notations.

2.4 Generic Design and Construction Process Protocol

2.4.1 Background

Development of the Generic Design and Construction Process Protocol (GPP) was undertaken as a research project funded by the UK Engineering and Physical Sciences Research Council (EPSRC). It was a direct response to the publication of the Latham Report [LATHAM] which identified fragmentation and confrontational relationships as being the greatest barriers to improving quality and productivity in the construction industry. It took the view that the manufacturing industry suffers less from such problems having introduced a number of process improvement initiatives over a period of time. A particular approach from the manufacturing industry was adopted as a consistent means of formulating project development.

2.4.2 Framework

The GPP aims to provide a framework for carrying out any construction project. It considers that the lifecycle of a project development is described in terms of four main stages:

- Pre-project
- Pre-construction
- Construction
- Post-construction

It then divides these stages into ten phases, each of which is numbered:

Phase	***Description***
0	Demonstrating the need
1	Conception of need
2	Outline feasibility
3	Substantive feasibility study and outline financial authority
4	Outline conceptual design
5	Full conceptual design
6	Co-ordinated design, procurement and full financial authority
7	Production information
8	Construction
9	Operation and maintenance

Table 2: GPP Phases

It also establishes a number of sub-processes (that are referred to as ‘activity zones’) which include functional expertise (architects, engineers, constructors etc.) across the whole spectrum of the task (supply, production, client input etc.). The activity zones are:

- Development management
- Resources management
- Design management
- Facilities management
- Health and Safety, Statutory and Legal management
- Project management
- Process management
- Production management
- Change management

2.4.3 The Stage Gate Approach

This is an approach that recognises the need for work to be carried out during a stage or phase of the project development following which a review is undertaken. The review is termed a ‘gate’ that has to be passed through before proceeding to the next stage or phase. At a ‘gate’ the outcome of a review may be:

GO	Everything OK, continue to next phase or stage
CONDITIONAL	Subject to certain actions being taken, continue to next phase or stage
NO GO	Action needs to be taken to increase quality, further review needed.

Table 3: Stage Gate Definition

Gates are identified as being either ‘hard’ or ‘soft’

- A ‘hard’ gate requires the completion of all activities within the phase or stage. Project development is halted until this is achieved.

- A ‘soft’ gate allows non-completion to be identified and carried over until the next gate is reached. Project development is not halted.

2.4.4 Activity Zones

Activity zones are described in terms of the management role being performed rather than in terms of disciplinary identification of the actor performing the role. Roles are as described in the table below:

Activity Zone	***Role/Responsibility***
Development management	Creating and maintaining business focus throughout the project to satisfy both relevant organisational and stakeholder objectives and constraints.
Resources management	Planning, co-ordination, procurement and monitoring of all financial, human and material resources including establishing the overall budget
Design management	The design process which translates the business case and project brief into an appropriate product definition.
Facilities management	Ensuring the cost efficient management of assets and the creation of an environment that strongly supports the primary objectives of the building owner and/or user.
Health and Safety, Statutory and Legal management	Identifying, considering and managing all regulatory, statutory and environmental aspects of the project.
Project management	Implementing the project effectively and efficiently to agreed performance measures in close collaboration with process management.
Process management	Developing and making operational the process protocol together with planning and monitoring of each phase of the work.
Production management	Ensuring the optimal solution for the buildability of the design, the construction logistics and organisation for delivery of the product.
Change management	Communicating project changes to all relevant activity zones and the development and operation of the legacy archive.

Table 4: GPP Activity Zones

2.4.5 Phases

In the complete Generic Process Protocol [GPP GUIDE], the description of phases is given in terms of:

- Prior requirements for phase
- Activities during the phase
- Deliverables of the phase
- Goals of the phase
- Gate status

For present purposes, only the goals of the phase (other than the implicit goal of proceeding to the next phase) and the deliverables of the phase need to be understood. The ideas of the deliverables are contained in the information flow matrices shown in Appendix A.

Phase	Goals	Deliverables
0	Establish the need for a project to satisfy the clients business requirement	Stakeholder list (initial) Statement of need (initial) Business case Costs Options Risks Benefits Project execution plan Process execution plan
1	Identify potential solutions to the need and plan for feasibility	Stakeholder list (final) Statement of need (final) Project brief (initial) Business case (updated) Design brief Project execution plan (updated) Process execution plan (updated)
2	Examine the feasibility of options presented in phase 1 and decide which of these should be considered for substantive feasibility	Project brief (revised) Business case (updated) Project execution plan (updated) Process execution plan (updated) Project success criteria (initial) Performance measures (initial)
3	Gain financial approval (up to phase 5)	Project brief (updated) Business case (updated) Procurement plan (initial) Concept design plan CDM assessment[3] (initial) Project execution plan (revised) Process execution plan (revised) IT communications strategy(initial) Performance measures (updated)
4	Identify major design elements based on the options presented	Project brief (revised) Business case (revised) Outline concept design Project execution plan (revised) Gantt chart Quality plan Cost plan (initial) Procurement plan (updated) CDM assessment (revised) Process execution plan (revised) IT communications strategy(revised) Performance measures (updated)
5	Conceptual design and all deliverables ready for detailed planning approval	Project brief (updated) Business case (updated) Procurement plan (updated) Design team membership Work package sourcing plan Preliminary equipment requirements Full concept design Cost plan (updated) Maintenance plan (initial) CDM assessment (updated) Project execution plan (updated) Process execution plan (updated) IT communications strategy(updated) Performance measures (updated)
6	Fix all major design elements to allow the project to proceed. Gain full financial approval for the project	Project brief (updated) Business case (updated) Procurement plan (updated) Product model Cost plan (updated) Maintenance plan (updated)

[3] CDM refers to the Construction Design and Management regulations that are applied by law to the execution of all building construction projects within the United Kingdom.

Phase	Goals	Deliverables
		CDM assessment (updated) Project execution plan (updated) Process execution plan (updated) IT communications strategy(updated) Performance measures (updated)
7	Finalise all major deliverables and proceed to construction.	Project brief (finalised) Business case (finalised) Procurement plan (updated) Product model (co-ordinated) Cost plan (finalised) Production process map Phasing Interfaces between work packages CDM assessment (finalised) Project execution plan (finalised) Process execution plan (finalised) Performance measures (finalised)
8	Produce a product that satisfies all client requirements. Handover the building as planned.	Product model (operational) Handover plan As built records Service and operation information Commissioning information Defects lists
9	Operate and maintain the product effectively and efficiently.	

Table 5: GPP Phases Description

2.4.6 Deliverables Development

According to the GPP, a number of deliverables undergo development and change during the lifecycle. Four major states of a deliverable are defined namely:

- Initial Preliminary information presented
- Updated Current information is updated
- Revised Major changes affect content and/r context
- Finalised Information is agreed and is unlikely to change

Stage -->	0	1	2	3	4	5	6	7	8	9
Deliverable										
Stakeholder list										
Statement of need										
Business case										
Project execution plan										
Process execution plan										
Project brief										
Design brief										
Project success criteria										
Performance measures										
Procurement plan										
Concept design plan										
CDM assessment										
IT communications strategy										
Outline concept design										
Cost plan										
Full concept design										
Maintenance plan										
Product model										
Production process map										
Handover plan										

initial updated revised

finalized

Table 6: GPP Deliverables Development

2.4.7 Analysis of Deliverables Types in GCPP

It should be remembered that the activity zones within the GCPP relate to management activities and not to specific design, construction or operational activities. Therefore, the analysis given below relates to the types of deliverable for management functions.

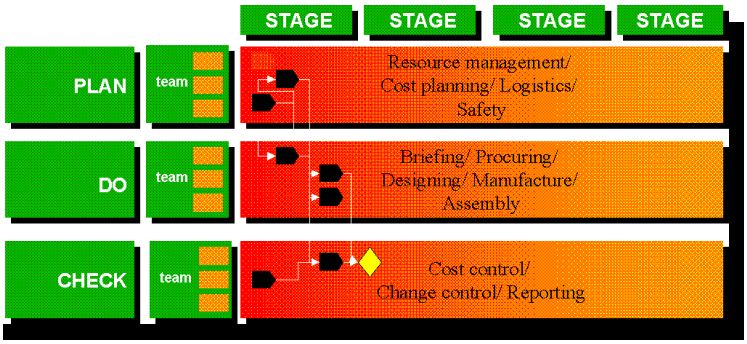
Typing of deliverables is by a classification of types within which particular deliverables may be identified.

- Cost Plans
  - Cost plan
  - Budget
- Designs
  - Concept design plan
  - Outline concept design
  - Full concept design
  - Product model[4]
- Legal/Statutory Assessments
  - CDM assessment (UK Construction Design and Management Regulations)
  - Health and Safety plan
  - Quality plan
- Lists
  - Stakeholder list
  - List of team members (design, construction)

[4] The term 'product model' is used in the GPP to denote a geometrically and functionally co-ordinated set of information enabling the project to deliver the product. It is not used in the sense of a conceptual product data model or information model rendered in a formal data definition language.

  - Defects list (also known as punch list)
- Performance
  - Performance measures
- Schedules
  - Project execution plan
  - Production process map
- Strategies
  - Statement of need
  - Project brief
  - Business case
  - Design brief
  - IT communications strategy
- Work Plans
  - Maintenance plan
  - Procurement plan
  - Process execution plan
  - Handover plan

2.4.8 Modelling Processes in the Generic Process Protocol



The Generic Process Protocol uses a two dimensional diagramming approach that links actions and project stages. Each dimension is shown by what is termed a 'swim lane'. For each action, participants in the project team are also defined. Activities are shown at the intersection of the 'swim lanes' in which they occur and are connected by process flow lines.

Figure 3 shows an example of the technique [BACON]

Figure 3 : Example of GPP Process Model

This approach to preparing process model diagrams is also used within other industry sectors and in business process reengineering but is only recently becoming known in building construction.

2.4.9 Strengths and Weaknesses of the Generic Process Protocol

The Generic Process Protocol has three major strengths that make it a valuable tool in process analysis in building construction:

1. it is an approach that is borne entirely from efforts to understand approaches to working in building construction;, as a result if which,
2. it is a two dimensional approach that recognises not only communication between activities but also communication between the participants involved in those activities i.e. it allows the collaboration of participants in a project to be expressed. For general purposes then, it offers a more easily understood diagram than a UML collaboration diagram.
3. it can be easily given 'adornments' that enable not only the information delivered is understood but also the form in which the information is delivered. These 'adornments' simulate the use of stereotypes in UML diagrams.

For high level considerations therefore, it has a number of advantages over other process modelling approaches.

The principal disadvantage that can be seen is the question whether the stages that are contained in the Protocol truly reflect industry practices globally. To a large extent however, this can be seen as personal or local preference and the definition of stages Protocol could be further extended relatively easily to be global in nature.

3 Previous Process Model and Related Work

There is a significant body of work relating to the development of process models for the building construction industry. Most of this relates either to a generic level of process (without substantial detail of individual processes and activities) or to a functional level (which does not deal with the specifics of activities and does not closely map to a clearly defined generic level). However, taken in total, this work provides a substantial resource from which to develop an overall information flow scenario.

The following outlines the principal sources of reference and the benefit that they offer to development of the scenario outlined in this report.

3.1 Background Models

Most of the process models studied are defined using the IDEF0 notation and are drawn from projects that have, as a principal objective, the development of data models in the EXPRESS [ISO11] data definition language. However, some of the models do use a different approach.

3.1.1 EU Projects

A number of projects partially funded by EU programmes have developed process models for building construction. Elements of the following of projects have been studied:

- **ATLAS** Architectural process and data models
- **CIMSteel** Structural steel frameworks
- **COMBINE** Energy analysis
- **CONCUR** Concurrent engineering focussing on tendering processes. Includes models for the operations of particular contractors that are extrapolated to general processes.
- **CONDOR** Document management. Includes models for the construction operations for a major contractor that is extrapolated to a general process.
- **ELSEWISE** A project that defined a vision for technology development for the large scale engineering industry including a generic level process model.
- **PROCURE** Focussing on procurement processes. Includes models for the operations of particular contractors that are extrapolated to general processes.
- **VEGA** A technology project that carried out analysis of workflow models.

3.1.2 National Projects

- **Information Transfer in Building Services (UK)**

A detailed model of building services information flow with an emphasis on communication of information to/from the building services practitioner.

- **ICON (UK)**

A model of integrated construction developing the concept of aspect models and including a number of process models focussing on the construction phase of a project.

- **Generic Process Protocol (UK)**

A major development of a process protocol for building construction based on work carried out in the manufacturing industry (see section 2.4 for detailed overview).

- **NIDDESC (USA)**

Development of process and data models for piping, ducting and electrical systems for the US Navy Industries Digital Standards Exchange Committee.

- **Standing Committee for Computing and Data Coordination (UK)**

A substantial flow chart based development from an early stage in the development of computer applications for the building construction industry.

3.1.3 Standards Based Model Development

There are many process models that have been developed in conjunction with work in STEP, CIMsteel and IAI. These tend to focus on limited business cases. They are valuable in helping to focus on areas of the overall information flow.

Further information on particular processes developed is shown in section 6.4 (Current Model Coverage)

3.1.4 Other Work

- **General AEC Reference Model (Netherlands)**

The General AEC Reference Model [GARM 1988] is a high level data model. Intended for building construction, it is the first of the generic information models. It is primarily concerned with the decomposition of class (entity types) in the design stages of a project. However, it recognised that these represented only certain stages in the project lifecycle with other stages not dealt with by the model. To provide a temporal framework against which further information models could be developed, a high level class was introduced termed the 'Product Definition Unit'. From this abstract type, a set of subtypes was developed, each representing a state of development. Each subtype Unit has a precedes/succeeds relationship with other Product Definition Unit subtypes but this is not explicitly identified.

A Product Definition Unit is considered to have a set of Characteristics that may be required, expected or measured. There is an explicit relationship between each Product Definition Unit and the type of defining Characteristic.

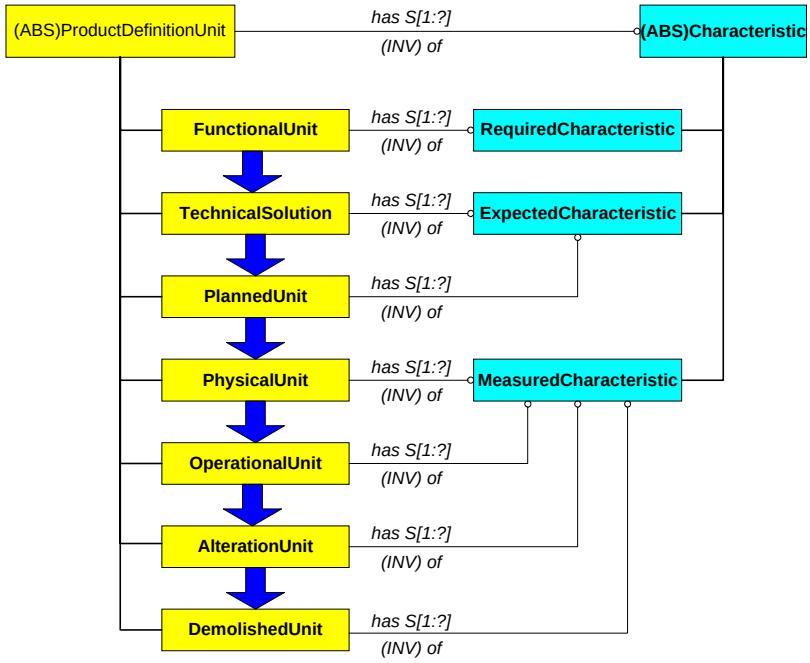


Figure 4 : GARM Product Definition Units

The GARM was always intended as a Reference Model that could be used as a framework for the development of more specific information models. The Product Definition Unit concept was conceived as a means of identifying the range of information models that might be required to fully describe a class (and a project) throughout its lifecycle. Other than the recognition that this would be the case, there has been little published that further develops the temporal concepts of GARM.

- **Information Transfer in Building (UK)**

During the mid-late 1980's, the 'Working Party on CAD Data and Other Information Exchange' of the UK National Economic Development Commission recognised the need for an overall process model for the industry that could be used to guide and structure information exchange requirements. It focussed on the RIBA Plan of Work [RIBA 1990] as a mechanism that set out the responsibilities and duties of architects. From this, it developed an information transfer matrix [NEDC 1990] that identified sending and receiving organisations for information transfer at different stages of the Plan of Work. This matrix is used as one of the start points for development of the Information Flow Matrices shown in Appendix A.

- **RIBA Plan of Work (UK)**

A list of tasks that are to be undertaken by architects at various phases within a project development, the RIBA Plan of Work acts as a primary document for contractual agreement between architects and clients in the UK where the architect takes the lead role. It provides an implicit process model.

- **HOAI (Germany)**

Provides the framework for fee payment to architects and engineers in Germany. To facilitate this, it subdivides the design and construction process from the viewpoint of architects and design engineers. However, it does not consider the viewpoint of the constructor or any of the sub-contract trades involved.

There are nine main processes outlined in the HOAI 'model':

1. programming (inception phase for analysis)
2. planning for preliminary design (the outline design)
3. planning for conceptual design (the schematic design)
4. planning for submission and permission (completing the design for the permission process)
5. planning for the execution documents (detailed design for working drawings)
6. prepare tendering (Bill of Quantities)
7. participate contract agreement (submit, validate tender, consultancy)
8. control of assembly (control of the execution work on site)
9. handover and documentation (control of the repair for handover, documentation, feed back)

Mapping between the major HOAI processes and those of the Generic Process Protocol is suggested as follows:

GPP Phase	***GPP Description***	***HOAI Phase Description***
0	Demonstrating the need	
1	Conception of need	
2	Outline feasibility	
3	Substantive feasibility study and outline	Programming
4	Outline conceptual design	Planning for preliminary design
5	Full conceptual design	Planning for conceptual design
6	Co-ordinated design, procurement and full financial authority	Planning for submission and permission
7	Production information	Planning for the execution documents
		Prepare tendering
8	Construction	Participate contract agreement
		Control of assembly
9	Operation and maintenance	Handover and documentation

Table 7: Mapping of GPP and HOAI Processes

From this, it can be seen that the HOAI has a weaker separation of process in the earlier development stages of a project in comparison with the GPP but has a stronger separation of process at the production information and construction stages.

This identifies areas where the GPP approach could, perhaps, be strengthened.

3.2 Classification

Classification systems have been developed to classify elements, materials and work sections. For developing an information flow scenario, those that handle work section classification are of interest. Work section classification can be used to identify the major processes that are undertaken in building construction. This provides the basic information needed for the scoping/function level of the process architecture.

Classification systems can be used to identify taxonomy (i.e. supertype/subtype relationships) but do not identify the containment, reactive or connective relationships that can exist between objects. For instance, containment, reactive, connective and communication relationships are not captured by classification.

Therefore, classification references have been used to guide the determination of activity within the information flow scenario but cannot be used to guide the identification of communication (messages) that pass between actors.

4 Processes in Building Construction

Conventionally, process models focus on activities, dependencies between activities and the information that is required by and results from the undertaking of activities. In the current case the focus is different. It looks instead at activities and who are the senders and receivers of information relating to that activity.

From this, the objective is to be able to inform model development not only of information requirements but also who are the actors that require that information. In terms of model architectures, this enables a clearer vision of how model should be developed (both at the information exchange/sharing and application software development levels)

The process model in this case is developed as a set of matrices that have the primary axes of actor and activity. The matrices are developed according to the project stages as set out in the Generic Process Protocol. Other elements of the Protocol are not fully incorporated into the matrix.

The matrices are intended to provide a high level view of the primary processes undertaken by actors carrying out principal roles in a building construction project. In this sense, they do not provide a totally detailed view.

4.1 Actor Roles

There are many roles that can be fulfilled by actors in building construction. All roles have to participate in the communication that is vital to the successful completion of a project. It is not possible to account for all of the possible roles that could exist within the matrices. Therefore, a subset of the possible roles has been defined based on major functional characteristics.

The roles that have been used are:

Actor	***Description***
Client	All activities of the actor that commissions and ultimately pays for the project together with the activities of the building owner and operator who may be different to the commissioning organisation.
Project Management	All activities concerned with management of the project. Whilst there may be a single designated Project Manager, it is likely that several actors may undertake project management roles at various levels and for various purposes.
Building Design	All activities that relate to the functional and aesthetic design of a project. This can include the traditional architectural role, landscape design, interior design as well as the design detailing role that may be undertaken by actors that otherwise fulfil a more traditional contractual role (depending on the type of contract executed and the point at which the actor is engaged).
Cost Management	All actors that play a role in managing cost. In the United Kingdom, the quantity surveyor is a discipline that specialises in this area but this designation is geographically limited. Additionally, other actors may have specific roles to play in cost management. For instance, services and structural designers may need to determine the extent of work done by a specialist contractor to facilitate payment.
C&S Design	The design of all elements that are concerned with the structural integrity of a project together with excavation, roads, large scale waste and drainage etc. It also encompasses specialist activities that may be related such as geology.
Services Design	The design of all active systems in a project that provide environmental conditioning. It is a wide designation that includes all mechanical, electrical and public health services together with specialist activities that may be related such as lighting, acoustics and building automation.
Contractor	The lead role in the construction works. It also encompasses the management of sub-contract activities and is exclusively concerned with the translation of the design into a physical reality.
Sub-Contractor	All specialised construction activities that are undertaken in support of the contractor. There are many actors in a project who will fulfil this role. Sub-contractors will typically execute a set of particular design requirements (mechanical, electrical, public health, piling, steelwork etc.)

Actor	*Description*
Sub-Sub-Contractor	All construction activities that are undertaken in support of a particular sub-contract requirement. There are many actors in a project who will fulfil this role including painting, joinery, insulation, ductwork manufacture and installation etc.
Supplier	All actors that supply goods and materials to the project. A supplier may also act as a contractor, sub-contractor or sub-sub-contractor.
Statutory Body	All organisations that provide primary services to a project (water, electricity, gas etc.) or that play a role in determining satisfactory design, construction and operation of the project (fire services, building regulations, health and safety etc.). The concept of statutory body also encompasses the idea of organisations that supply primary services in a deregulated environment.
Other	All other roles not specifically identified.

Table 8: Actor Roles Definition

4.2 Activities

The matrices are divided according to the stages of the project identified in [GCPP]. At each stage, a number of activities are identified. These are sorted into different major groups.

Within the matrices, activities are not related to each other in terms of time or sequence. This is not their purpose; other process modelling methods are more appropriate for this and are intended to be used for more detailed analysis.

4.3 Information Sender and Receiver

The matrices are developed using a simplified approach identifying potential senders and receivers of information for each identified task. It is based on the CRUD matrix technique described elsewhere in this report.

A potential sender of information is identified in the matrix by the letter ‘o’ whilst a potential receiver of information is identified by the letter ‘x’. For certain tasks, an actor may be both a potential sender and receiver of information. This case is identified by the letter combination ‘ox’. The ‘ox’ designation is used in place of breaking the task down further (which should in fact occur in a fully detailed model) as this would cause the matrices to grow to an unacceptable size.

Note that the ideas of whether information at a particular point is initial, updated, revised or finalised contained within the Generic Process Protocol are not within the scope of this report.

4.4 Information Flow Matrices

The information flow matrices are shown in Appendix A.

4.5 Diagramming the Information Flow Matrices

Diagrams that expand the information flow matrices are not developed within this report. However an approach has been developed for detailed model devepment within the ISTforCE project that is based on a modified form of the two dimensional technique of the Generic Process Protocol. This is described below.

- 'Swim lanes' are provided for both the stage or sequence in the project and for the actor role being undertaken.
- Each role has two swim lanes, one in the activity window where all activities are drawn, and the second in the communication window in which information flow lines originate or terminate.
- Each activity (or process) is named as for other process modelling techniques such as IDEF0.
- Information flow lines are annotated with either a circle (representing the –o- in the information flow matrices) at each role from which information originates or an arrow (representing the –x- in the information flow matrices). An information flow line represents *collaboration* between participants.
- An information flow line shown with an filled circle or arrow is used to identify a flow that occurs directly between actors.
- An information flow line shown with an unfilled circle or arrow is used to identify a flow that occurs through an Internet based information service (the service being implied rather than being shown as a separate role).
- Information flow lines can also be annotated with the data that flows along it.
- Further adornments can be added to the information flow lines to show the medium for communication (document, drawing etc.). In examples of using the Generic Process Protocol approach, graphical icons have been used for this purpose. Adornments of this nature represent *stereotypes* of the communication form.
- Within the actor role swim lane, specialist roles can be nested to identify internal communications. Alternatively, and particularly if the specialist role is external to the principal role, it should be identified as a separate swim lane.

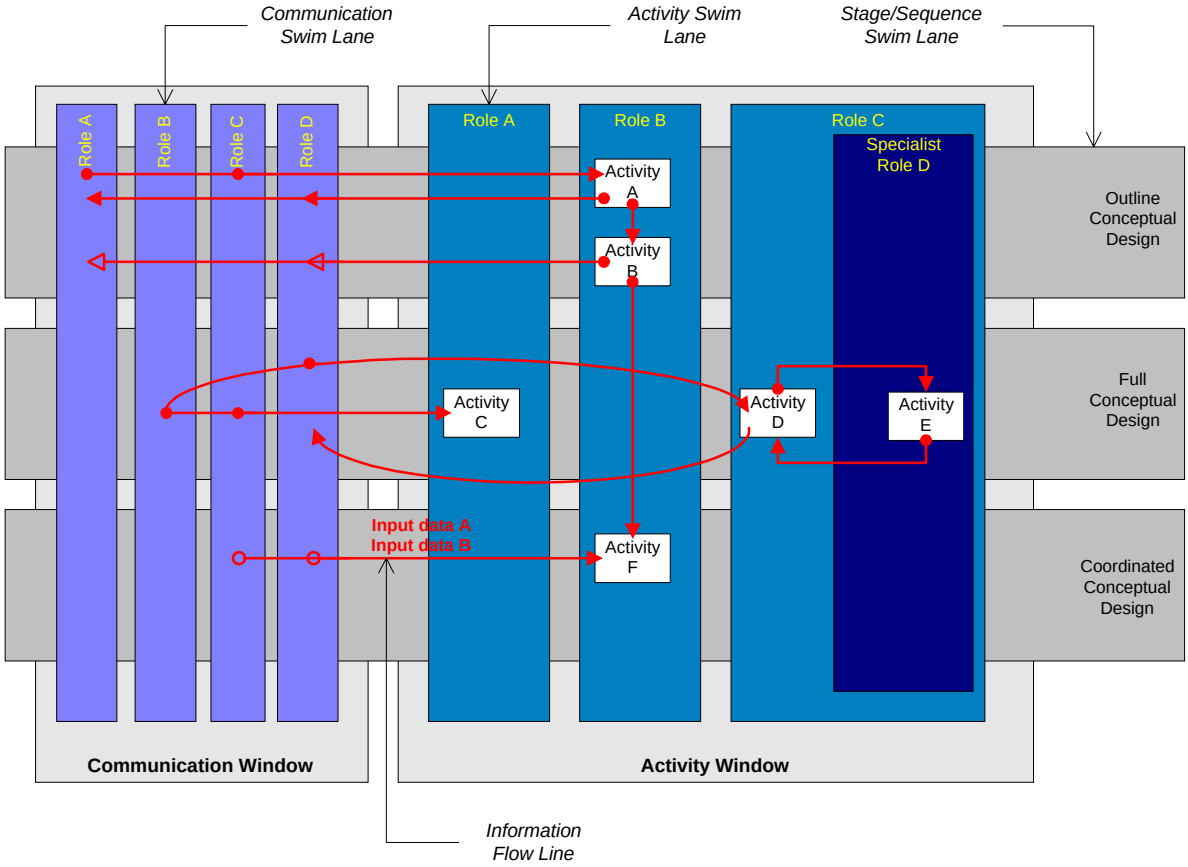


Figure 5 : Information Flow Matrix Diagram

4.5.1 Decomposition

It is possible to create a single diagram describing a complete information flow using this process. Alternatively, it is possible to decompose the diagram to provide progressively more detail. Starting from a stage based diagram, the individual stages can be broken down to show the more detailed information flows.

The roles shown at each level of decomposition do not have to be the same. Therefore, it is more appropriate to add specialist roles at lower levels of decomposition than at the higher levels. The tunnel techniques used in IDEF0 could be adopted for this purpose e.g. using (*rolename*) to identify information that is not further elaborated in a child or decomposition diagram and using)*rolename*(to identify information that is elaborated in a child or decomposition diagram but is not shown in a parent or composition diagram.

As more decomposition is added, the level of detail within particular processes becomes clearer and the focus on the actual exchange of information becomes clearer.

5 Matrix Analysis

5.1 Information Form (Document Type)

In [CONDOR], information is considered to be contained in documents. Two ways of looking at documents were defined, namely by category and by type. Generally, these are considered to be relevant to information generally with additions and modifications as identified below.

5.1.1 Information Category Classification

Categories determine major groupings of information according to a designation of the role of its usage.

CONDOR Name	***ISTforCE Name***	***Broad Definition***
Archive	Archive	Information that is stored for later reuse.
Commercial	Commercial	Information that is primarily concerned with commercial relationships and activities.
Contractual	Contractual	Information that relates to the operation of a contract
Financial	Financial	Information that has cost implication.
	Technical	Information that fulfils a primarily technical function.

Table 9: Information Category Classification

5.1.2 Information Type Classification

Types determine the nature of the information and/or its delivery mechanism.

CONDOR Name	***ISTforCE Name***	***Broad Definition***
Approvals	Approval	Request and/or authorisation to undertake an action or indicated satisfaction with an action undertaken.
	Cost Plan	Information concerning the cost of items at particular stages within a building construction project.
Library	External Reference	Reference to information that is available from an external, third party source.
	List	An ordered collection of items with each item being of the same structure (defects list, inventory etc.).
Letters	Mail	Formal, recorded communications including letters and email. This type is also extended to cover voicemail and other recorded telephone conversations however that record may be made.
Instructions	Order	An instruction to carry out an action.
	Payment	Requests, authorisation of execution of payment for goods and services provided.
Reports	Document	Information presented in a structured manner other than as described in one of the other type classifications.
	Schedule	Information that indicates the occurrence of actions over a period of time.
Drawings	Co-ordination	Geometric models, drawings, outlines, sketches and other pictorial designations (other than photographs).
	Standards, Codes and Regulations	Regulatory and statutory information that constrains actions.

Table 10 : Information Type Classification

Information may be classified as being either:

- **POINT** information, that is of one category and one type. The nature of this form of information is similar to conventional transaction based documents such as quotations, orders, invoices, etc.
- **BROAD** information, that is of more than one category and/or type. The nature of this form of information is similar to conventional drawing based exchanges.

5.2 Enterprise Model

The Enterprise Model sets out a global view of processes within a building construction project and separates them into a series of functional views. The primary parts of the model are the requirements, initially identified and ultimately satisfied together with the strategy of the client to achieve the transition from identification to satisfaction.

Within the box that is defined by these primary parts, processes are defined as being either core or support. The core processes are those concerned with the specialized aspects of developing a building construction project (including the design and construction processes associated with architectural, engineering and construction roles). Support processes are essentially concerned with providing the administration and management support to these specialized roles.

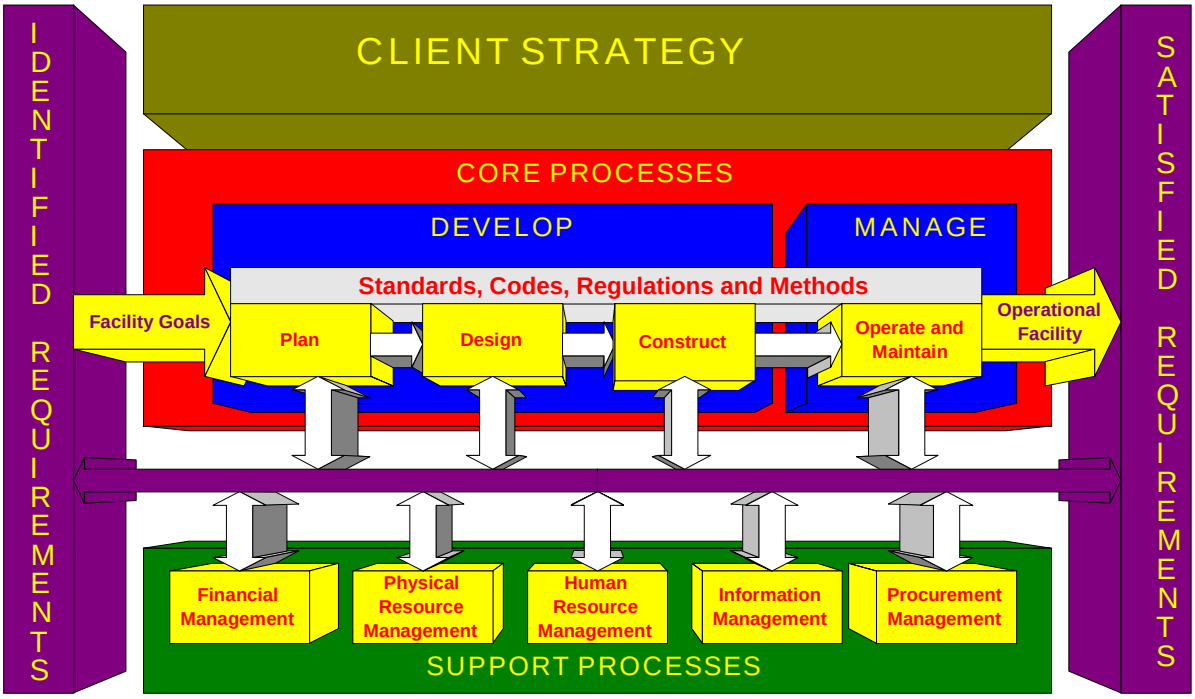
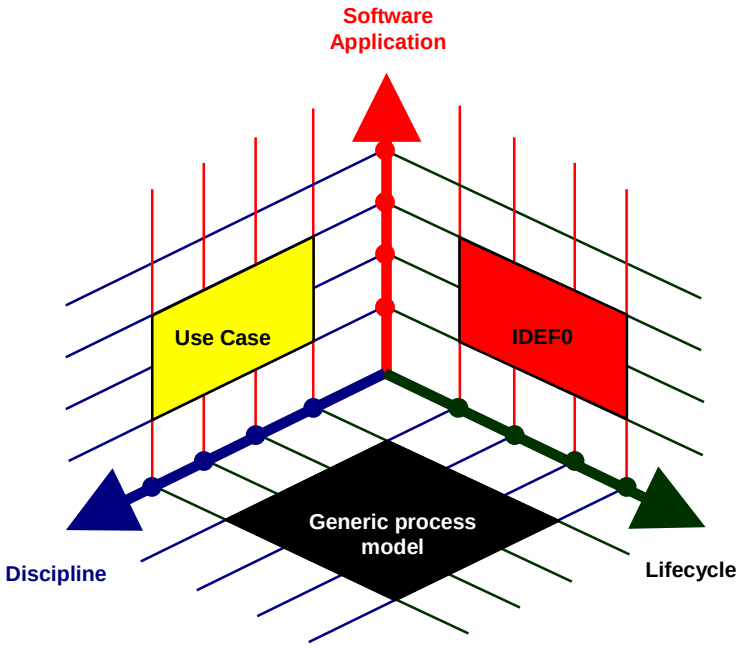


Figure 6 : Enterprise Model

5.3 Process Axes

In building construction, there are several axes that have to be considered in the development of process models. The key axes may be considered to be disciplinary (focussing on the roles of actors engaged in the process), lifecycle (focussing on the point within a project at which a process is occurring) and software application (focussing on the nature of the information that is required, developed or provided by the process).



In practice, notations developed for process modelling to date do not fully satisfy the full range of requirements set by these axes. However, from the graph above, it is possible to map the capabilities of these notations to determine the extent to which they do satisfy requirements.

However, each notation does actually meet the requirements of more than one axis. For the key notations considered, it was observed that in fact each notation met well the requirements of two axes as follows:

- Generic Process Model [GPP] (Lifecycle and Discipline)
- IDEF0 (Lifecycle and Software)
- Use Case (Discipline and Software)

Figure 7 : Process Axes

From this, it can be concluded that
1. each notation can be used to fulfil a different purpose
2. each purpose is relevant to the development of a complete process model
3. a process architecture can be developed that utilises the strengths of each notation and overcomes their weaknesses

5.4 Process Architecture

The Enterprise model and consideration of the process axes gives rise to a layered process architecture that is symmetrical with the layered architecture of the IFC Object Model. Each layer within the architecture defines the form in which processes should be developed.

The **kernel layer** defines the major processes and the interrelationships between these processes. It is particularly useful in the overall identification of business processes and in their improvement and reengineering. It is appropriately defined using an approach based on GCPP.

The **functional layer** extends the major processes in the kernel layer and identifies their individual functions and the information input and an output requirement of those functions in general terms. It is appropriately defined using the IDEF0 approach.

The **usage layer** extends the functions identified within the functional layer. It takes the information requirements defined and breaks them down further into specifically identified items of information. It also identifies more specifically the actors involved in each information transaction (extending the concept of actor to any external influence on a system including databases and other software applications). It is appropriately defined using the Use Case approach.

The **resource layer** extends processes that are of a general nature. Other processes at the functional and usage layers can call them. It is appropriately defined using the Use Case approach.

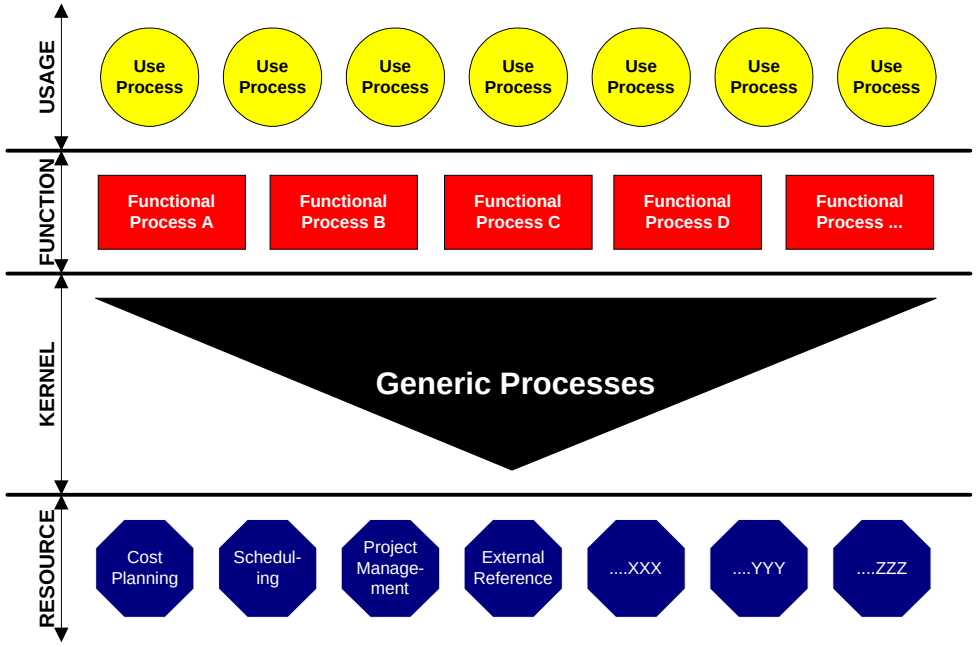


Figure 8 : Process Architecture

5.4.1 Process Architecture Rules

Rules should be applied to the ability of one process to call upon and use the services of another process. These may be defined as:

- The kernel layer defines the generic processes and their principal relationships. It identifies all of the processes that are extended by the functional layer and the resource layer.
- The functional layer can call processes that are defined in the resource layer and other processes that are defined in the functional layer but cannot reference processes within the kernel layer.
- The usage layer can call processes that are defined in the resource layer and other processes that are defined in the usage layer but cannot reference processes defined in the kernel and functional layers.

5.5 Process Decomposition

Within building construction, many processes are cyclical in that they have the same flow of information throughout the various phases of a project but at each stage, the available information becomes more detailed. This enables progressively increased accuracy in the outcome of the process. An example of this can be seen from the development of the process model for cost planning defined within the IAI Cost Planning project [IAI-ES2]. The introduction to the usage scenario for the model states that:

'As more information becomes available, objects can be decomposed and more detailed cost plans provided. The process of developing a cost plan for each cost planning stage has been analyzed and found to be essentially the same. Therefore, a generic process has been defined which can be applied at each cost planning stage. The difference at each stage is how objects are decomposed and how costs and cost modifiers are applied.'

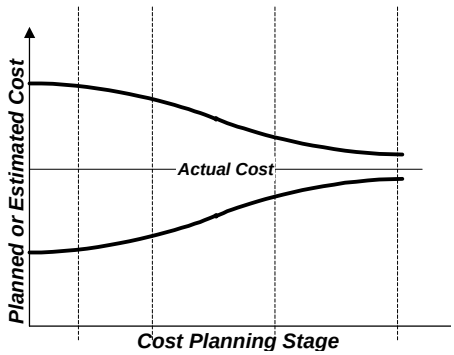


Figure 9 : Cost Accuracy Envelope

For costing therefore, an envelope can be defined that shows how accuracy increases as more information becomes available at each stage. This shows that the tolerance around the resulting actual cost progressively decreases.

The same principle has been seen to apply to the process of developing construction specifications and can also be seen to apply to design processes.

5.5.1 Process and Object Decomposition

The key aspect to the development of cyclic process models is the state of development of objects at different stages. As the objects decompose into more detailed objects that capture more information, so greater accuracy becomes possible.

Typically, at each stage of a cyclic process, the level of detail relates to particular object decomposition levels. These can be characterised as:

- Whole building level
- Spatial level
- Element level (e.g. wall, door, window etc.)
- Element type level (e.g. single skin wall, cavity wall etc.)

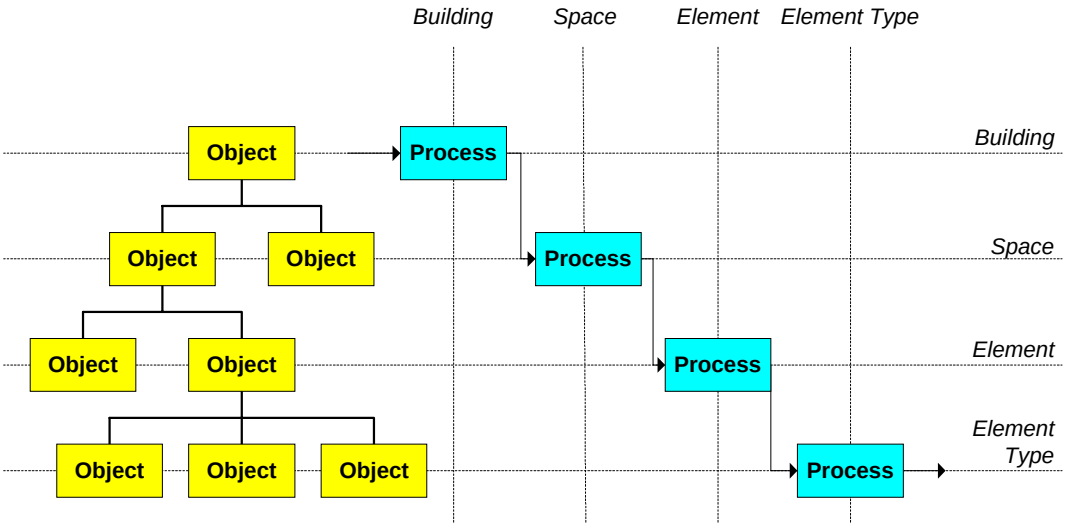


Figure 10 : Cyclic Processes and Object Decomposition

From the object viewpoint, the levels are equivalent to different subtypes of the IfcElement class within the IFC Object Model.

It should be noted however that not every process being undertaken within a building construction project need be, or will be at the same level of object decomposition concurrently.

6 Interface Analysis

6.1 Direct/Indirect Communication Through A Process Model

Conventionally, a process model seeks to identify the output of an activity that can be used as the input to another activity or as a deliverable from the entire process. It will also usually try to identify the actor(s) involved in a process so as to drive the communication of that information. This is the basis upon which the matrices in this report are developed.

For an overall process model of building construction (at whatever level of detail) it is virtually impossible to identify every discrete 'information transaction' that will occur or the precise participants in the project who will be involved in the transaction. Whilst this could be done on an individual project through the completion of a detailed schedule, even here it can be difficult.

The inability to target precisely which information goes to whom and when on a building construction project is a principal cause for project costs to exceed expectations and for claims for delay and liquidated damages to occur. Many studies over a long period of have looked at the extent of this cost overrun and virtually all of them arrive at a figure of between 15% and 20% of total project cost.

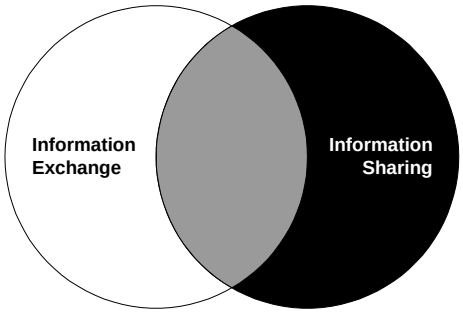
This provides one of the reasons for the rapid growth of interest in Internet based information management systems for the building construction industry. Here, the information can made available by the sender to all other project participants that have an interest in receiving it. It becomes their responsibility to retrieve rather than being the responsibility of the sender to provide it.

An Internet based information management systems acts as another actor in the building construction process. However, in terms of the direction of communication shown in a process model, it has a strange impact. Effectively, it is a sender of information. However, in practice, it does this on receipt of a request to do so from other actors. When showing an Internet based system as an actor in the process model therefore, requests from other actors to it for downloading information are implied and not shown.

In a detailed process model developed according to the ISTforCE extension, the implied request could be accommodated by indicating the receipt of information by using a symbol other than an arrow (e.g. use of a square at the point of receipt).

6.2 Shared and Exchanged Information

Two scenarios for information communication can be identified from the process model. These can be identified as information sharing and information exchange.



Information exchange can be described as essentially a single transaction for a specific purpose. There is a distinct sender and a distinct receiver of the information. The transaction is one way and usually fulfils a particular business purpose in its own right. Typically, an information exchange is best served through the transmission of a file.

Information sharing can be described as essentially a traffic of information flowing between sender(s) and receiver(s) where the same information set may be added to and amended progressively. Two way communication is established amongst all members of a sender/receiver group and the communication usually fulfils a project based purpose. Typically, information sharing is best served through the use of a project database.

Figure 11 : Information Exchange/Sharing

These are very sweeping descriptions and, in practice, there is a large overlap between information exchange and information sharing. An important aspect is that a information from a file that has been 'exchanged' should be able to be incorporated into the project database and become available for sharing.

6.3 Exchange and Sharing Scenarios

The following table presents a table of exchange and sharing scenarios. Each scenario is categorised according to the information type classification outlined in table XXX. The table develops further the summary of data exchange scenarios presented in the VEGA project [VEGA D501a].

Usage	***Information type***	***Share/exchange***	***Form of Information***
Unstructured information	Mail	exchange	Mail, letters.
Structured information in documents	Document	exchange	Contracts, specifications, reports, brief, strategy.
Project plans and schedules	Schedule	share	Project plans and schedules, design schedules, delivery schedules, maintenance plans and schedules etc.
Cost plan information	Cost plan	exchange	Bills of quantities, schedules of rates.
Business information	Order Payment Approval	exchange	Product orders, delivery notes, invoices etc.
Project management	Order Payment Approval	exchange/share	Work orders, project costs, approvals.
Information from external data sources	External reference Standards, Codes and Regulations	exchange	Product data, standards, codes, regulations, design data.
Item by item lists of information	List	exchange	Defects lists, commissioning, inventories, histories.
Updating of design models	Shape Representation	share	Design details at each project stage.
Co-ordination	Shape Representation	share	Spatial co-ordination, functional co-ordination.
Hand-over of as built design information	Shape Representation Document	exchange	Operating and maintenance records

Table 11 : Information Sharing/Exchange Scenarios

6.4 Current Model Coverage

Within industry and standardisation efforts such as ISO STEP, CIMsteel and IAI, there are a number of scenarios that are supported to a greater or lesser extent. At present, there is no integration between these efforts. However, it is to be expected that these will progressively come together over time.

Scenarios currently defined within these efforts include:

- STEP
  - Explicit shape representation (standard defined as ISO 10303 Part 225)
  - 2 dimensional drawing data exchange (STEP CDS project in Germany and SCADEC project in Japan)
  - Furniture manufacture (FunSTEP project)
- CIMsteel
  - Structural steel frameworks
- IAI
  - *Current*

- HVAC ducting
- Fire compartmentation
- Space planning
- Cost estimating
- Work orders
- Scheduling
- Classification
- Externally referenced documents
- Externally referenced properties
- Asset recording and inventory
- Move management

- *Planned*
  - Reinforced concrete frameworks
  - Financial information in facilities management
  - Thermal load analysis
  - Codes and standards

6.5 Model Coverage Gap Analysis

Although a number of processes supporting particular business cases have already been defined, there are still many more that require definition before there can be said to be a reasonably complete coverage of building construction needs. Even for those that have been defined, there is a need for further work before they can be said to fully handle the information exchange/sharing needs of the business cases that they purport to represent.

In determining the major gaps in model coverage for the building construction industry, the current version of the IFC Model (IFC 2x[5]) has selected as a basis. The rationale for this selection is that the IFC Model:

- has the greatest scope and extent of models currently developed for the industry;
- is presently supported by leading commercial off the shelf packages including Architectural Desktop 2 (Autodesk), ArchiCAD (Graphisoft), AllPlan (Nemetschek), SMOG (Olaf Granlund) for Release 1.5.1, and will be supported by Visio Technical (Microsoft), Timberline and several others for Release 2.0;
- is developed as a Core Model concept specifically to support inter-role exchange and sharing of information;
- is extensively used as a baseline model for many research projects for building construction including EU supported projects including CONCUR, eCONSTRUCT, PROCURE, VEGA and others as well as being the target for the detailed scenario development in ISTforCE.

The gap analysis below? identifies areas of coverage required by information models. This is to concentrate attention more on the sharing/exchange requirements than on the particular interests of the role in a disciplinary context.

6.5.1 Co-ordination

The ability to define the geometry of elements is present within the IFC Model. However, the semantic definition of a number of elements that participate in co-ordination remains a fundamental requirement.

6.5.1.1 Spatial Co-ordination

For spatial co-ordination, the objective is to ensure that elements do not encroach upon the space allocated for another element. At the simplest level, this is clash checking where the element must not encroach on the actual physical space of another element. A more complex requirement is when an element must not encroach to within a zone set around another element. This requires the assignment of space around elements. It becomes more complex in the situation where some encroachment may be allowed (soft clashing).

Soft clashing in spatial co-ordination is distinguished from functional co-ordination as its requirements are concerned with spatial allocations and not the functional relationship between elements.

[5] Publicly issued at the IAI International meetings in London on October 27th 2000.

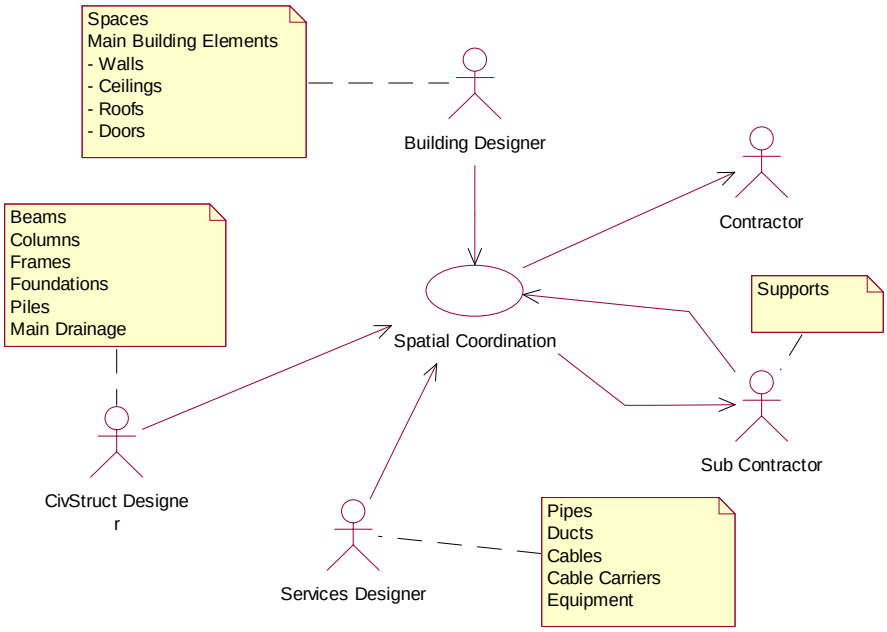


Figure 12 : Outline Use Case for Spatial Co-ordination

In particular, identification of the following additional types of classes to support spatial co-ordination is required:

- all forms of structural element (beams, columns, frames, foundations, piles etc.);
- electrical equipment (lighting, power outlets, distribution boards etc.);
- cabling;
- cable carriers (conduit, trunking, tray, ladder etc);
- additional piping and ducting including waste, drainage, rainwater, sewerage etc.;
- manholes, traps, etc.;
- communication outlets (voice and data outlets, PA);
- sensors and alarms.

6.5.1.2 Functional Co-ordination

Functional co-ordination requires most of the same classes as spatial co-ordination. However, it is more concerned with the functional relationships that exist between elements in a given set of circumstances. Additional information may be required to describe the functional relationship.

Functional co-ordination can cover a wide range of needs including (amongst others):

- limitations on the adjacency of types of space (e.g. plant room next to operating theatre);
- limitations on the adjacency of element to space (e.g. water pipe over book store or joint in water pipe over electrical enclosure);
- limitations on proximity of element types (restrictions on space between gas and electrical pipes, parts of beams through which pipes and ducts can pass).

Many of the functional co-ordination considerations are also closely related to development of support for standards, codes and regulations.

There will be a need for development of extensive classification support to distinguish classified object types for functional co-ordination. For instance, whilst space is a class, individual space objects will need to be classified according to their space type in order to meet the needs of functional co-ordination.

Functional co-ordination will not be achieved through the information model (this will be dealt with via applications or external rule bases). However, the information to support functional co-ordination can be provided.

6.5.1.3 Reflected Ceiling Plan

A reflected ceiling plan is a particular form of co-ordination which brings together all of the ceiling mounted objects in a space so that their configuration, construction and performance can be analysed.

It requires all of the elements that spatial co-ordination needs with the addition of:

- ceiling, ceiling tile, T-bar and T-bar support

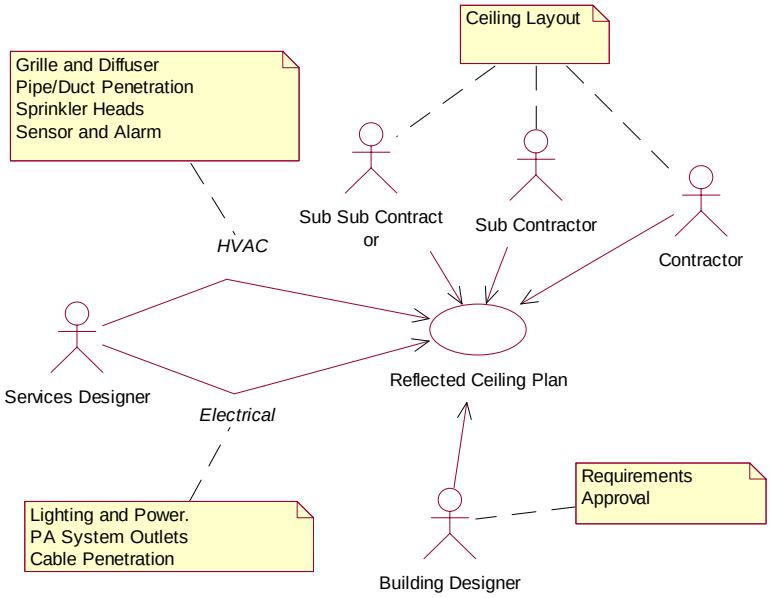


Figure 13 : Outline Use Case for Reflected Ceiling Plan

6.5.1.4 Builders Work

Builders work is defined as a form of co-ordination because it describes a relationship between elements. It is the relationship which is important since it defines how one element will be passed through or supported by another element. Typically, additional information will be required for the relationship. Examples include:

- provision of a sleeve and/or seal for a pipe or cable passing through a wall;
- provision of timber framing to a hole through which an air duct passes;
- provision of a base to support heavy plant items.

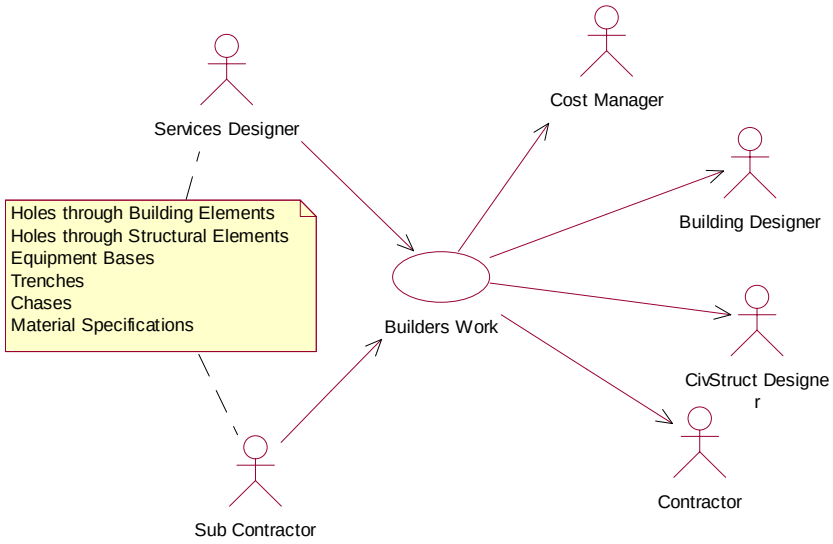


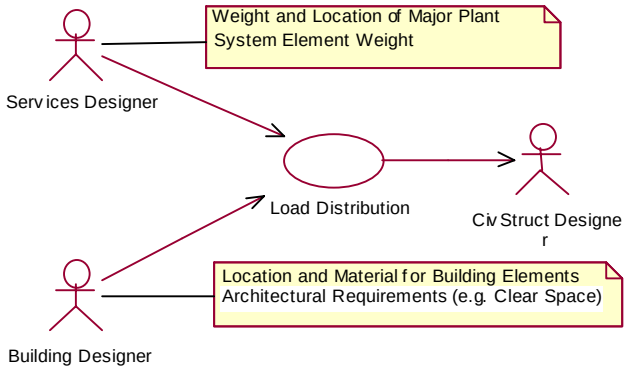
Figure 14 : Outline Use Case for Builders Work

The following requirements need to be met by an information model to support builders work:

- specialisation of element to element relationships to give builders work element types;
- possibility of features inclusion in the model as a particular specialisation of element to element relationships.

6.5.2 Civil/Structural

6.5.2.1 Load Distribution



Load distribution enables the structural engineer to be aware of the weight and configuration of elements in a building so that the structural solution can be determined.

Weight should be dealt with as a characteristic property since it may be required in multiple scenarios (e.g. shipping and operating weights needed for logistics and move management as already included in the IFC Model.

Additionally, any architectural requirements that may constrain the solution can be communicated.

Figure 15 : Outline Use Case for Load Distribution

6.5.2.2 Geotechnical

Geotechnical requirements covers the need for information concerning geology, soil conditions, seismic activity and other related factors that may affect the site and the design and construction of a building(s) on that site. Identification of geotechnical requirements can have a fundamental impact on the building through the definition of foundation and other structural requirements, building weight and other factors.

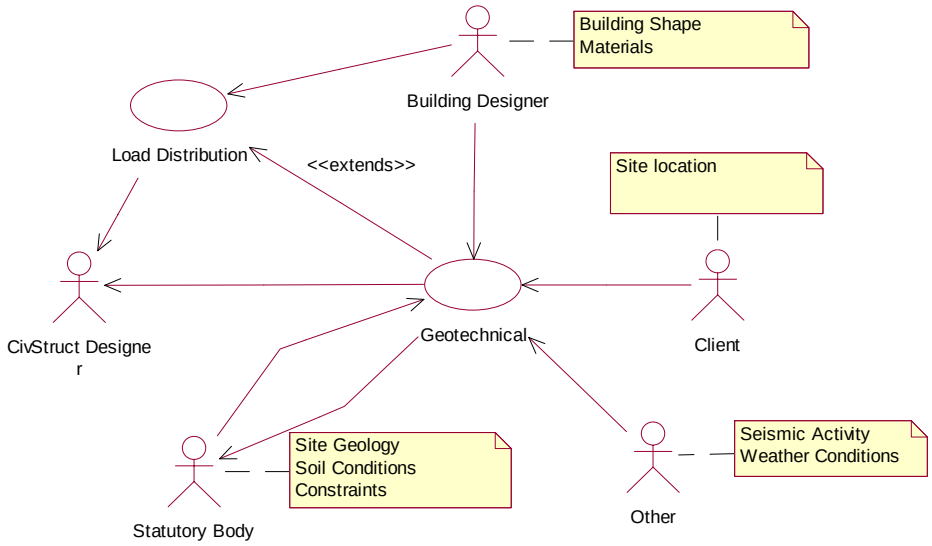


Figure 16 : Outline Use Case for Geotechnical Requirements

The following requirements need to be met by an information model to support geotechnical requirements:

- outline building shape and material usage intentions
- geology of the site
- soil conditions at the site
- constraints affecting construction in that type of soil
- seismic activity in the region
- weather conditions including historical weather records (flooding, wind speed, storm etc)

The Geotechnical Use Case extends the general Load Distribution Use Case

6.5.3 Services

6.5.3.1 Power Requirements

Power requirements are separated into temporary and permanent needs. Temporary needs include the power supplies that are required for tools, plant and equipment used during construction for which a temporary supply is required. Permanent needs include for the provision of all elements within a building that are electrically powered (fans, chillers, compressors, fan coil units etc.). Provision of power also has to take into account all loose equipment that requires power such as computers, copiers, etc.).

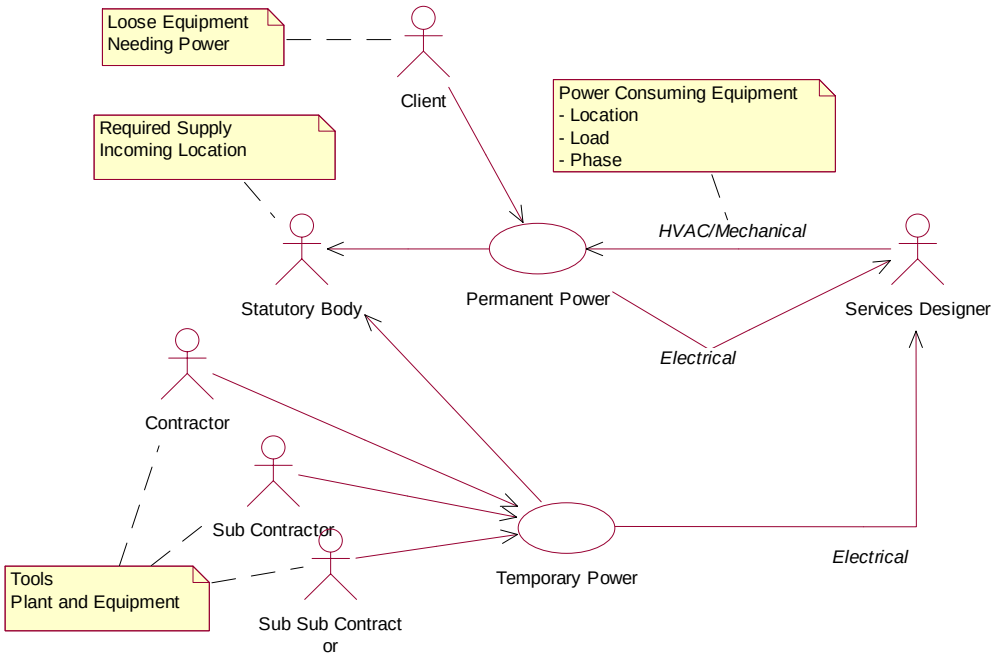


Figure 17 : Outline Use Case for Power Requirements

The following requirements need to be met by an information model to support power requirements:

- extension of electrical characteristics to provide more complete data (running current, starting current, power factor etc.);
- provision of electrical elements including starter, contactor, distribution board, power outlet, motor control centre, conductor, transformer, etc.;
- identity of phase in conductor.

6.5.3.2 Lighting

Lighting design requires knowledge of spaces and surfaces within a space. For daylighting, the impact of natural light entering through windows and skylights needs to be assessed. To establish the illumination levels and glare conditions required, information from the client about the tasks to be performed is necessary.

On completion of the lighting design, luminaires are selected and positioned by the services designer and switching arrangements determined. They are then installed, typically by the services sub-contractor. Luminaires and lamps require maintenance whilst in use.

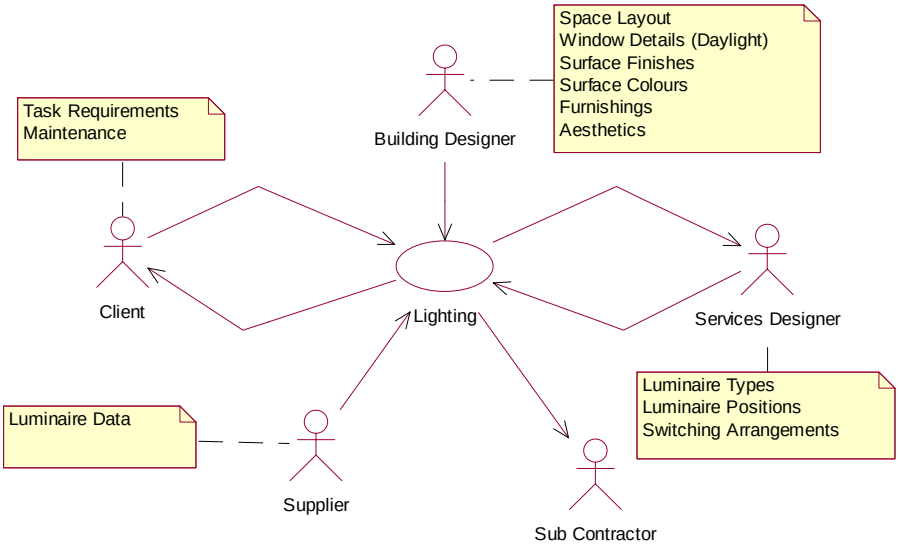


Figure 18 : Outline Use Case for Lighting Requirements

The following requirements need to be met by an information model to support lighting requirements:

- lighting design criteria including illumination level and glare indices
- daylighting factor requirements
- luminaire/lamp type requirements for aesthetic needs
- special factors affecting luminaire/lamp selection (colour temperature, utilisation, maintenance)
- switching requirements

6.5.3.3 Communications

Communications represents all the voice and data services that are used in a building. It may also be extended to cover alarm indication and annunciation as necessary that are also fundamental communication requirements.

Communications form part of the design and construction process as for other forms of functional design. They also have a significant role in building operation and particularly in the movement of people and equipment around a building or organisation. Whilst movement of people and furniture is currently accommodated by the IFC Model, movement of communication equipment and, more particularly, IT addresses is not.

The following requirements need to be met by an information model to support communication requirements:

- provision of outlet types for voice and data;
- provision of equipment types for communication;
- extension of cable types (from general electrical needs) to cover specific communication types;
- unique addressing of equipment and outlets;
- provision of alarms and annunciation equipment.

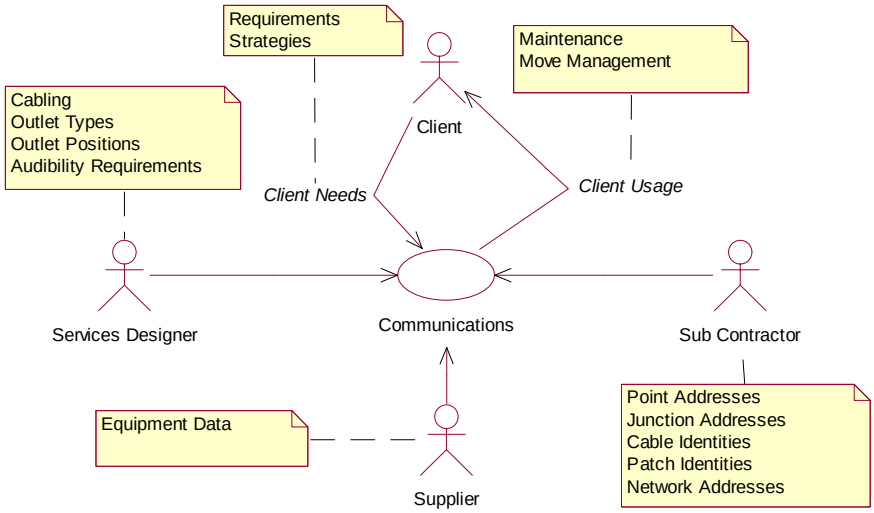


Figure 19 : Outline Use Case for Communications

6.5.4 Fire Precaution, Prevention and Action

Fire precaution, prevention and action brings together a wide range of needs that need to be communicated at all stages of the project. These include:

- Space layout and intended usage (for licensing requirements);
- Compartmentation and escape route identification (partially covered in the current IFC Model);
- Smoke and flame propagation;
- Fire extinguishing elements used, their location and capability;
- Safety measures incorporated in the event of a fire;
- Fire ground availability for fire service usage in the event of a fire.

There is a huge potential in the sharing of fire precaution/prevention information, not least being the ability of a fire service to gain direct access to a shared model when attending a fire to check for building configuration BEFORE committing personnel to action within a hazardous environment.

As well as classes that are required for communication of design and co-ordination information, there are additional classes and attributes that are required for fire prevention, precaution and action including:

- fire rating of elements;
- surface spread of flame characteristics;
- classification of space and other elements according to hazard;
- identification of escape route (topologically and by space);
- location, type and capability of loose fire extinguishing equipment;
- identification of hydrants and their capacity;
- signage;
- emergency lighting including back up power supply provision;
- designation of external space as the fireground in the event of a fire;
- alarm audibility characteristics.

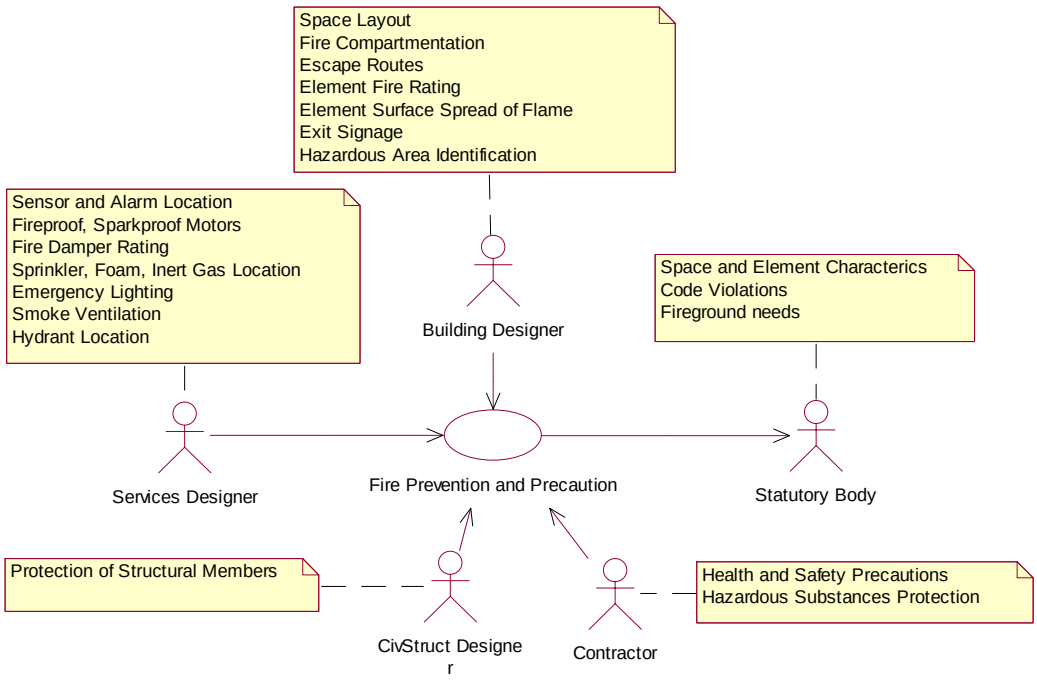


Figure 20 : Outline Use Case for Fire Precaution, Prevention and Action

6.5.5 Building Shape and Functional Design

6.5.5.1 Building Shape

Building Shape provides information from the building designer at each stage of the design that enables the other design roles to develop their solutions to the building needs and enables the cost manager to progressively develop the cost plan.

Provision of building shape is considered to be a cyclical process at each stage of the design. As more information develops and the building design becomes more refined, the increased information available allows the other design roles to progressively refine their own designs, improving the accuracy of load analysis and gaining greater accuracy with the location of their functional elements.

In this case, the building shape requirement has been extended to include not only shape, but also identification of elements and design requirements. The identification of elements and their attributes enables the progression of other design.

Inclusion of the project manager as a receiver of information also enables the progressive assessment of plans and schedules for the design and construction work to be developed.

The role of the client is that of approval that the building shape being proposed meets with the user and stakeholder requirements.

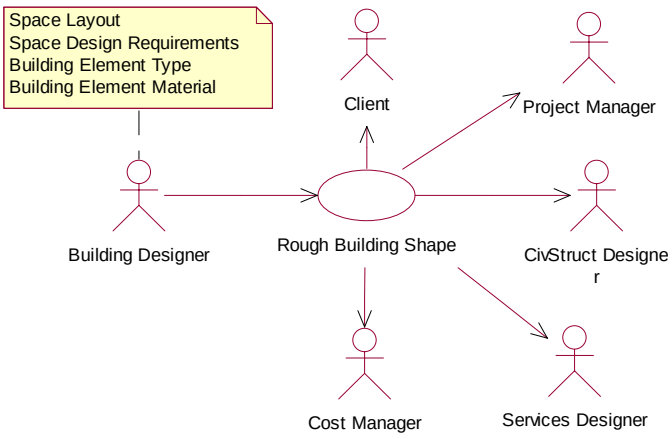


Figure 21 : Outline Use Case for Building Shape

6.5.5.2 Functional Design

The reverse role for building shape is that of functional design whereby the civil/structural, services and any other involved design roles communicate the results of their design work to the building designer, project manager, cost manager and client. Classes required for achieving the sharing/exchange of functional design information are broadly the same as those required for spatial and functional co-ordination.

This Use Case covers a broad spectrum of requirements and provides for the feedback of design information generally. It is possible to break out each use case individually in the same manner as for lighting and power requirements, load distribution and transportation. This is not done within this report as the number possible could grow to be very large.

6.5.6 Constraint Checking

Every actor in a building construction project is a ‘consumer’ of standards, codes and regulations. Virtually all design, construction and operating/maintenance process is subject to regulatory or organisational constraint in some form.

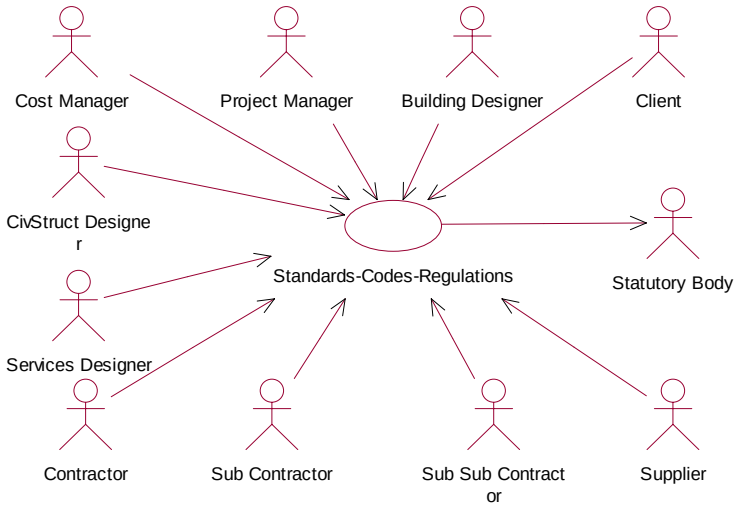


Figure 22 : Outline Use Case for Constraint Checking

An information model cannot, and should not, try to deal directly with conformance to constraints. These are best stored in an external rule base that can be consulted by an application to check for conformance. The information model should provide for the information that is required to enable the checking process to occur.

When considering constraint checking, it is best not to try to build in specific constraint mechanisms into something intended to be as generally applicable as the IFC Model. Apart from any other considerations, constraints tend to be regional or national in nature and not global. However, the information required to enable the checking of a particular type of constraint will typically be similar regardless of location (e.g. constraints required for disabled access to a building).

Constraint checking may be carried out against a single constraint or against multiple constraints concurrently. To a large extent, this will determine whether information is encoded using shared information mechanisms or e-Commerce type point to point communication.

For multiple constraint checking, the requirements of spatial coordination, functional coordination, building shape and functional design may apply depending on the constraints concerned.

6.5.7 Transportation

Transportation is considered to cover lifts (elevators), escalators, moving walkways and other powered conveyors and to include both electrically and hydraulically powered equipment. In most cases however, the primary interest will be lifts.

Transportation elements represent a significant cost element on a project and a significant amount of design and construction effort. It is vitally important to share information as early and as completely as possible for this requirement since the costs of remedial action as a result of something not occurring quite as planned may be very high.

There are many roles associated with the design and construction of transportation since, particularly for lifts, there are many needs including structural, electrical, HVAC and contractor services support as well as the need to meet the functional and aesthetic requirements of the client and building designer. Although not shown on the diagram for space reasons, the cost manager also plays a role in the development of transportation.

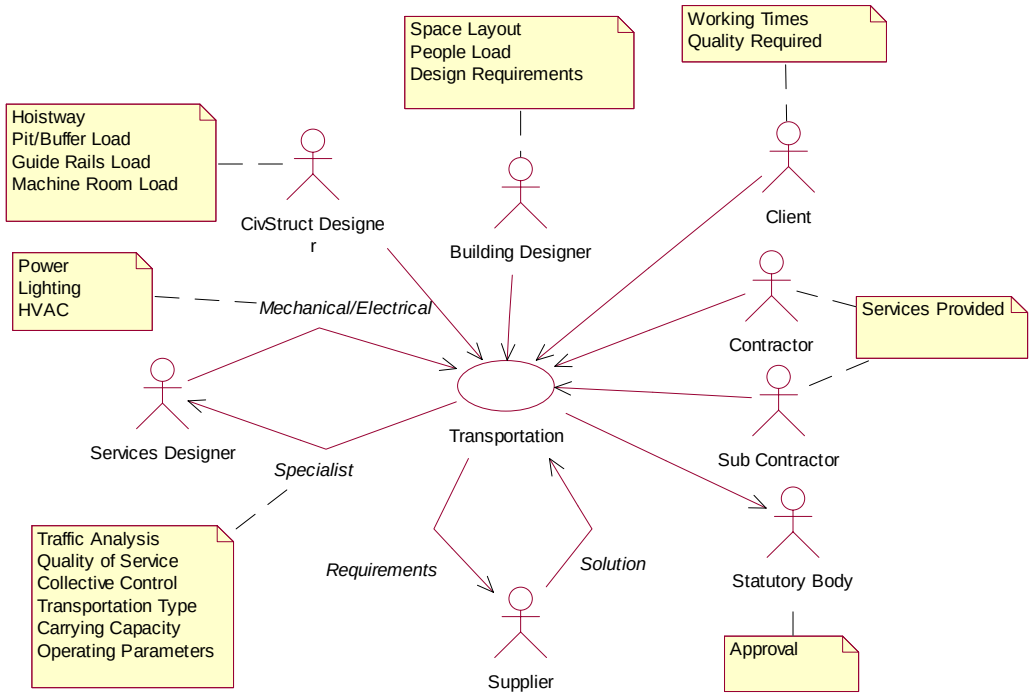


Figure 23 : Outline Use Case for Transportation

Presently, there is minimal coverage of the requirements for transportation within the IFC Model. Those that are provided deal with shape representation with some semantically significant classes. There is a substantial requirement for additional capability in the model to meet transportation needs including:

- Transportation element type (lift, escalator, moving walkway, conveyor)
- Hoistway and pit space identification
- Car and car components (door, panels, mirrors, cills)
- Operating panels
- Guides and shoes
- Buffers
- Collective control components
- Landing elements

Many of the requirements for other functional design needs (HVAC, electrical) and contractor services are met by other use cases presented in this section including spatial and functional co-ordination and builders work.

6.5.8 Information Representing e-Commerce Services

For e-Commerce services, communication is expected to be in the form of messages encoded in XML rather than in the form of ISO 10303 Part 21 files.

There are a number of information flow requirements that represent point to point contact but from which information has to be made available for inclusion into project database. Predominantly, these requirements fall under the information type classifications indicated below:

- information referenced from external data sources
  general requirements for communication of information referenced from external data sources are covered in the current IFC Model through the use of property definitions but there is a need for the specification of individual property sets that form the content of a communication
  - product data
    - product shape
    - product characteristics
    - product operating and maintenance data
    - product cost
  - design data
    - from design guides
    - from previous projects
  - cost data
    - previous project costs
    - labour allocations
    - indices for geography
    - indices for project type
- order
  - supplier
    - supplier orders
    - acknowledgements
    - delivery notes
  - project
    - project order
    - work order
    - change order
    - daywork
- payment
    - invoices
    - interim requests
    - final accounts
    - statements
    - remittances

- approval
  - appended authorisation
- list
  - punch/defects lists
  - commissioning schedules
  - inventories
  - design/construction/FM team
  - transmittal
- document
  the capability to reference a document is covered by the current IFC Model but there remains the need to specify structures for the communication of document types that are specific to building construction needs.
  - contract
  - specification
  - inspection
  - ad-hoc report
- schedule
  schedules are partially covered by the current IFC model but require extension
  - design schedule
  - project plan
  - project schedule
  - maintenance plan
  - maintenance schedule
  - commissioning schedule
- cost plan
  cost plans are partially covered by the current IFC model but require extension
  formulation of cost plans is frequently subject to regional or national requirements

6.6 Model Development Path

In [BAZ], the areas of greatest need for new model functionality are identified as:

- enable e-Commerce
- enable complex structural calculations
- enable electrical design and wiring
- enable civil engineering for buildings
- enable the use of 2-D CAD drawings

Items 1 and 5 in this list make sense in the context of sharing/exchange of information. However, items 2-4 appear to be more concerned with the traditional approach of developing role/disciplinary needs (as with STEP Application Protocols and previous IAI work) than with the inter-role needs identified in the gap analysis above.

However, the criteria that are set down for filling model development gaps are seen as valid. These criteria are:

- develop areas that will spur the development of other areas;
- develop areas that will bring interoperability to the largest number of existing industry software applications;
- develop model components that are likely to be implemented in “flagship” software (where flagship software are the major applications that are widely used in industry);

The requirements shown in the gap analysis are considered to fulfil the criteria shown above. The question then is the order in which these gap requirements should be developed bearing in mind the finite availability of cost and human resource to carry out the work.

Because the requirements identified are multi-role (by design), the key is the provision of classes that support the ‘business case’ of the requirement. It is not like a model that satisfies the needs of a particular role and a particular functionality within that role in which only a limited number of classes are defined. The objective is to define a wider range of classes but (perhaps) with less attributes.

Given that the IFC 2x Model now has a stable core that provides the basic structuring and supertyping required by most of the classe that can be envisaged, this is now seen to be a real possibility. This is supported by the development of e-commerce messages that can be used to ''seed and feed'' project databases.

The following is a suggestion of a possible roadmap for the requirements identified

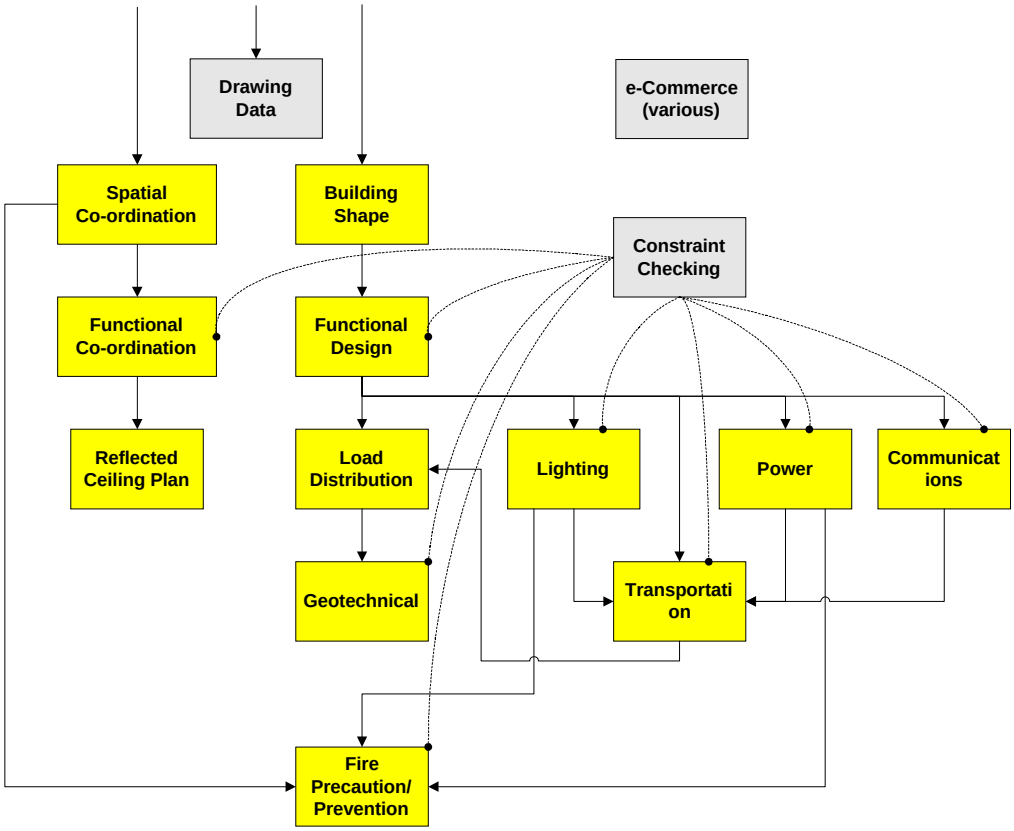


Figure 24 : Outline Developments Road Map

7 References

BACON	**Bacon M.** , *Aligning IAI and Industry: Taking Stock*, Presentation to the IAI International Council Meeting, Munich, October 1999
BAZ	**Bazjanac V.** , *Filling the Gaps*, IAI Technical Advisory Group, October 2000
BRECP	**Stevens R.F. and Monument L.** , *A Study Of Coding And Data Co-ordination For The Construction Industry: Structural Engineering Design*, Current Paper 5/69, Building Research Station, 1969 **Foster A., Webster J. and Johnston H.P.** , *A Study Of Coding And Data Co-ordination For The Construction Industry: Mechanical Engineering Services*, Current Paper 6/69, Building Research Station, 1969 **Johnston H.P.** , *A Study Of Coding And Data Co-ordination For The Construction Industry: Electrical Design And Contracting*, Current Paper 7/69, Building Research Station, 1969 **Farrar C.H. and Malthouse R.F.W.** , *A Study Of Coding And Data Co-ordination For The Construction Industry: Quantity Surveying, Product Manufacturing And Merchanting*, Current Paper 8/69, Building Research Station, 1969 **Britten J.R.** , *A Study Of Coding And Data Co-ordination For The Construction Industry: Contractors Management*, Current Paper 9/69, Building Research Station, 1969 **l'a Nelson J.** , *A Study Of Coding And Data Co-ordination For The Construction Industry: Instructions To Operatives*, Building Research Station, Current Paper 10/69, 1969
BRITE R1101UK	**van Rijn T. and Storer G.** , *Process Model for Industrial Partner Taylor Woodrow*, Deliverable R1101UK, Brite-EuRam BE 96-3016 CONCURrent Design and Engineering in Building and Civil Engineering, 1997
BSRIA TN9	**Wix J.** , *Information flow in building services*, Technical Note 9/86, Building Services Research and Information Association, 1986
CONDOR	**Bew M.** , *Kvaerner Construction Limited*, Deliverable D113, D121 & D122, ESPRIT 23105
CIMsteel 3	*CIMsteel Integration Standards Part 3: Activity Model*, University of Leeds, 1995
ELSEWISE VISION	*Recommendations for ICT vendors and developers in the large scale engineering industry*, Pamphlet, ESPRIT 20876 – ELSEWISE, 1998
ELSEWISE205	**Watson A.** , *Activity Models for LSE Projects*, Deliverable D205, ESPRIT 20876 – ELSEWISE, 1998
FPS183	*Function Definition Modelling Using IDEF0*, Federal Information Processing Standard 183, National Institute for Standards and Technology, 1993
GARM 1988	**Gielingh W.F.** , *General AEC Reference Model*, TNO Building and Construction Research, BI-88-150, October 1988
GPP GUIDE	**Kagioglou M. et al.** , *A Generic Guide to the Design and Construction Process Protocol*, University of Salford, 1998
GPP FINAL	**Kagioglou M. et al.** , *Process Protocol Final Report*, University of Salford, 1998
IAI-1	*An Introduction to the IAI and the Industry Foundation Classes*, International Alliance for Interoperability, 1999, www.iai.org.uk
IAI-CB2	*Client Briefing*, IAI Project Reference CB1, International Alliance for Interoperability, 1999
IAI-ES2	*Estimating: Cost Planning*, IAI Project Reference ES2, International Alliance for Interoperability, 1999
IAI-FM1	*Facilities Management: Maintenance*, IAI Project Reference FM1, International Alliance for Interoperability, 1999
IAI-ST2	*Structural Engineering: Reinforced Concrete Structures*, IAI Project Reference ST2, International Alliance for Interoperability, 2000
ICON1	**Aouad G. et al** , *Integrated Databases for the Design, Procurement and Management of Construction. Final Report*, University of Salford, July 1994

IFC2X	*IFC 2x Final Release*, International Alliance for Interoperability, October 2000, www.iai.org.uk
ISO11	*ISO 10303-11:1994, Industrial Automation Systems - Exchange of Product Model Data - Part 11: Implementation Methods; EXPRESS Language Reference Manual.*
ISO21	*ISO 10303-21:1994, Industrial Automation Systems - Exchange of Product Model Data - Part 21: Implementation Methods; Clear Text Encoding of the Data Structure.*
KHIV2	*King Henry IV Part 2*, William Shakespeare, 1598
LATHAM	**Latham M.** , *Constructing The Team*, HMSO, 1994
LUITEN 1994	**Luiten G.T.** , *Computer Aided Design for Construction in the Building Industry*, G.T. Luiten, 1994
NEDC 1990	**Wix J. and Cornick T.** , *Information Transfer in Building*, pp16-23, National Economic Development Office, 1990
NIDDESC E	*Electrical/Cableway Application Protocol Version 1.0*, Navy Industry Digital Data Exchange Standards Committee, 1993
NIDDESC P	*Piping Application Protocol Version 1.0*, Navy Industry Digital Data Exchange Standards Committee, 1993
PROCURE R1101b	**Heim A. and Csavajda C.** , *Corporate business processes*, Deliverable R1101b, ESPRIT 29948 – Information and Communication Technology (ICT) at Work for Large Scale Engineering PROCUREment Chain, 1999
PROCURE R1101b_FE	**Seren K. and Valikangas P.** , *Process Model for Industrial Partner Fortum Engineering*, Deliverable R1101b_FE, ESPRIT 29948 – Information and Communication Technology (ICT) at Work for Large Scale Engineering PROCUREment Chain, 1999
RIBA 1990	*RIBA Management Handbook*, RIBA Publications Ltd, 1990
SPEC	**Gelder J.** , *Specifying Buildings*, NATSPEC Pty Ltd, 1995
UML	*UML V1.3 alpha R5, Object Management Group,* www.omg.org *, March 1999*
UNICLASS	*Unified Classification for the Construction Industry*, RIBA Publications, 1997
VISMOD	**Quatrani T.** , *Visual Modeling with Rational Rose and UML*, Addison-Wesley, 1998
VEGA D103a	**Bakkeren W. et al** , *A Model of Workflow: Specification of a Model for the Definition of Workflows in Virtual LSE Enterprises*, Deliverable D103a, ESPRIT 20408 – VEGA, 1996
VEGA D501a	**Steinmann R.et al** , *End-Users Requirements*, Deliverable D501a, ESPRIT 20408 – VEGA, 1996

APPENDIX A INFORMATION FLOW MATRICES

Stage	Role ----> |----------| V Activity V	Client	Project Management	Building Design	Cost Management	C&S Design	Services Design	Contractor	Sub-Contractor	Sub-Sub-Contractor	Supplier	Statutory Body	Other	Notes
1	**Conception of Need**													
Background Information														
	Client Data	o	x											Background information from the client relating to the project
	Maps		x										o	Cartographic authority
	Site Plans	o	x	x		x	x						o	Client and site records
Lists														
	Stakeholder List	o	x	x	x	x	x	x	x					List of people having an interest/involvement in the project.
Strategy														
	Statement of Need	o	x	x	x	x	x							Project type, occupants, occupancy, occupancy standards, processes, actors, conditions, environmental limitations, other factors. The statement of need is periodically updated throughout the project.
	Business Case	o	x	x	x	x	x	x	x					
Standards, Codes and Regulations														
	Applicable Standards and Procedures	ox	ox	ox	ox	ox	ox	ox						Sets down the standards and procedures that are to be adopted throughout the project. Various statements in this regard may be required and these may be updated periodically throughout the project
Plans														
	Project Execution Plan	x	o	x	x	x	x							
	Process Execution Plan	x	o	x	x	x	x							
Briefs														
	Project Brief	o	x	x	x	x	x							Overall outline of objectives for the project including construction.
	Design Brief	o	x	x	x	x	x							Outline of design requirements for the project including architectural, structural, environmental.
Approvals														
	Request		o	o	o	o	o							Work submitted and approval requested
	Approve	o	ox	ox	ox	x	x					o		Approval given to work submitted. If approval is not given, further work needs to be done and resubmitted.

Stage	Role ----> |----------| V Activity V	Client	Project Management	Building Design	Cost Management	C&S Design	Services Design	Contractor	Sub-Contractor	Sub-Sub-Contractor	Supplier	Statutory Body	Other	Notes
2	**Outline Feasibility**													
	Internal Study Results	o	x											
	Rights			x									o	
	Outline Planning			o										Authorization from planning authority
	Local Cost Data				x								o	Materials and labour weightings
	Similar Project Costs				x								o	Unit costs from projects of a similar nature.
	Project Success Criteria	o	ox	x	x	x	x							Notification of success criteria to contractors on appointment
	Approvals													
	Request		o	o	o	o	o							Work submitted and approval requested
	Approve	o	ox	ox	ox	x	x					o		Approval given to work submitted. If approval is not given, further work needs to be done and resubmitted.

Stage	Role ----> |----------| V Activity V	Client	Project Management	Building Design	Cost Management	C&S Design	Services Design	Contractor	Sub-Contractor	Sub-Sub-Contractor	Supplier	Statutory Body	Other	Notes
3	**Substantive Feasibility**													
	Standards, Codes and Regulations													
	Planning and Regulatory Requests	o	o	o		o	o						x	
	Planning and Regulatory Authorizations	x	x	x		x	x						o	
	Strategy													
	Quality Assurance	x	ox	ox	ox	ox	ox							Quality assurance procedures relating to the project and also to organizations participating in the project.
	IT Strategy	x	ox	ox	ox	ox	ox							Standards and practices to be observed in the use of IT including drawing and layer conventions, data exchange, metadata, email usage etc.
	Document Control Procedures	x	ox	x	x	x	x							Document control procedures relating to the project and also to organizations participating in the project. Also relates to procedures for the use of Internet based project management and Extranet capabilities.
	Feasibility Design. Architecture		x	o	x	x	x							
	Floors (number and areas)	x	x	o										
	Elevations (areas of)													
	Feasibility Design. Structure		x	x		o								
	Geology					x							o	
	Sewers, Roadwork's etc.					x							o	
	Topography		x	x		o								
	Soils Investigation		x	x		o								
	Site Conditions		x	x		o								
	Adjacent Structures					x							o	
	Superstructure													
	Footprint (approximate plan shape and proportion)		x	x		ox								
	Types and magnitudes of load		x	x		o								
	Distribution of loads (area and concentrated)			x		o								
	Load cases (primary combinations of loads)			x		o								

Stage / Role ----> |----------| V Activity V	Client	Project Management	Building Design	Cost Management	C&S Design	Services Design	Contractor	Sub-Contractor	Sub-Sub-Contractor	Supplier	Statutory Body	Other	Notes
Gross vertical, horizontal loads and moments			x		o								
Foundations													
Overall loads & load patterns on ground (incl. adjacent buildings)		x	x		o								
Foundation type(s) pad/strip/piled/raft		x	x		o								
Feasibility Design. Services		x	x			o							
Available Statutory Services						x						o	Location and capacity of gas, water, power, communications, sewers etc.
Preliminary Loads (Loss/Gain)			x			o							Initial estimates of thermal loads to be met
Power Requirements			x			ox							Initial estimates of electrical loads to be met
Space Requirements			x			o							Initial estimates for plant, riser and distribution space
Lifecycle Costing	x					o							Initial estimate for lifecycle cost
Schedules													
Design Schedule	x	o	x	x	x	x							
Construction Schedule	x	o	x	x	x	x							
Procurement Plan	x	o	x	x	x	x							
Cost Plan. Feasibility	x	x		o									
Report Feasibility	x	o											
Approvals													
Request		o	o	o	o	o							Work submitted and approval requested
Approve	o	ox	ox	ox	x	x					o		Approval given to work submitted. If approval is not given, further work needs to be done and resubmitted.

Stage	Role ----> |----------| V Activity V	Client	Project Management	Building Design	Cost Management	C&S Design	Services Design	Contractor	Sub-Contractor	Sub-Sub-Contractor	Supplier	Statutory Body	Other	Notes
4	**Outline Conceptual Design**													
	Standards, Codes and Regulations													
	Statutory Assessment	o	o	o		o	o						x	Statutory requirements needing to be met.
	Building Regulations	x	x	x		x	x						o	Building regulations requirements needing to be met
	Strategy													
	Quality Assurance	x	ox	ox	ox	ox	ox							Quality assurance procedures relating to the project and also to organizations participating in the project.
	IT Strategy	x	ox	ox	ox	ox	ox							Standards and practices to be observed in the use of IT including drawing and layer conventions, data exchange, metadata, email usage etc.
	Document Control Procedures	x	ox	x	x	x	x							Document control procedures relating to the project and also to organizations participating in the project. Also relates to procedures for the use of Internet based project management and Extranet capabilities.
	Lists													
	Stakeholders List	o	x	x	x	x	x	x						List of people having an interest/involvement in the project.
	Design Team List	x	o	x	x	x	x	x						List of members of the design team. Periodically updated throughout the project.
	Outline Scheme Layout													
	Space requirements	x	x	o	x	x	x							Determination of space needs, affinities and adjacencies
	Space layout	x	x	o	x	x	x							Initial space layout to enable further design
	Outline Structure Design													
	Soils Investigation		x	x	x	o								
	Superstructure													
	Layout of main superstructure linear members (beams/columns)		x	x	x	o								
	Foundations													
	Layout of main foundation elements (pads, strips, pile groups, raft)		x	x	x	o								
	Structural Material Assumptions													
	Structural frame (steel, precast/in-situ concrete, timber)		x	x	x	o								

Stage	Role ----> |----------| V Activity V	Client	Project Management	Building Design	Cost Management	C&S Design	Services Design	Contractor	Sub-Contractor	Sub-Sub-Contractor	Supplier	Statutory Body	Other	Notes

	Decking (in-situ, steel trough & concrete, beam & block, hollow core etc)		x	x	x	o								
	Retaining structures. Walls (in-situ concrete, precast etc)		x	x	x	o								
Services Load Analysis														Evaluate spatial data
	Adjacent Structures			o			x					o	o	Assess impact of adjacent structures for shading, air movement
	Heat Loss													Area and volume, fabric types, temperatures
	Heat Gain													Area and volume, fabric types, temperatures, people load, equipment load, electrical load
	Lighting			x			o							Task definition, glare limitations
	Air Volumes			x			o							Ventilation requirements, crack length assessment
Outline Services Design														
	Existing Services Location						x					o	o	Number, size, location, capacity
	Systems Outline Design Information	x	x	x		x	o							Piped services, ducted services, power, lighting, internal waste and drainage and rainwater, control systems, voice and data, alarm systems, other services. Provisional size, location and route inc. terminals
	Plant Room Layout			x		x	o							Space requirement
	Vertical Transportation	ox	x	x		x	ox				ox			Traffic analysis, number of units, size, drive type, motor space, pit.
	Builders Work			x		x	o							Equipment weights; major holes, bases and trenches
	Plant and Equipment Needs						ox				ox			Preliminary catalogue, quotation
Schedules														
	Design Plan and Timetable		o	x	x	x	x	x						Schedule for completion of the design work
	Approximate Construction Times		x	x	x			o						Estimate of time to construct
	Approximate Procurement Plan													
Cost Plan. Outline			x		o									Estimate of cost to construct
Report and Agree Outline Design		x	o											
Approvals														
	Request		o	o	o	o	o				o			Work submitted and approval requested
	Approve	o	ox	ox	ox	x	x				x	o		Approval given to work submitted. If approval is not given, further work needs to be done and resubmitted.

Stage	Role ----> |----------| V Activity V	Client	Project Management	Building Design	Cost Management	C&S Design	Services Design	Contractor	Sub-Contractor	Sub-Sub-Contractor	Supplier	Statutory Body	Other	Notes
5	**Full Conceptual Design**													
	Standards, Codes and Regulations													
	Planning Application			o									x	Application for permission to proceed
	Local Authority Clarification					o							x	Clarification of issues relating to local planning and zoning requirements
	Building Regulations	x	x	x		x	x						o	Building regulations requirements needing to be met
	Statutory Clarification					ox							ox	Clarification of issues relating to statutory requirements
	Planning Consent		x	ox	x	x	x						o	Granting of permission to proceed
	Strategy	x	o	x	x	x	x							
	Quality Assurance	x	ox	ox	ox	ox	ox							Quality assurance procedures relating to the project and also to organizations participating in the project.
	IT Strategy	x	ox	ox	ox	ox	ox							Standards and practices to be observed in the use of IT including drawing and layer conventions, data exchange, metadata, email usage etc.
	Document Control Procedures	x	ox	x	x	x	x							Document control procedures relating to the project and also to organizations participating in the project. Also relates to procedures for the use of Internet based project management and Extranet capabilities.
	Design Plan and Timetable		o	x	x	x	x	x						
	Scheme Design. Architect													
	Compartmentation		x	o	x	x	x	x						
	Escape Route		x	o	x	x	x	x						
	Building Fabric		x	o	x	x	x	x						Material and construction
	Ceilings		x	o	x	x	x	x						
	Scheme Design. Structure		x	x		o								
	Meteorological Data					x							o	
	Materials Use and Quality	x	x	x		o								
	Soils Investigation	x	x	x		o								
	Size Main Structural Elements (Beam, Column, Slab)													
	Degree of composite action (beam>slab)			x		o	x							
	Member properties (stiffness etc)			x		o	x							
	Size Foundations			x		o	x							
	Size Reinforcement			x		o								

Stage	Role ----> |----------| V Activity V	Client	Project Management	Building Design	Cost Management	C&S Design	Services Design	Contractor	Sub-Contractor	Sub-Sub-Contractor	Supplier	Statutory Body	Other	Notes
	Structural Analysis													
	Superstructure: Loads		x	x		o								
	Superstructure: Resulting element forces/stresses		x	x		o								
	Superstructure: Load and force combinations		x	x		o								
	Superstructure: Permitted forces/stresses		x	x		o								
	Superstructure: Design (not detailing) of elements and necessary		x	x		o								
	Superstructure: Adjustment of superstructure layout		x	x		o								
	Superstructure: Resizing of elements		x	x		o								
	Foundations: Column loads (vertical, horizontal, moment) from superstructure analysis		x	x		o								
	Foundations: Design (not detailing) of elements (pads, pile groups/piles, raft etc).		x	x		o								
	Foundations: Resizing of elements		x	x		o								
	Retaining Structures: Ground properties		x	x		o								
	Retaining Structures: Ground loads (primarily horizontal ground pressures)		x	x		o								
	Retaining Structures: Design (not detailing) of retaining walls		x	x		o								
Services Load Analysis														
	Meteorological Data						x						o	
	Heat Loss			x			o							
	Heat Gain			x			o							
	Zones for Services	x	x	x		x	o							
	Lighting	x		x			o							Lighting source data
Scheme Design. All Services			x	x			o							
Stage	**Role ----> |----------| V Activity V**	Client	Project Management	Building Design	Cost Management	C&S Design	Services Design	Contractor	Sub-Contractor	Sub-Sub-Contractor	Supplier	Statutory Body	Other	**Notes**

	Systems Scheme Design Information	x	x	x	x	x	o							Piped services, ducted services, power, lighting, internal waste and drainage and rainwater, control systems, voice and data, alarm systems, other services. Size, location, route, weight, terminal position.
	Plant Room Layout			x		x	o							
	Vertical Transportation			x	x	x	ox				ox			
	Major Plant Location and Weight		x	x	x	o								
	Builders Work			x	x	x	o							
	Special Services			x	x	x	o							
Cost Plan. Concept Design														
	Estimate of Preliminaries		x		ox	o	o							
	Scheme Cost Plan		x	x	ox		o							
Conceptual Design		x	ox	o		o	o							
Approvals														
	Request		o	o	o	o	o				o			Work submitted and approval requested
	Approve	o	ox	ox	ox	x	x				x	o		Approval given to work submitted. If approval is not given, further work needs to be done and resubmitted.

Stage	Role ----> |----------| V Activity V	Client	Project Management	Building Design	Cost Management	C&S Design	Services Design	Contractor	Sub-Contractor	Sub-Sub-Contractor	Supplier	Statutory Body	Other	Notes
6	**Coordinated Design**													
	Standards, Codes and Regulations													
	Statutory Assessment	o	o	o		o	o						x	Statutory requirements needing to be met.
	Strategy	x	o	x	x	x	x							
	Quality Assurance	x	ox	ox	ox	ox	ox							Quality assurance procedures relating to the project and also to organizations participating in the project.
	IT Strategy	x	ox	ox	ox	ox	ox							Standards and practices to be observed in the use of IT including drawing and layer conventions, data exchange, metadata, email usage etc.
	Document Control Procedures	x	ox	x	x	x	x							Document control procedures relating to the project and also to organizations participating in the project. Also relates to procedures for the use of Internet based project management and Extranet capabilities.
	Detail Design. Architecture													
	Daylight		x	o	x	x	x	x						
	Furniture		x	o	x	x	x	x						
	Finishes		x	o	x	x	x	x						
	Detail Design. Structure		x	x	x	o	x	x						
	Materials Use and Quality	x	x	x		o								
	Soil Analysis	x	x	x		o								
	Structural Form	x	x	x		o								
	Superstructure Design													
	Connections in steel and timber frames	x	x	x		o	x							
	Reinforcement layout, sizing, shape, cover in concrete elements	x	x	x		o	x							
	Load Conditions					o								
	Foundation Design													
	Reinforcement layout, sizing, shape and cover	x	x	x		o	x							
	Retaining Structures													
	Reinforcement layout, sizing, shape and cover	x	x	x		o	x							
	External Services					o	x					x		

Stage	Role ----> |----------| V Activity V	Client	Project Management	Building Design	Cost Management	C&S Design	Services Design	Contractor	Sub-Contractor	Sub-Sub-Contractor	Supplier	Statutory Body	Other	Notes
	Building Regulations Check	x	x	x		o						x		
	Code Compliance					ox						x		
Services Simulation														
	Thermal	x	x				o							
	Lighting	x	x				o							
	Air Movement	x	x				o							
	Smoke Movement	x	x				o							
Detail Design. Services														
	Systems Detail Design Information	x	x	x	x	x	o							Piped services, ducted services, power, lighting, internal waste and drainage and rainwater, control systems, voice and data, alarm systems, other services.
	Plant Room Layout			x		x	o							
	Vertical Transportation	x	x	x		x	o							
	Builders Work		x	x	x	x	o							
	Special Services		x	x	x	x	o							
	Building Regulations Check						ox							
	Code Compliance						ox							
Coordination														
	Power to Plant						ox							
	Power Outlet Location			x		x	o							
	Services Terminal Location			x		x	o							
	Clash Detection			x		x	o							Services/services, services/structure, services/fabric, structure/structure, structure/fabric.
Schedules														
	Design Schedules		ox	ox	ox	ox	ox							Schedule for carrying out design work including schedules for particular roles.
Cost Plan. Coordinated Design														
	Intermediate Cost Checks		x	x	o	x	x	x						Periodic cost checks as design progresses. Contractor may be involved if known/nominated at this point.
	Detail Cost Plan		x	x	o	x	x	x						
Advice on Assembly				x				o						
Reconciliation/Coordination			o	x	x	x	x	x						
Coordinated Design		x	ox	o		o	o							
Approvals														
	Request		o	o	o	o	o				o			Work submitted and approval requested
	Approve	o	ox	ox	ox	x	x				x	o		Approval given to work submitted. If approval is not given, further work needs to be done and resubmitted.

Stage	Role ----> |----------| V Activity V	Client	Project Management	Building Design	Cost Management	C&S Design	Services Design	Contractor	Sub-Contractor	Sub-Sub-Contractor	Supplier	Statutory Body	Other	Notes
7	**Production Information**													
	Standards, Codes and Regulations													
	Statutory Assessment	o	o	o		o	o						x	Statutory requirements needing to be met.
	Qualification													
	Advertise for Bid	o	o					x	x	x	x			Place advertisement for organizations that wish to carry out work to respond.
	Prequalified Contractors List	o	o	x	x	x	x	x	x	x	x			Receive requests for qualification and all supporting financial, technical, contractual information. Examine information and accept organizations that meet criteria onto prequalified contractors list.
	Production Information Architectural													
	Specialist Quotations		x	x	x	x	x				o		o	Request and Provide
	Specifications		x	o	x									Information concerning materials and workmanship to be incorporated into bid documents.
	Schedules		x	o	x									Finishes, Doors, Windows, Ironmongery etc.
	Production Information. Structural													
	Specialist Quotations		x	x	x	o							o	Request and Provide
	Superstructure	x	x	x	x	o	x							
	Foundations	x	x	x	x	o	x							
	External Services	x	x	x	x	o	x							
	Builders Work													
	Specifications	x	x	x	x	o								Information concerning materials and workmanship to be incorporated into bid documents.
	Schedules	x	x	x	x	o								Bar Schedules, Steelwork Schedule
	Production Information. Services													
	Specialist Quotations		x				x						o	Request and Provide
	Systems Production Information	x	x	x	x	x	o							Piped services, ducted services, power, lighting, internal waste and drainage and rainwater, control systems, voice and data, alarm systems, other services. To include connectivity details, insulation, support, access, spacing, installation requirements, protection, finish etc.
	Plant Room Layout	x	x	x	x	x	o							
	Vertical Transportation	x	x	x	x	x	o							
	Builders Work		x	x	x	x	o							
	Special Services	x	x	x	x	x	o							

Stage	Role ----> |----------| V Activity V	Client	Project Management	Building Design	Cost Management	C&S Design	Services Design	Contractor	Sub-Contractor	Sub-Sub-Contractor	Supplier	Statutory Body	Other	Notes
	Specifications	x	x	x	x		o							Information concerning materials and workmanship to be incorporated into bid documents.
	Schedules	x	x	x	x		o							Valves, Air Handling Units, Heaters, Air Terminals, Chillers etc.
Coordination														
	Power to Plant						ox							Provision of electrical/hydraulic/pneumatic power to plant items taking into account required characteristics and load.
	Power Outlet Location	x	x	x			ox							Positioning of electrical power outlets, switches etc. and coordination with other services, structural and architectural requirements.
	Services Terminal Location	x	x	x			ox							Positioning of services terminal outlets and coordination with other services, structural and architectural requirements.
	Clash Detection	x	x	x		x	o							Services/services, services/structure, services/fabric, structure/structure, structure/fabric.
Schedules														
	Provisional Contract Schedule		x	x			o	x						The main schedule for outlining the time required for completion of the contract.
	Provisional Sub-Contract Schedule		x	x			o	ox	ox	x	x			Schedules that outline the time required for completion of sub-contracts. Sub-contract schedules may be nested into the contract schedule.
	Provisional Maintenance Plan	x	x	o		o	o							Planning of scheduled maintenance activity (determination of period between carrying out particular tasks)
	Provisional Procurement Plan	x	x	o	o	o	o							Planning of procurement to meet contract and sub-contract schedules and other related factors.
Cost Plan														
	Bills of Quantities		x	x	o	x	x	x	x					List of materials and quantities that will form the basis of a bid (where appropriate)
	Request Bid	o	o		o			ox	ox	x	x			Bid request issued to qualified organizations
	Receive Bid		x				x	ox	ox	o	o			Bid received from qualified organizations
Project Documents			x		o	o	o							
Project Documents			o					ox	ox	x	x			
Plant Requirements								o	x					
Order														
	Appoint Contractor	o	ox					x					x	Execution of contract to carry out construction
	Appoint Sub-Contractors	o	ox					ox	ox	x				Execution of contracts to carry out sub-contract works
	Appoint Suppliers	o	ox					ox	ox	ox	x			Execution of orders to predetermined suppliers (see also Supplier Information under the Construction stage).
Site and Survey Details			x			o		x						

Stage	Role ----> |----------| V Activity V	Client	Project Management	Building Design	Cost Management	C&S Design	Services Design	Contractor	Sub-Contractor	Sub-Sub-Contractor	Supplier	Statutory Body	Other	Notes
8	**Construction**													
	Pre-Construction													
	Requirements Schedule	x	x	x	x	x	x	ox	ox	ox	o			
	Site Layout	x	x	x	x	x	x	ox	x	x				
	Access and Infrastructure	x	x	x	x	x	x	ox	ox	x		ox		
	Plant and Equipment Procurement	x	x	x	x	x	x	ox	ox	ox	x			Ordering, delivering, invoicing and payment for plant and equipment required. (see also Supplier Information)
	Quality Assurance	x	ox	ox	ox	ox	ox	ox	ox	ox	o			Quality assurance procedures relating to the project and also to organizations participating in the project.
	Document Control Procedures	x	ox	x	x	x	x	ox	x	x	x			Document control procedures relating to the project and also to organizations participating in the project. Also relates to procedures for the use of Internet based project management and Extranet capabilities.
	Standards, Codes and Regulations													
	Building Regulations	x	x	x		x	x	ox	x			ox		
	Health and Safety Regulations	x	x	x	x	x	x	ox	x			ox		
	Local Regulations	x	x	x	x	x	x	x	x			ox		
	Lists													
	Construction Team	x	x	x	x	x	x	o	ox	x				Persons and organizations involved in construction.
	Design Team	x	o	x	x	x	x	x	x	x				Persons and organizations involved in design
	Stakeholder List	o	x	x	x	x	x	x	x	x				List of people having an interest/involvement in the project.
	Method of Construction		x			x		o						
	Information Issue													
	Revised Drawings	x	x	ox	x	ox	ox	x	x	x	x			Periodic revisions to drawings required as construction progresses.
	Modified Specification Notes	x	x	o	o	o	o	x	x	x	x			Periodic revisions to specification requirements as construction progresses.
	Notifications	ox	ox	ox	ox	ox	ox	ox	ox	ox	ox	ox		Notifications of work to be carried out including statutory notifications required.
	Meeting Notes	ox	ox	ox	ox	ox	ox	ox	ox	ox	ox			Notes of meetings held
	Supplier Information													
	Deliveries							x	x	x	o			Delivery information concerning supplied equipment.
	Supplier Invoices and Payment							o	o	o	x			Invoicing and payment of goods supplied.
	Test Certificates		x	x		x	x	x	x	x	o			Test certificates for goods supplied.
	Order													

Stage	Role ----> |----------| V Activity V	Client	Project Management	Building Design	Cost Management	C&S Design	Services Design	Contractor	Sub-Contractor	Sub-Sub-Contractor	Supplier	Statutory Body	Other	Notes
	Purchase Orders							o	o	o	x			Orders for the purchase of supplied equipment. This also includes requisitions for equipment that may be held in store by a contractor or sub-contractor acting as his/her own supplier
	Work Orders		o		x			x	x					Instructions to carry out work.
	Change Orders		o		x			x	x					Instructions to carry out a change to work already done
	Dayworks		o		x			x	x					Work to be undertaken on a time and materials basis which is to be measured after completion.
Financials														
	Financial Implications		x		o	x	x							Statement of any implications on the work that a current financial status may have, including implications of additional work requirements and extensions.
	Claims for Extension and Costs		x		x			o						Claims made for extensions in time in which to complete work and the costs that will result from such extension.
	Interim Applications		x		x			o						Periodic requests for payment for work done.
	Authorize Payment	x	o											Authorization for payments to be made.
	Payment	o						x	x					Execution of payment following authorization.
	Contract Financial Statement		x		o									Statement of costs relating to the contract.
	Sub-Contract Financial Statement		x		x		o							Statements of cost relating to sub-contracts.
Schedules														
	Contract Schedule		x		x			o						The main schedule for outlining the time required for completion of the contract.
	Sub-Contract Schedule		x		x		x	x	o					Schedules that outline the time required for completion of sub-contracts. Sub-contract schedules may be nested into the contract schedule.
	Handover Schedule	x	x	x	x	x	x	o	o	o				Schedule for handing over the work to the client.
	Maintenance Plan	x	x	x		x	x	o	o	o				Planning of scheduled maintenance activity (determination of period between carrying out particular tasks)
Approvals														
	Request		o	o	o	o	o	o	o	o	o			Work submitted and approval requested
	Approve	x	x	x	x	x	x	x	x			x		Approval given to work submitted. If approval is not given, further work needs to be done and resubmitted.
Inspect, Test and Commission														
	On Site Inspections		o	o		o	o	x	x	x	x			Certificates of inspections carried out on site.
	Off Site Inspections		o	o		o	o	x	x	x	x			Certificates of inspections carried out off site.
	Calibration			x		x	x	x	x	x			o	Certificates of calibration for instruments used in testing and commissioning.
	Tests		o	o		o	o	x	x	x	x			Certificates of tests carried out.

Stage	Role ----> |----------| V Activity V	Client	Project Management	Building Design	Cost Management	C&S Design	Services Design	Contractor	Sub-Contractor	Sub-Sub-Contractor	Supplier	Statutory Body	Other	Notes
	Commissioning Requirements	x	x				o	x	x	x				Schedule of requirements for commissioning work including expected results.
	Commissioning Results	x	x	x			x	x	o	o	o			Schedule of actual results of commissioning.
Records														
	Record Information	x	x	ox		ox	ox	o	o	o	o			Warranties, drawings, schedules
	Owners Manual, Data	x	x	ox		ox	ox	o	o	o	o			O&M manuals, maintenance plan, asset list, spares list, contact list, standard work orders
Lists														
	Defects Lists	o	o	o		o	o	x	x	x	x			Lists of remedial work to be carried out.
Final Account														
	Sub-Contractor	x	x		x	x	x	ox	ox	o				Final accounts of costs submitted by sub-contractors.
	Contractor	x	x		x			o						Final accounts of costs submitted by the contractor.
	Professional	x	o	o	o	o	o							Final account of costs submitted by professional organizations (the members of the design team).
	Make Payment	o	x	x	x	x	x	ox	ox	x				Payment of final accounts.

Stage	Role ----> |----------| V Activity V	Client	Project Management	Building Design	Cost Management	C&S Design	Services Design	Contractor	Sub-Contractor	Sub-Sub-Contractor	Supplier	Statutory Body	Other	Notes
9	**Operation and Maintenance**													
Lists														
	Assets	x	ox	ox		ox	ox	o	o					Assets installed/constructed for financial and maintenance purposes.
	Inventories	x	ox	ox		ox	ox	ox	ox	o	o			Equipment and facilities by individual item. There will be a number of different types of inventory required including space, furniture, equipment (various types), spares etc.
	Human Resources	o	x	x	x	x	x	x	x					People engaged in the facility
	Communications	x	ox				ox		o					Telephone, fax, email, network address
	Organization	o	x	x	x	x	x	x	x					Organization chart
	Assignments	o	x	x	x	x	x	x	x					Assignment of assets and equipment to people, spaces, organizational units etc.
	Emergency Contacts	x	ox	ox		ox	ox	ox	ox		ox	ox	ox	Points of contact in an emergency.
Schedules														
	Maintenance Plan	x						ox			o			Planning of scheduled maintenance activity (determination of period between carrying out particular tasks)
	Maintenance Schedule	x						ox			o			Scheduling of maintenance activity (assignment of tasks to a particular time)
	Other Plan													Planning of other scheduled activities including cleaning, decoration, etc.
	Other Schedules	x						ox			o			Scheduling of other activities including cleaning, decoration, shutdown etc.
	Calendars	o						ox			o			Indications of time that identify when events occur, resources are available etc.
Work Orders														
	Work Order Request	x						x					o	Request for work to be carried out in response to a particular situation (not otherwise covered by the provisions of scheduled maintenance).
	Work Order Issue	x						ox	x		x			Issue of order to carry out work
	Work Order Record	x						o						Records of maintenance work carried out.
	Permit To Work	o						x	x		x			Issue of permit to carry out work
Insurance														
	Inspect	x						ox					o	Details of insurance inspections undertaken.
	Test	x						ox					o	Details of tests carried out as required by insurance provisions.

Stage	Role ----> |----------| V Activity V	Client	Project Management	Building Design	Cost Management	C&S Design	Services Design	Contractor	Sub-Contractor	Sub-Sub-Contractor	Supplier	Statutory Body	Other	Notes
	Policies	ox											ox	Insurance policies in place.
Inspect														
	Records	x						o						Records of inspections carried out.
	Calibration	x						o						Records of instrument calibrations.
Maintenance Contract														
	Prequalified Contractors List	o	o					x						Receive requests for qualification and all supporting financial, technical, contractual information. Examine information and accept organizations that meet criteria onto prequalified contractors list.
	Maintenance Specification													Requirements for undertaking of a maintenance contract
	Request for Bid													Bid request issued to qualified organizations
	Receive Bid													Bid received from qualified organizations
	Appoint Contractor													Execution of contract to carry out maintenance work
Spares														
	Quotation							x	x	x	o			Costs from suppliers for the provision of spares.
	Purchase Orders							o	o	o	x			Orders for the purchase of supplied equipment. This also includes requisitions for equipment that may be held in store by a contractor or sub-contractor acting as his/her own supplier
	Deliveries							x	x	x	o			Delivery information concerning supplied equipment.
	Supplier Invoices and Payment							o	o	o	x			Invoicing and payment of goods supplied.
Agreements														
	Tenant	ox											ox	Tenancy agreements with other users of a building.
	Leasing	ox											ox	Leasing agreements with organizations leasing all or part of a building.
Disposal														
	Demolish	ox	ox										ox	Demolish the building.
	Lease	ox											ox	Retain ownership but lease all or part of a building to others.
	Sell	ox											ox	Sale of all or part of a building
Small Works														Small works includes for work requiring design and specification that is undertaken by an external contractor who may not be the maintenance contractor. Funding for the work is usually considered to be found from a capital budget rather than a revenue budget. Requirements for communication of design and construction information generally follow those for major construction in stages 0-8 shown above although the formality of communication and detail will normally be expected to be less.