A PROCESS BASED INFORMATION ARCHITECTURE

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# TABLE OF CONTENTS

LIST OF FIGURES ......................................................................................... iv
ACKNOWLEDGMENTS .................................................................................. v

CHAPTER 1: A PROCESS BASED INFORMATION ARCHITECTURE

1.1 Introduction ............................................................................................ 1-1
1.2 Computer Integrated Construction Research ........................................... 1-1
1.3 Integrated Building Process Model (IBPM) ........................................... 1-2
1.4 PBIA Objectives and Context .................................................................. 1-2
1.5 Research Methods and Intermediate Results ......................................... 1-3
  1.5.1 Simplify the IBPM and classify information ...................................... 1-3
  1.5.2 Decompose information for each of the five principle categories ....... 1-3
  1.5.3 Synthesize process and information elements .................................... 1-4
  1.5.4 Refine the information architecture .................................................. 1-5
  1.5.5 Test the information architecture ...................................................... 1-5
  1.5.6 Remove Project specific attributes and generalize the model .......... 1-6
  1.5.7 Test portions of the PBIA in specific applications ............................ 1-6
  1.5.8 Develop database prototype ............................................................. 1-8
  1.5.9 Consolidate the information architecture in one report .................... 1-10
1.6 Reader's Guide ....................................................................................... 1-11

CHAPTER 2: PROCESS MODEL

2.1 Background ........................................................................................... 2-1
2.2 Breakdown and Description ................................................................... 2-1
  2.2.1 Manage Facility .............................................................................. 2-1
  2.2.2 Plan Facility ................................................................................... 2-3
  2.2.3 Design Facility .............................................................................. 2-3
  2.2.4 Construct Facility .......................................................................... 2-3
  2.2.5 Operate Facility ............................................................................ 2-3
2.3 Attributes and Links .............................................................................. 2-4
2.4 Analysis and Limitations ........................................................................ 2-4

CHAPTER 3: PRODUCT MODEL

3.1 Background ........................................................................................... 3-1
3.2 Breakdown ............................................................................................. 3-1
3.3 Limitations ............................................. 3-1

CHAPTER 4: PROCESS CONTROL MODEL

4.1 Background ............................................. 4-1
4.2 Breakdown ............................................. 4-1
4.2.1 Resources ........................................... 4-1
4.2.2 Contracts, Changes, and Obligations .......... 4-4
4.2.3 Team ............................................... 4-4
4.3 Limitations ............................................. 4-8

CHAPTER 5: FEEDBACK MODEL

5.1 Background ............................................. 5-1
5.2 Breakdown ............................................. 5-1
5.3 Limitations ............................................. 5-3

CHAPTER 6: PROJECT CONSTRAINTS

6.1 Background ............................................. 6-1
6.2 Breakdown and Description ....................... 6-1
6.2.1 Economic .......................................... 6-1
6.2.2 Political ........................................... 6-3
6.2.3 Resources .......................................... 6-3
6.2.4 Physical ........................................... 6-3
6.2.5 Legal ............................................... 6-3
6.3 Limitations ............................................. 6-4

CHAPTER 7: USE OF MODELS AND CONCLUSIONS

7.1 Use of Models ........................................... 7-1
7.1.1 A Constructability Information Classification Scheme .......... 7-1
7.1.2 A Construction Crew Evaluation Model .................... 7-1
7.1.3 An Organisational Based Information Architecture ............. 7-2
7.1.4 A Construction Space Planning Method .................... 7-2
7.1.5 Use of Model by Students ............................ 7-2
7.2 Conclusions ............................................. 7-2

APPENDICES

A Bibliography ............................................. A-1
LIST OF FIGURES

Figure 1.1: First Version of Information Architecture ........................................ 1-7
Figure 1.2: Simplified PBIA .................................................................................. 1-8
Figure 2.1: Provide Facility Breakdown .................................................................. 2-2
Figure 2.2: Process Element Attributes ............................................................... 2-5
Figure 3.1: Building/Site Level Breakdown ......................................................... 3-3
Figure 3.2: Architectural Systems Breakdown .................................................... 3-4
Figure 3.3: Architectural Sub-System Instance ................................................... 3-5
Figure 3.4: Technical Systems ............................................................................. 3-6
Figure 3.5: Technical Systems Breakdown ......................................................... 3-7
Figure 3.6: Technical Systems Breakdown Continued ....................................... 3-8
Figure 3.7: Technical Sub-System Instance ........................................................ 3-9
Figure 3.8: Structural Systems Breakdown .......................................................... 3-10
Figure 3.9: Structural System Instance ............................................................... 3-11
Figure 3.10: Structural Sub-System Instance ...................................................... 3-12
Figure 4.1: Process Controls Breakdown ............................................................ 4-2
Figure 4.2: Resources Breakdown ....................................................................... 4-3
Figure 4.3: Contracts Breakdown ....................................................................... 4-5
Figure 4.4: Team Breakdown .............................................................................. 4-6
Figure 4.5: Team Instance ................................................................................... 4-7
Figure 5.1: Feedback Breakdown ....................................................................... 5-2
Figure 6.1: Constraints Breakdown ..................................................................... 6-2
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Victor Sanvido
Associate Professor
Chapter 1

A PROCESS BASED INFORMATION ARCHITECTURE

1.1 Introduction

This report describes the Process Based Information Architecture developed by the CIC research program at Penn State. The purpose of this technical report is to document the condition of the PBIA, such that it can be used by other readers. We have focused on the graphical models and minimized verbal content. For these readers, we have not provided any literature review. We recognize that there are many successful modeling efforts underway around the world at this time. These are referenced in our papers cited in this report.

The objectives of the Process Based Information Architecture are to identify the information required to manage, plan, design, construct and operate a facility. This was accomplished by analyzing the Integrated Building Process Model (IBPM) which defines the essential processes required to provide a facility. (Sanvido et al, 1990) The information that flowed between the processes in the IBPM was grouped into five key classifications (Sanvido 1990b). Each classification of information is explained in detail in chapters two to six.

1.2 Computer Integrated Construction Research

Computer Integrated Construction (CIC) is an emerging research field. Its development is largely fueled by the success of Computer Integrated Manufacturing research in the manufacturing industry. CIC involves the application of computers to better manage information and knowledge in their various forms with the goal of totally integrating the managing, planning, design, construction and operation of facilities (Sanvido 1990). In order to utilize the computer, the users need a clear definition and architecture to organize classify and manage the required information. Many universities and research
laboratories are actively working in the CIC area. Their work in product modeling, process modeling and developing integrated prototypes is reported in papers cited in this report.

The central goal of the CIC Research Program at Penn State is to define and develop better methods and computer tools to integrate the management, planning, design, construction and operation of facilities. The contribution of this research will be to define a framework for representing and integrating the key decisions and intent of the various participants in the process, and to look for new methods that take advantage of the computer's full capabilities.

1.3 The Integrated Building Process Model (IBPM)

The first step in the research process was to develop a conceptual model, or framework, of the processes and information required to provide a facility. This process model, developed from the view point of a "master builder," (Sanvido et al. 1992) identifies the essential processes required to manage, plan, design, construct and operate buildings. The Integrated Building Process Model (IBPM) (Sanvido et al. 1990) identifies all major functions required to provide an operational facility to the end user over the life of the facility. The model also identifies the information that is produced and utilized by each function. It was developed using the IDEF0 modeling methodology [Harrington (1985)] to four hierarchical levels of detail. A total of twenty two building case studies were used to develop and test this model.

1.4 PBIA Objectives and Context

With this background, the team set out to define and classify the information required to support the defined processes in the IBPM. The PBIA was developed for buildings with the following properties:

1. The owner, planner, designer, constructor and operator can be identified.
2. The facility is built in a free enterprise economic system.
3. The building is in one of the following stages of its life: planning, design, construction or operation.
4. The project participants are receptive to the research team and sufficient checks on information are possible.
1.5 Research Methods and Intermediate Results

The PBIA was developed through the following steps:
1. Simplify the IBPM and to identify major classes of information to support it.
2. Decompose the information for each of the five principal categories.
3. Synthesize the process and information elements.
4. Refine the information architecture using professionals with different backgrounds.
5. Test the information architecture by applying it to a design build project.
6. Remove project specific attributes and generalize the model to building projects.
7. Test portions of the PBIA in specific applications.
8. Develop a database prototype.
9. Consolidate the information architecture in one report.

1.5.1 Simplify the IBPM and classify information

The IBPM in its original form had many elements and flow lines. In order to simplify the model, the elements that flow between two given sub processes were grouped and designated with one arrow. Secondly, elements that were similar and generic to several sub functions were identified (Sanvido 1990). When examining the process models, it becomes apparent that the information that is used to provide the facility can be divided into five categories. These generically similar information elements form the components of the Information Architecture. These are: information describing the methods used to provide the facility, or the process elements; information describing the physical properties of the facility, or the product elements; information describing the management directives to the planner, designer, constructor and operator, or the process control elements; information describing feedback loops from the planner, designer, constructor and operator to the manage function, or the feedback elements; and finally, information describing the factors that impact the project, or the constraint elements. These are defined in detail in Sanvido et al. (1992).

1.5.2 Decompose information for each of the five principal categories

This analysis of process model defined five categories of information in the Process Based Information Architecture. The PBIA (Sanvido 1990) further sub-divided information to three levels of detail and identified the source and destination of such packages. For example, the product information was divided into information packages
such as the facility idea, planning information, design information, and construction information. The planning information was divided into the program, site information, project execution plan and facility planning knowledge. While these categories are more explicit than the parent category, they do not identify measurable pieces of information.

To further explore the content of the PBIA, the Product Information was divided into elements that make up a system and the systems that make up a building (Khayyal and Sanvido, 1991). This decomposition led to the development of a simple product model that divided systems into functional units. For example the architectural system divided the building into floors, external envelope and vertical connectors. These decomposed into rooms, horizontal connectors and service spaces. Rooms were then decomposed into components. Khayyal further made a classification system to identify these elements. This was then implemented in a hypermedia environment and frames were structured to hold several types of information including function, form, cost and time data. (Evt et. al. 1992)

1.5.3 Synthesize process and information elements

The next step was to synthesize the various packages of design information found in the field (defined by the IBPM) with the product portion of the model. This is a check to ensure that items are not overlooked. This was reported in a paper titled "Linking Levels of Abstraction of a Building Design" (Sanvido 1992). The paper first recognized the similarities between the relationship of the manage function to each of the plan, design, construct, and operate processes. A generic relationship between the manage function and the generic "contracted" functions was defined. The inputs, outputs, constraints and mechanisms were generically defined for each of these functions.

The second important contribution of this paper was that it provided a logical tie between the processes and the various product information packages. Each product information package was loosely linked to various levels of the product model developed earlier. This was our first attempt at logically defining the product information content based on aggregations from the process model.

Our modeling efforts were driven by trying to put a logical organization to all the information required to drive the process of providing a facility to an owner. In effect we were trying to create a virtual information base similar to that of the master builder earlier this century. Sanvido, Fenves and Wilson (1992) combined the research at these three
research programs and collaboratively identified the informational, behavioral, and computing attributes of a virtual master builder. It is notable that several industry-wide, project-specific and technological barriers to the implementation of this concept were also identified.

1.5.4 Refine the information architecture using professionals with different backgrounds

In the spring of 1992, the principal author taught a graduate course in information architecture design at Penn State. The course introduced students to various modeling languages and current models for facilities, including the conceptual schema discussed above. Using this knowledge, the class set out to define and test a comprehensive information architecture. The class’s goal was to identify and classify the information related to each conceptual category element. Identifying attributes of each class and the relationships among classes were ancillary goals. The resulting structure was then tested with information from an actual facility.

The method used to identify the information classes of each category element included three steps. In the first step, individuals divided the task of literature review and each developed a preliminary list of classes. Next the group (group size varied by category) brainstormed a revised list. This list was the basis for the testing in the next section. After this step, the team applied their structure to model the project information of a local 200,000 s.f. design build project.

1.5.5 Test the information architecture by applying it to a design build project

To further develop the information architecture, a group of twelve students with various backgrounds tested the framework on a large design build project. The project test case was the Penn State Research Park.

The team divided the task of testing the classes against actual project data. Each individual identified a portion of project data corresponding to the class under study and collected data from documents such as the program, specifications, drawings, and contracts; and via interviews with project personnel and site observations (for data that was not documented). Information relevant to the category was then mapped against the revised lists. Finally, the group met again, discussed the results of the test and agreed
upon a final class breakdown. The structure, definitions and examples were then documented in an unpublished Technical Report. (Sanvido et al. 1992) A partial outline of their breakdown is presented in Figure 1.1.

Since groups worked independently on information categories, the resulting structures were not defined with the same philosophy. After completing this report, the group listed several limitations and lessons learned. Several key issues which required further consideration were:

1. All models should be project independent. Part of the Team/Experience model was developed with project specific classes.
2. Several models overlap information types, such as Design Information in Resources and Product. These need to be addressed when the relationships are defined.
3. Several models carry repetitive structures such as Equipment in Technical Subsystems of the Product model. These can probably be consolidated to a simpler design.

1.5.6 Remove project specific attributes and generalize the model to building projects

The goal for this revision was a product model that would enable classification of most types of facilities. The classes of information which were specific to the project studied and the sector of the market studied were simplified and consolidated. A significant focus was placed on standardizing the classification philosophy. The Product Model Architecture (PMA) (Khayyal and Sanvido, 1991), was simplified. After review by the CIT research team and several professors with relevant expertise, a revised model was developed (see Figure 1.2).

During development several issues were found and remain unsolved. In many instances the resolution was to leave the decision to the user. This creates a problem in standardization of building elements and should be addressed.

1.5.7 Test portions of the PBIA in specific applications

Sanvido and Messner (1992) decomposed the Process Control Information into subcategories. As an example, the Facility Team was decomposed into sub teams e.g.,
management team, and further into individual positions e.g., the construction manager for the owner. This construction manager in turn has several subordinate functions, such as preconstruction, field representative or commissioning, reporting to him/her. The contract, experience and resource elements were similarly decomposed.

**Figure 1.1 - First version of Information Architecture**

<table>
<thead>
<tr>
<th>Process: (To level 1)</th>
<th></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Product: (To sub-system level)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Facility --&gt;[Land, Infrastructure, Buildings]</td>
<td></td>
</tr>
<tr>
<td>Land --&gt;[Landscape, Resources]</td>
<td></td>
</tr>
<tr>
<td>Arch. System --&gt;[Envelope, Floor, Vertical Connectors]</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Process Control: (First level)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Team/Experience --&gt;[Facility Champion, Management Team, Planning Team, Design Team, Construction Team, Operations Team]</td>
<td></td>
</tr>
<tr>
<td>Contracts --&gt;[Owner-Contractor, Owner-Design/Builder, Owner-CM, Owner-Architect, Contractor-Subcontractor, Architect-Consultant]</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feedback: (First two levels)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimization &amp; Performance --&gt;[Cost, Schedule, Quality]</td>
<td></td>
</tr>
<tr>
<td>Cost --&gt;[Labor, Material, Subcontracts, Equipment, Overhead]</td>
<td></td>
</tr>
<tr>
<td>Schedule --&gt;[Production Rate, Sequence Logic, Resource Acquisition]</td>
<td></td>
</tr>
<tr>
<td>Quality --&gt;[Labor, Equipment, Material, Process Control, Management]</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Constraints: (First level)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>External Constraints --&gt;[Environmental, Economical, Labor, Political, Legal, Technological]</td>
<td></td>
</tr>
<tr>
<td>Team Member Constraints --&gt;[Corporate Policy, Economical, Labor, Political, Legal, Technological]</td>
<td></td>
</tr>
</tbody>
</table>
Figure 1.2 - Simplified PBIA

| Facility ->| [Infrastructure, Buildings] |
| Infrastructure --| [Land, Transportation Network, Utilities, Furnishings, Equipment] |
| Architectural System --| [Envelope, Floor, Vertical Connectors] |
| Envelope --| [Roof, External Wall, Soffit] |
| Floor --| [Horizontal Connector, Service Space, Room] |
| Vertical Connectors --| [Stairway, Elevator, Escalator, Service Shaft] |
| Any Subsystem --| [Furnishing, Finishes, Equipment] |
| Finishes --| [Wall Surface, Floor Surface, Ceiling Surface, Port] |
| Electrical --| [Distribution, Emergency Power] |
| Communication --| [Distribution, Emergency Communication] |
| Fire Protection --| [Fire Proofing, Suppression, Alarm, Detection] |
| Lighting --| [Distribution, Emergency Light] |
| HVAC --| [Insulation, Modification, Distribution] |
| Security --| [Reaction, Barrier, Alarm, Detection] |
| Plumbing --| [Distribution, Drain, Vent] |
| Acoustic/Vibration --| [Distribution, Dissipation] |
| Any Subsystem --| [Equipment, Control, Passageway, Port] |
| Structural Systems --| [Foundation, Super Structure] |
| Foundation --| [Footing, Pile, Retaining Wall] |
| Super Structure --| [Slab, Beam, Wall, Column] |
| Any Sub-System --| [Member, Connection] |

The constructability information was linked to the product model, the process and the process control information. It was implemented in a Multimedia environment using construction project data (Hanlon and Sanvido 1993).

### 1.5.8 Develop database prototype

The Hyper Information Architecture (HIA), is a tool for defining the relationships and attributes of information elements. The HIA incorporates the process model down to level two and the product model down to the component level. It is meant to be flexible to model modifications and additions, and provide robust data input capabilities.

The HIA was developed in a five step process. The first step was to define the HIA limitations concerning data storage capacity, flexibility for modifications and flexibility
for model linkage. Next, the classification scheme, information storage format, and model structure for the product model were designed and implemented. This structure enabled population of facility specific models. The third step was to assess lessons learned from the product model design and implement a process structure requiring similar capabilities. The fourth step was to design links between models. Up to this point, the Information Architecture research had not devised an appropriate scheme of linking models or model elements. The final step was to define a strategy for integrating other models.

Designing the HIA helped to define and refine some of the information architecture characteristics by forcing thought about the relationships and testing its completeness. We were able to conclude that each attribute of the process model should be linked to one other model. After discussing each attribute that had been defined, the model that it should be linked to was also defined. For example, the activity "Provide Facility" has an output attribute "Operational Facility" which is a member of the product model and should be linked to it. The primary information about an operational facility would be found in the Product Model. Although these links have been defined they are beyond the scope of this report. However, the method of linking attributes is important.

Also, through the process, we found that the structural system of the Product Model was limited and needed to be redefined. Through interviews we were able to define a new breakdown for structural systems.

Process/Product link establishment was defined to only take place from the process. It was first developed to go either way but after deliberation it was changed. The problem arose from the definition of model links based on process attribute. If the same logic is applied to the product, we are totaled. The product attributes, form and function, come from and go to several processes. One could provide a list but it would be best if each part of the attribute was associated with its source process and destination process. This becomes quite complex.

A similar problem exists with process/product links. Some processes like "Develop Design" output "Design Data" to possibly hundreds of products. Manually defining these links would be very inefficient. In the future an automated way of establishing those links and providing navigation through them is needed.
Building the HIA was an exercise to help analyze our work and to provoke new thought. If we were to attempt this again, we would need to make it more adaptable and provide a query manager.

1.5.9 Consolidate the information architecture in one report

In an attempt to finalize a simple, generic, and consistent format for storing information, the model was further revised during the last phases of the information architecture development. Some of the changes that have been made since the most recent revision of the draft report (Sanvido et al. 1997) include:

1. The structural system in the Product Model was redefined in order to allow greater flexibility. Through interviews we developed a new decomposition:
   Structural Systems --->[Foundation, Lateral Force Resist., Roof Framing, Envelope, Floor Framing]
   Any Structural System --->[Slab, Beam, Wall, Column, Bracing]
   Any Sub-System --->[Framing Element, Connection]

2. The Process Control Elements, Resources, Contracts and Team are no longer decomposed into categories relating to the five main process elements. The revised structure consists of generic element decompositions applicable to all processes.

3. The coding scheme was simplified to allow for an unlimited number of identical elements.

4. The attributes for all models were simplified to types of information that should be found in each model instead of specific information that each element should provide.

The following five chapters of the report is a summary of the current model breakdown. This compilation of the PHLA elements is a comprehensive structure for information storage. Although the relationships between models and individual elements have been explored, this structure is limited to a hierarchical decomposition of model elements with some discussion about linking entities.

This model structure will provide the basis for future Information Architecture development. Future work may include:
• Defining model and entity relationships.
• Providing a scheme for linking elements, and
• Implementing the architecture into a computer based tool with convenient storage and retrieval of information and knowledge.

1.6 Reader's Guide

Chapters Two through Six define the revised breakdown of the principal categories of information in the PBIA. The chapters define the hierarchical decomposition of the five categories: Process Model, Product Model, Process Control Model, Feedback Model, and Constraints Model. Each chapter describes the method and scheme used to classify the information elements for the category, as well as the limitations of each model. Graphical representations of the models are also included. The terms found in each of the models are defined in the appendices. The report is concluded with Chapter Seven which discusses applications of the Information Architecture. Several research programs which used the models to solve construction problems are also described.
Chapter 2

PROCESS MODEL

2.1 Background

A process model defines inputs, outputs, constraints, mechanisms and sub-processes of the activity being modeled. This chapter presents a process model for the provision of a facility. The structure of the process decomposition is taken from the Integrated Building Process Model (IBPM) (Sanvido 1990). The organization of elements in the upper level of this model is shown in Figure 2.1. The IBPM is developed by using the IDEF0 modeling methodology [Harrington (1985)] which shows all the information elements which flow between the different processes. This chapter will focus on showing the structure of these process information elements in the IDEF1X methodology. The chapter also presents a structure for storing attributes and for showing links to other information models. The attributes defined for process elements include: inputs, outputs, controls and mechanisms. An input undergoes a process or operation and is transformed into an output. Controls influence this process and mechanisms perform this process. For a detailed description of the attributes, see the glossary in Appendix B. The information elements which flow between the different processes will be classified in Chapters 2 through 5.

2.2 Breakdown and Description

The process model for the provision of a facility is broken into five main processes (Figure 2.1). These processes are defined as follows:

2.2.1 Manage Facility includes all the business functions and management processes required to support the provision of the facility from planning through operations. These activities focus on converting a facility idea, time and money into a facility team, documents and contracts, facility management plans, and resources to support the project. This function runs for the duration of the facility life. It is controlled by two major factors,
Figure 2.1: Provide Facility Breakdown
performance information about the facility as a whole and information to optimize subprocesses within the facility e.g., constructability information. The facility champion is the key to ensure the success of this function.

2.2.2 Plan Facility encompasses all the functions required to define the owner's needs and the methods to achieve these. These activities translate the facility idea into a program for design, a project execution plan (PEP), and a site for the facility. Major controls are constraints imposed by project participants (e.g., the owner or engineers), the facility plan, the contract, and optimization information. Other outputs include facility planning knowledge and information on the performance of the team.

2.2.3 Design Facility comprises all the functions required to define and communicate the owner's needs to the builder. These activities translate the program and execution plan into bid and construction documents and operations and maintenance documents that allow the facility to meet the owner's needs. Controls or constraints include program and site information, the contract, facility planning knowledge transferred to the design team, the PEP and the design plan. Again, facility design knowledge and information on the performance of the design team is another output.

2.2.4 Construct Facility includes all functions required to assemble a facility so that it can be operated. These activities translate resources (e.g., materials) in accordance with the design into a completed facility. Typically appropriate facility operations and maintenance documents are generated. As a result, facility construction knowledge and information on the performance of the construction team is generated. Controls include bid and construction documents and criteria, the PEP, facility design knowledge transferred to the team, the contract and the construction plan.

2.2.5 Operate Facility comprises all of the activities which are required to operate and maintain a facility for a user. In addition, operating knowledge, and information on the performance of the team is generated. This process is controlled by the facility construction knowledge available to the team, the facility operating and maintenance documents, the PEP, the operating plans and the contract. A Glossary of Terms is provided in Appendix B to define unique meanings of words used in this model. For more details on this breakdown of processes refer to the IBPM (Sanvido 1990).
2.3 Attributes and Links

Each information element in the process model has attributes and links or connections to the other information models in the following chapters. The structure of a process model information element is shown in Figure 2.2. This figure shows the attributes of a process as being the description, inputs, outputs, constraints and mechanisms of the process. The many links from the process model to the other information models relate to these specific attributes. Information concerning the process inputs, outputs, controls and mechanisms is more appropriately classified in other information models. Therefore, the links are used so that this information can be accessed through the process model.

2.4 Analysis and Limitations

This process model shows a method for generically classifying all the process information used in providing a facility. It is necessary to keep the terms generic so that all projects can be referred to by using a similar numbering scheme. Some of the shortcomings of the model are that since it is generic, it is sometimes difficult to determine the cutoff points between the different processes, e.g., when does schematic design end and design development begin.

This model only shows the upper levels of the process model. In order to implement the model, the model should be developed to a more detailed level. This could potentially make the model very large and confusing.

This model lacks a structure for representing the importance and difficulty of performing the different processes. These attributes could be added to the model in the future, but this information tends to be quite subjective. If these attributes are added to the model, a formal measuring system must be developed to measure these attributes. Much of this information might be found in the Feedback model.

The process model is one of the two information models which provides the foundation for the information architecture. The second key information model is the product model which is described in the next chapter.
Chapter 3

PRODUCT MODEL

3.1 Background

This chapter presents the product model of a facility as part of an information architecture. The model is based on IDEFIX modeling methodology, and the generic scheme proposed by Khayyal. This is an approach to break down a facility and its assemblies into objects with information attributes. In order to store these attributes in the proper location and avoid redundancy, a hierarchical structure was used to organize information. Items are stored according to their primary functions but information regarding other functions may be stored in the attributes. The purpose of this model is to provide an organization and categorization of information describing Product elements in terms of the attribute categories, Function and Form.

3.2 Breakdown

Figures 3.1-3.10, divide a facility into several levels. These are the Building/Site, Sub-System, Type, Component, System, and Part levels. Objects at different levels have different degrees of detail in this hierarchy of information. Entities within each level are broken down into unique, detailed categories of information at the next lower level. However, entities of the Sub-System Level and Component Level share information categories at the next lower level. Note that objects in the Structural System also share information stored at the Sub System Level. A Glossary of Terms is provided in Appendix C to define unique meaning of words used in this model.

3.3 Limitations

This model provides a means for organizing and categorizing information related to product elements. An object is stored according to its primary function with secondary information
stored in the attributes. Here arises the conflict of distinguishing between primary and secondary functions. One may find that due to the complexity of an object, it is necessary to store information in multiple places. Also, when an item interfaces with more than one system, information is stored in each. For example, a light switch may be stored in two places. Design information about the light it controls is stored in Technical–Lighting–Distribution–Control. Construction information about which wires it energizes is stored in Technical–Electrical–Distribution–Control. This information may overlap and be stored redundantly. The model also fails to provide a method for connecting these information elements.

While the elements in the model have been defined, there are often cases when the user must further define an object. For example, the floor is defined as a collection of spaces connected by the same primary horizontal transportation system. However, floors may vary slightly in elevation, requiring the user to determine if this change in elevation is also a change in floors. A similar problem exists with vertical connectors. The user must determine the number of stairs needed to be classified as a vertical connector. Complete population of the model is not yet feasible because infrastructure has only been defined to the Type level.
Figure 3.3: Architectural Sub-System Instance
Figure 3.4: Technical Systems
Figure 3.6: Technical Systems Breakdown Continued
Figure 3.7: Technical Sub-System Instance
Figure 3.8 Structural Systems Breakdown
Figure 3.9: Structural System Instance

KEY

SS = BS7
SS = Structural System
E = Building
S7 = System Type
(SP, SL, SR, SE, SO)
Chapter 4

PROCESS CONTROL MODEL

4.1 Background

This chapter presents a scheme for classifying the information that governs the method and sequence of a process activity. It has been acknowledged that this information is generally not subdivided or classified to any great depth in practice. Rather, an owner selects contract terms, clauses, facility teams, and resources based on experience and intuition.

This chapter is an attempt to formalize some of the logic used in these decisions. It attempts to provide a consistent format for representing the contents of information for three process control elements: Resources, Contracts Changes and Obligations, and Team.

4.2 Breakdown

An overview of the Process Control Model is provided in Figure 4.1.

4.2.1 Resources

A resource, as defined by Webster's Dictionary, is something that lies ready for use or that can be drawn upon for aid or to take care of a need. Figure 4.2 divides resources into all the physical or information elements which are inputs, mechanisms, or controls to a process. Classes of resources include Information, Financial Resources, Time, Infrastructure, Human Resources, Space, and Physical Resources. Some classes of resources have been further defined at a lower level. Not every process will require resources from every category. The critical attributes defined for resources include: availability, supply, function, quality and cost.
Figure 4.2: Resources Breakdown
It is also important to note that resources are also a class of the Constraints Model. However, the information stored in the Constraints model focuses on the limitations that the resources place on activities.

4.2.2 Contracts, Changes and Obligations

The contract is an important tool in the process control methodology. It essentially spells out or clarifies the responsibilities and actions of each party in the relationship. The project team is composed of many members who work independently and are simultaneously interdependent on others. The contract is the legal document which can reinforce these responsibilities and ensure team members work together. The contract can be construed as a positive control measure, although recent trends in the construction industry indicate otherwise, as evident in the increasing number of litigation cases.

Contracts can take various forms and involve numerous strategies. The contract segment of the process control model is based on common generic portions of most major contracts. Figure 4.3 shows Scope, Cost, Time and Parties as classes of information included in the contract segment of the model. These areas were extracted from numerous contracts written by various professional agencies. The model does not specify the drafter or agency responsible for the format, length, or content.

Attribute categories for Contracts, Changes and Obligations include: terms of agreement, contract history, risk allocation and professional standards.

4.2.3 Team

The team is essential for any activity. While each activity may require different team organizations, we have defined a simplified generic breakdown that can be applied to all activities. Teams can be so unique that a detailed summary would be limited in its applicability. The model defined in Figures 4.4 and 4.5, includes a breakdown of project teams with an additional breakdown of how individual teams at all levels may be organized. The key team attributes are group dynamics, individual experience, work activities, and organization. A Glossary of Terms is provided in Appendix D which defines unique meanings of words used in this model.
Figure 4.3: Contracts Breakdown
Figure 4.4: Team Breakdown
Figure 4.5: Team Instance
4.3 Limitations

The Process Control section of this model is strictly a categorization of those elements that act as inputs, mechanisms and controls to processes. This model does not provide any link to the product or process models. Although information concerning their function can be stored in the attributes, there is no direct connection to elements in other models that the Process Controls influence. Because every operation or activity is governed by process controls, there exists the potential to link a process control tree to each Process element. However this would be an extremely complex model, abundant with redundant information storage since many processes share controls.

The Team breakdown also has limitations. This section of the model is very broad because each team is unique. There is no standard organization for project teams or work units. Therefore, this breakdown does not attempt to describe the relationships between team members or team organizations. The decomposition is limited to a project team with an unlimited number of hierarchical levels of unidentified horizontal team relationships. For example, a project team consisting of owner representatives may form a contractual relationship with a combination of architects, engineers, contractors and construction managers all of which would be at the Contractor Level. The relationship between these Contractor Level Teams cannot be summarized in this model. Also, individual teams and work units, have unique organizations ranging from vertical or horizontal chains of command to chaos.
Chapter 5

FEEDBACK MODEL

5.1 Background

This chapter presents a method and scheme for classifying the feedback information required to provide a facility. This information affects the control of various subprocesses within the Manage, Plan, Design, Construct, and Operate functions. This feedback information has two elements, optimization information and performance information.

Optimization information is planning information about possible methods of design, construction, operation or maintenance which is used to improve the efficiency of the provision of a facility. Performance information addresses the progress of activities which, when compared to the plan, is interpreted to assess the status of the project and the appropriateness of the plan or method selections. In a simpler context, optimization information is forecasting information used to make decisions. Performance information is actual progress information used to review and update decisions.

5.2 Breakdown

The information element breakdown for feedback on methods is shown in Figure 5.1. The top level box describes the attributes of the particular method. Information concerning methods may be described by both optimization and performance information. The three sub-elements of optimization information include designability, constructability, and operability/maintainability. The three sub-elements of performance information include cost, quality, and schedule.

This model defines the decomposition of Feedback information down to the second level. For more details concerning constructability information, refer to "Classifying
Constructability Information" (Hanlon and Sanvido, 1993). A Glossary of Terms is provided in Appendix E to define unique meaning of words used in this model.

5.3 Limitations

The classification system developed appears to provide a systematic approach for storing the information. Its major contribution is the identification of the feedback elements to be considered. These will hopefully initiate questions about the selection of an "optimum" method or the performance of the current method. Again, this model provides a format for storing information about a specific process but does not provide a scheme for linking information to the other models.
Chapter 6

CONSTRAINTS MODEL

6.1 Background

The final elements in the information architecture to be described in this report are constraints. Constraints are defined as the boundaries and limitations in which a project or process must be performed. These constraints may come in the form of a limit to the quantity or quality of a resource, or a guideline which influences behavior. A constraint can be considered part of a control element to a process, which was described in Chapter 2. Because many constraints can have a significant bearing on the project or processes, it is important to define the critical categories of constraints so that they may be considered at the start of every project. This chapter is an attempt to formalize the types of constraints. An illustration of this breakdown is provided in Figure 6.1.

6.2 Breakdown and Description

The Project Constraints Model is decomposed into five categories of constraints: Economic, Political, Resource, Physical and Legal. These constraints may be either external constraints which influence an entire project and the conditions under which its processes are performed, or internal constraints which only influence individual team members' ability to perform processes. Countless constraints may exist, therefore, this breakdown is just a categorization of constraints to consider. Because the constraint elements are significantly varied in nature each of the elements have a unique set of information attributes.

6.2.1 Economic

The economic environment has a significant influence on the financing of the project. Items within the economic constraints which will influence the work include: economic
Figure 6.1: Constraints Breakdown
system, currency value, currency stability, economic growth, and construction market growth. Attributes of the Economic constraints include: economic stability, currency, and currency value.

6.2.2 Political

The political constraints consists of factors inherent in the governing organizations overseeing processes in a particular location. Items to consider within the political constraints include: political system, governing organizations, and government policies. Attributes of the Political constraints include: political system type, government officials, and political stability.

6.2.3 Resources

Each project has an environment for gaining resources. These resources can be purchased, rented or used within that location or moved to different locations. Specific resources which can be gained from location include: human resources, physical resources, space, financial resources, and knowledge. Attributes of the Resource constraints include: quantity, availability, quality and cost.

6.2.4 Physical

The physical constraints consist of factors which exist in a specific location. These factors include but are not limited to: terrain, geology, weather and natural disasters. Attributes of the Physical constraints include: location, weather conditions and probability of natural disasters.

6.2.5 Legal

The legal environment influences the laws imposed by the governing bodies and the enforcement of these laws within a location. Items which must be considered are: the legal system, laws and regulations which include safety regulations, building codes and labor laws and lastly, the enforceability of laws. Attributes of the Legal constraints include: tax requirements, codes/registration requirements, and legal restrictions. A Glossary of Terms is provided in Appendix I to define unique meanings of words used in this model.
6.3 Limitations

There are several types of control elements that have been described in this report, all of which may be considered to influence processes, such as design drawings, which influence the construction process. These other control elements are easily confused with constraints, but must be considered separately. The most significant reason for this separation is the bearing that constraints have on a project and the need to address the constraints which will impact a particular project. Constraints are one of the few information elements which originate outside the process and product models. This makes it difficult to determine exactly what constraints are affecting a process and how critical these constraints may be to a process. A constraint which is overlooked may cause significant setbacks or delays if it comes to light in the middle of a process.

The most obvious limitation is the lack of detail in which we are able to model these constraints. Although different types and examples of each have been identified, it is apparent that countless constraints may exist. Instead of attempting to list them all here, it is more useful to state the importance of identifying those from each category that affect an individual project.

In addition, there is no method to give weight to certain constraints which are more significant or critical than others. Again, this characteristic can be considered to be project specific yet still an important element to consider when identifying constraints.

It is also not possible to identify exactly which constraints affect which processes in the model. This diversity could present a standardization problem in the classification of information. It will suffice to say that most constraints affect several processes in the model.
Chapter 7

USE OF MODELS AND CONCLUSIONS

7.1 Use of Models

This section discusses several uses of the Information Architecture as a disciplined method to solve pressing construction problems and provides a brief conclusion. The researchers in the CIC laboratory used the Information Architecture in conjunction with the Integrated Building Process Model presented in Technical Report No. 1 to address several industry problems. Four applications focused on exploring different levels and aspects of the models. Several students also used the model to organize project information. Specific details follow.

7.1.1 A Constructability Information Classification Scheme

Eric Hanlon (Hanlon, 1993) developed a classification, storage and retrieval system for organizing constructability ideas for use by designers and constructors at different levels of product aggregation and stage of the process. He was able to successfully achieve these goals for reinforced concrete construction projects with seven experts in the field. He had several minor suggestions for the use of the models. His software tested the model in detail.

7.1.2 A Construction Crew Evaluation Model

Kirby Kuntz (Kuntz, 1994) focused his effort on defining a model, which when followed, would ensure that projects that established and supplied crews to the specified level would achieve better performance than those who violated the model. He expanded the lowest level process in the construction portion of the IBPM, "Do the work," and linked it to the lowest level of the information architecture. He was able to show that use of these two models at their lowest level of decomposition is feasible and that the models are expandable
to customized needs. The model was tested extensively on several projects in one company.

7.1.3 An Organizational Based Information Architecture

John Messner (Messner, 1994), on the other hand, tested the models at their upper levels. He developed a methodology, process model and information architecture that assisted a company in deciding which projects they should pursue. John proposed a process model which when decomposed would yield an activity called "Provide Facility," the top level of the IRPM. His Information Architecture when decomposed included process, product (or facility), environment, commitment and organization information. This upper level model showed that the Information Architecture held true and could fit into this context. He successfully tested the model on ten projects.

7.1.4 A Construction Space Planning Method

David Riley (Riley, 1994) developed a method to classify and plan the space requirements for multi story buildings. He developed the "Plan Construction" activity in the IRPM in detail. He also classified space requirements by trade type and by level in the product model. He mapped specific information requirements to the Information Architecture. He was able to collect rules to drive the process and tested the framework on four major projects.

7.1.5 Use of Model by Students

The Information Architecture was presented to over one hundred students in a senior level class. The Information Architecture acted as a guideline to successfully help them organize project information for their senior project building.

7.2 Conclusions

This is the third version of the Process Based Information Architecture. It classifies the information required to provide facility into five major categories and into several subcategories. The model has been tested on a large design build project and again to a lesser extent on over 100 projects. The model has been very useful to guide software development and to scope MS and Ph.D. level theses. We have further tested the
Information Architecture in conjunction with the IBPM in four specific areas described above. The model is presented in its final form as a working tool. We hope that you are able to realize its full benefit and encourage further discussion on its use and shortcomings.
Appendix A

BIBLIOGRAPHY


A-2


Appendix B
Process Model Glossary of Terms

Acquire Construction Services (C1): In this function, the construction team is selected and organized. This typically involves assigning in-house personnel to the project and hiring the needed subcontractors, consultants, and other additional staff. The appropriate contracts and agreements are coordinated.

Acquire Services to Provide Facility (M4): This is the process of soliciting the required services to provide the desired facility and assembling the facility team.

Acquire/Provide Resources for Facility (M5): This is the process of acquisition, allocation, and the distribution of resources required to provide the facility.

Assign Planning Team (P1): All processes to establish the planning team which may be assembled with in-house personnel, external planning professionals or a combination of both. Acquiring planning services may include: qualifying potential professionals, requesting proposals, evaluating proposals and issuing the planning services contract.

Build the Facility (C4): In this function, the physical work of converting the available resources into the designed facility is performed. This function concludes with the start-up and turnover of the facility.

Communicate Design to Others (D5): This is the process by which the "completed" design is formalized and relayed to other parties such as the Constructor, Owner, and Facility Manager by some medium, usually the contract documents.

Construct Facility (C): All functions required to assemble a facility so that it can be operated. These activities translate resources (e.g., materials) in accordance with the design into a completed facility. Typically, appropriate facility operations and maintenance documents are generated. As a result, facility construction knowledge and information on the performance of the construction team is generated.

Control: An attribute of the process elements. Control elements are entities or information which influence or determine the process of converting inputs to outputs.
Controls may limit the activity or allow the activity to occur but will not be affected by the activity itself. Examples include design information, contracts, project constraints, etc.

**Design Facility (D):** All the functions required to define and communicate the owner's needs to the builder. These activities translate the program and execution plan into bid and construction documents and operations and maintenance documents that allow the facility to meet the owner's needs.

**Develop Design (D4):** Process performed to continue the refinement and the selection of the design.

**Develop Program (P4):** The process where the program is developed by considering the feasibility study information, user needs, and project constraints. The purpose of developing a program is to define, in detail, the project scope and size or capacity.

**Develop Project Execution Plan (P5):** The process in which the Project Execution Plan (PEP) is created. The PEP, also called the project master plan (Wheeler 1978), defines the owner's approach to project delivery options and strategy for acquisition of services. The PEP is the project's front end plan which covers the whole project life cycle, i.e., planning, design, procurement, construction, operations, maintenance and disposal (if required).

**Develop Solutions (O4):** Once a problem is identified, several alternative plans are developed by people with sufficient technical knowledge and expertise, or by automated mechanisms (computers, control panels, etc.).

**Develop System's Schematics (D3):** The process of refining and elaborating upon the feasible concepts, usually performed by architects and engineers. Schematics include more specific information and system requirements which have been gained by analysis of the concepts.

**Develop Work Scope and Needs (M2):** This involves defining the proposed work as completely as possible. The scope of work defines what is required of all parties in the project, the services that each will provide, and the type of support each can expect from the owner.
Establish Management Team (M1): This function serves to establish an initial project organization, which then acts as an initial steering team/committee, having a detailed work plan. This function also assesses internal capabilities and resources to be used in providing the facility.

Evaluate Conditions and Detect Problems (O3): The monitored information at this stage is evaluated with regard to standards, user requirements, and the operations plan. Problems, if any, are located and identified.

Explore Concepts (D2): The process of exploring the general concepts concerning the initial layout of the facility; general requirements of the design; and other such areas. Once multiple concepts have been formed, those deemed feasible are passed along, with the information gained, to the Develop System's Schematics phase.

Implement Plan (O6): This function is the execution of the physical operations and maintenance functions. In cases of breakdowns, action is taken in accordance with the selected plan.

Input: An attribute of the process elements. An input to a process is an entity or information which undergoes a process or operation and is transformed into an output of the process. Examples include materials, funding, etc.

Maintain Design Information and Models (D6): This process takes the information generated within the design phase and acts as a design information database for the design team. It receives, stores, updates, and distributes the information to the various stages and personnel involved with the design.

Manage Facility (M): All the business functions and management processes required to support the provision of the facility from planning through operations. These activities focus on converting a facility idea, time and money into a facility team, documents and contracts, facility management plans, and resources to support the process.

Manage Operations (O1): This function is parallel to the other five functions at this level, and it provides short-term planning and management for meeting the required operating standards of the facility and for its maintenance. This includes scheduling and
acquiring necessary services and resources to support all operations and maintenance functions that are related to the facility.

**Mechanism:** An attribute of the process elements. Mechanisms are entities which perform a process or an operation. They describe how a process is accomplished. Examples include the project team, equipment, etc.

**Monitor Facility Condition and Systems (O2):** This function oversees the various systems and the required environment defined by the facility. This includes recording operations data and other information that is specific to the facility.

**Operate Facility (O):** All activities which are required to operate and maintain a facility for the user. Operating knowledge, and information on the performance of the team is generated in this process.

**Output:** An attribute of the process elements. An output of a process is an entity or information which is created by a function. Examples include the building, design information, contracts, project execution plan, etc.

**Plan and Control the Work (C2):** In this function, the construction work is directed and controlled. The primary output is the construction execution plan which establishes the strategies for organizing the construction team, providing resources, and building the facility. The execution plan is revised and updated based on feedback from performing the work.

**Plan Facility (P):** All the functions required to define the owners needs and the methods to achieve these needs. These activities translate the facility idea into a program for design, a project execution plan (PEP), and a site for the facility.

**Plan/ Control Facility (M3):** The planning process includes: developing plans for resource acquisition; executing the plan; controlling the facility; and setting the methods, sequences, schedules, budgets, and quality of output from each of the technical phases. The control function continually monitors the actual performance, compares it to the planned performance, and plans and implements any changes found necessary.
Provide Resources (C3): In this function, all of the resources needed to construct the facility are acquired and allocated. The mobilized site is an important output of this function.

Select and Acquire Site (P6): All the activities which are required to choose and purchase or lease a project site.

Select Plan of Action (O5): The process in which a plan of action is developed to solve an identified operations problem.

Study /Define Needs (P2): This process starts with the "Facility Idea" and generates the plans for meeting the user's needs.

Study Feasibility Of Alternatives (P3): The process of analyzing the feasibility of the different alternatives. The feasibility study includes economic feasibility, technical feasibility and environmental feasibility studies.

Understand Functional Requirements (D1): The acquisition and synthesis of information pertinent to the design of the desired facility. This takes into account the management's design plan, the project execution plan, the program and site information, and the functional limitations.
Appendix C
Product Model Glossary of Terms

**Acoust./Vibr.** (Acoustic and Vibration systems) A Technical System which controls the effects of natural or man-made vibration and sound within the facility. Systems for increasing sound or vibration are categorized as distribution systems. Those for reducing sound or vibration are grouped as dissipation systems.

**Alarm** A Sub-System of the Security or Fire Protection Technical Sub-Systems which provides audible or visual notification of a threatening emergency locally or off site.

**Arch. Sub-System** (Architectural Sub-System) A generic structure which describes the Furnishings, Finishes, and Equipment of a Sub-System level entity in the Architectural system.

**Arch. Systems** (Architectural Systems) The building systems which define the space, form, and aesthetic functions. These systems are linked with the Technical and Structural systems where their Sub-Systems visually impact a space.

**Barrier** A Sub-System of the Security Technical system which includes systems that provide security through a stationary obstruction. A barrier is either always present or is manually controlled. Examples of such systems are bullet proof glass in a bank or locks on doors and windows.

**Beam** A linear Sub-System of the Structural System which connects columns or walls. It typically carries horizontal loads but can be a sloping member. It usually supports a slab except in cases such a X-Bracing. Special structural Sub-Systems such as ring beams are also included here but do not fit the generic definition.

**Bracing** A Structural Sub-System providing lateral stability and resistance to rotation. Examples may include K-Bracing and X-Bracing.

**Building** A physical collection of connected spaces which have an Architectural and Structural system. Most buildings also include a Technical system but it is not mandatory. These spaces support the overall function of the building within the facility. In situations
where there are adjacent buildings, the user or designer defines the boundary conditions between buildings.

**Ceiling Surface:** Provides a detailed description of the Ceiling Surface Finish of an Architectural Component. For example, this would include for example: color, texture, material type, pattern, etc.

**Column:** A linear Sub System of the Structural System which carries vertical loads, although it can be a sloping member. It usually transfers the loads of the building from one floor to the next and to the foundation.

**Communication:** A Technical System which provides a means of communication within the building and to the exterior world. This would include voice, data and video systems. Systems which provide a primary communication mechanism are included in the Distribution Sub-System category. Special backup systems are separated in the Emergency Communication category.

**Connection:** The space shared by two or more Structural Members and all the items necessary to join the members.

**Control:** Component of a Technical Sub-System which provides the user with control to the Sub-System's function. Ex: Technical–Electrical–Distribution–Control may include switches.

**Detection:** A Sub-System of the Security or Fire Protection Technical Systems which provides detection of potentially threatening emergencies. It transfers information about this situation to other systems for action to take place. Examples of such systems are smoke, fire or intruder detection systems.

**Dissipation:** A Sub-System of the Acoustic/Vibration Technical System which dissipates sound or vibration energy. Examples include: resilient mounting brackets, equipment isolation pads, and acoustical drop ceiling panels.

**Distribution:** A Sub-System of many Technical Systems. Its purpose is to distribute "something" from its source to its point of use. An example of "something" typically
distributed includes: air, sound, water, natural gas, light, data and video. This system encompasses all Components required to enable the System to meet its function.

**Drain:** A Sub-System of the Plumbing Technical System which discharges human and routine housekeeping wastes from a building to the municipal sewer services.

**Electrical:** The Technical System which provides distribution of municipal and emergency electrical power to the building and its occupants. The electrical distribution Sub-Systems include all items from the service entrance to the interface of another Technical system or a port for use by Architectural Equipment.

**Elevator:** An Architectural Sub-System which provides a vertical transportation system within the building. Typically it is a suspended cage or car which moves vertically.

**Emergency Comm.:** (Emergency Communication) A Sub-System of the Communication Technical System which provides a means of emergency communication within the building and to the external world. An example would be a back-up satellite system for a primary terrestrial (land based) system.

**Emergency Light:** A Sub-System of the Lighting Technical System which provides a means of emergency lighting within the building.

**Emergency Power:** A Sub-System of the Electrical Technical System which provides emergency power to the building. It includes all Components to generate and distribute the emergency power to the building.

**Envelope:** The Architectural System which is visible on the exterior of a building. It includes Exterior Wall, Soffit and Roof Components. Typically it is the "skin" of a building and separates the inside from the outside. This element provides information about the aesthetics and form of the envelope.

Also, a Structural System including items such as masonry walls. This element provides information about the envelope's role in transferring loads.

**Equipment:** It is a Component of the Architectural and Technical Sub-Systems. It is a device which requires power to perform its function. Therefore, it must interface a Technical System port to obtain this power. If the device is capable of being moved to
another part by an unskilled person it is Component of the Architectural System. Otherwise, it is Component of the Technical system. Examples of Technical equipment are as follows: air handling unit, in-line water pump, etc. Examples of architectural equipment are as follows: refrigerator, washer, dryer, etc.

**Escalator:** A Component of the Vertical Connectors Sub-System which is a moving stairway consisting of treads linked in a belt.

**External Wall:** A Sub-System of the Envelope Architectural System which includes all external walls. Occasionally there is little distinction between a roof and external wall. Ultimately the final classification of an envelope component is left to the user.

**Facility:** A building or group of buildings and Infrastructure which makes possible some activity.

**Finishes:** A Component of every Architectural Sub-System. It describes the aesthetic characteristics of the Sub-System's surfaces, including the wall, ceiling, floor and port surfaces. Characteristics would include color, shape, size, texture, etc.

**Fire Protection:** A Technical System which provides for the life safety and/or structural integrity of a building in a fire situation.

**Fire Proofing:** It is a Sub-System of the Fire Protection Technical System which insulate the objects from heat of a fire. Examples of this are spray on fire proofing, concrete encasing, flame resistant drywall, etc.

**Floor:** It is a Architectural System and is comprised of three types of spaces: Horizontal Connectors, Service Spaces and Rooms. A floor is a collection of space(s) connected by the same primary horizontal transportation. These spaces may vary slightly in elevation. It is difficult to define a floor when elevations of contiguous spaces vary. For example, a split level house could have a different number of floors depending on user interpretation. Therefore, in such cases the final decision as to what is a floor is left to the user or designer.

**Floor Framing:** A Structural System providing support for the floor.
**Floor Surface:** Provides a detailed description of the floor surface finish of an Architectural Component. This would include for example: color, texture, material type, pattern, etc.

**Form:** A category of information attributes for product elements. Information related to size, shape, etc.... May include information related to its non-primary elements. Ex: The architectural attributes of Technical-Electrical-Distribution-Port, a wall socket, may be stored in the attribute category, form.

**Foundation:** A Structural System. It includes the components necessary to transfer loads from the Super Structure to the earth or resist earth loads. Sub-Systems include Slabs (Spread Footings), Columns (Piles) and Walls (Retaining Walls), generically described as slabs, columns and walls respectively in the model structure.

**Framing Element:** A Component for the Structural Sub-Systems. Framing Elements provide the physical connection between members. Examples may include, stiffeners, gussets, brackets, welds, and bolts.

**Furnishing:** A Component of every Architectural Sub-System. It describes end user items that do not interface a Technical System Component. Examples are desks, table, chairs, bookshelves, curtains, etc.

**Function:** A category of information attributes describing both the strength and performance of product elements. The attributes may include information about the object's non-primary elements.

**Horiz. Connector:** (Horizontal Connector) A Sub-System of the Floor System. It is the space which allows for horizontal transportation between any Floor and/or Vertical Connector Sub-Systems.

**HVAC:** (Heating, Ventilation and Air Conditioning) A Technical System whose function is to maintain desired climatic conditions of a space.

**Infrastructure:** It is a Building/Site Level element of a Facility. The overall system of elements, exterior to the buildings, which support the building's function.
Insulation: A Sub-System of the HVAC Technical System which hinders the flow of heat.

Land: A Type Level element of the Infrastructure. It is the contour, composition, landscaping and legal rights of the land designated for a facility.

Lateral Force Resist.: (Lateral Force Resisting) A Structural System designed to resist lateral forces such as wind loads. Sub-Systems of this system may include shear walls and braced frames, generically described as walls and bracing in the model structure.

Lighting: A Technical system which provides the generation and distribution of light throughout a building. Systems which provide a primary lighting mechanism are included in the Distribution Sub-System category. Special backup systems are separated in the Emergency Lighting category.

Modification: A Sub-System of the HVAC Technical System which changes the physical properties of fluids used to alter or maintain the environmental conditions of a space. A Modification Sub-System may heat, cool, humidify, etc.

Passageway: Component of a Technical system Sub-System which provides a channel through which "something" flows or passes. For example, ductwork channels air, pipes channel fluids, wires channel electricity, conduits channel wires, etc.

Plumbing: A Technical System within a building which provides for the supply or discharge of liquid or gaseous substances throughout the building. This does not include any items which are used by HVAC System. Examples of this are: hot and cold water supply, gas lines, storm drains, sewer lines, etc.

Port: It is a Part of the Architectural and a Component of the Technical System. It is a interface between a Technical System and the Architectural System. In the Technical System, it is Component of a Sub-System. In the Architectural System, it is found at the Part level under the Finishes category. The aesthetic attributes of the Port such as color, shape, size, etc. are stored in the Architectural System. The Technical attributes such as register throw, receptacle voltage, etc. are found in the Technical System. A unique example is presented when considering a water closet. A water closet is a piece of technical equipment which interfaces two plumbing distribution systems (supply and drainage).
Each system has its own port. The supply port is the inlet valve external to the fixture and the drain port is the external trap.

**Reaction:** A Sub-System of the Security Technical System which includes all systems whose purpose is active reaction for security purposes. An example of such a system is an automatic door locking mechanisms.

**Roof:** A Sub-System of the Envelope Architectural System which provides the “cap” or top of a building. A special case of this is an A-frame building. The sloping external members are roofs and the ends are external walls.

**Roof Framing:** A Structural System that supports the roof. Structural Sub-Systems of the roof Framing System include Bar Joist, PC Plank and 2 Way Slab.

**Room:** A Sub-System of the Floor Architectural System. A space which contains all physical objects which serve the function of its users. Typically a room is the continuous space bounded by walls, a floor and a ceiling. A room provides the space for building occupants to function.

**Security:** A Technical System which provides active and passive security protection as well as detection and alarm systems.

**Service Shaft:** A Sub-System of the Vertical Connectors Architectural System. It provides a vertical passageway for supporting Technical Systems. Examples include vertical shafts for pipes, ducts, electrical conduit, etc.

**Service Space:** A Sub-System of the Floor Architectural System which includes spaces used to support the functions of the building. Such spaces are usually not seen by the occupants and general public, e.g., mechanical and electrical rooms etc.

**Site Equipment:** A Type Level element of the Infrastructure. It is a device which requires power to perform its function. Therefore, it must interface a Utility or Building Technical System to obtain this power. Examples include: water fountains, site lighting, site telephones, lawn sprinklers, etc.
Site Furnishings: A Type Level element of the Infrastructure. It describes facility objects that do not require power. Examples are park benches, signs, fencing, flag poles, etc.

Slab: A Sub-System of the Structural System. A horizontal structural plane or deck within a building's structural system. Typically slabs are level, but they may slope.

Soffit: A Sub-System of the Envelope Architectural System which includes all visible undersides of overhangs and porches.


Struct. Sub-System: (Structural Sub-System) A generic structure which describes the Framing Elements and Connections of a Sub-System level entity in the Structural System.

Struct. System: (Structural System) A System present in every building. The permanent physical elements of the building which transfer loads to the ground.

Suppression: A Sub-System of the Fire Protection Technical System which actively extinguishes a fire. Examples include sprinkler systems, halon systems, etc.

Tech. Sub-System: (Technical Sub-System) A generic structure which describes the Equipment, Controls, Passageways, and Ports of a Sub-System level entity in the Technical System.

Technical System: A System Level entity of a building which describes all Technical Sub-Systems. A technical system allows a building to meet its intended function by providing the necessary technical resources. Typically these systems interface the Infrastructure to obtain or release such resources.

Trans. Network: (Transportation Network) A Type Level element of the Infrastructure which includes all items necessary to support transportation of people and materials to and from the facility. Examples include roads, sidewalks, tunnels, runways, etc.
Utilities: A Type Level element of the Infrastructure which includes all items necessary to supply and remove resources, information and wastes to and from the facility. Examples include telephone lines, sewage lines, power lines, water lines, etc.

Vent: A Sub-System of the Plumbing Technical System which freshens or removes air or other gases from a space. This also includes elements of the drainage system which enable it to function properly.

Vert. Connectors: (Vertical Connectors) An Architectural System which provides a means of vertical transportation within the building.

Wall Surface: Provides a detailed description of the wall surface Finish of an Architectural Sub-System. This would include for example: color, texture, material type, pattern, etc.

Wall: A Sub-System of the Structural System. A planar assembly which serves to transfer vertical loads, separate, divide, or protect areas of a building. Walls, include sturvy wall, shear wall, curtain wall, masonry wall, etc.
Appendix D

Process Control Glossary of Terms

Availability: An attribute of Resources relating to how soon and how easily a resource can be acquired.

Contract History: An attribute of Contracts. Changes and Obligations.

Contr. Level Teams: (Contractor Level Teams) The second level of Team. These teams have a contract with the owner and include such organizations as the general contractor, the architectural/engineering firm and the construction managers.

Contracts, Changes, Obligations: Legal process control elements. Agreement between two or more people or agencies to do something, especially set forth in writing and enforceable by law.

Cost: An attribute of Resources. It is the amount of money which requires expenditure in order to obtain a resource. This may include wages for labor or unit prices for physical resources. It is somewhat more difficult to define a cost for the abstract resources such as information. The cost of time may include damages per day for delayed finishes.

Cost is also a class of contract information. It is the amount of money which requires expenditure in order to obtain the services or product specified in the contract. This cost may be in terms of the processes or the design requirements.

Design Specs.: (Design Specifications) A sub element of both Cost and Scope. The cost of a project and the scope may be defined in terms of the finished product requirements: performance and service characteristics.

Equipment: Non human mechanism resource which requires power or fuel.

Financial: A class of Resources. These resources, including capital and fees, may act as inputs to the processes. Capital are the funds used to start a project or support a project which have not been generated as income from the project. Fees are the income generated from doing work on the project.

Function: An attribute of Resources defining the role of the resource as it relates to the processes.
Group Dynamics: An attribute of Team. Group dynamics is concerned with the performance of the team as a whole. It includes issues such as team cooperation, team experience, and cohesiveness.

Human Resources: A class of Resources. The human mechanisms which perform a process or operation. They include persons performing managerial functions or physical work.

Individual: A work unit, part of a team, is comprised of individuals whose function is to perform a task—a sub function of an activity. For example, some individuals who are laborers, are tasked with providing the effort to install work in place.

Individual Experience: An attribute of Team. This is the experience that each individual brings to the job. Experience related to similar industry projects and specific assignments or tasks can be beneficial to the work unit's performance. Individual experience may also indicate special skills, and knowledge.

Information: A class of Resources. Information, including facts, figures, data and knowledge which aid in the determination of methods and sequences of processes.

Infrastructure: The elements exterior to the building which support the processes. Infrastructure resources include general utilities: electric, telephone, water, sewer, and gas lines required to support a facility.

Labor: The human mechanism resources consisting of the workforce responsible for completion of a specific task or piece of work.

Managerial Labor: The human mechanism resources consisting of individuals who contribute to the running of an office and other project activities but do not participate in physical labor. This category of human resources also includes office labor: support staff, secretaries, and janitors.

Materials: A class of Resources including raw materials needed by construction workers to complete a project (bricks, concrete, drywall, etc.).

Nth Sub. Team: (Nth Subcontractor Teams) The subcontractors at level "n". The Team breakdown does not have a limited number of levels. This models allows for an infinite number of subcontractors. These subcontractors are contracted to do work by the team one level higher.
**Organization:** An attribute of Team describing the structure of responsibility and the functions and duties of the team members.

**Parties:** A class of Contract information. The parties are those people or organizations who have entered into a contractual agreement.

**Physical Resources:** A class of Resources including equipment, tools and materials.

**Process:** A sub-element of both Cost and Scope. The cost and scope of the work can be defined in relation to the processes required by the contract.

**Professional Standards:** An attribute of Contracts, Changes and Obligations.

**Project Team:** The upper level of Team. It consists of a group of people or organizations dedicated to the process of providing a facility. Some team members may include the owner and/or owner representatives.

**Quality:** An attribute of Resources which measures and compares the characteristics of the resources against some desired standard.

**Resources:** The Process Control elements which are inputs or mechanisms to processes. Resources include both physical and information elements.

**Risk Allocation:** An attribute of Contracts, Changes and Obligations. This information attribute describes how project risk is shared between the contracted parties.

**Scope:** A class of Contract information which establishes a complete breakdown of work requirements. The scope is defined in the contract in terms of the processes required or the design specifications.

**Space:** A class of Resources. Space encompasses the areas and paths required to perform an activity.

**Sub. Level Teams:** (Subcontractor Level Teams) The third level of Team. These are organizations contracted to do specialized work by the contractor level teams. These teams do not have a contract with the owner. Examples of subcontractor level teams may include electric contractors, steel contractors, plumbing design consultants, etc.

**Supply:** An attribute of Resources. This attribute indicates whether or not a resource has been delivered.
Team: A Process Control element which acts as a mechanism for an activity. The team is a group of people or organizations dedicated to completing some work activity or task.

Team Leader: An individual of a team who provides guidance, instruction, and representation for the team. At the lower levels where teams are very task specific, there may not be an individual deemed as team leader but instead one or more people providing leadership characteristics.

Terms of Agreement: An attribute of Contracts, Changes and Obligations which specifically states.

Time: Time is an information class of both Resources and Contracts. Time is the duration allotted for activities to be performed. In the Contract, time designates the project duration. However, in resources, time designates a specific process duration.

Tools: Non human mechanism resource which does not require power or fuel. Examples of tools include office supplies, drawing tools, individual and shared construction tools.

Work Activities: An attribute of Team. These are the specific activities or group of tasks assigned to a particular work unit.

Work Unit: A team of individuals working together to perform a specific activity.
Appendix E
Feedback Model Glossary of Terms

Constructability: A class of optimization information gathered through the construction processes. This information forecasts the performance of construction methods chosen.

Cost: Information about all of the costs incurred in providing a facility. This includes forecasted and actual information for labor costs, material costs, equipment costs, overhead costs and subcontracts costs.

Designability: A class of optimization information gathered through the design processes. This information forecasts the performance of design methods chosen.

Feedback on Methods: Information on the procedure or method used to perform a process or create a product. The method is described at a high level in terms of its attributes. It is further described by its associated cost, schedule, and quality. The information is divided into optimization information and performance information.

Operab./Maintain.: (Operability / Maintainability) A class of optimization information gathered through the operation and maintenance processes. This information forecasts how the operate and maintain processes will perform.

Optimization Attributes: A description of a method that provides relationships between labor, equipment, and materials required. Also included are rules for assessing appropriate and proper use of a method.

Optimization Information: Information used to integrate expertise of participants in providing a facility. This includes designability, constructability and operability information. This information is used to forecast the results of a particular method so that the most appropriate method can be selected to meet the project objectives.

Performance Attributes: Properties of a method that describe how it has been or is currently being executed.
**Performance Information:** Information about the progress of methods which, when compared to the plan or optimization information, is interpreted to assess the status of the project and the appropriateness of the plan.

**Quality:** Information about the requirements to achieve the quality level desired for a method. This includes forecasted and actual information for the quality of labor, equipment, materials, process control and management.

**Schedule:** Information about the timing, logical order and production of all the activities needed in providing a facility. This includes forecasted and actual information for production rates, sequence logic and resource acquisition.
Appendix F
Constraint Model Glossary of Terms

Constraints: Factors which limit the ability to perform a process.

Project Constraints: All of the constraints which affect processes in the provision of a facility. Project Constraints include external constraints which affect the entire project and all team members and internal constraints which apply to individual teams and are introduced to the project by a team.

Economic Constraints: The control elements which limit the ability to obtain, transfer, or secure funding. These constraints have a significant influence on financing the project.

Political Constraints: Outside influences on decisions from governing organizations.

Resource Constraints: Limits to the resources which provide the boundaries to the inputs and mechanisms of activities.

Physical Constraints: Factors of the location which determine the conditions under which a facility must exist and processes must be performed.

Legal Constraints: Written or common laws which are applicable to a process.