AN INTEGRATED BUILDING PROCESS MODEL

by

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COMPUTER INTEGRATED CONSTRUCTION

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FOREWORD

The Computer Integrated Construction (CIC) Research Program at Penn State was started in 1987 with a large grant from the National Science Foundation. This grant enabled the research team to develop the fundamental process models defining the scope of the activities required to provide a facility. The research team comprised up to twenty researchers at various stages of its life. It included faculty and research assistants from Architectural and Industrial Engineering, an academic advisory board from five of the leading research schools in the country and a five member industrial advisory board representing experts in each of the phases of the facility life cycle.

This report defines the roles and essential functions required to provide a facility to the end user. This document is the consolidation of a large modeling effort, hence all the research methododology and case study details are not included. It is written to give an explanation of the model, not how it was developed. Researchers who require details and supporting information are directed to the six complementary reports (technical reports two to seven). They define the functions required to manage, plan, design, construct and operate a facility and the selection of a process modeling tool respectively.

There are several other complimentary studies resulting from this work which are detailed in subsequent technical reports issued by the CIC research program.

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ABSTRACT

This technical report presents a generic integrated process model of the activities required to provide a facility. The model includes the managing, planning, design, construction and operations of a facility. In addition to the processes, identification is also given for inputs, outputs, constraints, and mechanisms associated with each function.

The report starts out with an introduction to computer integrated construction (CIC), and defines the methodology and objectives of the model, its scope, and the research activities required to achieve this goal. The second chapter orients the reader to the $IDEF_0$ modeling methodology, defines the upper level of the model, and discusses its evolution and validation. The following chapters define the components of this model, namely, managing, planning, designing, constructing and operating the facility. Finally the benefits of this model and future work are outlined.

ACKNOWLEDGEMENTS

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INTRODUCTION

1.1 THE CIC PROJECT

The National Science Foundation has funded a nineteen member interdisciplinary team together with ten advisors, to explore methods and means of enhancing the use of computers in all phases of the life of a constructed facility. The objective of this Computer Integrated Construction (CIC) project (Sanvido, 1987) is to provide an open information architecture to support the provision of a facility. The team comprises Penn State Architectural and Industrial Engineering researchers together with McDonnell Douglas and selected industry professionals. The intent is to benefit from the pioneering work related to Computer Integrated Manufacturing (CIM) achieved at Penn State by applying similar advances to construction.

The first major thrust of the project was to develop an Integrated Building Process Model (IBPM) that accurately represents the essential functions required to manage, plan, design, construct, operate and maintain a facility. The second half of the project, based on the IBPM, is to define the information and its attributes that are required to drive the system. The major benefit of this exercise is the development of a generic dynamic process and information model that can be applied to a specific project to develop and link the everyday models, eg., budgets, drawings, and specs used to provide the facility.

This report consolidates the results of phase one of the project, namely the definition of the Integrated Building Process Model (IBPM).

1.2 OBJECTIVE - DEVELOP THE INTEGRATED BUILDING PROCESS MODEL

The primary objective of this report is to develop a model of the essential functions required to provide a facility to the end user. These functions include the managing, planning, design, construction, and operations of a facility. This project has chosen buildings as the primary application area, although the models are applicable to any type of facility. Applications and uses for the model will be proposed which can improve current management practices.

Specific objectives are:

1 Determine the essential processes required to provide and maintain a facility over its life.
2 Select a modeling methodology to represent these processes.
3 Develop the Integrated Building Process Model (IBPM).
4 Validate the IBPM.

1.3 SCOPE OF WORK

The IBPM will be developed for buildings with the following properties:

1 Between 75,000 and 250,000 square feet of usable floor space.
2 The owner, planner, designer, constructor and operator can be identified.
3 The facility is built in a free enterprise economic system.
4 The building is in one of the following stages of its life: planning, design, construction or operation.
5 The project participants are receptive to the research team and sufficient checks on information are possible.
6 The projects are located within a one day drive from State College.

1.4 RESEARCH METHODS

The following methods were used by the research team to accomplish the stated objectives:

1.4.1 Determine the Essential Processes Required to Provide and Maintain a Facility Over Its Life

The project team searched the literature for models describing any portion of the life cycle of a building. Many models were found including models by Wheeler (1978), Sanvido (1984,1985), Vanegas (1987), Parshall (1987), Cumberpatch (1983), etc. They varied from narrow rigid closed models to open models showing overviews of parts of the life cycle. Most models tied closely to job descriptions and were non dynamic - they depicted a steady state function.

Discussion with the industry advisory board researchers and visits to local buildings in various stages of their life showed that our definition of the building life cycle as design, construction and facilities management had to be expanded. Hence, building activities with similar processes were grouped as follows:

Manage Facility - 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, contracts, facility management plans and resources to support the goals.

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

Design Facility - All functions required to define and communicate these 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.

Construct Facility - All functions required to assemble a facility so that it can be operated. These activities translate the design into a completed facility along with appropriate facility operations and maintenance documents.

Operate Facility - All of the activities which, when combined with the facility, are required to provide the user with an operational facility.

1.4.2 Select a Modeling Methodology to Represent These Processes

Several modeling tools in use in the construction industry were reviewed for their modeling capability rather than content. Input-process-output models arranged in a hierarchy showed high potential, but the lack of a rigid method for decomposition to low levels of detail was a problem.

Ten manufacturing and industry modeling tools were analyzed. These included entity relationship models and process models, such as: SADT; $IDEF_0$; HIPO; Data Flow Diagrams: Structural Charts; Warnier/Orr Diagrams; Jackson's Diagrams; Chen's E-R Model; STRADIS; SQL; and SAMM (Chung, 1989).

A set of criteria for the model were developed. These were summarized into four categories, viz., technical merit (i.e. able to represent information and functions); ease of use; compatibility with the manufacturing and construction industry; and availability to the industry.

$IDEF_0$ (Integrated 1981) was selected as the most appropriate modeling tool. Chapter 2 introduces the modeling methodology. It serves linear processes very well e.g. constructing a facility, but it does not provide an intuitive representation of similar parallel iterative activities as found in the lower levels of design. Despite this these activities can be modeled.

1.4.3 Develop the Integrated Building Process Model (IBPM)

The IBPM was developed in the $IDEF_0$ format to five levels of detail. This included node trees, definitions, function outlines, and diagrams, describing the processes and flows of information. The model was first developed by the research team. Detailed models have been reviewed three times by the industry advisory board, twice by the academic advisory board and by many other practitioners. The IBPM was progressively refined and improved using the results of each investigation and discussion. The model has undergone three major revisions prior to the current form. These are called the Red, Blue and Green models. Chapter 2 has further details of the earlier versions. Valuable input to the model was obtained from the advisory board members, including leaders in the construction field from both academia and the industry.

1.4.4 Validate the IBPM

Once the model was developed, companies and projects were selected to serve as case studies. The criteria for the selection of these projects included the willingness of the company to allow personnel to be interviewed. Questions were developed to ask key personnel during the case studies to identify the specific tasks involved in providing the facility, and to identify the key inputs, constraints, outputs and mechanisms required to support these activities. The use of documents and other methods of information transfer, and the content of the information at different stages in the process was identified. Interviewees included foremen, field staff, project managers, general managers, partners and presidents.

The "Provide Facility" level of IBPM was checked at each site. Each portion of the process, e.g. design, construction was validated on projects that were in that specific phase of the life cycle. Table 1.1 lists the portion of the IBPM checked on specific projects. Complete validation is not assured by this sample of 22 projects, but the researchers found that they had to make minor changes in details of the lower level model to explain some site phenomena. Thus no major evidence was found, based on any site visited, to refute this model.

1.5 ORGANIZATION OF THE REPORT

Chapter 2 discusses the modeling methodology selected for this project, and describes the upper levels of the IBPM. The model's evolution is also discussed. Chapters 3 through 7 describe the details of the manage, plan, design, construct, and operate portions of the model respectively. Chapter 8 concludes the model and points the reader to related works. A select bibliography and comprehensive glossary are included.

Table 1.1 Description of Projects Used to Test the Integrated Building Process Model

Model	Company Description	Project Description
Provide Facility	All Projects	Average size building 125,000 ft^2
Manage Facility	National Insurance Investment Developer Metropolitan Developer/ Facility Operator Regional Design-Build Contractor National Supplier of Pre-Engineered Buildings	Two 125,000 ft^2 Office Buildings Four 125,000 ft^2 Office Buildings 25,000 to 75,000 ft^2 Buildings 25,000 to 75,000 ft^2 Buildings
Plan Facility	Large Institutional Owner with In-House Planning Capability Regional Design-Build Contractor National Supplier of Pre-Engineered Buildings	100,000 ft^2 Laboratory, Conference and Office Space Building 25,000 to 75,000 ft^2 Buildings 25,000 to 75,000 ft^2 Buildings
Design Facility	Mechanical Design Division of Company Electrical Design Division of Company Plumbing Design Division of Company National Supplier of Pre-Engineered Buildings	120,000 ft^2 Hospital 120,000 ft^2 Hospital 120,000 ft^2 Hospital 25,000 to 75,000 ft^2 Buildings
Construct Facility	Regional Construction Contractor Regional Design-Build Contractor Regional Design-Build Contractor Local Construction Contractor Regional Design-Build Contractor	Two Four-Story Commercial Office Buildings in Urban Setting Large High School Athletic Facility Large Single Family Luxury Homes Medium Sized Store 25,000 to 75,000 ft^2 Buildings
Operate Facility	Institutional Owner Power Supply Utility Institutional Owner Institutional Owner National Supplier of Pre-Engineered Buildings	Large University Campus Power and Support Facilities Medical School Facility Minimum Security Prison 25,000 to 75,000 ft^2 Buildings

Chapter 2

THE INTEGRATED BUILDING PROCESS MODEL

This chapter introduces $IDEF_0$ as the modeling methodology used to develop the IBPM. It then describes the context of the model before defining its first level. The final sections discuss the evolution of this model through three earlier versions and its validation through case studies.

2.1 THE $IDEF_0$ MODELING METHODOLOGY

In this section, the ICAM Definition Method is described. The structure and schematic representation of the $IDEF_0$ methodology is discussed, and the diagramming methodology is explained. For a detailed discussion, the reader is referred to publications by the Integrated Computer Aided Manufacturing organization (Integrated 1981).

The Integrated Computer Aided Manufacturing (ICAM) Definition Method (IDEF) is a set of structured analysis techniques for performing system analysis. Its main purpose is to provide engineering methods for analyzing and designing complex systems, and is used to understand and manage such systems (Wallace et al. 1987). IDEF supports multiple views of the system, and allows the system to be modeled from three different perspectives: Functional, Informational, and Dynamic.

In this report, the scope of modeling is limited to process modeling techniques. Therefore, the discussion will be limited to the functional model $IDEF_0$. The reader should keep in mind that functional modeling perspective is the first step in the IDEF modeling methodology, and informational and dynamic models may be developed in the future to create a comprehensive model of the construction process.

2.1.1 Schematic Presentation

Each box in the diagram represents a function which is an activity, action, process, operation, or a transformation (Integrated 1981). One or more inputs are transformed into one or more outputs using the mechanisms provided. The transformation process is controlled by one or more controls. Data is defined as any information or physical object which is transformed, constrains the function, or results from the function. The data entities are represented schematically in Figure 2.1.

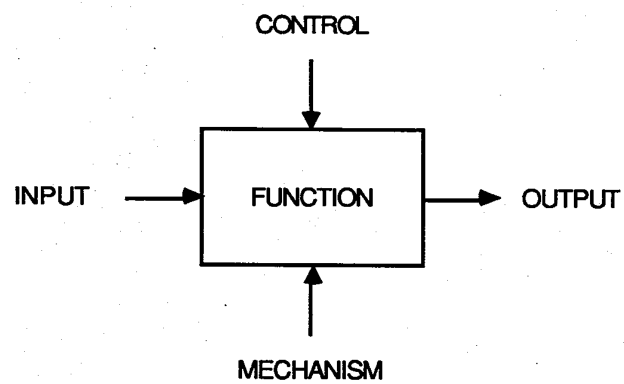


Figure 2.1: Schematic Presentation of the Function Box

Five entity types are used in the $IDEF_0$ modeling methodology: function, input, output, control, and mechanism. Each is briefly described below (Integrated 1981):

Function: An activity, action, process, operation, or transformation which is described by an active verb and an object is a function. The function is shown by the box in the diagram.

Input: An input is an entity which undergoes a process or operation, and is typically transformed. It enters the left of the box, and may be any information or material resource.

Output: Shown exiting the right side of the box, outputs include entities, such as data, which result from a process or objects which are created by a function.

Control: Control elements are entities 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. On the diagram, controls are shown entering the top side of the box.

Mechanism: Shown on the bottom side of the box, mechanisms are entities, such as a person or a machine, which perform a process or an operation. It describes how a process is accomplished.

An example is shown in Figure 2.2 which demonstrates the use of each data entity type.

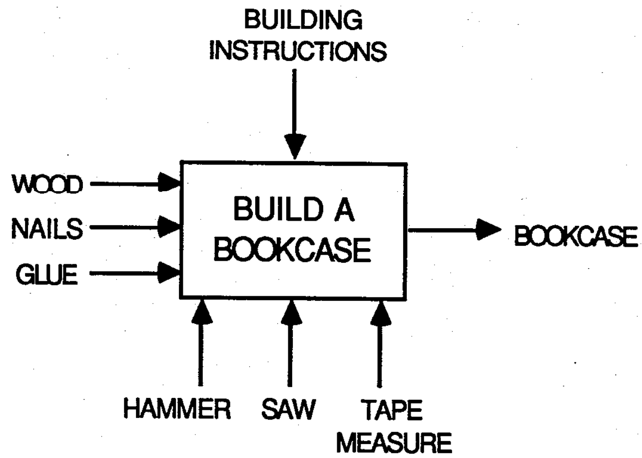


Figure 2.2: Example of a Function Box Center

2.1.2 Structure of $IDEF_0$

$IDEF_0$ represents a system by means of a model composed of diagrams, text, and glossary. The model is a series of diagrams with supportive documentation that break a complex subject into its component parts (Integrated 1981). The diagrams consist of boxes and arrows which express the functional activities, data, and function/data interfaces. Text accompanies each diagram which narrates the activities in the diagram. In the glossary, all terms used in the diagrams are defined.

Hierarchy of $IDEF_0$ Diagrams: $IDEF_0$ starts by representing the whole system as a single box with arrow interfaces to the environment external to the system. This box is decomposed into between three to six functions, each of which may be further decomposed into subprocesses. This top-down decomposition process may be continued, generating between three to six "child" or detail diagrams for each function on any given level. A hierarchy of diagrams results, as shown in Figure 2.3.

Gradual Exposition of Detail: The number of functions in each diagram is limited to a minimum of three and maximum of six. This limits the level of detail and complexity in any diagram while preventing the diagram from being trivial. The level of detail is also controlled by the position of the diagram in the hierarchy of diagrams. Each level of decomposition increases the amount of detail, resulting in a gradual exposition of detail. Decomposition along any given node is discontinued when the level of detail is sufficient for the application of the model.

Modularity of $IDEF_0$ Diagrams: When a box is decomposed, the scope of the function and its interface arrows create a bounded context for the subfunctions. The scope of the detail diagram fits completely inside its parent function, and

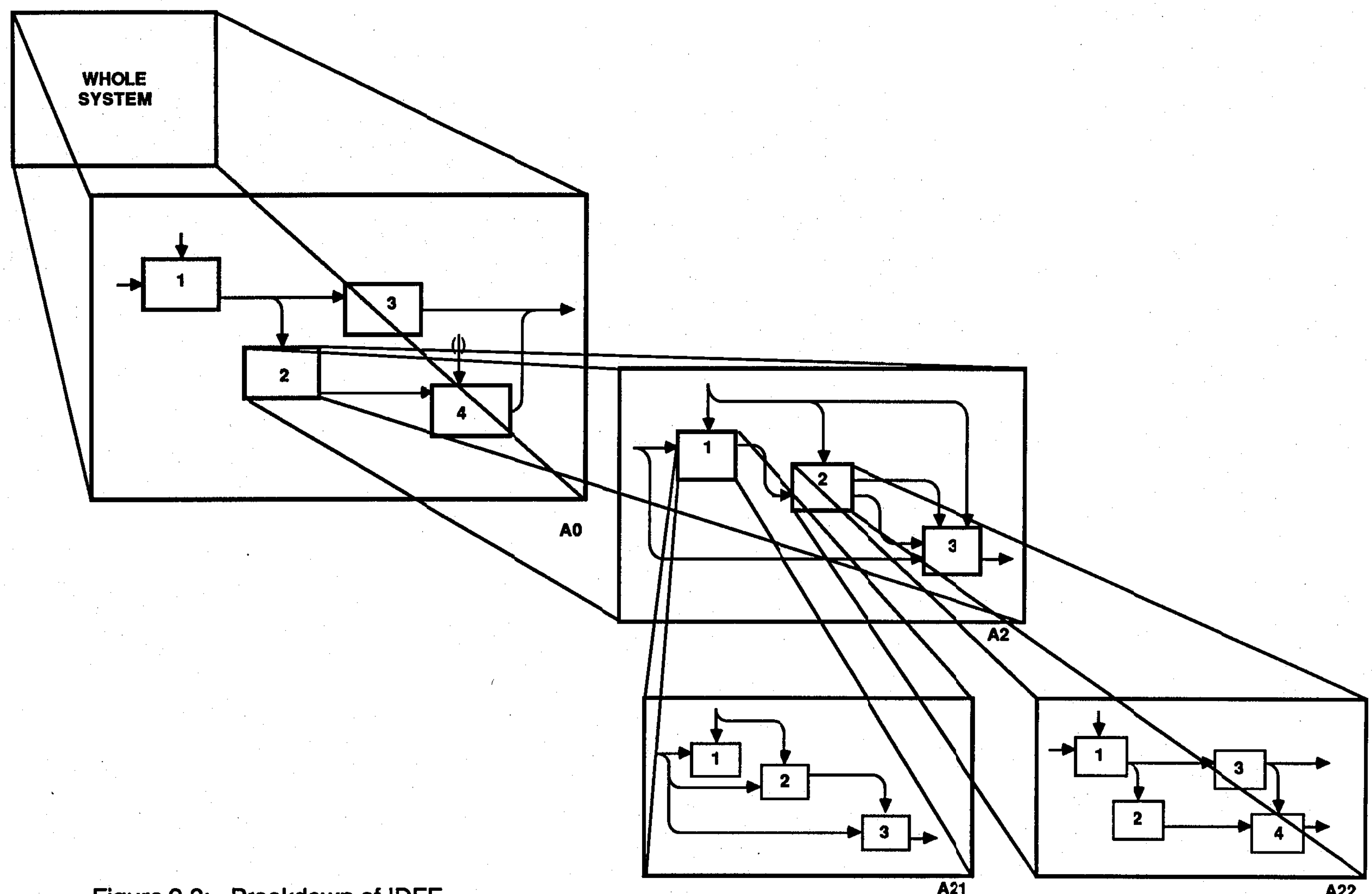


Figure 2.3: Breakdown of $IDEF_0$

the interface arrows of the parent box match the external arrows of the detail diagram. Therefore, all arrows which enter or exit the detail diagram must be the same arrows which interact with the parent diagram.

Numbering the IDEF$_0$ Diagrams: The highest level in the model which is the single box representation of the system is labeled A-0. The next level of decomposition shows the major functions of the system and is called the A0 level. Each box in this diagram is labeled from A1 up to A6 and is ordered in sequence. Decomposition of each box leads to diagrams A1 through A6. Further decomposition leads to additional digits placed after a decimal point, so that the diagram resulting from decomposing the first function on four successive levels is represented by A1.111. This numbering system allows the user to retrace the steps of decomposition through the parent function of each diagram. The models developed in this report place the decimal after the letter, e.g., M.1.

2.1.3 Reading IDEF$_0$ Diagrams

The IDEF$_0$ model is a series of diagrams arranged in a hierarchical manner. The model is read top-down, and the following sequence should be followed in reading it (Integrated 1981):

1. Scan the boxes in the diagram to get a general impression of what is being described.

2. Refer back to the parent diagram and note the arrow connections to the diagram. Try to identify a "most important" input, control, and output.

3. Find the central theme of the current diagram. Try to determine if there is a main path linking the "most important" input or control and the "most important" output.

4. Mentally walk through the diagram from upper left to lower right, using the main path as a guide. Study the overall content of the diagram.

5. Read the text and the glossary provided to gain a further understanding of the author's intent.

2.1.4 Tunnelled Arrows

To maintain integrity of the model, the diagrams must remain consistent from one level to the next. All data entities which interface with a function box must appear on its detail diagram as arrows entering or leaving the boundaries of the detail diagram. Exceptions may be made, however, with arrows which are tunnelled. Tunnelling indicates that the data conveyed by these arrows are not relevant to the particular level of detail. For example, all processes in the previous example in Figure 2.2 require time as a control. However, no new information is gained by showing time at each function. In such cases, it would be appropriate to show the data entity tunnelled at the highest level and not show it in the following levels.

Examples of tunnelled arrows are shown in Figure 2.4. Tunnelling on the connected end (e.g. C3, O1) indicates that the data entity may not be shown in lower levels of detail. Tunnelling on the unconnected end (e.g. I1, C2) represents data entities which may not be present in the higher level diagrams.

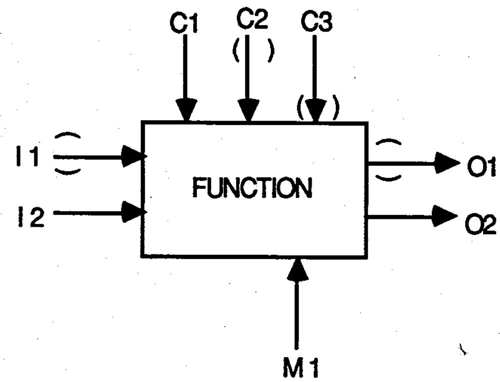


Figure 2.4: Example of Tunnelling

It is possible for tunnelled data entities to not appear for several levels, then reappear as a tunnelled arrow. To reduce confusion, such data entities should be labeled by their origin.

2.1.5 Layout of Model

The IBPM comprises a set of numbered flowcharts drawn using the $IDEF_0$ method described, a set of definitions of the functions in the boxes, and a glossary of definitions of labels on the arrows. Each drawing can be traced through its number in the title block to its origin in the parent diagram (located in the right hand lower corner of the box). The diagrams should be read first, then the supporting documents.

This concludes the explanation of $IDEF_0$. The IBPM, an $IDEF_0$ based model follows.

2.2 THE INTEGRATED BUILDING PROCESS MODEL

This section defines the Integrated Building Process Model (IBPM) via a series of figures and explanations. This section focuses on the context of the IBPM and the first layer. Full details of the models' lower layers together with supporting case studies can be found in Chapters 3 through 7.

2.2.1 The Context of the Model

The model was developed from the perspective of an observer outside the whole process. It is an abstract representation taken from observations of many building projects by the project team, advisors and other reviewers. The actual mechanisms used in the execution of the functions will depend on the project delivery method. This generic model, when complemented with the appropriate mechanisms, accounts for all contract delivery options.

Figure 2.5 sets the function "Provide Facility" within the context of an owner's/ user's view of their typical business operations. "Conduct Business" comprises the following three subfunctions:

Develop Business Opportunity: The owner's marketing team conduct market studies, identify new business opportunities and develop plans for new business operations or modification of current operations. The product of this function are: needs required to meet the new operational requirements, the facility idea, and the definition of the proposed new service/ product.

Provide Facility: This function is triggered by the needs of the new business operations. The nature of such needs will be the major influence on "Provide Facility." For example, marketing strategists may emphasize that the new service/ product has to be in the market in a specific time. This will then be reflected as a schedule constraint.

Conduct Business Operations: Provided with the needed facilities and other operating resources, the business operations will take place. In addition to influences set by "Develop Business Opportunity," this function will be subject to external constraints such as economy and market conditions.

2.2.2 The Boundaries of "Provide Facility"

Figure 2.6 is the $IDEF_0$ model of "Provide Facility" that defines the boundaries of the IBPM for this report. The IBPM includes all activities that are required to support the execution of this function. Figure 2.6 consists of a single block showing the inputs (facility idea, resources), the controls (external, and project participants' constraints), the mechanism (free enterprise economic system and facility champion), and the outputs (operational facility, facility experience, and the impact on environment). Three elements will be tunnelled, shown as an arrow with parentheses on one end. In this case they are the free enterprise economic system, the external constraints, e.g., weather, and the impact on the environment. This tunnelling of arrows means that they will not be shown at the next level of detail - they essentially add nothing to the model and clutter the drawing. These will reappear when their influence is specific to an activity.

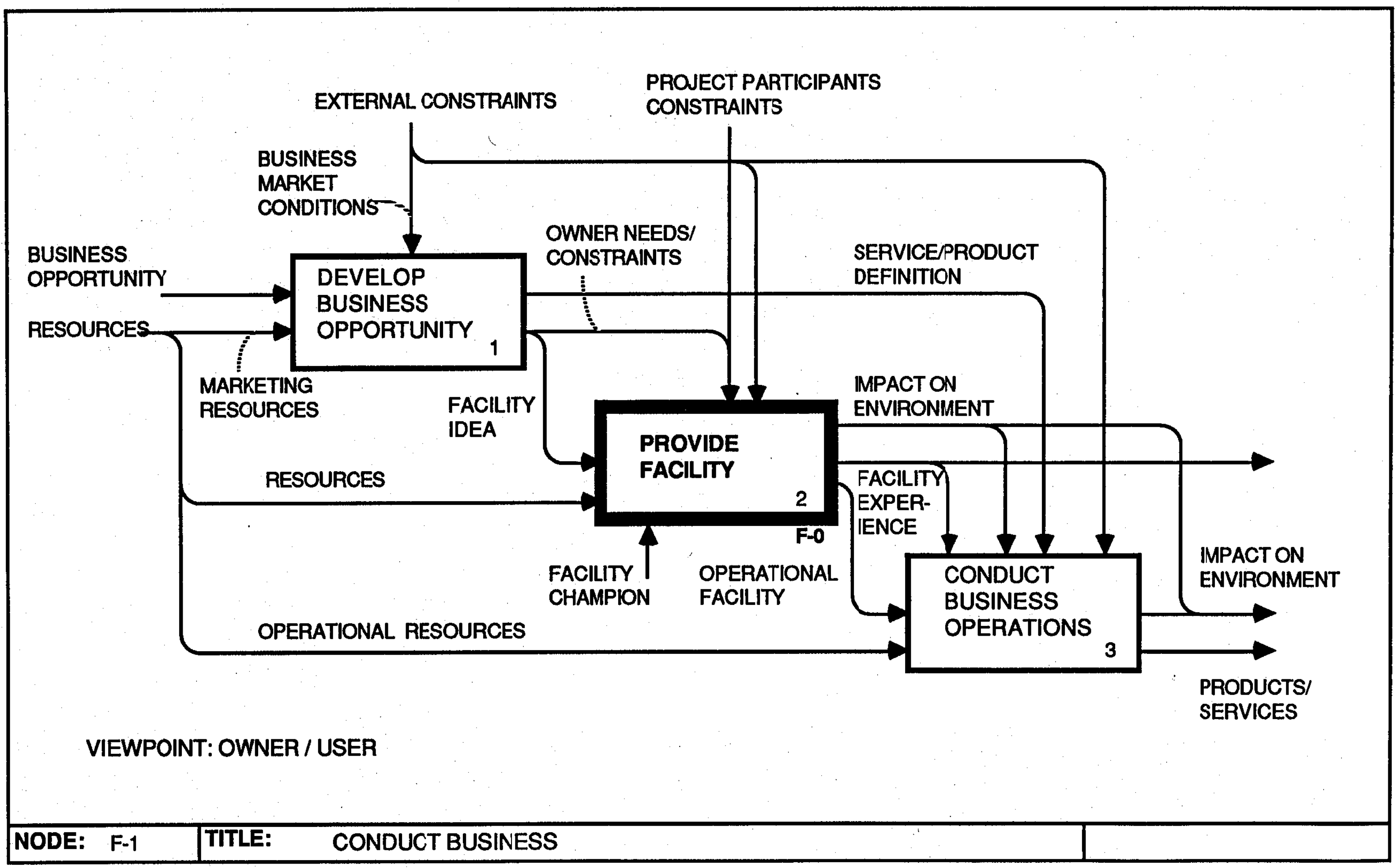
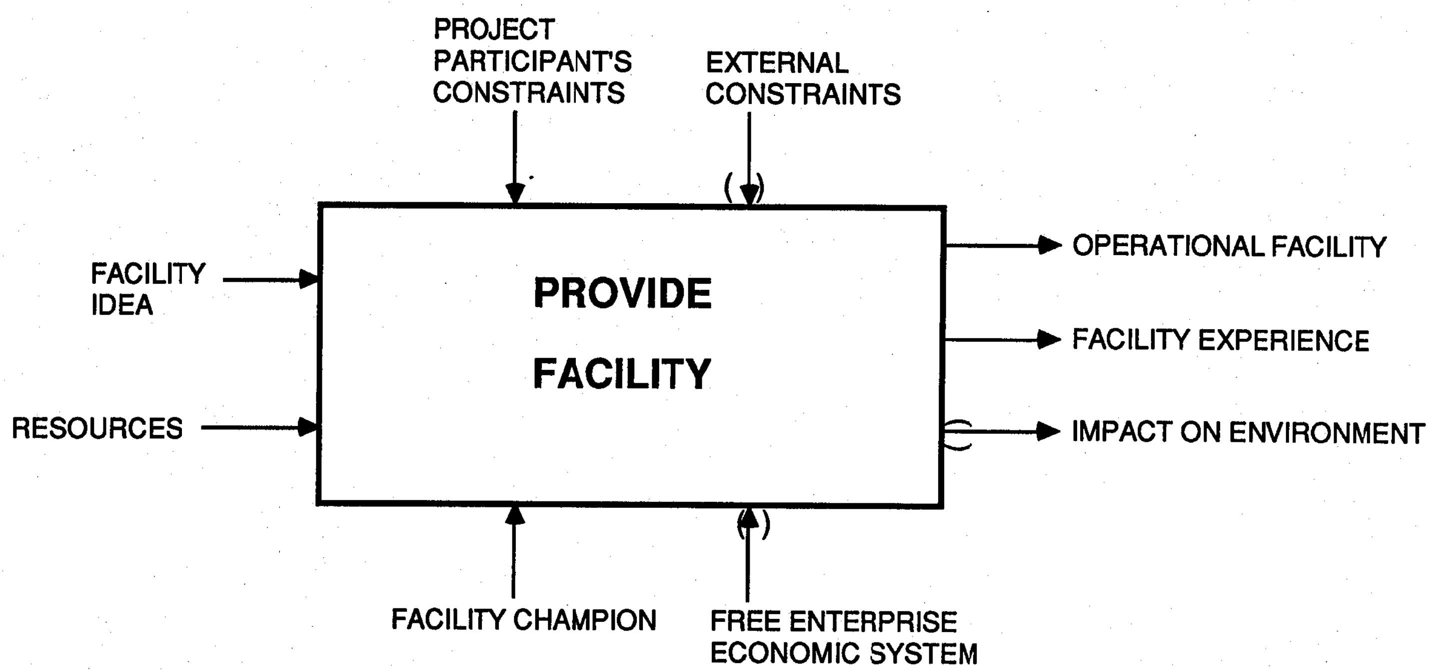


Figure 2.5: Conduct Business



Purpose : This model describes idealized owner's functions and their relationships in a construction process.

Viewpoint : The owner / User

NODE: F-0	TITLE: PROVIDE FACILITY	BY:	CHECKED BY:

Figure 2.6: The Boundaries of the IBPM

2.2.3 Components of "Provide Facility"

Figure 2.7 divides the process of "Provide Facility" into the following five subprocesses: Manage Facility, Plan Facility, Design Facility, Construct Facility, and Operate Facility. Detailed definition of these subprocesses follow.

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 - 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.

Plan Facility encompasses all the functions required to define the owners 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 engineer), the facility plan, the contract and optimization information. Other outputs include facility planning knowledge and information on the performance of the team.

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.

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.

Operate Facility comprises all of the activities which are required to provide the user with an operational facility. 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.

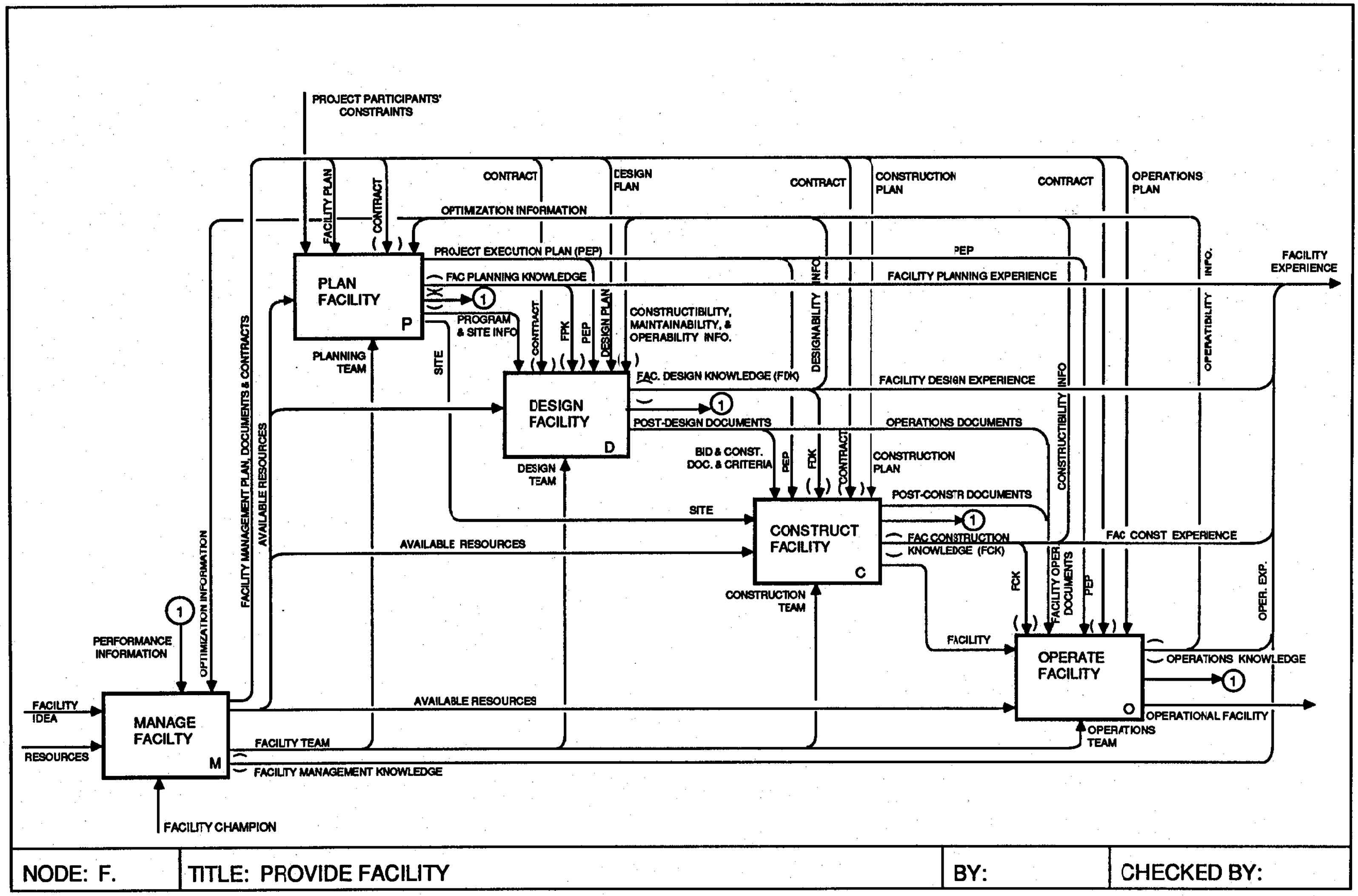


Figure 2.7: Provide Facility

The elements that flow between these functions and their decomposition are defined in chapters 3 through 7. The following sections track the development of the IBPM.

2.3 EVOLUTION OF THE IBPM

The IBPM has been developed through extensive interviews with experts and practitioners; twenty-two site visits; and multiple reviews by each of a five member academic panel and a five member industry panel. The IBPM has evolved through three earlier forms to its current stable form. Each of these three versions were developed by the researchers and reviewed by the advisory boards. Limited field testing to check sections of the model were performed.

2.3.1 First Version of IBPM

While the IBPM drawings may seem obvious and simple, they differ significantly from those first assembled by the project team. The first version of the IBPM (also known as the Red Model) is shown in Figure 2.8. The key functions are plan, design, construct and manage facility. The manage function is analogous to the current definition of operate facility. The Red Model combines technical and management functions and was heavily influenced by who performed the function. This model did not group like activities, but was organized along contracting lines, ignoring the role of the owner.

2.3.2 Second Version of IBPM

Figure 2.9 shows a second version of the IBPM (the Blue Model). The manage function was redefined as operate and maintain facility. Several feedback loops between the functions were inserted, e.g., operability information. Each of the four functions, viz. planning, design, construction and operations & maintenance were treated as combined business and technical functions.

The Blue Model describes the view that a contractor performing a limited portion of the project may have of the total process. In this case the business and technical functions are combined and treated as a whole. Subsequent review of this model showed that the business functions of each phase were very similar, in fact almost identical. Hence in order to effectively integrate the project it would be advantageous to combine the business functions. This eliminated much duplication evident in the Blue Model, and resulted in the Green Model.

2.3.3 Third Version of IBPM

Figure 2.10 shows the third major version of the IBPM (the Green Model). As mentioned previously, the Green Model separates the business functions (function M) from the technical functions (functions P,D,C,O) and groups them into manage facility. This explicitly recognizes the integrative functions

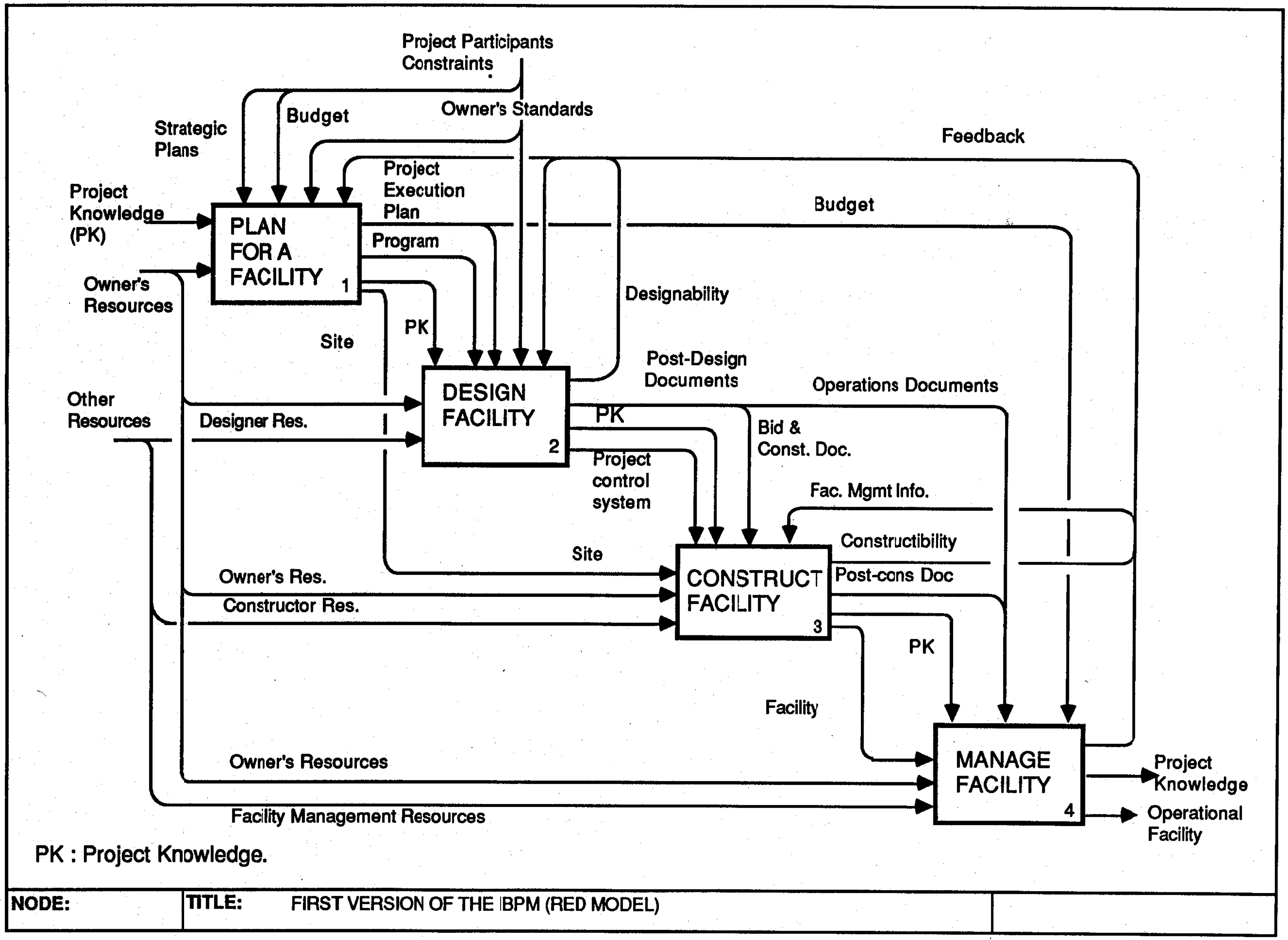


Figure 2.8: First Version of IBPM (Red Model)

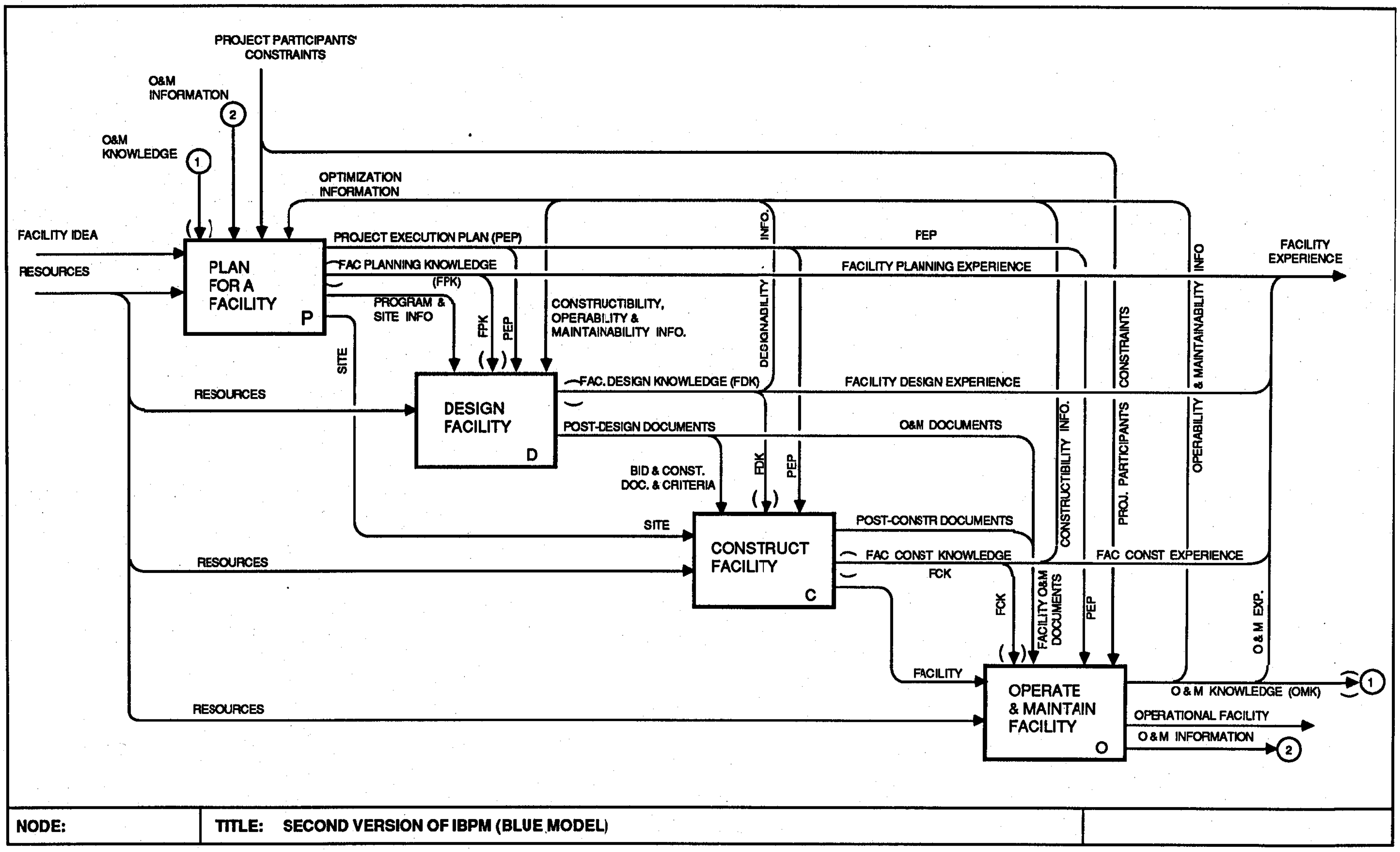


Figure 2.9: Second Version of IBPM (Blue Model)

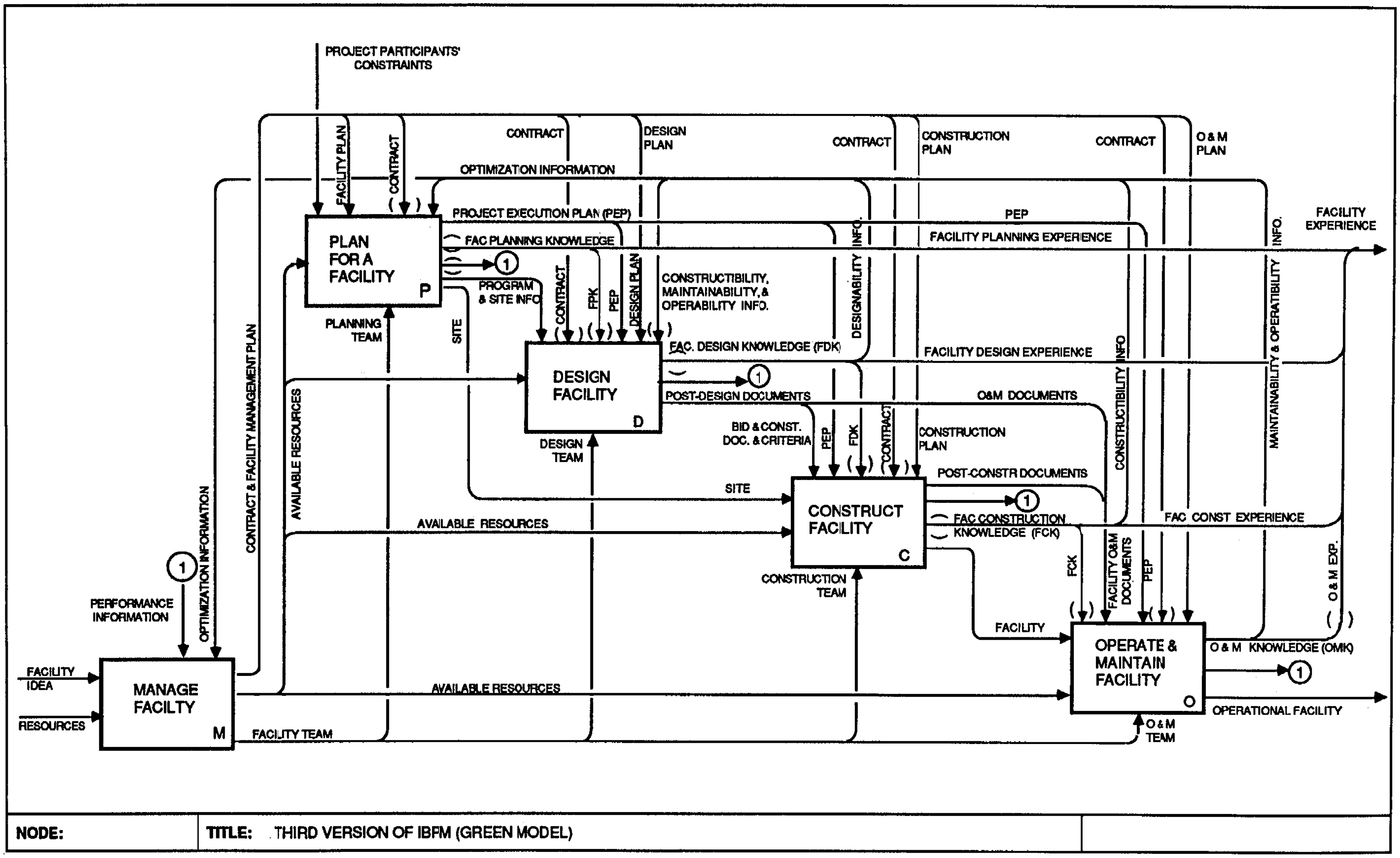


Figure 2.10: Third Version of IBPM (Green Model)

provided by the owner's project manager or an owner's agent. This agent assumes the role of the master builder and ensures that the flows between the subfunctions occur in a manner to support the completion of the desired facility as a whole.

By separating the management functions for each group and combining them into one generic management function called "management of the facility," the user of the model can focus on the technical data required to provide a facility. This consolidation of management functions does not include the management required to support and control the subfunctions as entities. This model recognizes that there are planning and control, service acquisition and resource acquisition functions that are performed at both the facility level and the subfunction level. These management functions thus show up in lower versions of the model, but are specific to the subfunctional task, e.g., design or construction.

2.4 VALIDATION OF THE MODEL

These models were validated or rather checked for major errors and omissions. Several sites were selected, and a total of 22 case studies (see Table 1.1) were conducted. The procedure for conducting a case study for each sub function in the IBPM, e.g., manage facility, is defined in detail in the respective technical reports. A summary is included here for completeness.

Criteria for selecting the companies and sites are defined in section 1.4. A series of non-leading questions was developed for checking each subfunction in the model. These focused on determining whether the functions in the model were correct, checking the flows in the model, and finally checking whether the absence of an element or the restriction of its flow caused problems on the site. Typical questions for any given function included:

> What are the key subfunctions required to perform the given function?
>
> What are the key inputs required to support the given function and who provides them?
> Cross check with provider of inputs.
>
> What are the outputs or products of the function and who receives them?
> Cross check with recipient of outputs.
>
> What are your goals for this activity? (cost, schedule, quality)
> Cross check with superior and subordinates.
>
> Who is responsible for, and what mechanisms are used to perform said task?
> Field check to verify.

This procedure was applied to all functions in the model. A second set of independent validation data is obtained by checking the lower level functions. The results of these questions when combined and "rolled up" into general elements and functions provide this second check on the upper level responses.

One minor modification was made to the model to move from the Green to the current and final version. This is the recognition of the facility champion as the key to providing the function.

The team thus has extremely high confidence in the validity of the model. It is important for the reader to review the exact definition of the terms in the model (provided in the glossary) to gain a comprehensive understanding of the IBPM. Wherever possible, industry terms have been used. In many cases the researchers found that interpretations among companies of supposedly standard industry terms was significantly different among companies. Hence the inclusion of the glossary.

2.5 SUMMARY

This chapter described the $IDEF_0$ modeling methodology. The context and upper level of the IBPM was presented. A description of the model's evolution and its validation was provided. The following chapters define the model in full detail.

Chapter 3

THE "MANAGE FACILITY" MODEL

As described in Chapter 2, Manage Facility includes all the business functions and management processes required to support the provision of the facility from planning through operations. The main purpose of the management process model is to generically define essential activities required to manage a facility, from its inception to its completion. Complete details of this model can be found in Technical Report No. 2 (Khayyal, 1989).

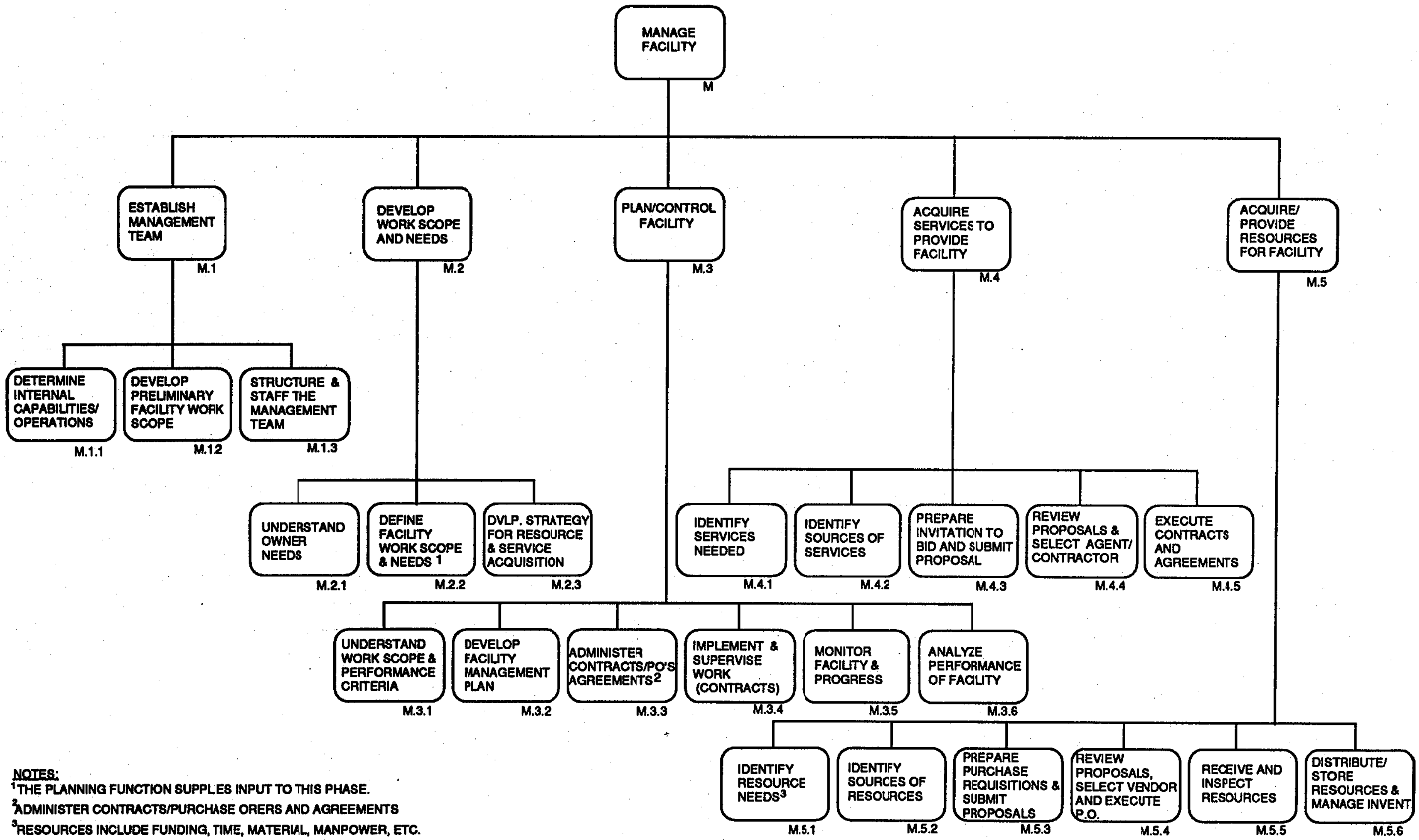
3.1 THE MANAGEMENT FUNCTION

Management of the facility provides all the support resources, personnel direction, and agents to transform a facility idea and the required resources into a facility. It administers contracts and solves financial and managerial problems that arise through the course of development of the facility. Specific activities include: initiation of a project organization; determination of project objectives, policies, and strategies (i.e., facility management plans) for development; definition of project workscope; plans for acquisition and control of resources and services; and allocation and distribution of funds, resources, and services required for provision of a facility. In addition, generation and processing of all documents and contracts required for performance of the management plans takes place in the management function.

3.2 MANAGE FACILITY

The management process model represents the activities that are required to bring about a completed facility from the viewpoint of the building user. The management process is decomposed into five major functions numbered M.1 through M.5. These functions are generic in that they only show an abstract representation of how the facility is provided.

An overview of all the functions included in the management model is shown in the function tree in Figure 3.1. This tree divides the functions into essential subactivities. The Manage Facility function is separated into the subfunctions of Establish Management Team, Develop Work Scope and Needs, Plan/ Control Facility, Acquire Services to Provide Facility, and Acquire/ Provide Resources for Facility. All of the functions and subfunctions are explained in the following sections. Definitions of all the terms used in the model are provided in the glossary (see Appendix B).



NOTES:
[1]THE PLANNING FUNCTION SUPPLIES INPUT TO THIS PHASE.
[2]ADMINISTER CONTRACTS/PURCHASE ORERS AND AGREEMENTS
[3]RESOURCES INCLUDE FUNDING, TIME, MATERIAL, MANPOWER, ETC.

Figure 3.1: Manage Facility Node Tree

The Manage Facility function is broken down into five subfunctions (see Figure 3.2). Each is explained in the following sections.

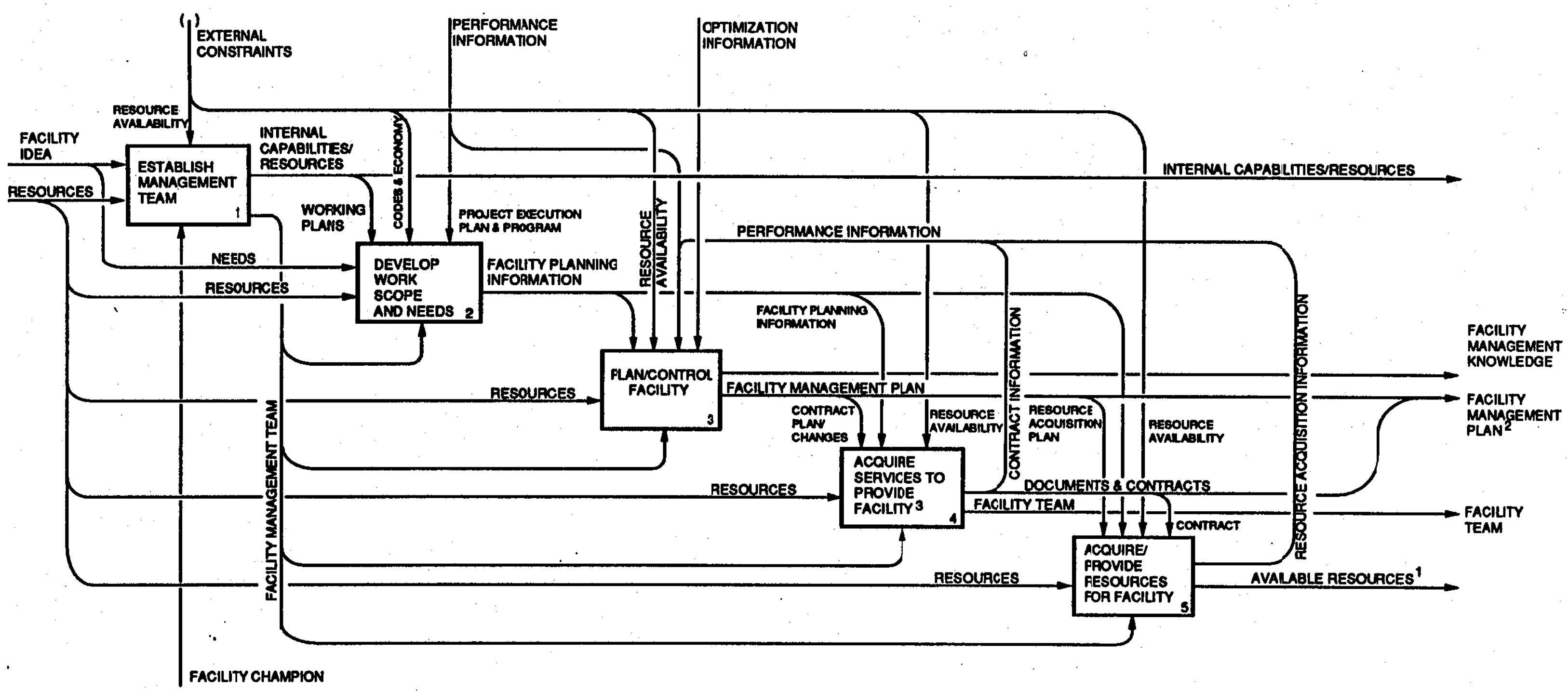
Establish Management Team (M.1): This function serves to establish an initial project organization, which then acts as an initial steering team/ committee, having a detailed work plan. This function also assesses internal capabilities and resources to be used in providing the facility. Additionally, a project brief is established so that a program for further action can be made (i.e., a determination of site ownership, boundaries, and rights of way). Essentially, this function forms the preliminary strategy by setting the initial objectives, and surveying internal resources available for providing a facility.

Develop Work Scope and Needs (M.2): 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. In addition, the owner's needs are defined and classified based on their priority. Once there is a clear description of the work and people involved in providing the facility, a policy/ strategy is developed for resource and service acquisition.

Plan/ Control Facility (M.3): 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.

Acquire Services to Provide Facility (M.4): This is the process of soliciting the required services to provide the desired facility and assembling the facility team. These services include planners, designers, constructors, and facility management personnel. These services are not usually, but occasionally may be acquired at the same time. An example of a situation where all the facility team players would be brought on board would be for turnkey/ design-build projects. For the management phase, this function includes all contracts and agreements between owner and designer, contractor, operator, etc. This does not include subcontracts between designer or contractor and subcontractors.

Acquire/ Provide Resources for Facility (M.5): This is the process of acquisition, allocation, and the distribution of resources required to provide the facility. This includes necessary information, financing, funding, time, site, material, equipment, manpower, operational support resources. This process also includes storage of the resources and management of the inventories (ensures delivery of services/ resources - expedites, tracks, pays, and examines quality of items received).



1 ONE SUCH RESOURCE IS FUNDS.

2 INCLUDES ALL CHANGES TO FACILITY MANAGEMENT PLANS AND DIRECTIVES.

3 THIS INCLUDES ALL CONTRACTS AND AGREEMENTS BETWEEN THE OWNER AND DESIGNER, CONTRACTOR, OPERATOR, ETC. IT DOES NOT INCLUDE SUBCONTRACTS AND AGREEMENTS BETWEEN AND AMONG DESIGNERS, CONTRACTORS, AND SUBCONTRACTORS.

NODE: M	TITLE: MANAGE FACILITY	BY:	CHECKED BY:

Figure 3.2: Manage Facility

3.3 ESTABLISH MANAGEMENT TEAM (M.1)

The Establish Management Team function is broken down into three subfunctions (see Figure 3.3). Each is explained in the following sections.

Determine Internal Capabilities/ Operations (M.11): Assesses in-house capabilities to provide a facility. This function assesses, steers and evaluates the roles and responsibilities of the initial facility team.

Develop Preliminary Facility Management Work Scope (M.12): This involves assembling the necessary criteria to develop a problem statement defining the need for a facility.

Structure and Staff the Management Team (M.13): This function develops strategies for organizing and staffing the project (i.e. consultants, QA/ QC staff, etc.) based on the given work scope. This also involves acquiring the services of the selected participants needed to provide a facility.

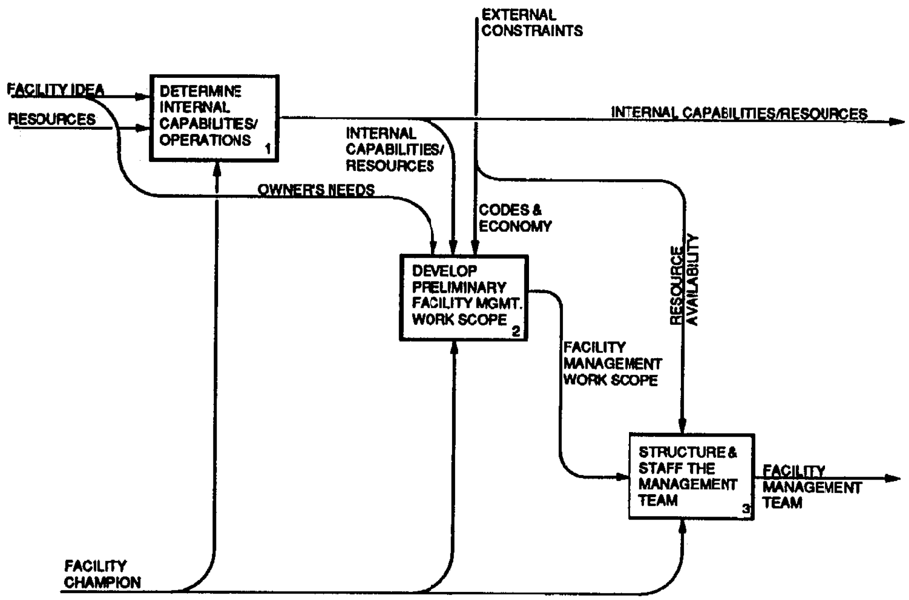
3.4 DEVELOP WORK SCOPE AND NEEDS (M.2)

The Develop Work Scope and Needs function is broken down into three subfunctions (see Figure 3.4). Each is explained in the following sections.

Understand Owner Needs (M.21): This function involves understanding all the programming needs/ aspects (i.e. goals, facts, concepts, and needs-money, space quality, etc.) required to build a facility.

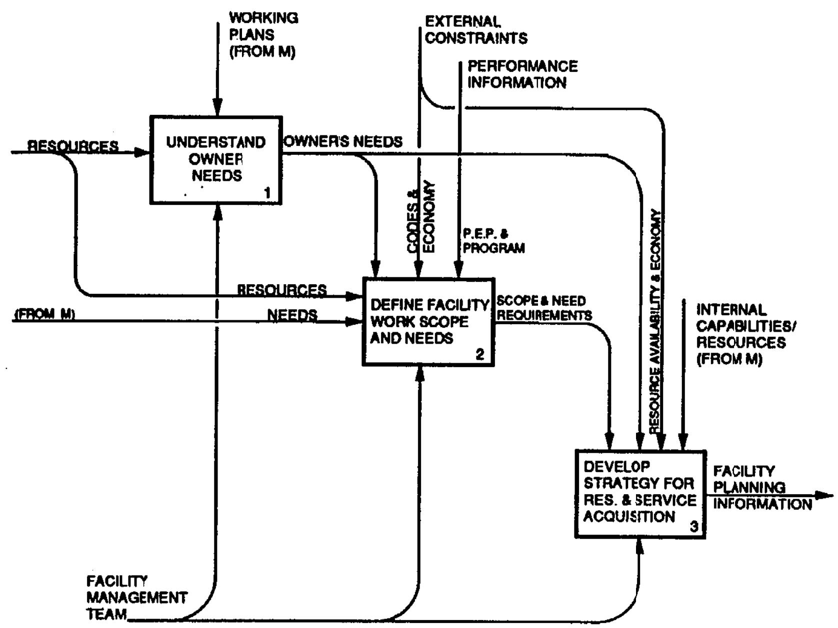
Define Facility Work Scope and Needs (M.22): This function serves to solidify the problem statement for the creation of a facility (i.e., scope of design, packaging of contracts, defining of the construction techniques preferred, etc.). It identifies the conditions and specific directions for the design, construct, and operate aspects of a facility and the methods for how each aspect is to be implemented. The information elements addressed in defining the work scope are: function, form, economy, and time. In addition, risk assessment is made based on: project complexity, site factors, financing, delivery time, functions, uses, and obstacles expected on a project.

Develop Strategy for Resource and Service Acquisition (M.23): This function serves to coordinate and steer all the variables involved with resource and service acquisition. The scope and need requirements, internal capabilities/ resources, and resource availability are accounted for. Then a direction/ strategy is developed for the quantity and method of procurement for resources and services needed to provide a facility.



NODE: M1	TITLE: ESTABLISH MANAGEMENT TEAM	BY:	CHECKED BY:

Figure 3.3: Establish the Management Team



NODE: M2	TITLE: DEVELOP WORK SCOPE & NEEDS	BY:	CHECKED BY:

Figure 3.4: Develop Work Scope and Needs

3.5 PLAN/ CONTROL FACILITY (M.3)

The Plan/ Control Facility function is broken down into six subfunctions (see Figure 3.5). Each is explained in the following sections.

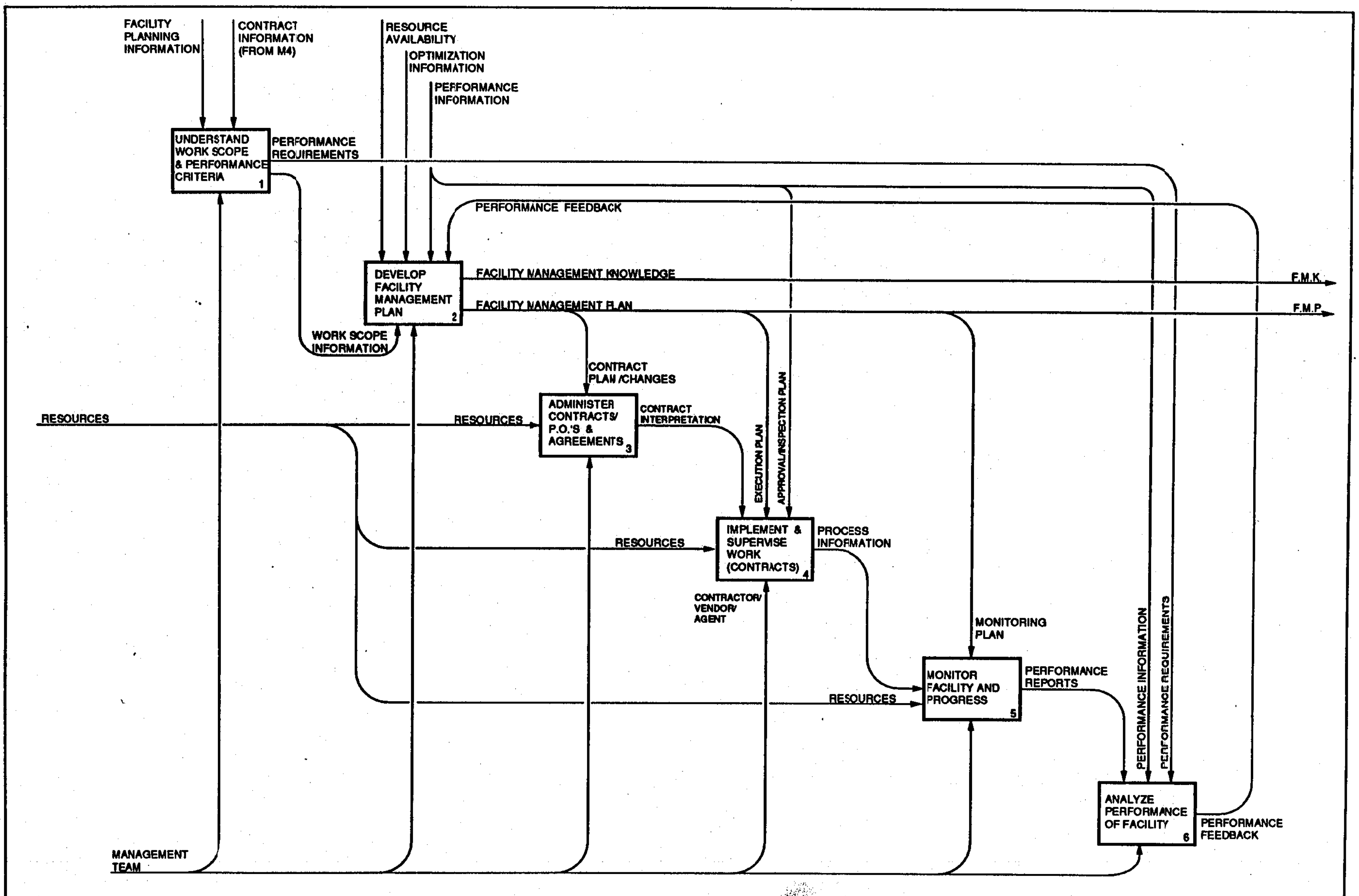
Understand Work Scope and Performance Criteria (M.31): Involves comprehending extent of work and standards set for the work. This allows scope inconsistencies among the prepared contract(s) to be raised and corrected. This function also involves evaluation of the time and money needed to deliver a facility (identification of parameters in which the work is to be performed).

Develop Facility Management Plan (M.32): Serves to guide execution and co-ordinate efforts of all phases of the facility management life cycle. This includes developing solutions, studying contract pricing alternatives, controlling documents, evaluating problems and making changes/ decisions/ schedules etc., to ensure successful project completion.

Administer Contracts/ Purchase Orders and Agreements (M.33): This function serves to handle communication problems, logistics, negotiate agreements, plan and process changes, enforce compliance (monetary, environmental), secure necessary permits/ insurance, maintain contract files, and handle contract closeouts (walkthrough inspections, completion notices, contractor evaluations, warranties, as-builts, etc.). In addition, it serves to check that contracts/ purchase orders get accomplished or followed up to ensure completion of the particular work item involved.

Implement And Supervise Work-Contracts (M.34): This involves implementing management decisions, monitoring field performance and taking action based on field contract administration responsibilities (i.e., backcharges, cost collection, progress billings and payments, contract interpretations, claims, contract closeout, facility start-up, mobilization, etc.). Quality assurance criteria and acceptance requirements are also developed. This function mainly serves to inspect the work as it is developed (and when completed), and it either accepts or rejects the results.

Monitor Facility and Progress (M.35): This function, first and foremost, is performed to ensure that the owner is getting what is wanted. This function involves walking the job and holding meetings, etc., to collect and release data specified in the plans, to control costs and cost records, and to control pricing and payment. It may also involve checking whether a contractor has insurance coverage or whether changes in the work are being priced correctly and paid for expeditiously. Some other functions include: monitoring the progress schedule, approving/ denying payment requests, controlling procedures for use/ possession of facilities prior to completion, and also monitoring/ assessing liquidated damages.



NODE. M3	TITLE: PLAN / CONTROL FACILITY	BY:	CHECKED BY:

Figure 3.5: Plan/ Control Facility

Analyze Performance of Facility (M.36): This serves to investigate and study unforeseen and existing circumstances related to meeting the expected requirements of a project. This includes reviewing contractor submittals and other data, and identifying problems. It measures achievements against goals for the projects; so that decisions for further action can be made. Essentially, this function analyzes all data from function M.35 (i.e. review of design, and construction progress, and the operations of the building).

3.6 ACQUIRE SERVICES TO PROVIDE FACILITY (M.4)

The Acquire Services to Provide Facility function is broken down into five subfunctions (see Figure 3.6). Each is explained in the following sections.

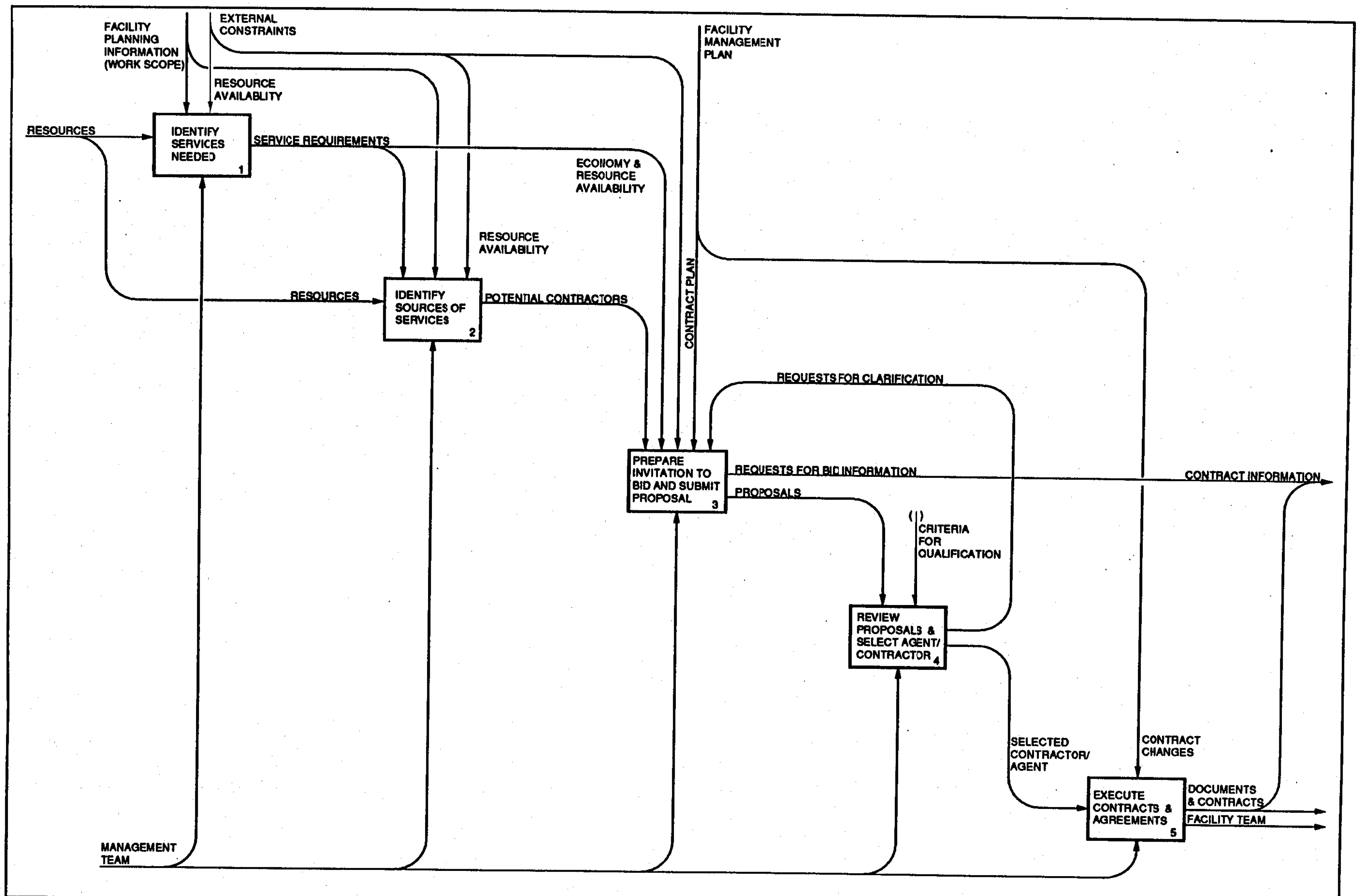
Identify Services Needed (M.41): This function identifies the primary functions necessary to provide a facility. These functions include the plan, design, construct, and operate subprocesses as well as other special services.

Identify Sources of Services (M.42): This includes determining the qualified parties who are capable of performing a service for a particular work item needed in providing a facility (i.e. potential agents/ contractors). The particular service requirements necessary for providing a facility and the work scope parameters (i.e. work packaging by outside firms, availability of services/ resources, etc.) control this function.

Prepare Invitation to Bid and Submit Proposal (M.43): This includes preparation of bid packages, instructions to bidders, development of contract proposal formats, and management of the bid cycle.

Review Proposals and Select Agent/ Contractor (M.44): Includes prequalifying selected agents/ contractors, for services to be rendered, based upon qualification data and from reviewing and analyzing bid proposals. After a thorough screening of the qualified parties, individual agents/ contractors are selected.

Execute Contracts and Agreements (M.45): Developing and providing the design and contract documents necessary to provide a facility (i.e., special and general conditions, addenda, etc.) as well as awarding the contract(s).



NODE: M4	TITLE: ACQUIRE SERVICES TO PROVIDE FACILITY	BY:	CHECKED BY:

Figure 3.6: Acquire Services to Provide Facility

3.7 ACQUIRE/ PROVIDE RESOURCES FOR FACILITY (M.5)

The Acquire/ Provide Resources for Facility function is broken down into six subfunctions (see Figure 3.7). Each is explained in the following sections.

Identify Resource Needs (M.51): This function assimilates a detailed listing of all resources required to furnish a facility. The information is gathered based on the work scope for providing a facility, the owner's purchasing policy, as well as the external constraints which may affect resource acquisition.

Identify Sources of Resources (M.52): This includes searching for all possible entities which may be capable of delivering the required resources needed to provide a facility (i.e. banks, suppliers, vendors, etc.).

Prepare Purchase Requisitions and Submit Proposals (M.53): This function includes preparation of requisitions and bid packages, instructions to bidders, development of a proposal format, and management of the bid cycle.

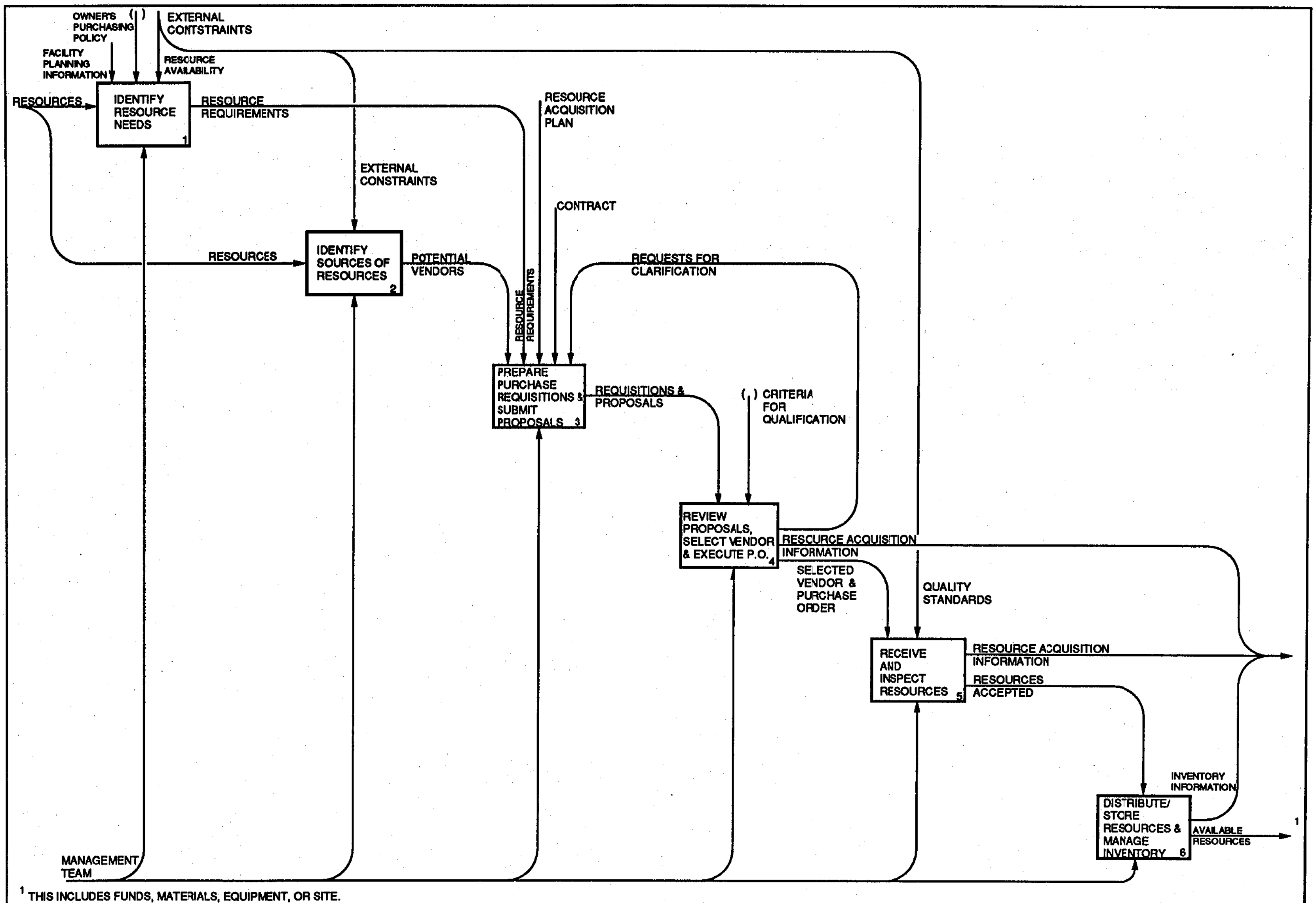
Review Proposals, Select Vendor and Execute Purchase Order (M.54): Includes prequalifying selected contractors/ vendors/ agents, for resources to be acquired/ provided, based upon qualification criteria and also from reviewing and analyzing bid proposals. Once this review is performed, contractors/ vendors/ agents are selected. In most cases, resources are acquired/ provided through purchase orders, which serve as the mechanism for resource acquisition.

Receive and Inspect Resources (M.55): The process of certifying the resources received against what was ordered (i.e. quality, required specifications, delivery condition, quantity, etc.).

Distribute/ Store Resources and Manage Inventory (M.56): This function serves to distribute all acquired resources to the respective players needing the purchased/ provided/ financed resources at the appropriate point in time. It serves as the central clearing house for all resources obtained; handling both inventory, storage and distribution. Resources here are meant to include funds, materials, equipment, manufacturing plant, or site(s).

3.8 SUMMARY

The above definitions of the functions in the Manage Facility Model briefly describe the basic tasks. Although the terminology used is abstract, they can be used to identify practical instances whereby user specific terminology can be applied (i.e. facility management plan [abstract] and pro-forma [developer specific]). The next chapter defines the Plan Facility Model.



NODE: M5	TITLE: ACQUIRE / PROVIDE RESOURCES FOR FACILITY	BY:	CHECKED BY:

Figure 3.7: Acquire/ Provide Resources for Facility

Chapter 4

THE "PLAN FACILITY" MODEL

This chapter presents the "Plan Facility" model. The model describes the planning process from the viewpoint of the owner's project manager. It consists of a series of related diagrams with supporting explanations and a glossary of definitions (see Appendix B for Glossary). The model will expose details of "Plan Facility" in a gradual manner, both in the graphical part of the model as well as the textual explanations. Complete details of this model can be found in Technical Report No. 3 (Guvenis et al., 1989).

4.1 THE PLANNING FUNCTION

"Plan Facility", driven by the owner's constraints, represents the development of the facility idea into plans (i.e., the program and the project execution plan) and into site information. These two are significant for the other functions in the overall Integrated Building Process Model (IBPM). They drive "Design Facility" which produces the "Design" that includes design calculations, construction documents and operations and maintenance (O&M) documents in addition to the associated undocumented information such as concepts developed and assumptions made by the designers. The "Design" and the "Plans" control the "Construct Facility" function which consumes construction resources to produce the operational facility and the related post-construction information (i.e., O & M manuals, as-built documents).

"Plan Facility" starts at the facility idea stage and ends with the plans and site information. Typically, this function is performed by the owner. Depending on the nature of the facility and the owner's experience, external planning services may be acquired as needed. The planning function is very critical for the owner due to the following reasons:

a) The owner is closely involved in the planning function. As a minimum, the owner participates in clarifying the project requirements and his critical concerns.
b) In the planning function the owner makes the project's major decisions. These may include the decision to (or not to) proceed with the project. Other decisions include the option to rent, buy, remodel, or build the facility.
c) The chance for a major influence on the project cost is higher at the planning stage.

4.2 PLAN FACILITY

Figure 4.1 shows the node tree which details the functional decomposition of "Plan Facility". The six sub-functions are:

P1 Assign Planning Team;
P2 Study / Define Needs;
P3 Study Feasibility;
P4 Develop Program;
P5 Develop Project Execution Plan (PEP); and
P6 Select and Acquire Site.

Figure 4.2 shows the $IDEF_0$ diagram which relates these functions to each other by means of inputs, outputs and constraints. Brief explanations of each of the above subfunctions are given in the following sections.

4.3 ASSIGN PLANNING TEAM (P.1)

This refers to establishing 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. This node is not expanded further in this report.

4.4 STUDY / DEFINE NEEDS (P.2)

This function starts with the "Facility Idea" and generates the plans for meeting the user's needs. To be successful, this function should be performed with user participation. Figure 4.3 divides this function into the following sub-functions.

Study User Requirements (P.21): The planning team studies the requirements set by the user and seeks clarification of these requirements from the user representative.

Evaluate Existing Facilities (P.22): The compatibility of existing facilities with current and future operations are evaluated. The cost of maintenance and associated expenses (e.g., operational shutdowns) might be of interest. Facilities with high O&M costs or those unsuitable for current or future operations should be either modified (i.e., remodeled or expanded) or disposed of: by sale, by transfer to another user, or by demolition.

Determine Users' Needs (P.23): By comparing facilities requirements against available facilities, the planning team defines the necessary facilities, or facility modifications.

Generate Alternatives (P.24): Providing a facility is normally possible by different means (e.g., buy, rent, build). This function explores such alternatives.

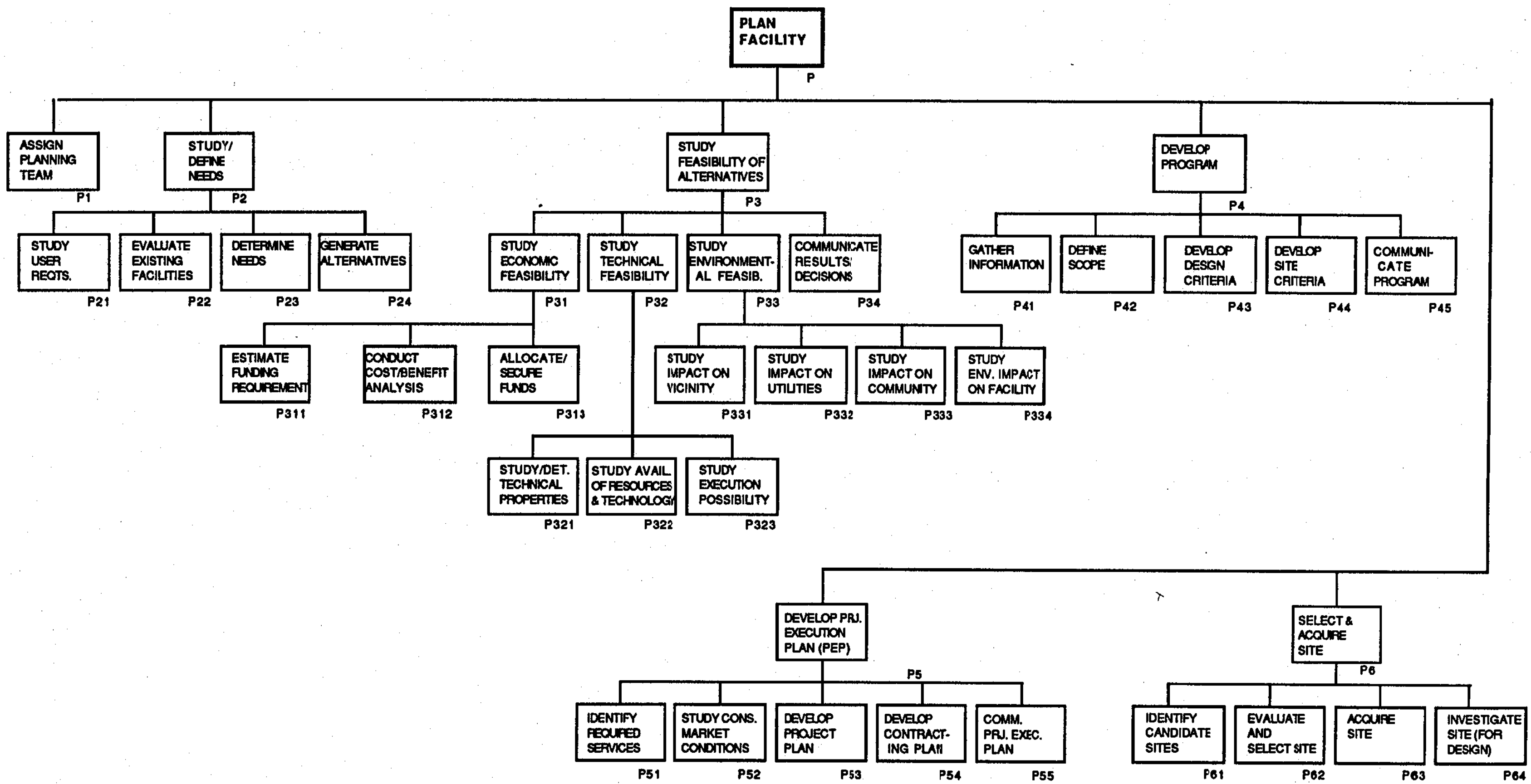


Figure 4.1: Plan Facility Node Tree

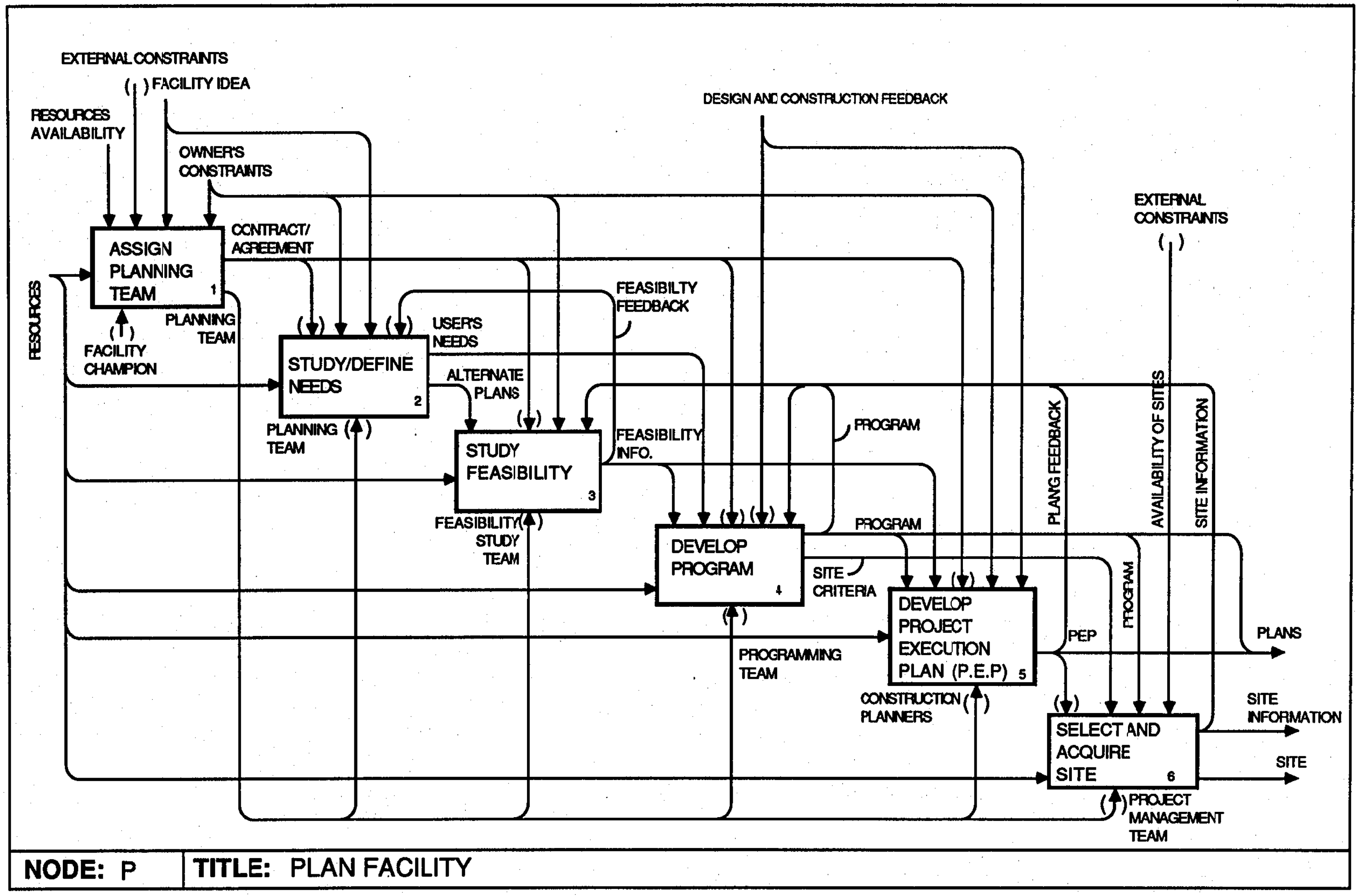


Figure 4.2: Plan Facility

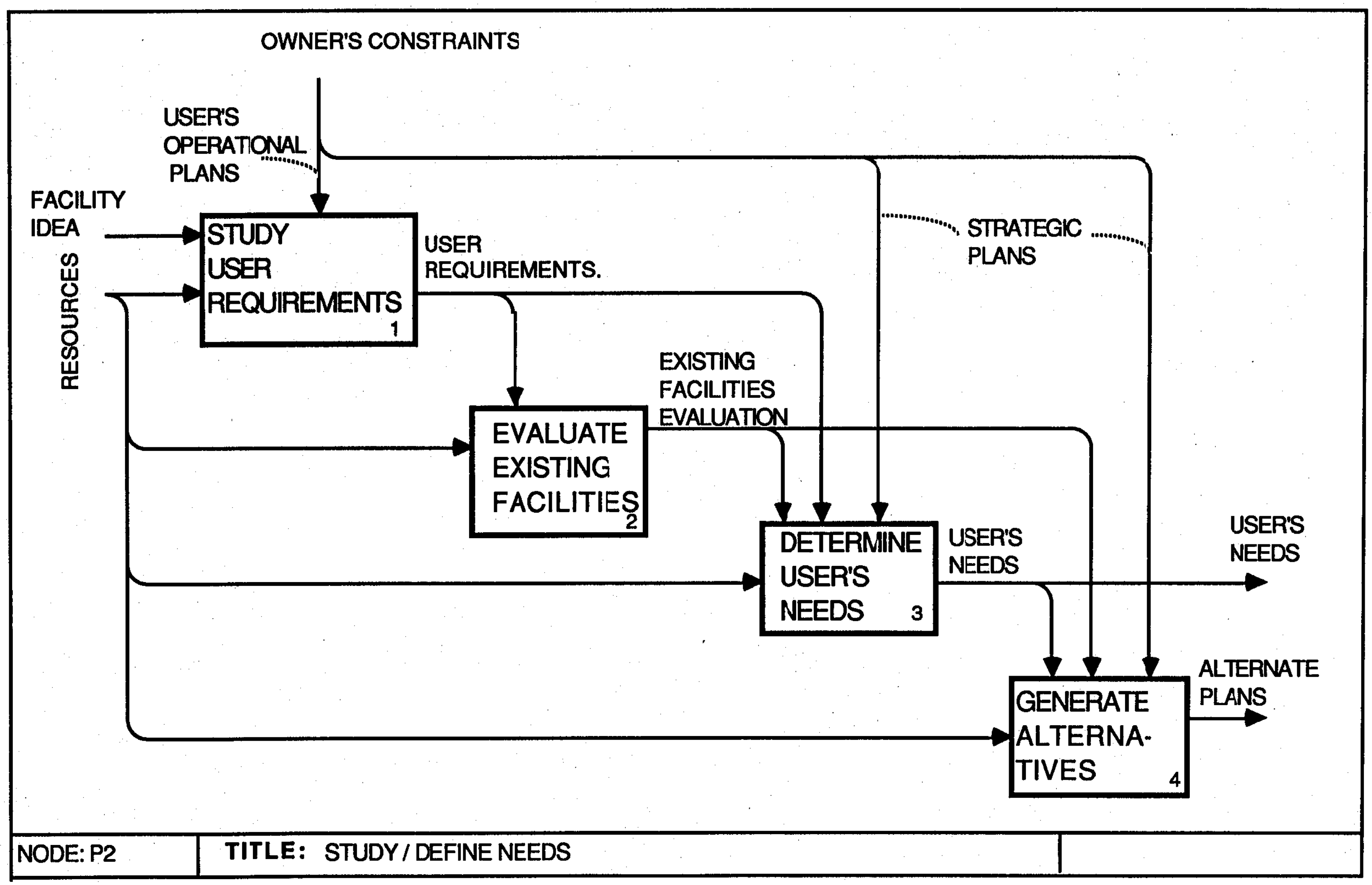


Figure 4.3: Study/ Define Needs

4.5 STUDY FEASIBILITY OF ALTERNATIVES (P.3)

The feasibility study includes economic feasibility, technical feasibility and environmental feasibility studies. These aspects which are shown in Figure 4.4 are also detailed below.

Study Economic Feasibility (P.31): As detailed in Figure 4.5, this function includes estimating the funding requirements, performing the project cost/benefit analysis and allocating and securing the project funds and their sources. The outcome of this study should answer the question: "Given owner's financial status, is it financially and economically possible to build the facility?"

Study Technical Feasibility (P.32): A breakdown of this function to its sub-functions is shown in Figure 4.6. This study should answer the question: "Given the available technology and resources is it possible to build the proposed facility?" Technological constraints such as material properties (e.g., structural, chemical) should be considered in constructability reviews.

Study Environmental Feasibility (P.33): A breakdown of this function to its sub-functions is shown in Figure 4.7. In this study the potential impact of the project on the environment (as enforced by regulatory authorities) and those of the environment on the project should be considered (Williams and Massa 1983). The consequences of these impacts may be sufficient to stop the project.

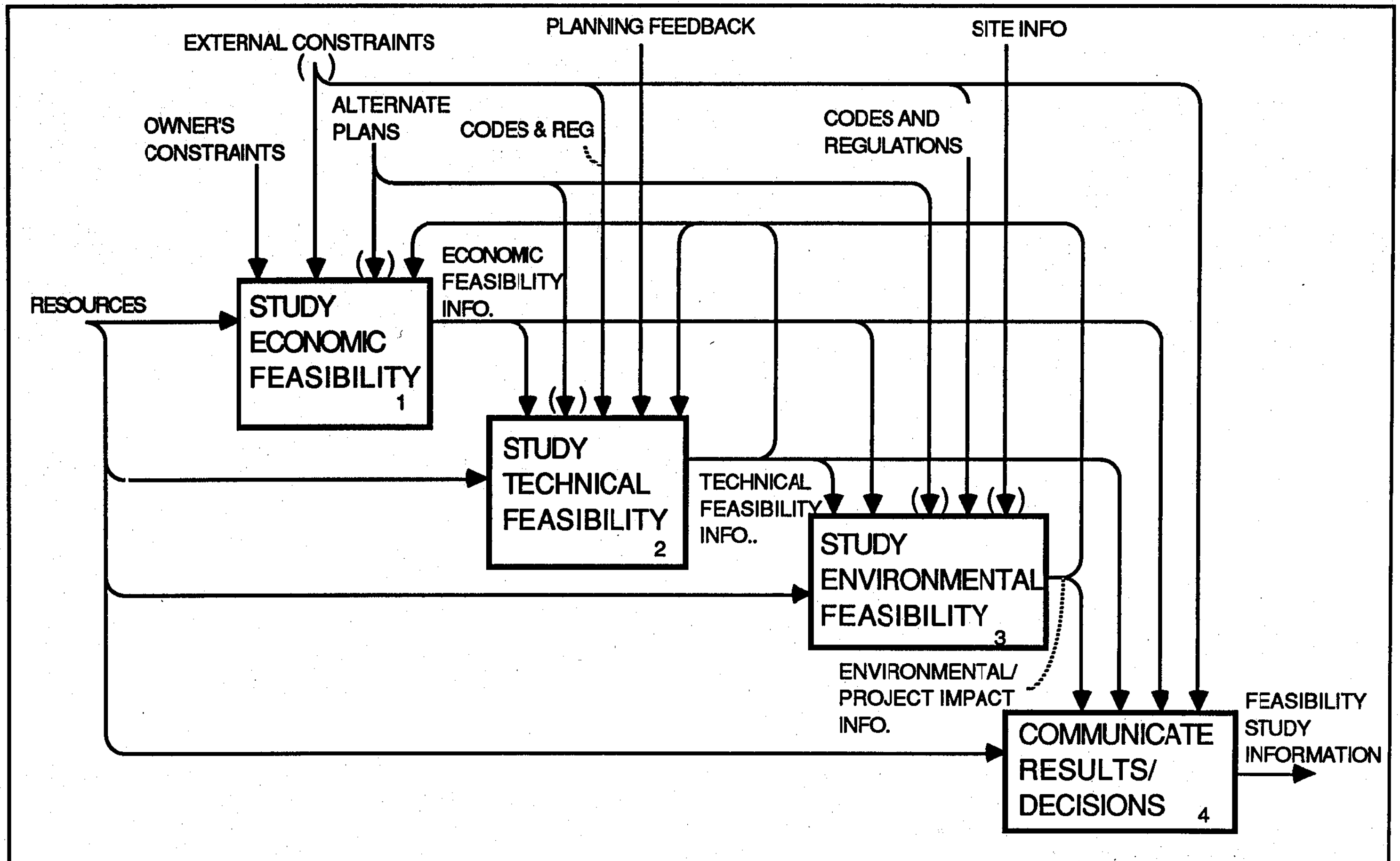
Communicate Results / Decisions (P.34): This function synthesizes the technical, economical and environmental studies, concluding with a decision to proceed with the project. If a decision to proceed is made, a plan of action which sets constraints such as the budget, schedule or scope of the project, will be issued .

4.6 DEVELOP PROGRAM (P.4)

The purpose of developing a program is to define, in detail, the project scope and size or capacity. According to AIA Document B141 (AIA 1977), the program should include the owner's design objectives, constraints and criteria, including space requirements and relationships, flexibility and expansibility, special equipment and systems. If the site is not predetermined, the program will include site criteria. Programming, as shown in Figure 4.8, includes:

Gather Information (P.41): The function includes collecting and understanding all the available information that describes the proposed facility. Different approaches may be employed including user interviews, questionnaires, literature research and visits to similar facilities.

Define Scope (P.42): Based on the information collected and the applicable constraints (e.g., budget, schedule) the scope of the project is defined.



NODE: P3	TITLE: STUDY FEASIBILITY OF ALTERNATIVES	

Figure 4.4: Study Feasibility of Alternatives

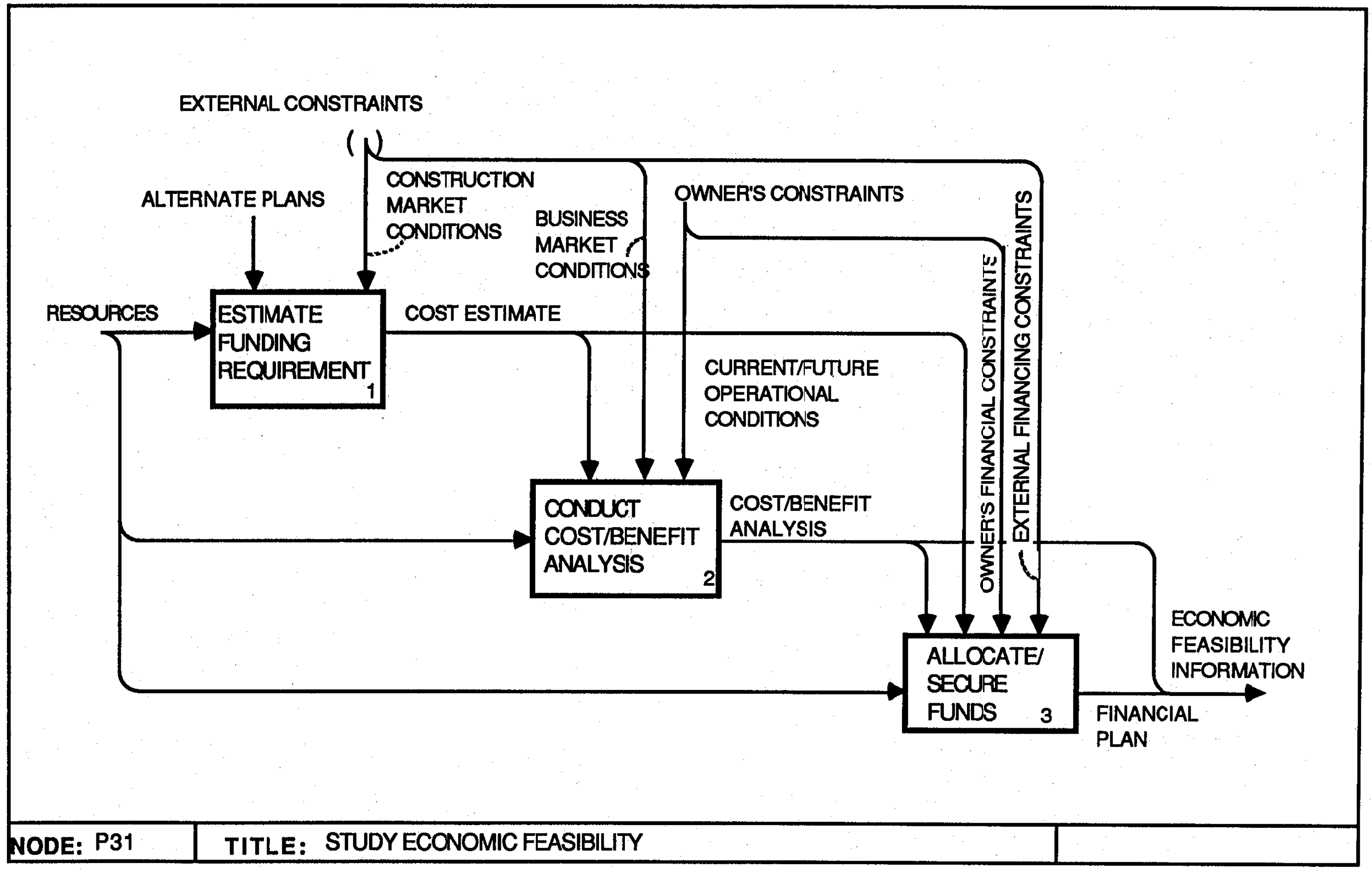


Figure 4.5: Study Economic Feasibility

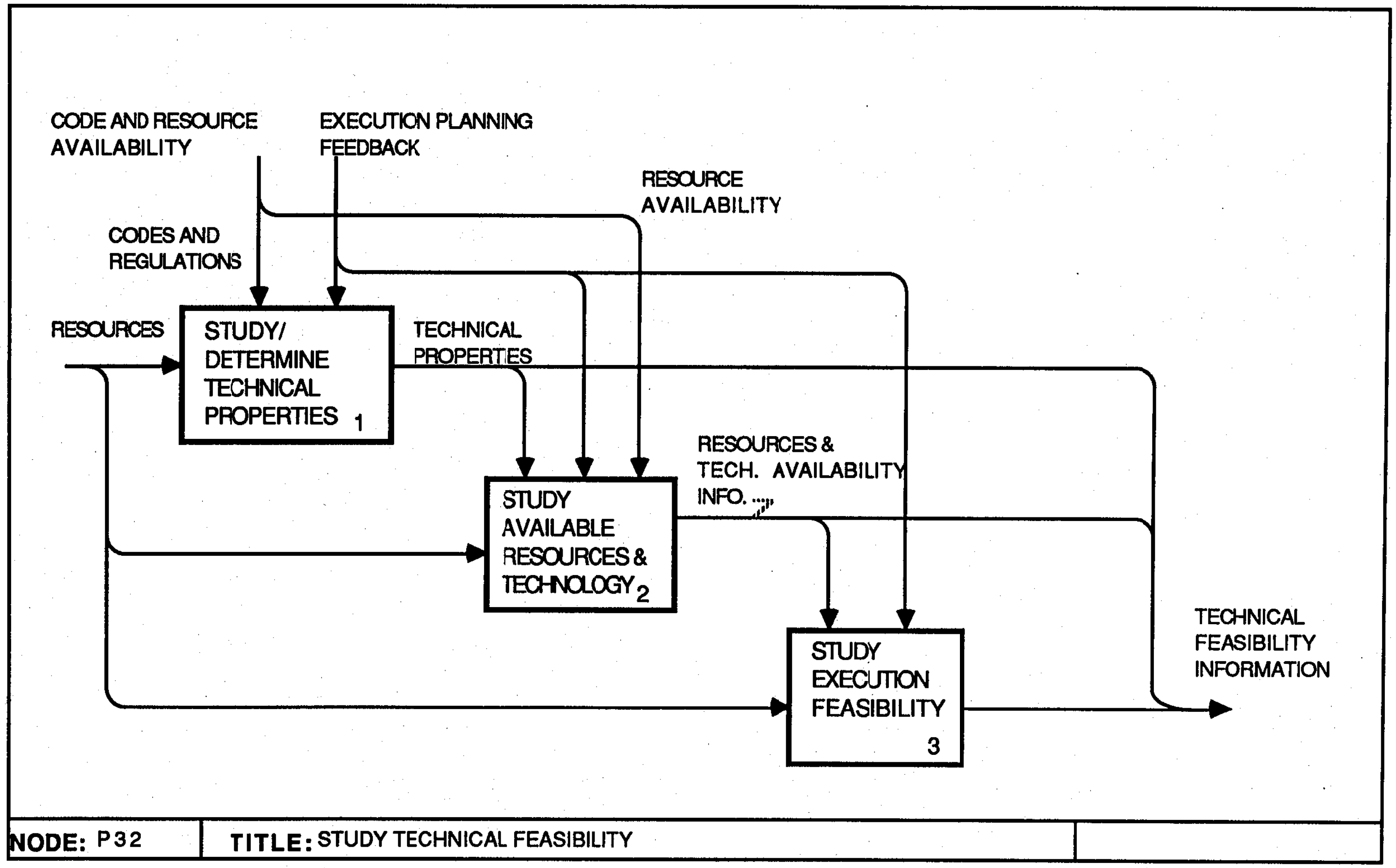


Figure 4.6: Study Technical Feasibility

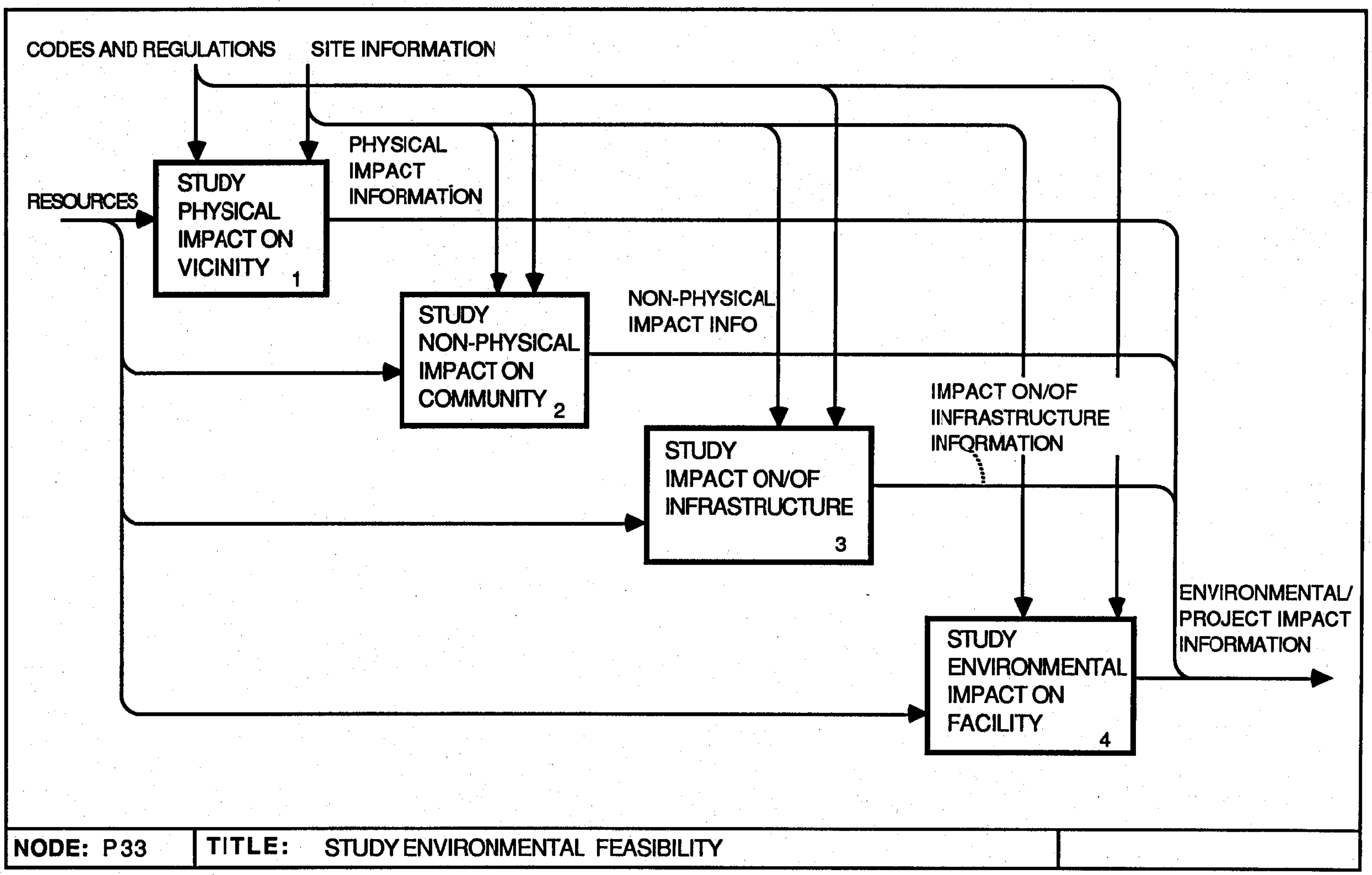


Figure 4.7: Study Environmental Feasibility

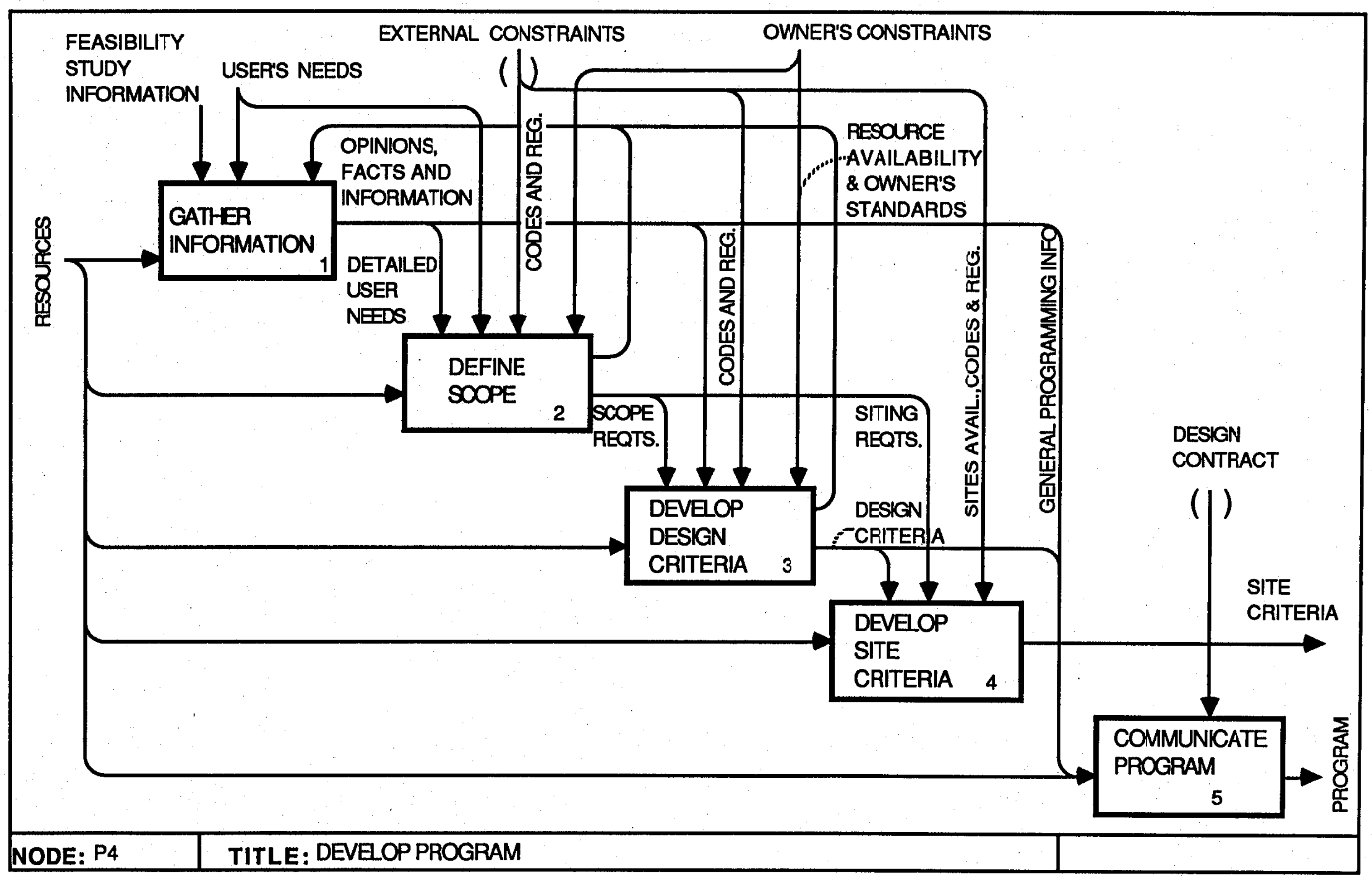


Figure 4.8: Develop Program

Develop Design Criteria (P.43): The design criteria are the sole guidelines that define of the expected quality of the facility design. They describe functional relationships between facility components, and specify desirable facility characteristics such as image, flexibility, operability and expansibility. The design criteria also include outline specifications of facility systems and components such as structural requirements floor loading), environmental requirements (e.g., HVAC, acoustics, lighting), power distribution, telecommunication, security and safety requirements.

Develop Site Criteria (P.44): Site criteria are developed to guide site selection. Only the key site characteristics should be included in these criteria. These may include the funds available, size, topography, location with respect to the owner's business market, and to the availability of infrastructure.

Communicate Program (P.45): This refers to transmitting the program document and other undocumented programming information to other project functions including design, feasibility study, execution planning, and site acquisition. Undocumented information may be transmitted via informal correspondence; i.e., meetings, telephone calls etc.

4.7 DEVELOP PROJECT EXECUTION PLAN (P.5)

The Project Execution Plan (PEP), also called the project master plan (Wheeler 1978), defines 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). Developing the PEP includes the following functions which are also shown in Figure 4.9:

Identify Required Services (P.51): This includes the recognition of necessary services such such as planning, design, construction, construction management, operations and maintenance.

Study Market Conditions (P.52): This includes studying present and projected level competition between service organizations, and the availability and cost of key resources (e.g., skilled labor, special material or equipment).

Develop Project Plan (P.53): The project plan describes the owner's approach to project execution such as project packaging and phasing. It includes the project master schedule with established major milestones including the owner's key review and approval points. The project plan also includes a budget that serves as the project cost control tool. It also describes the responsibility and authority of each of the project participants.

Develop Contracting Plan (P.54): The contracting plan describes:
a. Contract types (e.g., lump sum, reimbursable, unit price);
b. Contracting methods (e.g., competitive, negotiated), and

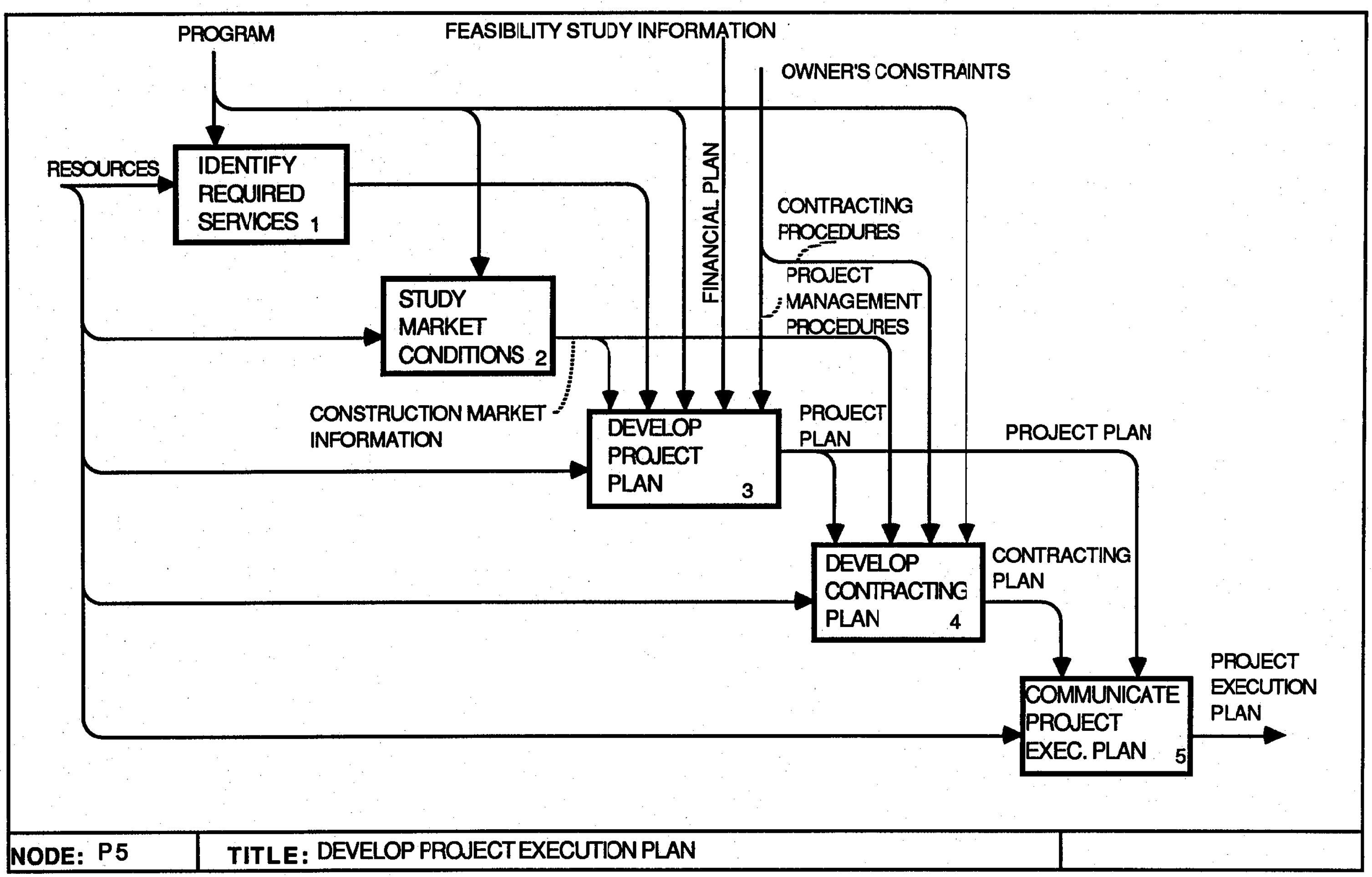


Figure 4.9: Develop Project Execution Plan

c. Project delivery strategy (e.g., fast track approach, design-build or sequential traditional approach).

Communicate the PEP (P.55): This refers to the process of communicating applicable PEP information to other project participants, affected parties such as those involved in related projects, and utility entities such as power, sewer and water organizations.

4.8 SELECT AND ACQUIRE SITE (P.6)

In many projects the site is a predetermined factor. But, if this is not the case, the site has to be properly selected in order to provide the best advantage to the proposed facility. Williams and Massa (1983) have developed a structured approach for siting major facilities. They identified many to be considered in selecting the site. Some of these factors are: (Williams and Massa 1983, Molnar 1983)

Geographical location
Suitability of size and configuration
Expansibility
Cost of land
Environmental factors
Applicable codes and regulations
Local infrastructure
Existing land use and conditions
Future area development
Availability of construction resources
Local traffic conditions

"Select and acquire site" is divided into four tasks as shown in Figure 4.10. These tasks are:

Identify Candidate Sites (P.61): Using the site criteria developed in the programming function, the planning team will identify some potential sites.

Evaluate / Select Site (P.62): This refers to the process of evaluating the candidate sites using the site criteria, and ranking them in order of preference. The product of this process is information about the selected site.

Acquire Site (P.63): This process includes all the activities required to acquire the site, including negotiation with the site owner(s) directly or with the help of a real estate agent. The output of this process is the site (i.e., site ownership title). It may be necessary to conduct geotechnical analysis in order to assure that the soil condition is suitable for the proposed structure. This function, however, is considered a part of "Investigate Site."

Investigate Site (P.64): This function includes all investigations (prior to and after purchasing the site), that determine the properties of the site. Site

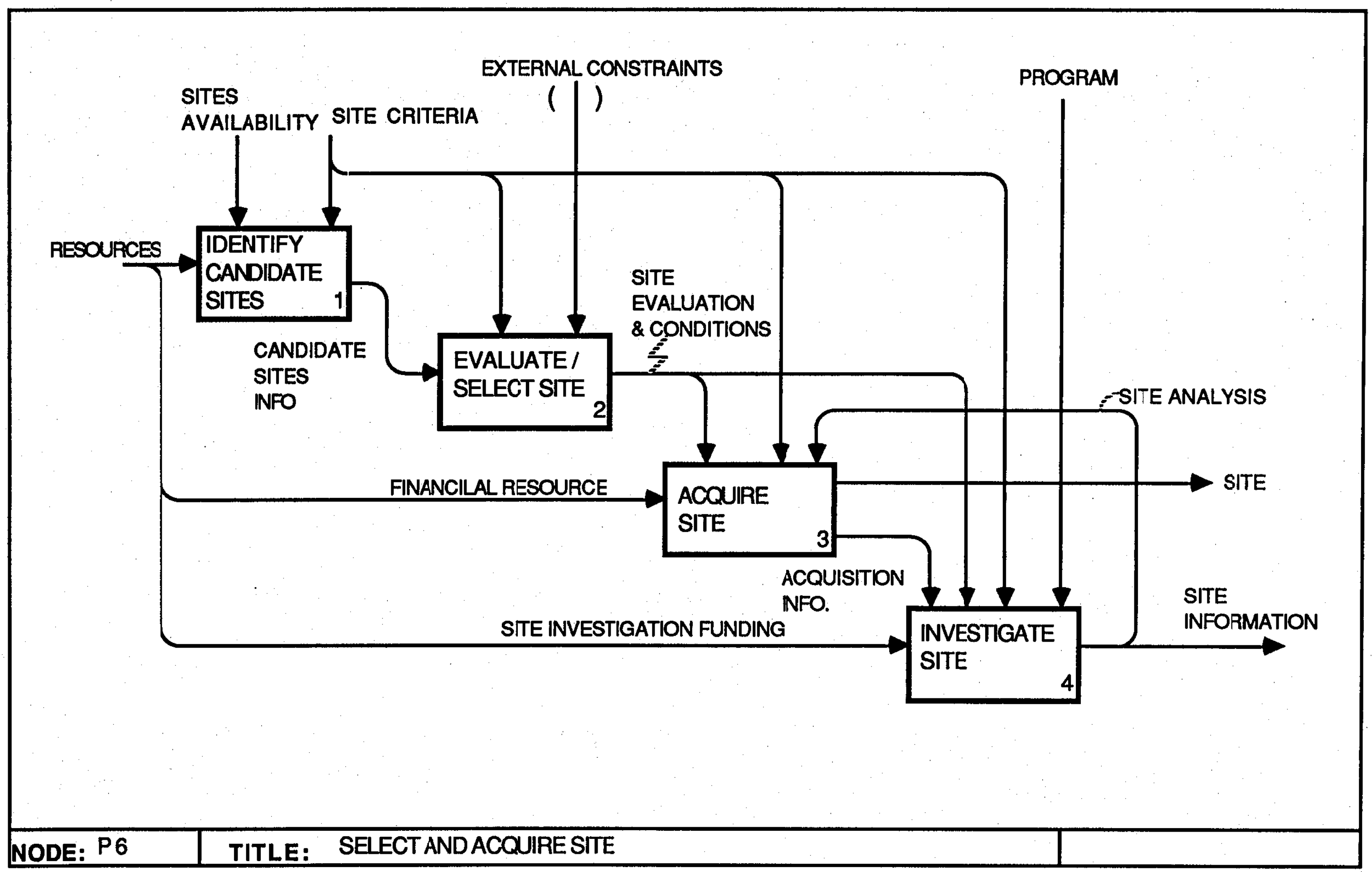


Figure 4.10: Select and Acquire Site

properties include site topography, soil bearing capacity, ground water level and sub-surface formation. This function is sometimes conducted after the acquisition of the site. However, the scale is contingent upon results of the site investigation. For example, if poor soil conditions were not expected, but found, the price of the site may decrease, or the sale may be void.

4.9 SUMMARY

This chapter presented the "Plan Facility" model as a series of related diagrams and textual explanations. Terms appearing on the model are defined in the Glossary (Appendix B). The next chapter presents a model of the design process.

Chapter 5

THE "DESIGN FACILITY" MODEL

As stated in Chapter 2, Design Facility comprises all the functions required to define and communicate the owner's needs to the builder. The design model represents the activities necessary to produce a facility design from the point-of-view of a person outside the design organization. The overall design process has been decomposed into six major functions numbered D.1 through D.6. The division of activities is along generally accepted industry standards. Complete details of this model can be found in Technical Report No. 4 (Norton, 1989).

5.1 THE DESIGN FUNCTION

The Design Function is driven by the site information and the program resulting from the planning phase. It includes the conceptual design, schematic design, detailed design, and working drawings phase. This model also defines the communication of the design as a major function. Currently, this is achieved through the production of working drawings and the review of submittals.

5.2 DESIGN FACILITY

Figure 5.1 depicts the relationships of the design functions and subfunctions. It shows the general breakdown of the design process. It does not represent any connectivity of functions on the same level, only connections between the levels. This diagram shows how the DESIGN FACILITY box (D) is decomposed into six subfunctions (D.1 through D.6). Each of these subfunctions, in turn, can be broken down into their constituent subfunctions and activities. A description of each of the nodes follows as the remainder of the model is explained in this chapter.

Figure 5.2 depicts the interrelationships of the primary nodes of the "Design Facility" process model. A brief description of each of these nodes is presented below.

Understand Functional Requirements (D.1): This focuses on 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.

Explore Concepts (D.2): General concepts concerning the initial layout of the facility, general requirements of the design, and other such areas are explored. Once multiple concepts have been formed, those deemed feasible are passed along, with the information gained, to the next phase.

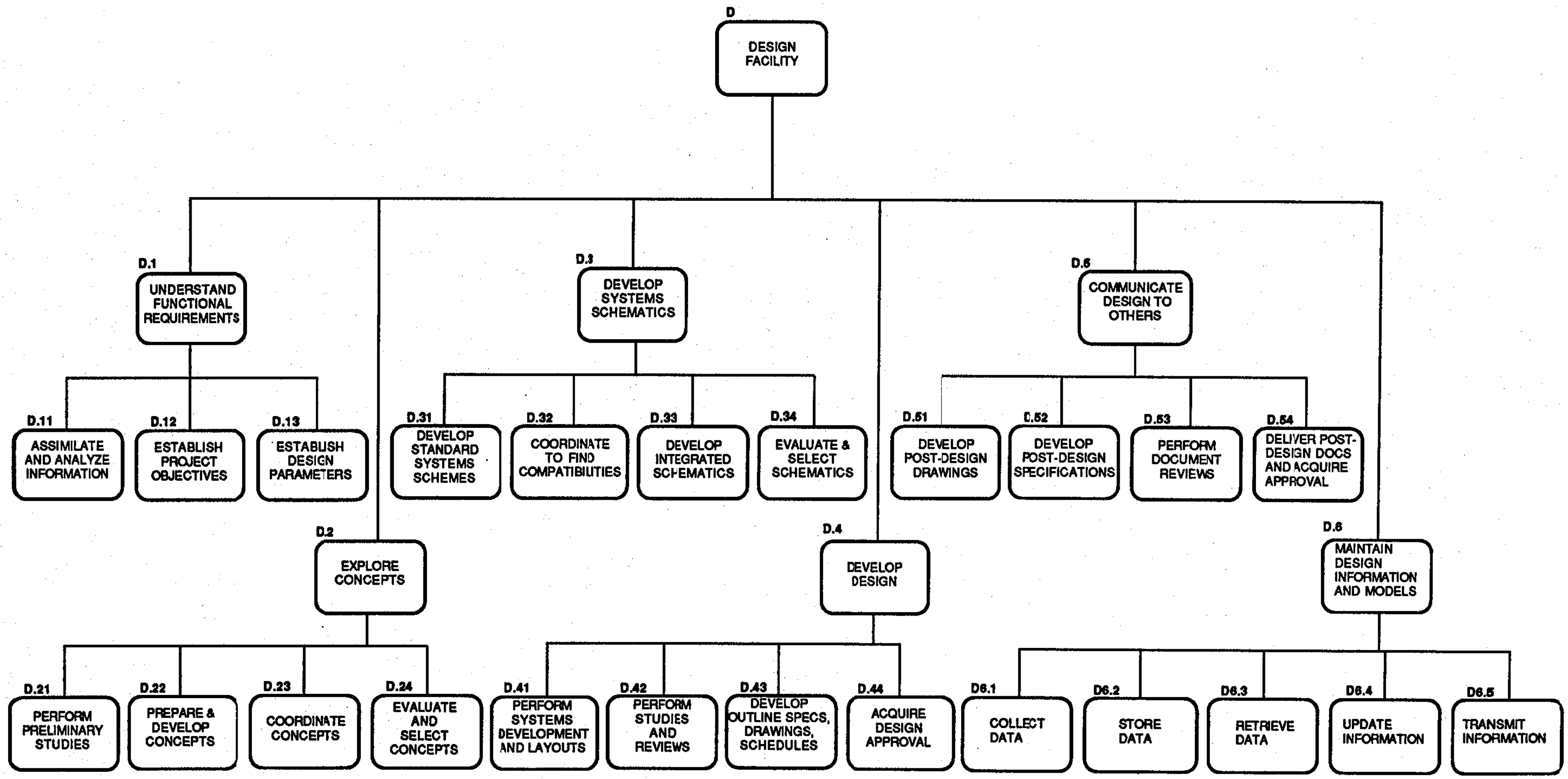


Figure 5.1: Design Facility Node Tree

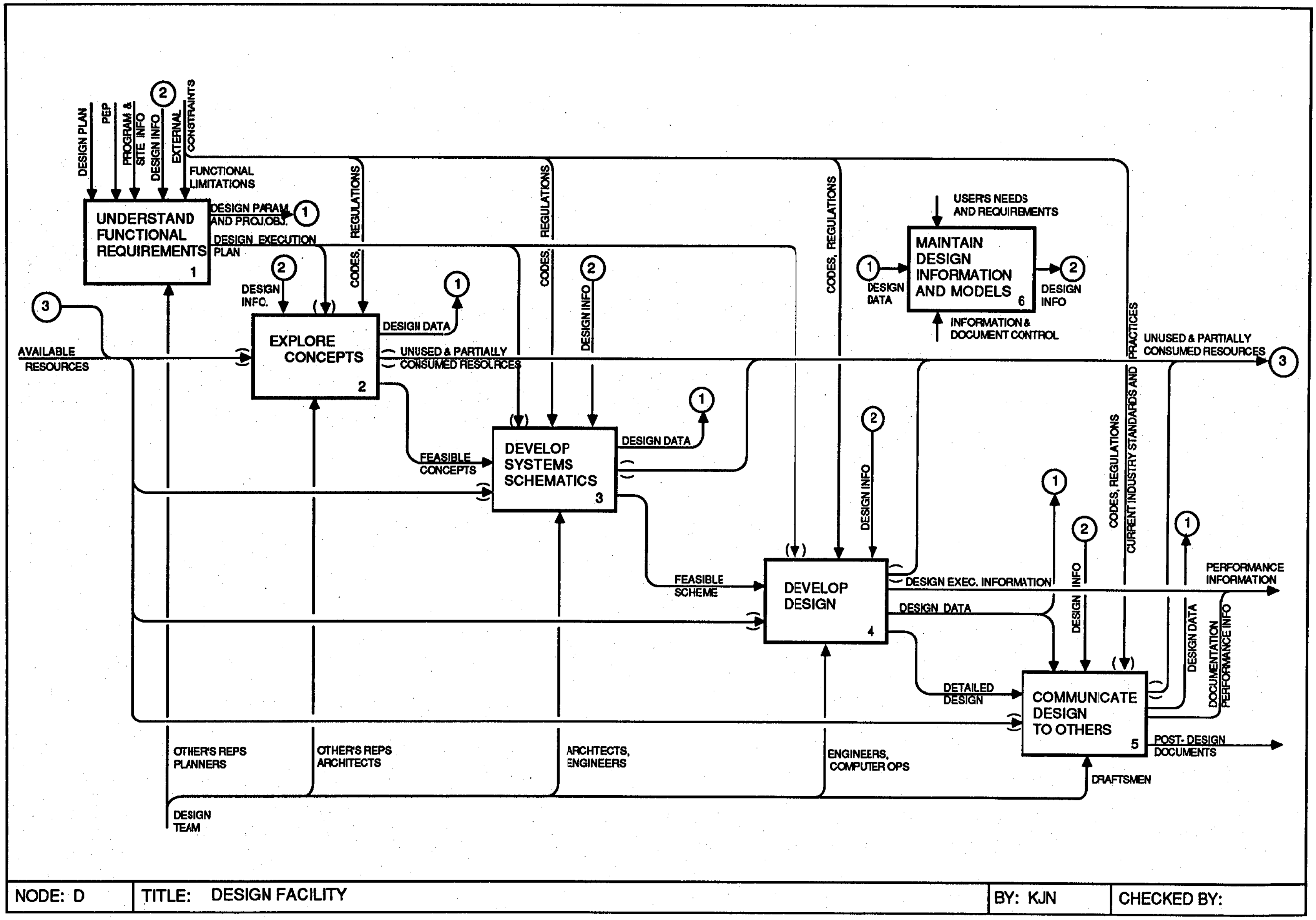


Figure 5.2: Design Facility

Develop System's Schematics (D.3): Here, the feasible concepts are refined and elaborated upon, usually by architects and engineers. Schematics include more specific information and system requirements which have been gained by analysis of the concepts. Typically, the number of concepts is further reduced as they are developed to the stage of schematics. Different structural systems, for example, will be considered to select the best solution. Once schemes are considered feasible, they are passed along.

Develop Design (D.4): The main function of this phase is to continue the refinement and the selection of the design. Here, the final design is selected from the remaining schemes and is fully detailed. Details are developed in each of the schemes which are simulated, often on a computer. These simulations aid in the further development of the design by showing inconsistencies, conflicts, etc.

Communicate Design to Others (D.5): 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. Often a formalized knowledge base is established. This base includes such items as the contract documents, the working drawings, computer disks and design personnel on site.

Maintain Design Information and Models (D.6): This step 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.

5.3 UNDERSTAND FUNCTIONAL REQUIREMENTS (D.1)

The first of the subfunctions, Understand Functional Requirements, is depicted in Figure 5.3. The overall function performed at this point is the acquisition and processing/ synthesis of information relating to the desired facility. The designer is attempting to gather as much information as possible from outside sources, e.g., the owner, users, regulatory agencies, municipalities, etc., so that he/she can begin the design process in the best, most informed position. Typically the information gathered includes the requirements of the owner and other parties. Code and legal research pertaining to such areas as systems design (BOCA, NEC, etc.), legal zoning in municipalities and environmental requirements (site drainage, underground storage tanks, septic systems, etc.) is also performed. Specifics are left for later stages of the design process; research is directed at the codes and other requirements that are applicable to the present project.

The first subfunction, Assimilate and Analyze Information, is the entry point for the information. Information is gathered and sorted to begin establishing requirements, desires, limitations, etc. The output of this subfunction is the design planning information which aids the designer in establishing the type and scope of the design to be performed. The second subfunction, Establish

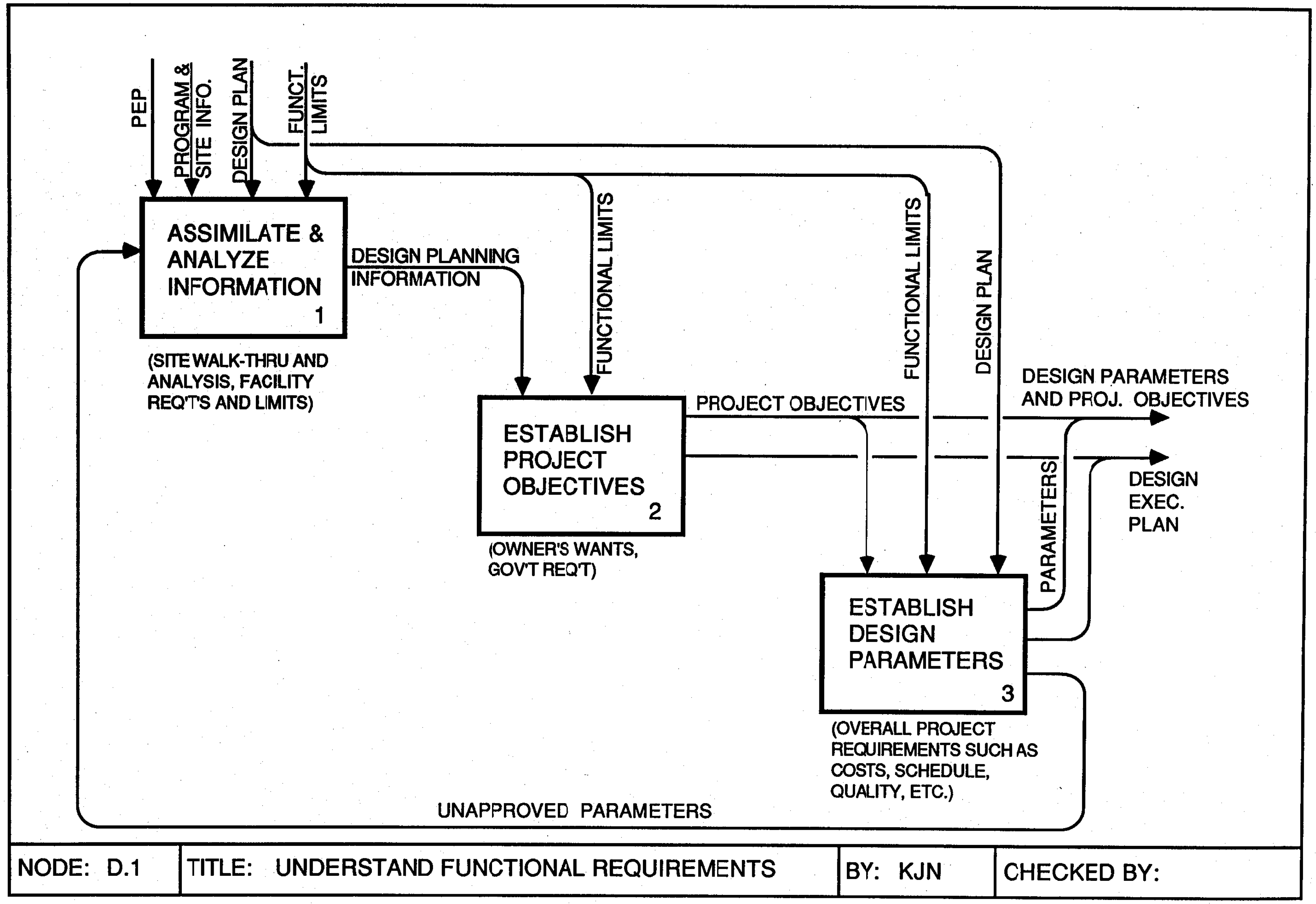


Figure 5.3: Understand Functional Requirements

Project Objectives, is controlled by the design planning information and functional limits placed on the design by the proposed operation of the facility. The objectives are the general goals of the project which the designer and other parties wish to meet with the completed design. The third subfunction, Establish Design Parameters, creates and clarifies the design limits, guidelines, and requirements such as overall cost limits, quality control guidelines, and scheduling requirements. Included in this subfunction is the approval of the parameters. If approval is not given, a return/feedback loop requires a reevaluation of the information.

Definitions of the subfunctions of D.1 shown in Figure 5.3 follow:

Assimilate & Analyze Information (D.11): This includes gathering of information from owner and/or planner concerning the design of the desired facility. Information can be collected via interviews and questionnaires. Typical activities may include a site walk-thru and analysis and determination of some facility requirements and limits.

Establish Project Objectives (D.12): The overall goals of the project are formulated and established. Goals may include establishing the desired facilities attributes as envisioned by the owner and/or operator, determination of the regulating agencies requirements, clarification of the scope of design, etc.

Establish Design Parameters (D.13): The establishment of design limits, guidelines, and project requirements such as costs, schedules and quality are the key activities.

5.4 EXPLORE CONCEPTS (D.2)

This stage, shown in Figure 5.4, is often considered the first phase of the design process and is where general ideas or concepts concerning initial layout of the facility, general design requirements, and other areas are explored. The design, at this point, is very nebulous. There are, often, multiple concepts in every area such as site use, architectural and other systems and materials. Once the concepts are developed, they are coordinated, checked and evaluated and typically one is selected.

The first subfunction, Perform Preliminary Studies, is an information gathering step. The information which these studies gain may have been missing or incomplete when it was passed on from the preceding stage. Examples of possible studies include spatial relation studies, circulation studies, traffic flow studies, and code conformance studies (particularly on existing facilities). The output of this step, the studies results, are a controlling factor in the development and coordination of the concepts.

Prepare and Develop Concepts, the second subfunction, is the step where the concepts are formulated and developed. In addition to the systems concepts, conceptual budgets and schedules may be developed. These concepts are

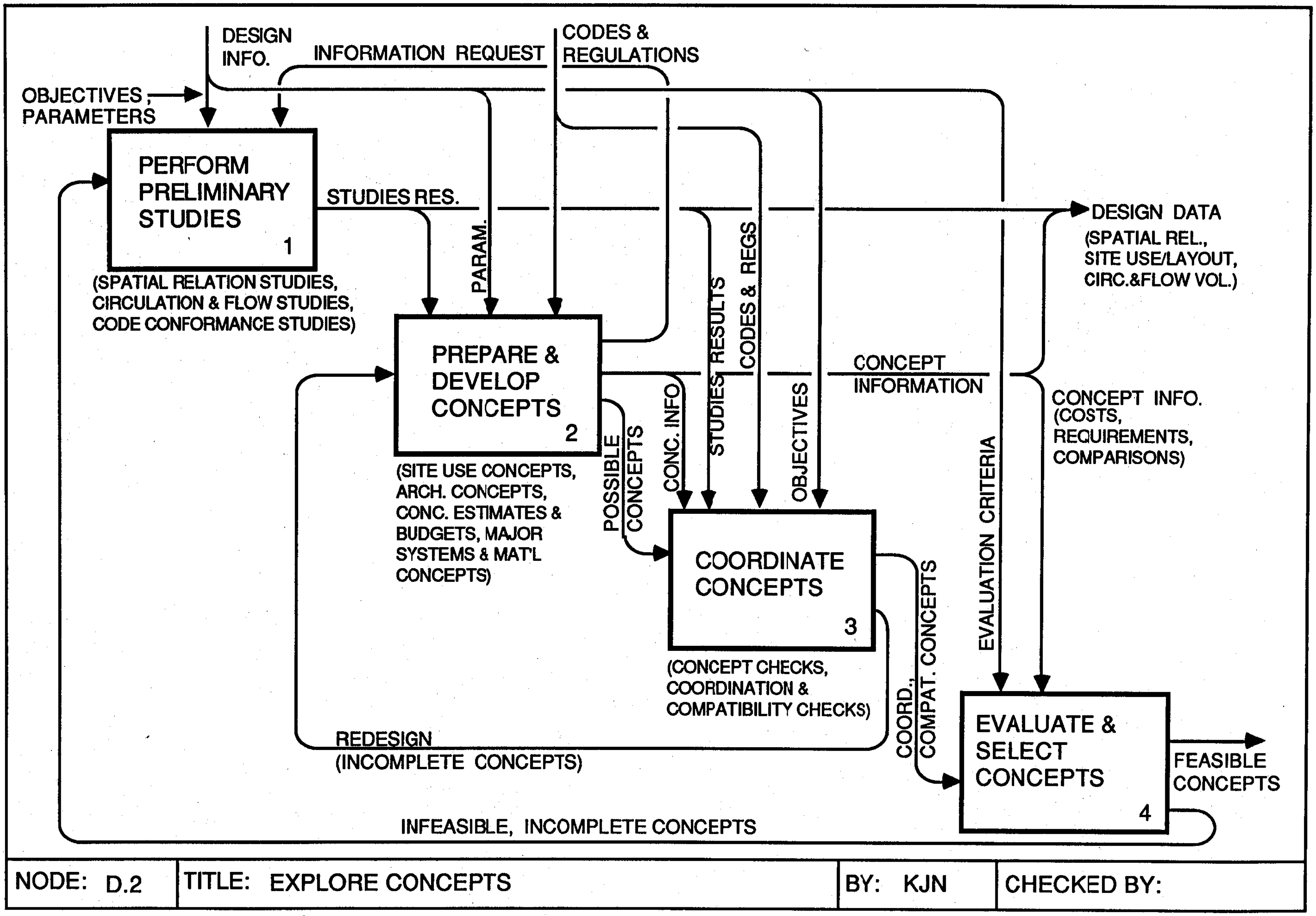


Figure 5.4: Explore Concepts

sent on to the third subfunction, Coordinate Concepts, where they are checked against the original objectives and parameters, codes and other regulations, and any other system concepts for compatibility. If there are incomplete or insufficient concepts, they are returned to D.22 for further development and/or corrections. If successfully coordinated, they are passed along to D.24, Evaluate and Select Concepts. Evaluation of the concepts is based upon predetermined evaluation criteria and other concept information. If the concepts are found to be infeasible and/or unapproved, they are returned to D.21 and the cycle is repeated.

Definitions of the subfunctions of D.2 shown in Figure 5.4 follow:

Perform Preliminary Studies (D.21): These studies are used to gain information which may be missing before design can "begin." Typical studies may include spatial relations studies, circulation and flow studies, general code reviews, etc.

Prepare & Develop Concepts (D.22): General concepts in such areas as site use, architectural considerations, major system types, and materials are explored. Conceptual cost estimates and budgets may also be developed.

Coordinate Concepts (D.23): Concepts are coordinated, reviewed, and checked. Coordination checks, compatibility checks, concept checks, and code conformance reviews are performed to show gross errors, oversights, etc.

Evaluate & Select Concepts (D.24): Concepts are evaluated, judged, and selected. Selection is based upon various criteria such as cost data, project requirements, design parameters, etc. Those concepts deemed feasible are passed along for further development.

5.5 DEVELOP SYSTEMS SCHEMATICS (D.3)

At this stage of the design, shown in Figure 5.5, the feasible concept(s) are refined and expanded into schema for the different systems in the facility. As the design of each system proceeds, it is coordinated with any other system schemes. The integrated schematics are developed further and then the systems schematics are evaluated and a final one is selected. The schematics define the logic of the various systems, such as electrical and mechanical systems.

In D.31, Develop Standard System Schemes, the feasible concepts are expanded upon by the inclusion of more detailed information as it is made available to the designer. Schemes concerned with space requirements of system components and system configurations. are investigated and refined before they are coordinated. The function of D.32, Coordinate to Find Compatibilities, is the general coordination of system schema between disciplines and organizations, if necessary. For example, a mechanical designer must coordinate his general requirements like space needs, ceiling-floor requirements and probable electrical power needs with other parties like

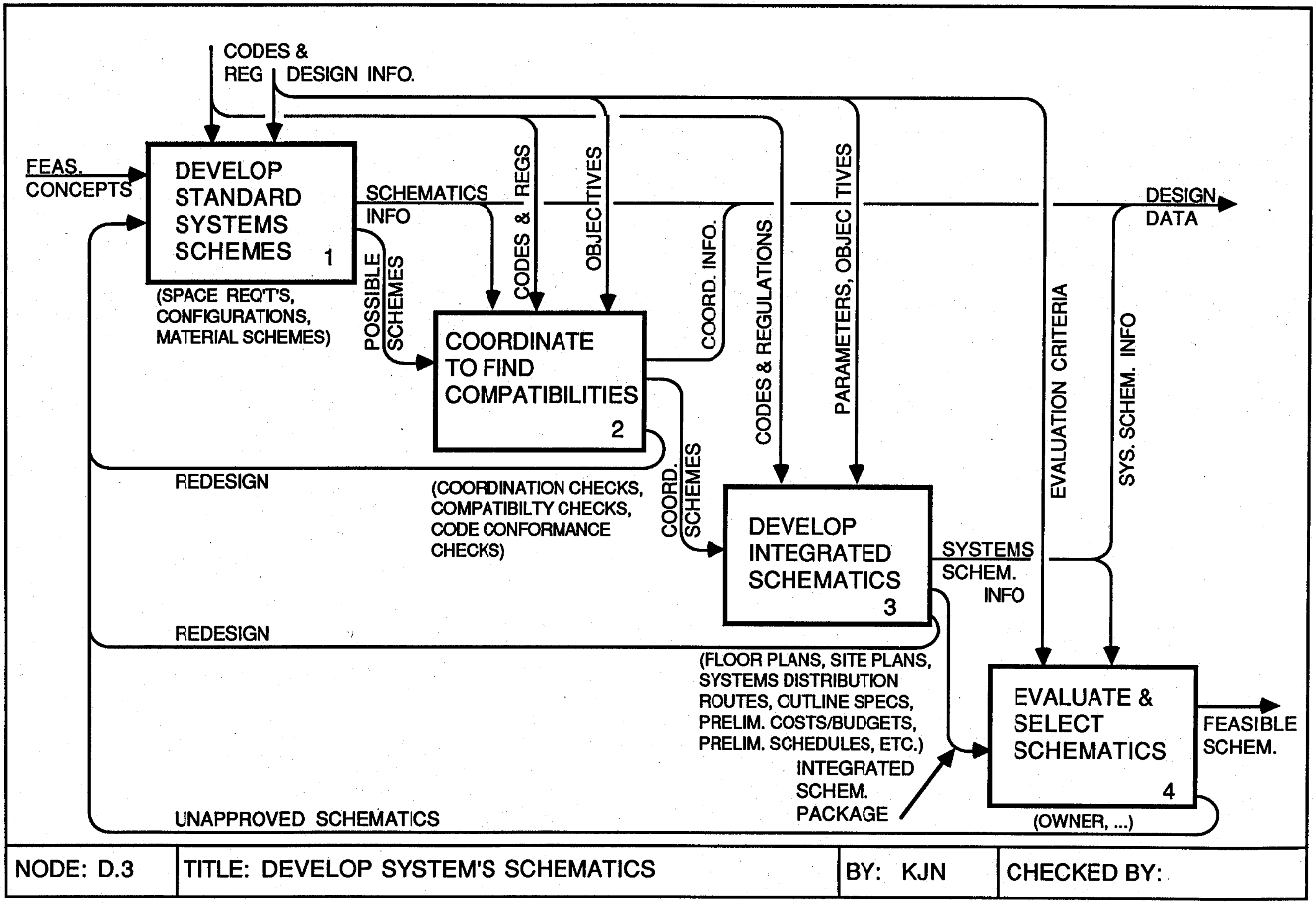


Figure 5.5: Develop System's Schematics

the architect, electrical designer, and structural designer. Other reviews such as compatibility and code conformance checks are performed to ensure the quality of the design and that it meets the owner's/ user's general needs. If successfully coordinated, the integrated schematics are developed further in D.33. If not, they are sent back for further refinement in D.31.

In D.33, Develop Integrated Schematics, such activities as systems distribution routing, development of initial floor plans, and the development of outline specs and preliminary costs/budgets are carried out. Attention is paid to the objectives and parameters as well as the codes and regulations as guides to the direction of the design. If there is something wrong with the design, it is returned to D.31 for redesign, otherwise, it continues on to D.34, Evaluate and Select Schematics. During this fourth subfunction, the schematics are reviewed by the owner, formally, as well as any other parties such as regulatory agencies. Also, approval of the schematics is sought from the owner. If they are unapproved for some reason, they are returned to D.31 and the process begins again.

Definitions of the subfunctions of D.3 shown in Figure 5.5 follow:

Develop Standard Systems Schemes (D.31): This is the determination of design considerations, such as structural system choices and mechanical systems types on a discipline level. Schemes concerning space requirements, systems configurations, and material selections are investigated (i.e., steel versus concrete, central heat versus decentralized heat, etc).

Coordinate To Find Compatibilities (D.32): System schema between discipline and organizations are coordinated on the macro-level (i.e., ceiling-floor sandwiches for structural, mechanical, and plumbing disciplines). Further checks and reviews such as compatibility checks, quality reviews, and code conformance checks are also performed.

Develop Integrated Schematics (D.33): Here the development and integration of the coordinated schemes is continued. Floor and site plans, system distribution routes, outline specs, and preliminary costs/budgets and schedules are developed. This information and associated documents are the foundations for the future post-design documents.

Evaluate & Select Schematics (D.34): Schema are evaluated, judged, and selected based upon criteria such as cost data, project requirements and design parameters. Those deemed feasible are passed along for further development.

5.6 DEVELOP DESIGN (D.4)

This phase of the design process, shown in Figure 5.6, is used to flesh out the design into the beginnings of its final form. General detailing of the design and its major components starts. The layouts which allocate space in zones are finalized. In addition, simulations and studies of the systems designs and the

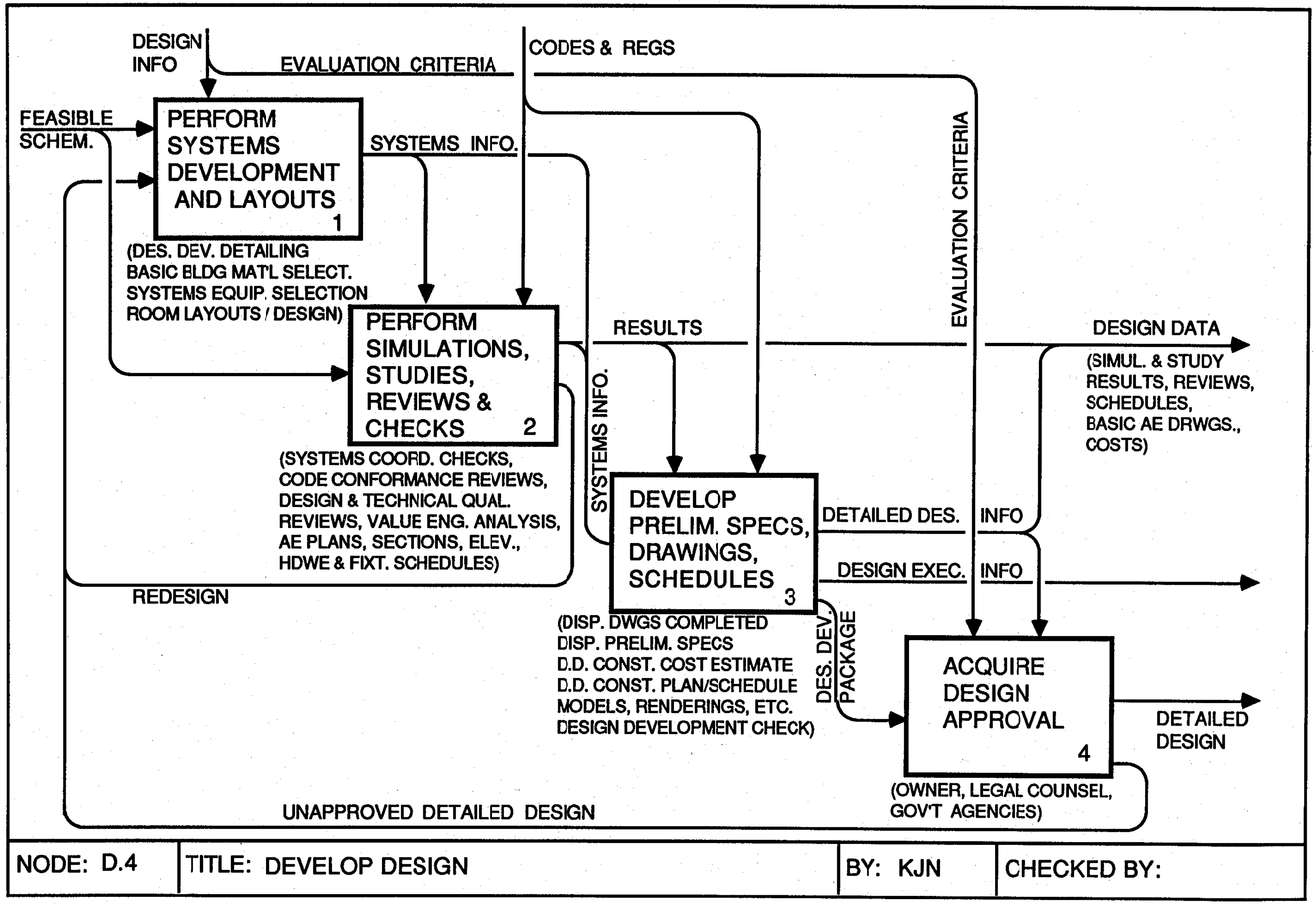


Figure 5.6: Develop Design

overall design are conducted with the reviews and checks. Development of the preliminary specifications, drawings, and schedules begins. This documentation is the basis for the development of the post-design documents. As the final point in this phase, final approval of the design (not necessarily of the documentation, however) is acquired.

Perform Systems Development and Layouts, D.41, is the subfunction which begins the detailing of the schematics which were passed along from function D.3. Typical activities include detailing, selection of major components of systems, and room (zone) layouts and design. The design must also undergo simulations, studies, reviews, and checks (D.42). These simulations and studies can cover real-time or mathematical computer-based simulations to small scale mock-ups of the facility or a system to value engineering analysis. Many of these studies are aimed at ensuring the design is going to work. Reviews and checks including coordination checks, code conformance reviews, and quality reviews are performed. If the design doesn't meet expectations or standards, it is returned to D.41 for further development. Otherwise, it is sent along to function D.43.

Develop Preliminary Specs, Drawings and Schedules (D.43) is where the "first draft" of the design documentation is created. Discipline specifications and drawings are completed. Cost estimates, schedules, and other matters are refined. Occasionally, models or renderings of the facility are also created at this point. The final step (D.44) is Acquire Design Approval. Approval is gained from the owner although other parties, such as legal counsel and governmental agencies, may review the design also. If the design is not approved, it is returned to D.41 for further refinement or corrections. If it is approved, it is passed along for the production of the final documentation.

Definitions of the subfunctions of D.4 shown in Figure 5.6 follow:

Perform Systems Development & Layouts (D.41): This is the continued refinement and development of each system's design. Detailing of the design begins as does the selection process for the building materials, system equipment, etc. Layouts develop of major rooms and/or zones.

Perform Simulations, Studies, Reviews, & Checks (D.42): Simulations and studies (mathematical, real-time, etc.) are performed on the design to determine if optimization, corrections, and the like are necessary. The standard coordination, compatibility, code conformance, and quality checks and reviews are performed as is any value engineering analysis required.

Develop Preliminary Specs, Drawings, Schedules (D.43): Detailed, often diagrammatic, drawings and preliminary specifications are produced. Cost estimates and schedules are refined. Models, renderings, etc. of the facility also may be produced.

Acquire Design Approval (D.44): Review and approval of the design by the owner, legal counsel, governmental agencies is accomplished as needed.

5.7 COMMUNICATE DESIGN TO OTHERS (D.5)

In this phase, see Figure 5.7, the final approved design is documented and communicated to other parties involved with the project such as the owner, any prospective constructors, and governmental agencies, if necessary. The post-design documents, often called contract documents or construction drawings and specs, are developed from the detailed design documentation and then reviewed. Finally, the post-design documents are delivered and final approval is sought.

The initial activities which occur are the development and production of the post-design drawings (D.51) and specifications (D.52) from the preliminary drawings and specs. The drawings include all plans, details, sections, elevations, systems plans, final system sizings, and any door, window and equipment. schedules. The specifications include the final engineering systems specifications, the overall general conditions, and any bidding documents if required. The combined post-design package then moves on to D.53, Perform Document Reviews.

Reviews are performed for coordination, code conformance, quality assurance, and regulatory requirements. The specs are reviewed for content, grammar, thoroughness, etc. Also, final cost estimates are formulated for possible use in the bidding for a constructor. If the reviewed documentation is found incomplete or incorrect, they are returned to D.51 and/or D.52 for further work. If they pass the reviews, they go on for final approval (of the documents and design, if necessary) and delivery to involved parties. If they are not approved, they are returned for further work and/or corrections.

Definitions of the subfunctions of D.5 shown in Figure 5.7 follow:

Develop Post-design Drawings (D.51): This is the production of final drawings including plans, details, sections, elevations, and system plans with room finish schedules, completed equipment schedules, etc. Final system sizings and similar calculations are performed.

Develop Post-design Specs (D.52): Final specifications are developed for all disciplines and systems. Bidding and/or contract documents are included.

Perform Document Reviews (D.53): Coordination of documents between various disciplines is completed. Final reviews and checks are performed as is the development of final cost estimates.

Deliver Post-design Documents & Acquire Approval (D.54): Documents are delivered to the owner, legal counsel, regulatory agencies, and other parties as needed. Final approval is acquired.

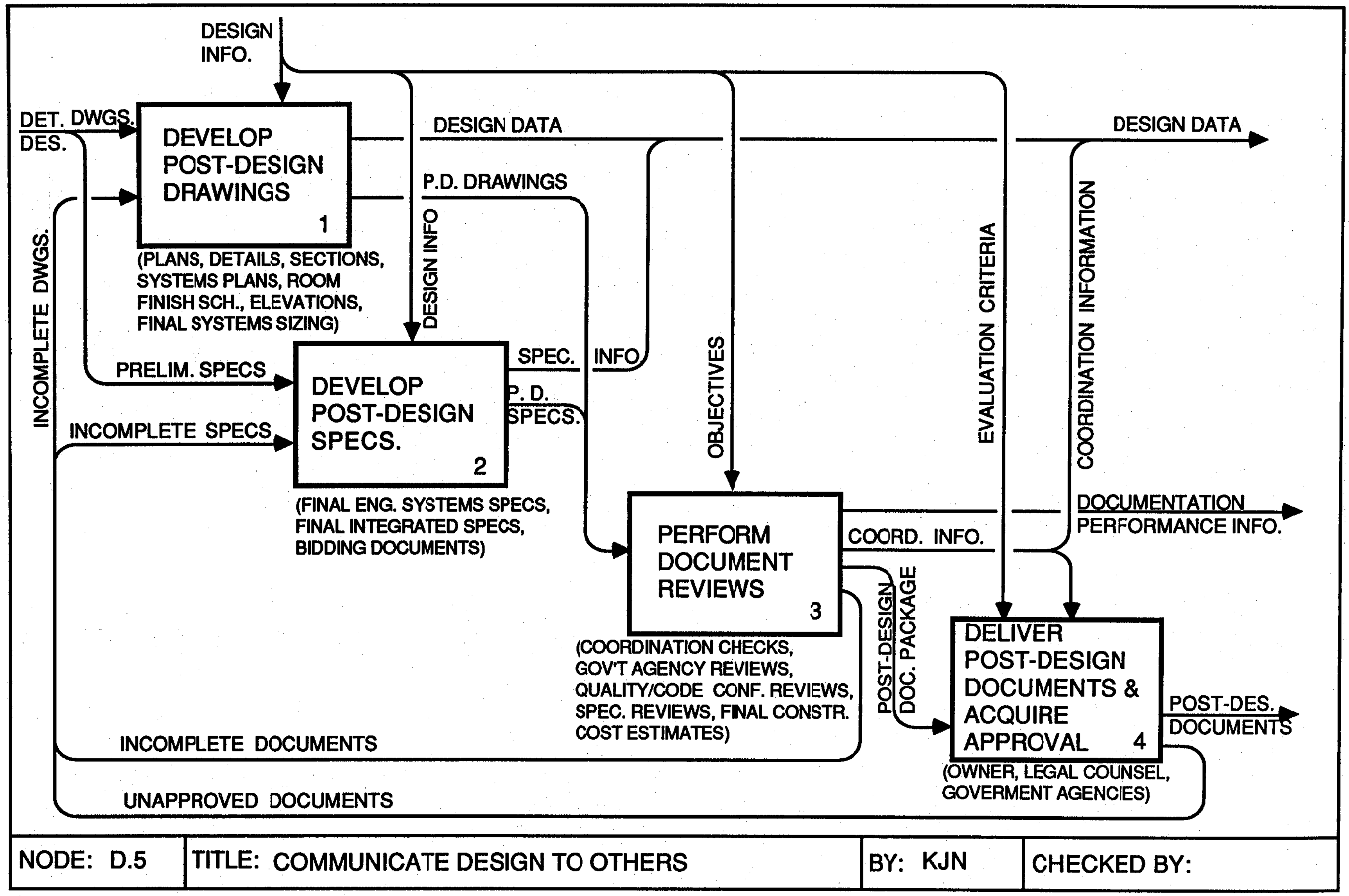


Figure 5.7: Communicate Design to Others

5.8 MAINTAIN DESIGN INFORMATION AND MODELS (D.6)

The function performed here (see Figure 5.8) is the continual maintenance (collection, storage, updating, and transmission) of the design information. Design data is collected (D.61) from every phase of design. It is then stored (D.62) in some media (e.g., files computer memory, etc.) until it is called for. When demands for information are received, the data is retrieved (D.63) and updated and formatted (D.64) for the particular user's needs. When the data has been updated (or otherwise altered), it can be considered Design Information and not simply raw Design Data. After the information is prepared, it is transmitted (D.65) to the party who requested it.

The manner in which this whole process is accomplished can vary from organization to organization. In one firm, it may be performed using some type of computer-based data or knowledge base whereas in another company, it may be performed manually. Information collected in one phase of the design process may be used in subsequent phases on the same project or on later projects. If it is available for use on later projects, it becomes part of a historical database which may or may not be a formal system.

Definitions of the subfunctions of D.6 shown in Figure 5.8 follow:

Collect Data (D.61): Raw data generated by various processes (i.e., performance of studies, development of concepts, etc.) during the design activities is gathered in preparation for storage and/or synthesis into useful information. Examples of such data may be studies results, circulation and flow volumes, coordination information, etc.

Store Data (D.62): The Design Data is stored in a number of places (computer memory, personnel memories, files, etc.) where it is available for future processing if required.

Retrieve Data (D.63): Governed by information needs from some party, the data is recalled from storage and prepared for processing of some kind into information.

Update Information (D.64): The synthesis of the data into information, followed by the "formatting" of the information into a useful form for the user is accomplished. Updating occurs when new information is incorporated into an existing set of information or existing information is transformed.

Transmit Information (D.65): The useful information is delivered to the user who requested it.

This completes the formal presentation of the "Design Facility" process model.

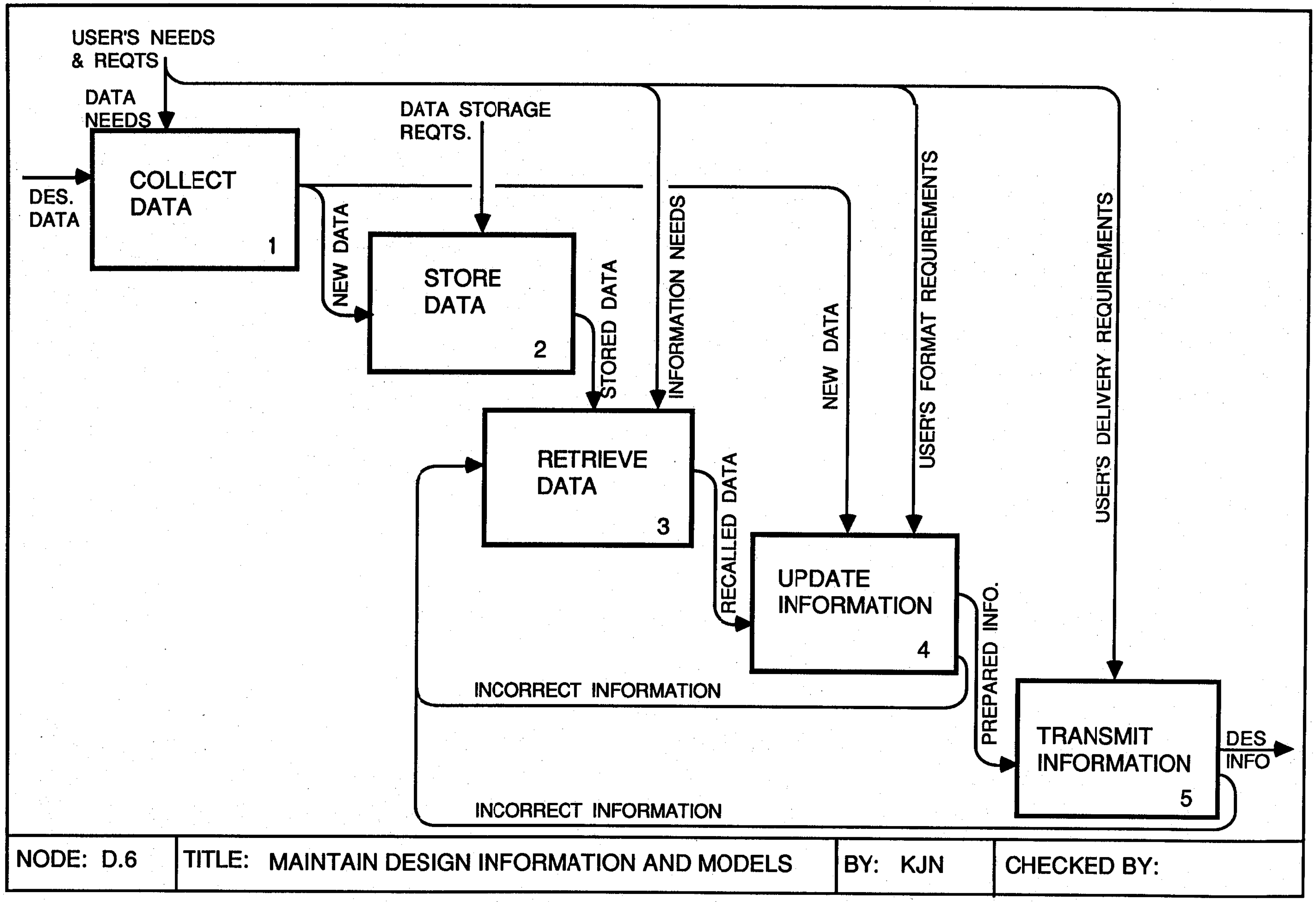


Figure 5.8: Maintain Design Information and Models

5.9 SUMMARY

This chapter presented the "Design Facility" model as a series of $IDEF_0$ diagrams with textual explanations. The Glossary in Appendix B defines the terms in the models. The next chapter focuses on the construction of the facility.

Chapter 6

THE "CONSTRUCT FACILITY" MODEL

This chapter focuses on the Construction Facility Model. Full details of the model can be found in Technical Report No. 5 (Hetrick and Khayyal 1989).

6.1 THE CONSTRUCTION PROCESS MODEL

The Construct Facility function represents the entire construction process as typically performed by a general contractor or construction manager responsible for building a facility. In this function, a site and resources are converted into a facility. The resources include building materials, equipment, labor-hours, energy, time, and money. Time and money are important inputs to all the functions in the process, but they are only shown in the higher levels of the model in order to minimize redundancy. The work is executed based on the bid and construction documents and criteria, and the project execution plan which is provided by the owner. The external constraints (including the weather, government regulations, available technology, and the economy), directly impact the construction process. The two main information outputs of the process are post-construction information and facility construction knowledge. Post-construction information includes as-built drawings and recommended operations and maintenance procedures. Facility construction knowledge is the information and knowledge that results from constructing the facility and the related experience that can be used in the future.

An overview of all the functions included in the construction model is shown in the function tree in Figure 6.1. The Construct Facility function is separated into the subfunctions of Acquire Construction Services, Plan and Control the Work, Provide Resources, and Build the Facility. All of the functions and subfunctions are explained in the following sections. Definitions of all the terms used in the model are provided in the glossary (see Appendix B).

6.2 CONSTRUCT FACILITY

The Construct Facility function is broken down into four subfunctions (see Figure 6.2). Each is explained in the following sections.

Acquire Construction Services (C.1): 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.

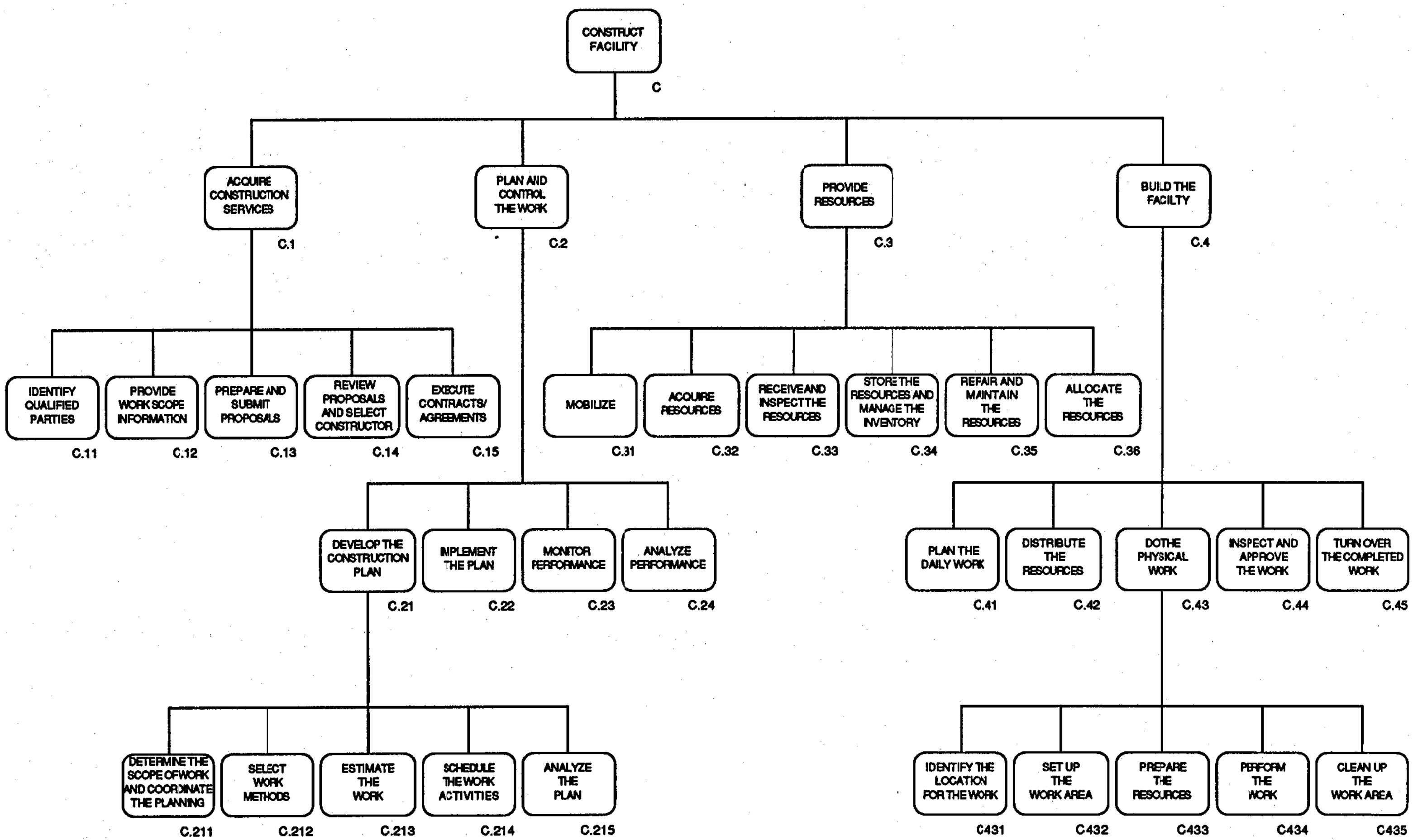


Figure 6.1: Construct Facility Node Tree

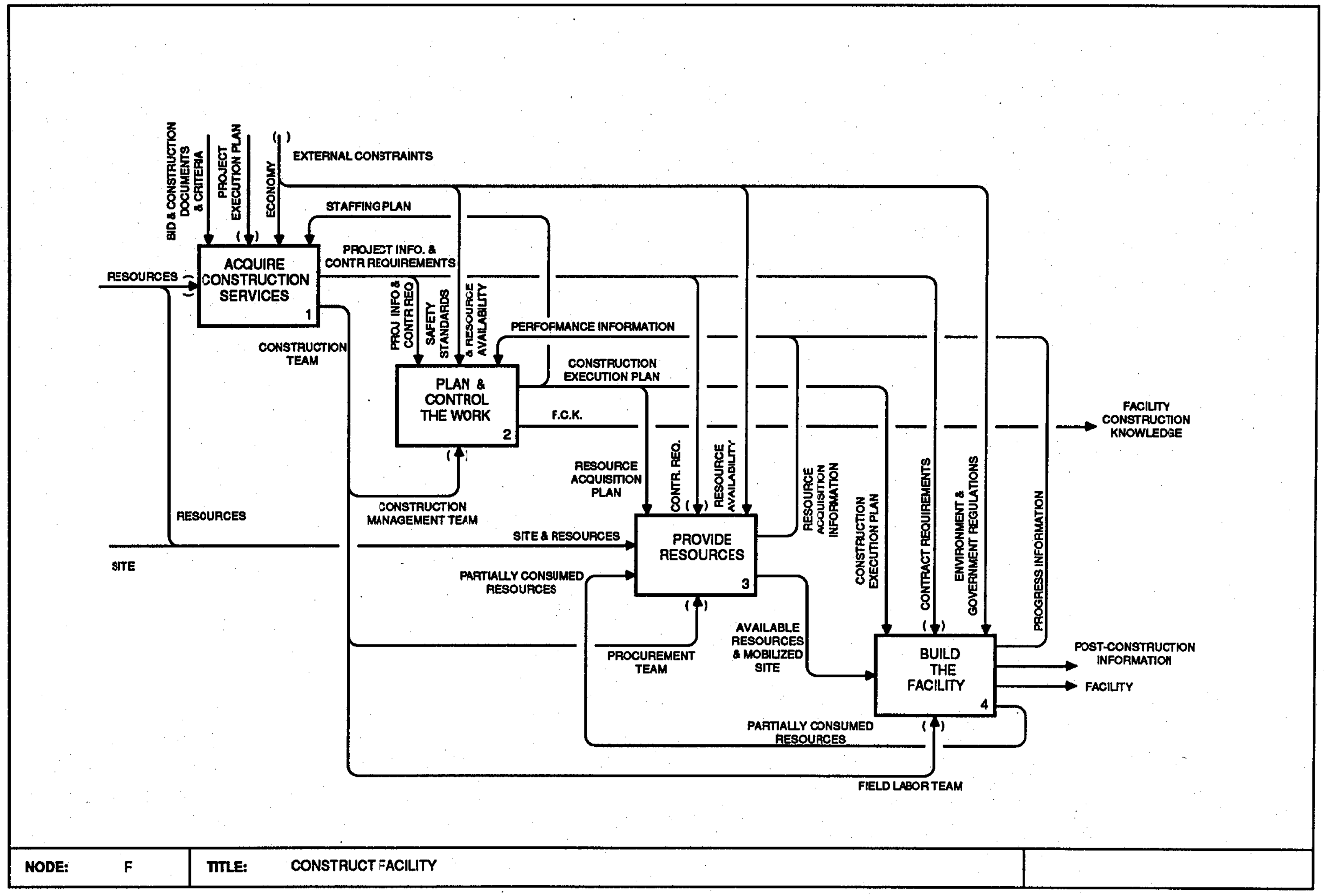


Figure 6.2: Construct Facility

Plan and Control the Work (C.2): 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. The execution plan is comprised of the staffing plan, resource acquisition plan, and the construction execution plan.

Provide Resources (C.3): 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.

Build the Facility (C.4): 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.

6.3 ACQUIRE CONSTRUCTION SERVICES (C.1)

The Acquire Construction Services function is broken down into five subfunctions (see Figure 6.3). Each is explained in the following sections.

Identify Qualified Parties (C.11): In this function, the parties qualified to perform aspects of the work as specified in the staffing plan are identified. The output of this function might be several subcontractors who will be invited to bid on a work package.

Provide Work Scope Information (C.12): In this function, work scope information is communicated to the qualified parties. Invitation-to-bid documents including the plans and specifications are supplied. Briefings or site visits might be conducted.

Prepare and Submit Proposals (C.13): In this function, the qualified parties develop bid prices and plans based on the work scope information taking into account the economy and other external variables.

Review Proposals and Select Constructor (C.14): In this function, the proposals are reviewed and checked against the intended work scope. A constructor is selected based on the criteria set by the staffing plan including contractor reputation, budget parameters, schedule objectives, and quality standards.

Execute Contracts/Agreements (C.15): In this function, agreements are negotiated and the contracts between parties are formalized.

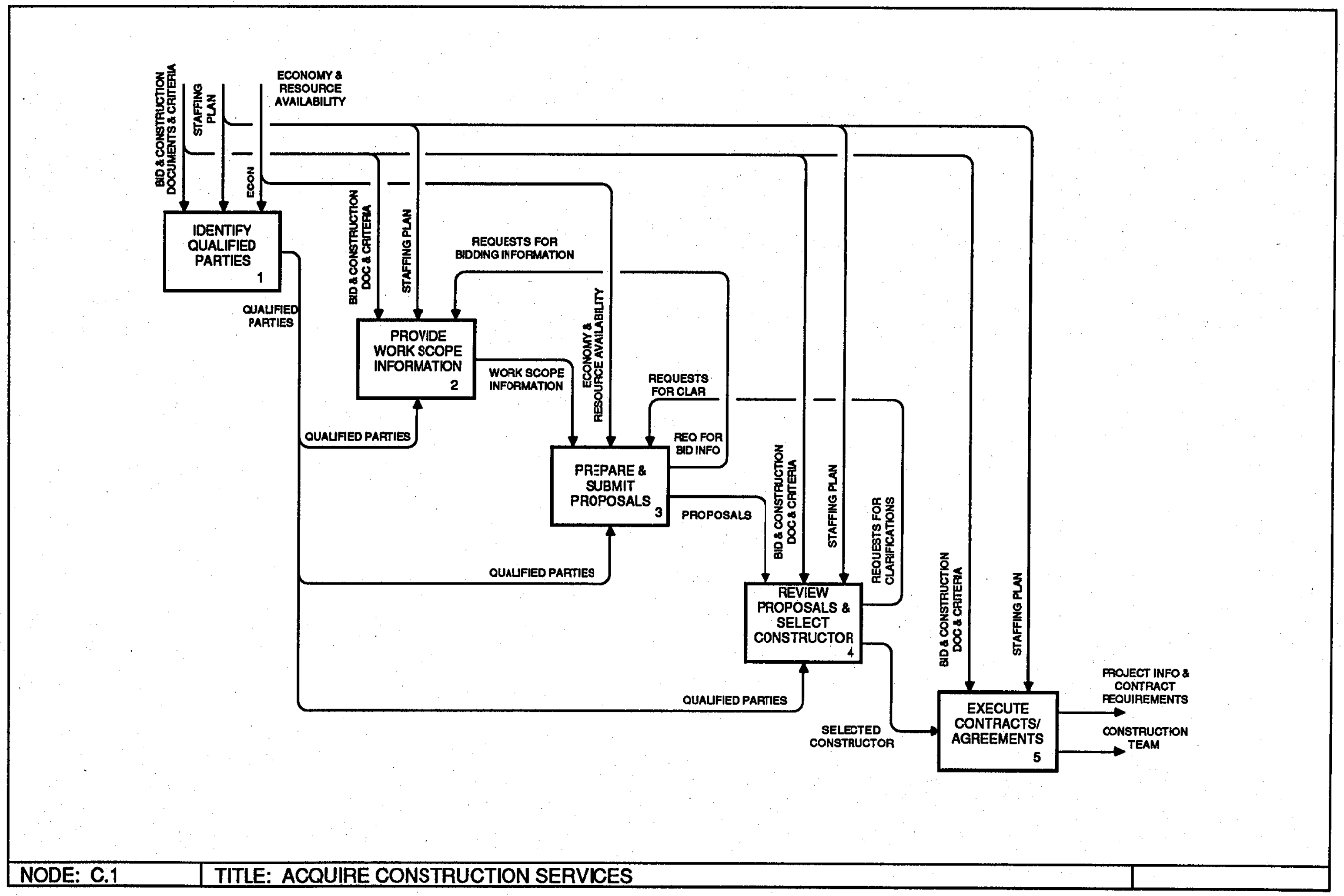


Figure 6.3: Acquire Construction Services

6.4 PLAN AND CONTROL THE WORK (C.2)

The Plan and Control the Work function is broken down into four subfunctions (see Figure 6.4). Each is explained in the following sections.

Develop the Construction Plan (C.21): In this function, the construction plan including work methods plans, estimates, and schedules, is formulated. During construction, the plan is revised based on the performance feedback.

Implement the Plan (C.22): In this function, the construction plan is converted into the execution plan. Budgets and aggressive schedules are developed for use by the procurement and field labor teams. The execution plan is revised to reflect changes in the construction plan. Communications with the owner and designer in the form of submittals and shop drawings are handled as part of this function.

Monitor Performance (C.23): In this function, the work is monitored and the performance feedback information is coordinated for use in developing performance reports which will be used to analyze job progress. Historical data is accumulated and stored for use on other projects.

Analyze Performance (C.24): In this function, the status of the work is evaluated, problems are identified and investigated, and the sources of problems are located. The need to make changes to the construction plan is determined and communicated as performance feedback. Adherence to the contract cost, schedule, and quality requirements is checked.

6.5 PROVIDE RESOURCES (C.3)

The Provide Resources function is broken down into six subfunctions (see Figure 6.5). Each is explained in the following sections.

Mobilize (C.31): In this function, the job trailers, laydown areas, parking areas, and other site facilities are set up. The temporary power, temporary phone, and other temporary services are acquired. The necessary permits, insurance policies, construction bonds, etc., are obtained.

Acquire Resources (C.32): In this function, the needed resources as shown in the material takeoff are obtained in accordance with the schedule taking into account the delivery, inventory, and maintenance feedback information.

Receive and Inspect the Resources (C.33): In this function, the acquired resources are checked as they are delivered to verify that the quantity and quality of the order is correct.

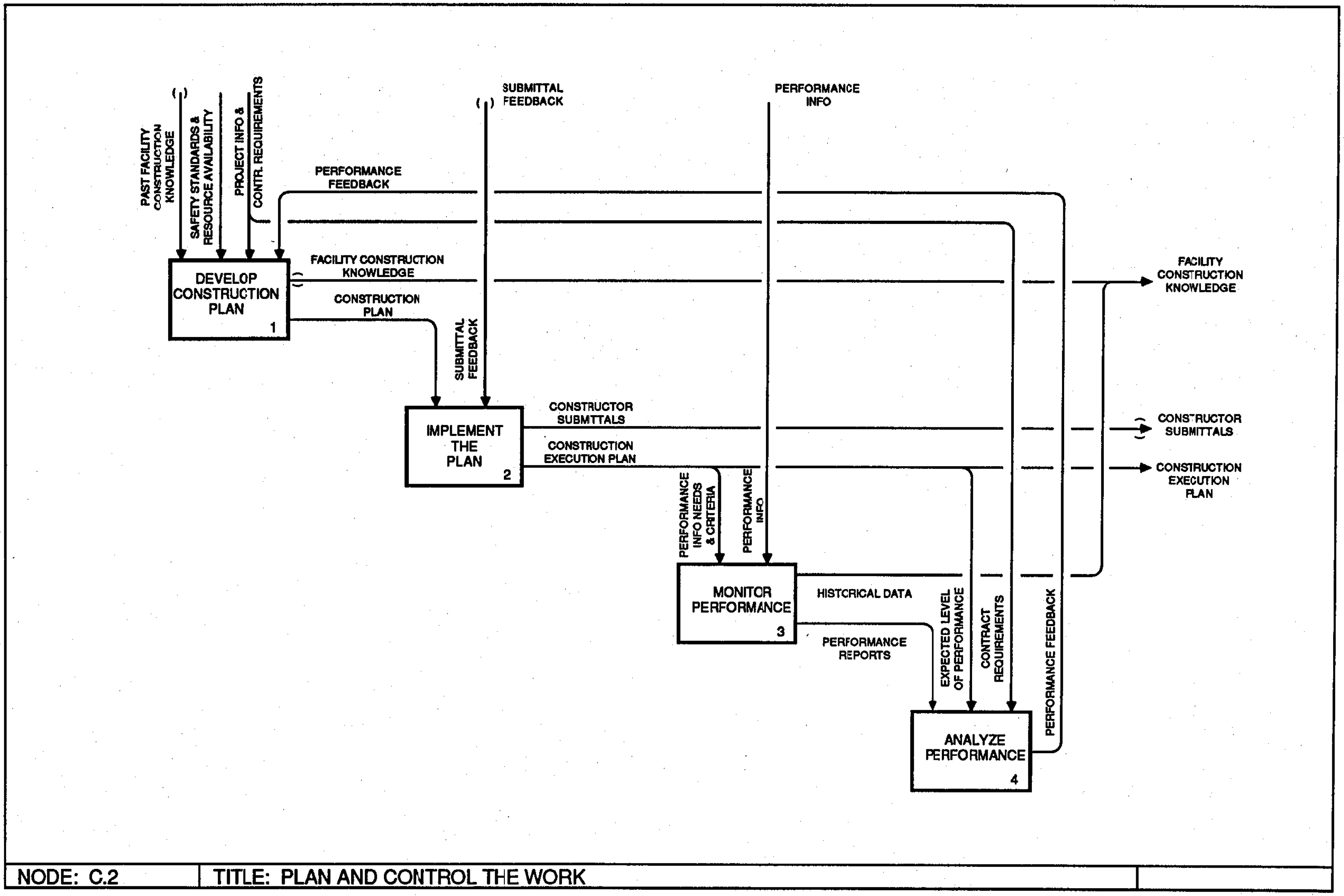
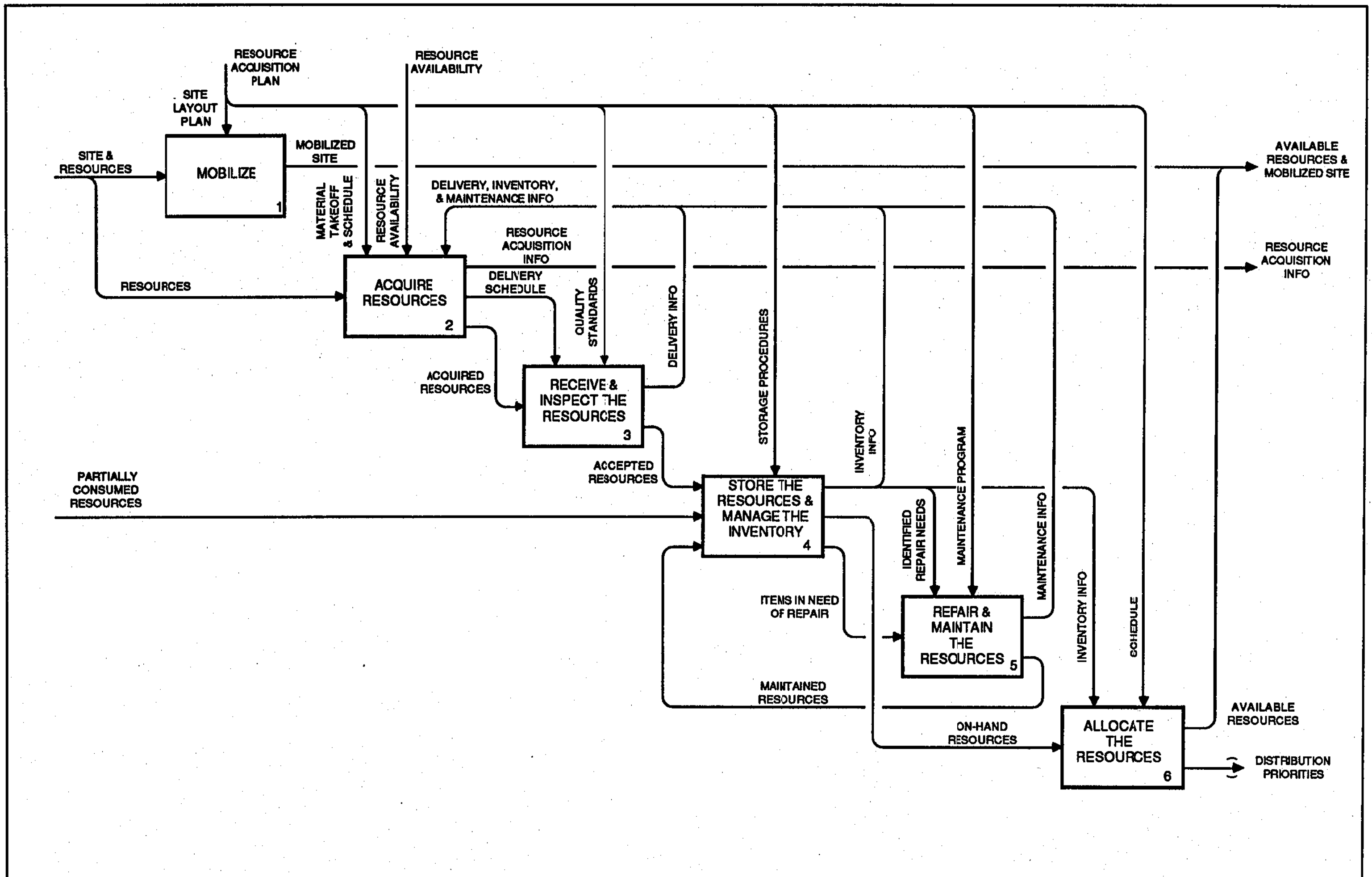


Figure 6.4: Plan and Control the Work



NODE: C.3	TITLE: PROVIDE RESOURCES	

Figure 6.5: Provide Resources

Store the Resources and Manage the Inventory (C.34): In this function, the resources are stockpiled and the on-hand inventory is tracked. The materials, supplies, and equipment are inspected and the needed repairs are identified.

Repair and Maintain the Resources (C.35): In this function, the routine preventive maintenance is performed as specified in the maintenance program and the items in need of repair are fixed.

Allocate the Resources (C.36): In this function, the distribution priorities for the on-hand resources are determined based on the construction schedule, available inventory, and the need for resources. The control of resources is allocated as the resources arrive on site.

6.6 BUILD THE FACILITY (C.4)

The Build the Facility function is broken down into five subfunctions (see Figure 6.6). Each is explained in the following sections.

Plan the Daily Work (C.41): In this function, people utilize field experience to give instructions for conducting the daily work based on the construction execution plan and feedback from performing the previous work. The environment and government regulations directly impact this plan.

Distribute the Resources (C.42): In this function, the needed resources are physically transported to the appropriate work areas as specified by the daily distribution plan and distribution priorities.

Do the Physical Work (C.43): In this function, the resources are converted into completed elements of the designed facility.

Inspect and Approve the Work (C.44): In this function, the completed work is checked to assure that the quantity, quality, and location of the product is sufficient and that the contract requirements were fulfilled. The owner, designer, constructor, code inspectors, and other government officials approve the constructed facility.

Turn Over the Completed Work (C.45): In this function, the building systems are tested and adjusted, the occupancy permit is obtained, and the facility is started up. Operation information is provided to the owner. Any legal claims are resolved as a part of this function.

6.7 DEVELOP THE CONSTRUCTION PLAN (C.21)

The Develop the Construction Plan function is broken down into five subfunctions (see Figure 6.7). Each is explained in the following sections.

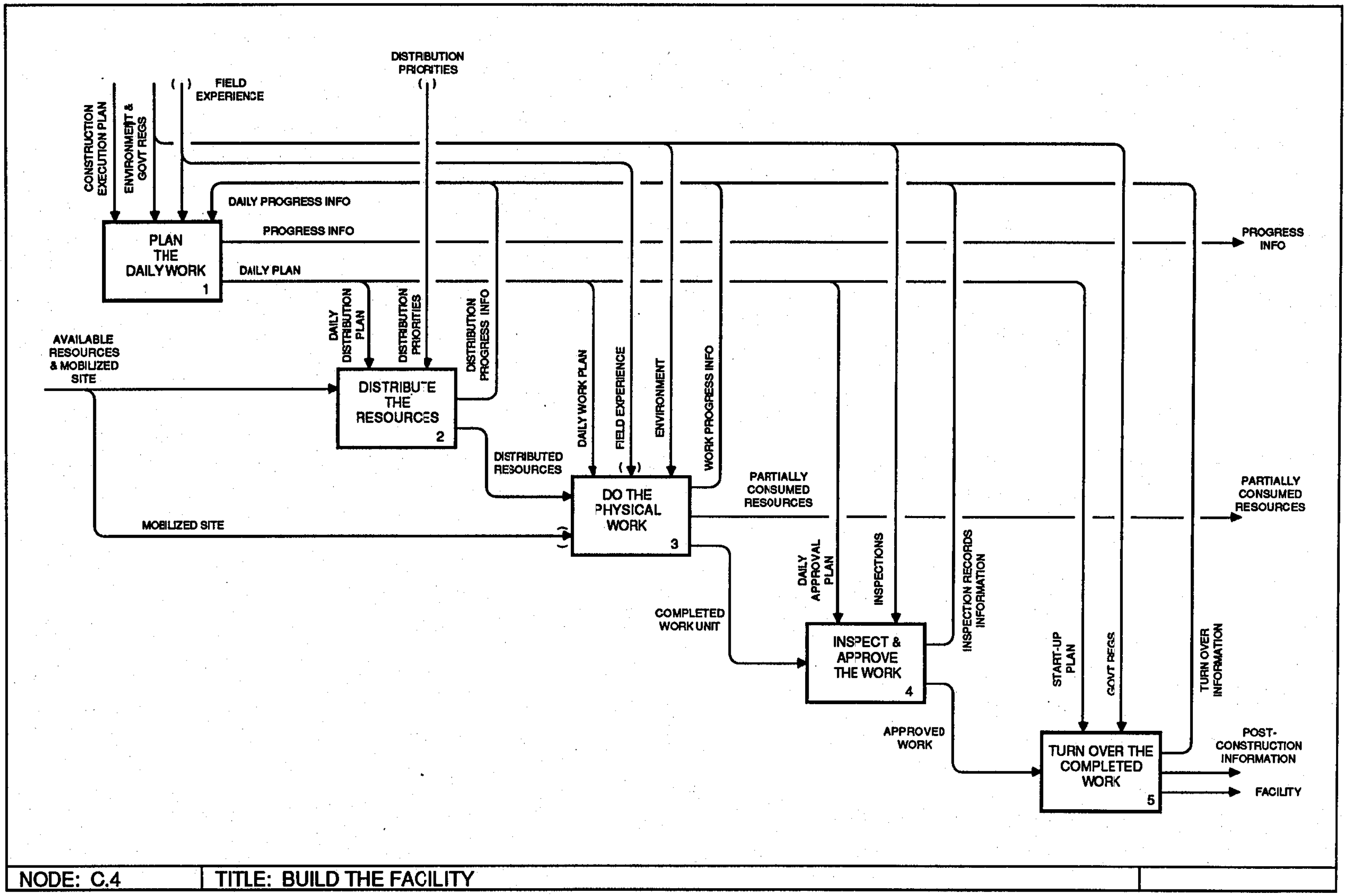
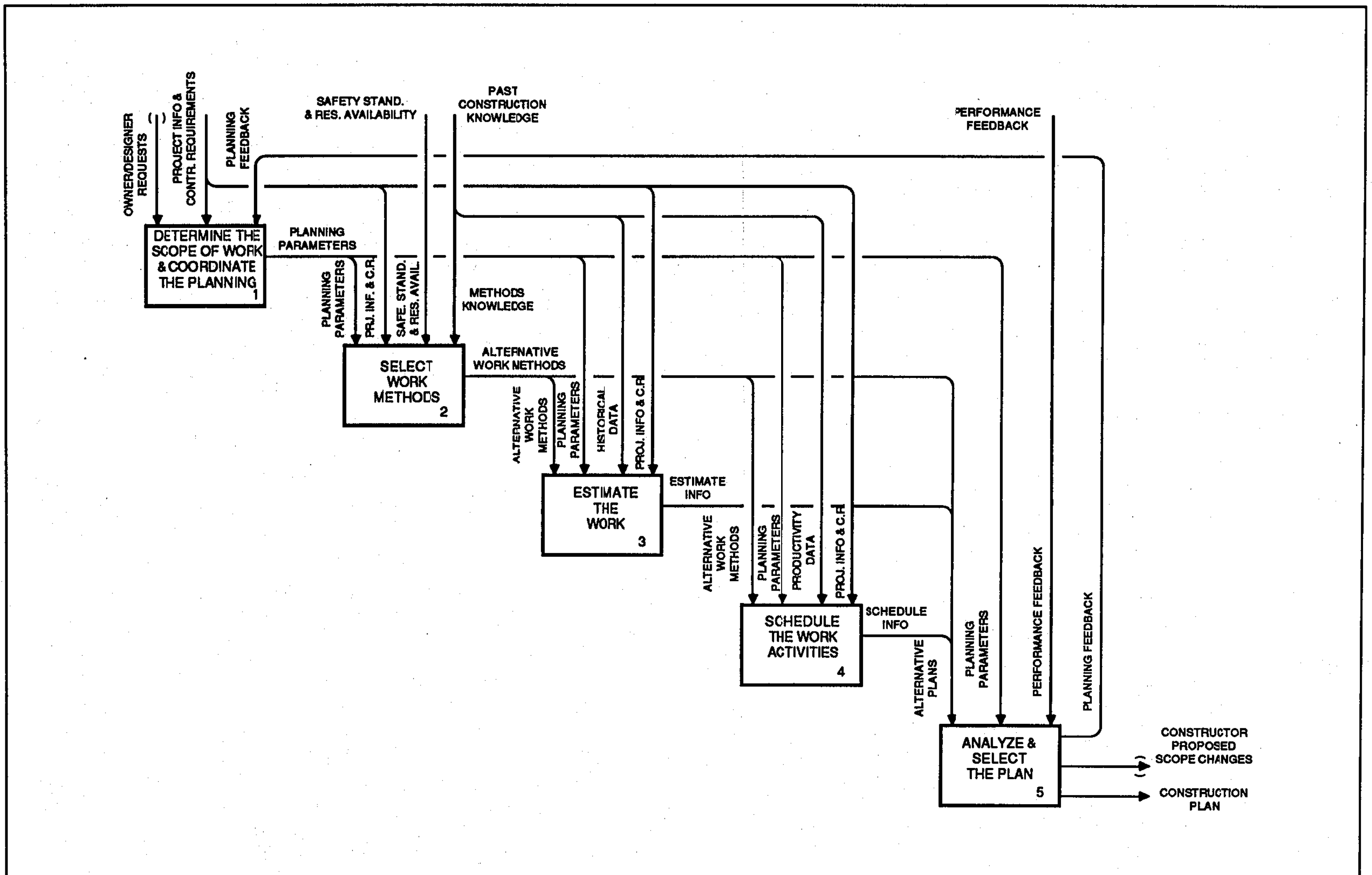


Figure 6.6: Build the Facility



NODE: C.21	TITLE: DEVELOP THE CONSTRUCTION PLAN	

Figure 6.7: Develop the Construction Plan

Determine the Scope of Work and Coordinate the Planning (C.211): In this function, the scope of work, as required by the contract requirements or requested by the owner or designer, is defined. The planning guidelines and goals are established. Decisions made concerning methods, cost, and schedule are communicated as part of the planning parameters.

Select Work Methods (C.212): In this function, the techniques which could be used to construct the facility are identified, based on methods knowledge, project information, safety standards, resource availability, and the planning parameters.

Estimate the Work (C.213): In this function, the resource needs and the anticipated costs associated with these needed resources are forecast, based on historical data, project information, alternative work methods, and the planning parameters.

Schedule the Work Activities (C.214): In this function, the durations of activities are estimated, the interrelationships between tasks are identified, and activity starts and finishes are planned, based on productivity data, project information, alternative work methods, and the planning parameters.

Analyze and Select the Plan (C.215): In this function, alternative plans are reviewed, portions of plans are approved, the need for replanning is determined, scope changes are proposed, and the construction plan is formalized.

6.8 DO THE PHYSICAL WORK (C.43)

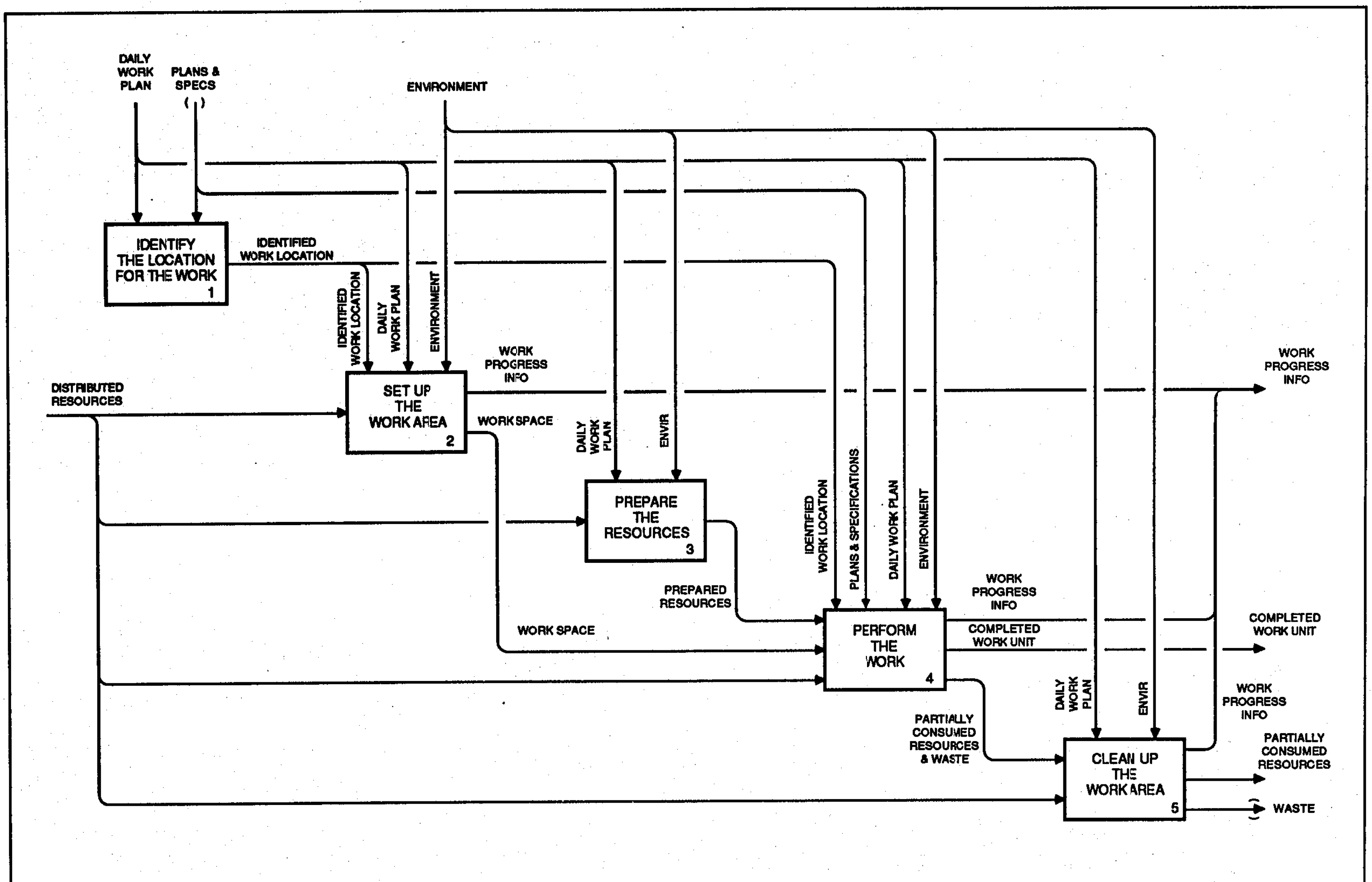
The Do the Physical Work function is broken down into five subfunctions (see Figure 6.8). Each is explained in the following sections.

Identify the Location for the Work (C.431): In this function, the physical location on the site where a component of the facility will be constructed is pinpointed, based on the plans and specifications.

Set Up the Work Area (C.432): In this function, the work space is established and organized (e.g., constructing scaffolding).

Prepare the Resources (C.433): In this function, the resources needed to conduct the work are mobilized and coordinated (e.g., mixing the mortar).

Perform the Work (C.434): This function is the core of the construction model. All of the other functions exist to support this process of converting resources into completed elements of the facility.



NODE: C.43 | TITLE: DO THE PHYSICAL WORK

Figure 6.8: Do the Physical Work

Clean Up the Work Area (C.435): In this function, the waste products are separated and removed from the improved site. Partially consumed resources, such as equipment and scaffolding, are salvaged for future use.

The above definitions of the functions in the Construction Process Model briefly describe the basic tasks. The findings from specific case studies, which support the validity of the Construction Process Model, are presented in the next chapter.

6.9 SUMMARY

The functions required to construct a facility have been defined. Two of the key subfunctions, developing the construction plan and doing the physical work are decomposed to a further level of detail. The next chapter defines the operations of a facility.

Chapter 7

THE "OPERATE FACILITY" MODEL

The "Operate Facility" model is intended to be as generic as possible so that the functions which make it up are valid for different facility types, sizes, systems, and services which are provided. This chapter orients the reader to the model before defining it. Full details of this model can be found in Technical Report No. 6 (Guvenis, 1989).

7.1 THE OPERATIONS FUNCTION

The operation of a facility includes all the activities which, when combined with the facility, are required to provide the user with an operational facility. Typical organizations responsible for the operations of a facility will separate the execution of these functions by systems e.g., electrical; architectural systems. They may also define subcategories that group similar activities for different systems. For example, preventive maintenance and corrective maintenance may be performed by different sections in an organization for multiple systems. The large variety in organizations performing this function led to several versions of the model. The final version groups like activities and does not separate systems.

7.2 OPERATE FACILITY

This section gives an overview of the function "Operate Facility." Figure 7.1 shows the node tree which summarizes the functional breakdown of the model and its different levels. An $IDEF_0$ diagram for the overall "Operate Facility" model is shown in Figure 7.2. The following paragraphs provide brief explanations for the functions. The breakdown follows a pattern that is analogous to Simon's (1960) decision making model which consists of the following four stages:

(a) Intelligence,
(b) Design,
(c) Choice, and
(d) Implementing solution.

The functions O.2 and O.3, namely "Monitor Facility Condition and Systems" and "Evaluate Conditions and Detect Problems" are analogous to stage (a); function O.4 (Develop Solutions) to (b); function O.5 (Select Plan of Action) to (c); and function O.6 (Implement Plan) to (d). There is an additional function called "Manage Operations" (O.1) which has a supportive role for the other five functions to exist. A graphical representation of the analogy is shown in Figure 7.3. Descriptions of these functions follow.

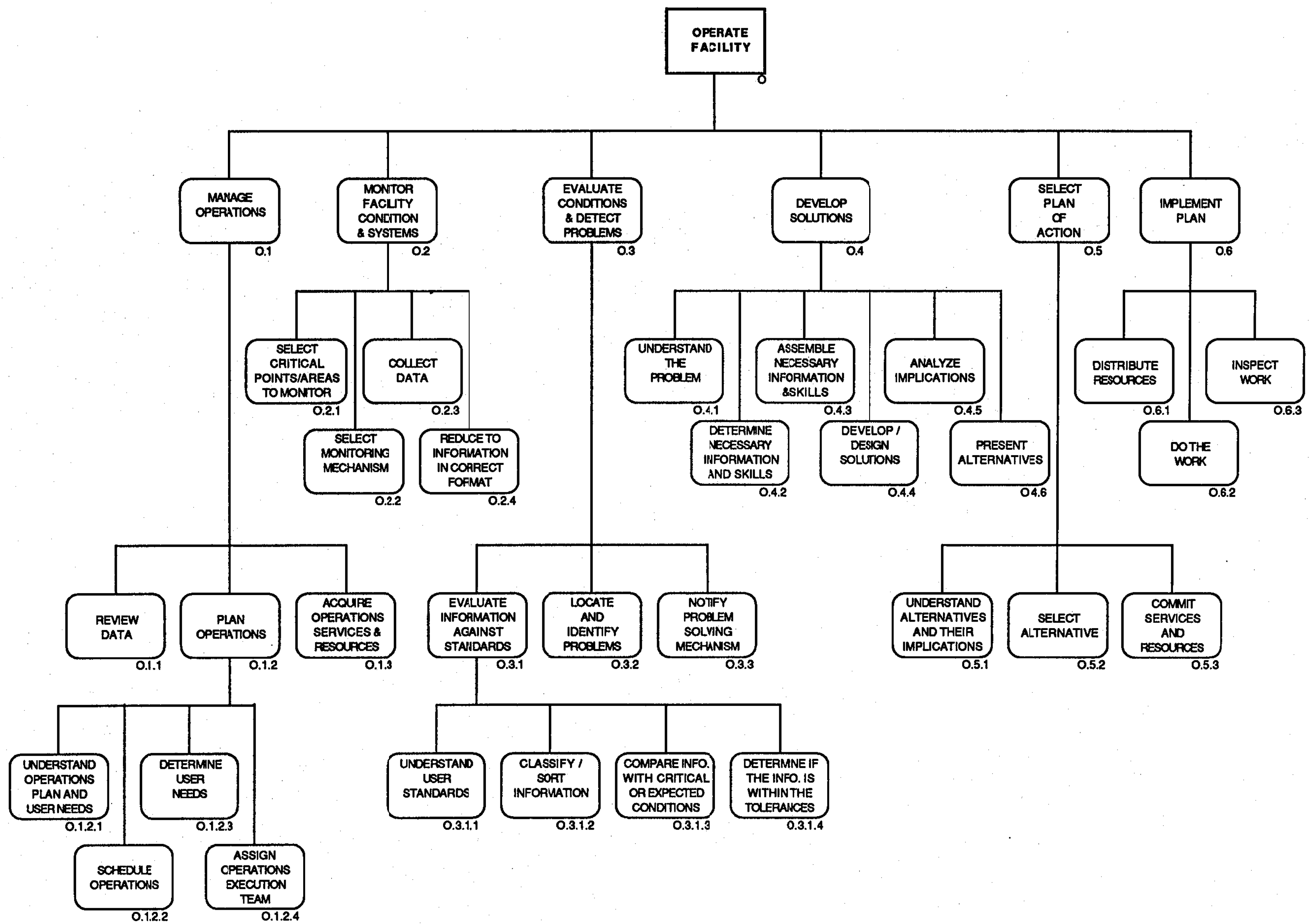


Figure 7.1: Operate Facility Node Tree

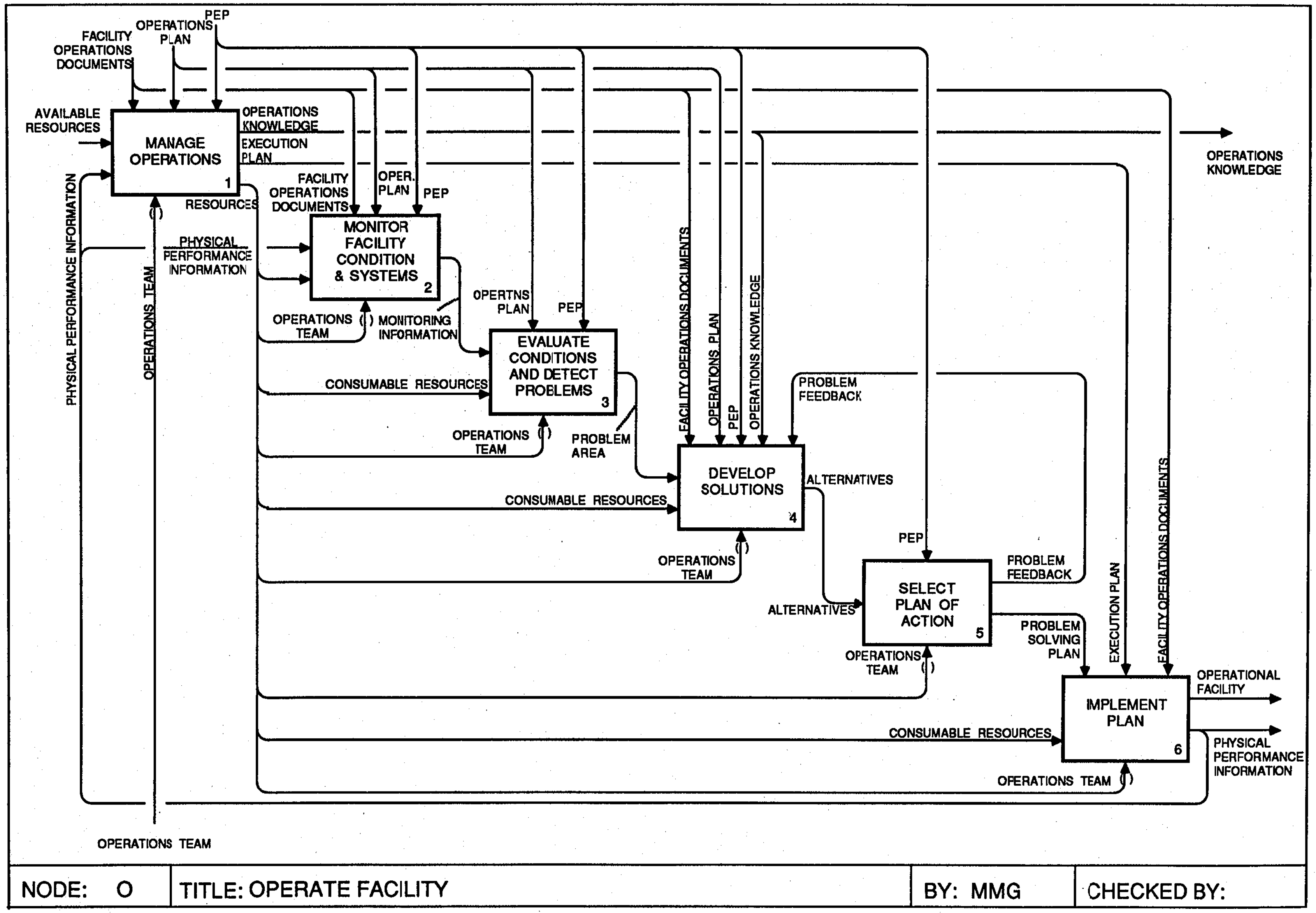


Figure 7.2: Operate Facility

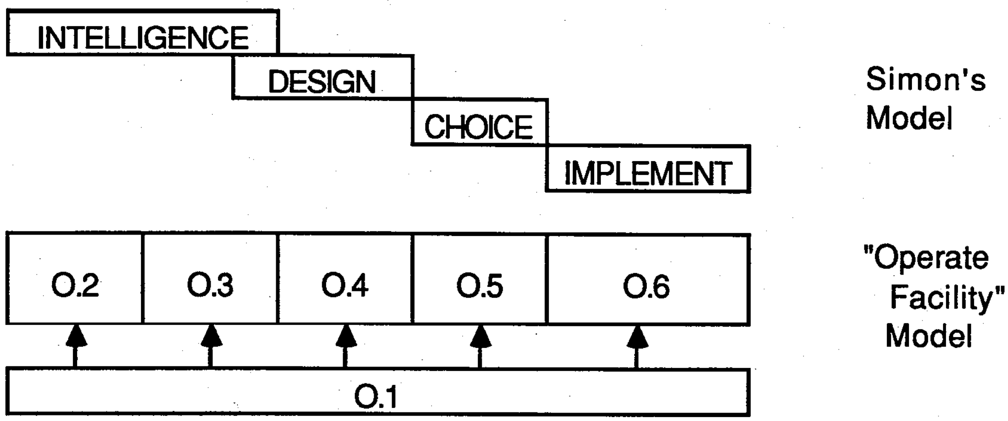


Figure 7.3: Analogy between the decision making model and the Operate Facility model.

Manage Operations (O.1): 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. The function generates the execution plan to the other functions, and the operations knowledge to the overall IBPM. The operations team which is shown as a mechanism is also an output since the same team (or part of it), together with other resources, is assigned or distributed to the rest of the functions.

Monitor Facility Condition and Systems (O.2): 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. The main input is the physical performance information which can be through inspection or an automated system. The output is the same information, but it is sorted, classified, or simplified in order to be used by other functions.

Evaluate Conditions and Detect Problems (O.3): 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. For example, the monitoring information can state that the water temperature for a heating system is *x* degrees. The O.3 function determines whether or not this is a problem, and if so, it locates the source and identifies the reason. It does not develop solutions.

Develop Solutions (O.4): 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.).

Select Plan of Action (O.5): When a number of plans are developed to solve a problem, the non-technical aspects are also considered. However, the plan to be implemented is usually selected by someone else who is usually from an upper level of management. There are exceptions to this of course, and in most cases it is a function of the size of the facility or the organization managing it. The smaller the organization the more likely that less people will be involved in the functions O.2 through O.5. Another exception is an automated monitoring system which can oversee and evaluate the operations, and within certain limitations develop solutions and implement them.

Implement Plan (O.6): 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. If there are no problems or breakdowns, the implementation activities follow the execution plan (scheduled or periodical maintenance, cleaning, turning systems on and off, etc.)

The following sections decompose functions O.1 through O.6.

7.3 MANAGE OPERATIONS (O.1)

This section takes a closer look at the manage operations function. Each function is presented with a page of definitions and notes, and its $IDEF_0$ diagram. The $IDEF_0$ diagram of O.1 is shown in Figure 7.4. Brief descriptions of the subfunctions follow.

Review Data (O.11): Reviewing the operations data and historical data - these data (as past experience) can always be helpful in developing plans and schedules.

Plan Operations (O.12): The planning/ replanning and scheduling that is necessary for implementing the Operations plan, and for the maintenance to support the operations.

Acquire Operations Services and Resources (O.13): The acquiring of all the resources and services needed by all operations and maintenance functions. It is important that this function not be confused with "Manage Facility" (node "M") in the IBPM. This function deals only with operations, short-term planning, and the acquisition of resources for the related tasks, whereas "Manage Facility" has

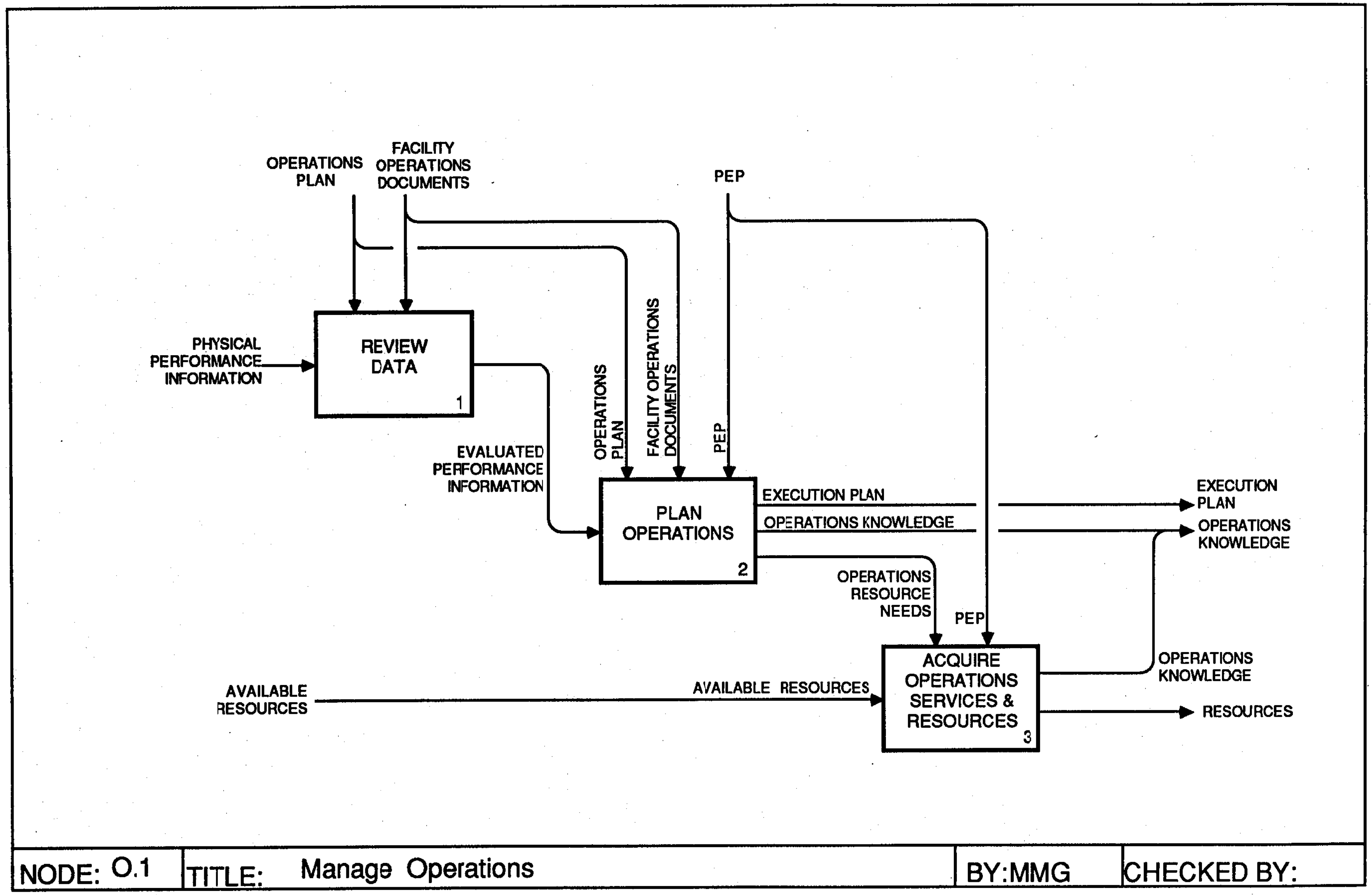


Figure 7.4: Manage Operations

a broader scope, longer range of planning, and the acquired resources are actually the facility managers, contractors who conduct the "Operate Facility" function.

7.4 MONITOR FACILITY CONDITION AND SYSTEMS (O.2)

The $IDEF_0$ diagram of O.2 is shown in Figure 7.5. Brief descriptions of the subfunctions follow.

Select Critical Points/Areas to Monitor (O.21): Select points/areas which would best represent the section(s) of the facility to be monitored.

Select Monitoring Mechanism (O.22): Select the mechanism/system which will carry out/assist in the monitoring process. This mechanism can be an automated system, an inspection team, the user, etc.

Collect Data (O.23): Collect all the information related to the operations of the systems in the facility.

Reduce to Information in Correct Format (O.24): Transform the monitoring data to information in a format which can be understood and/or further processed by all mechanisms.

The selected points (in O.21) are usually the most critical ones for testing the effectiveness of the systems and services. The selected mechanisms (in O.22) are different for each monitoring point or purpose. For example, for the exterior look of a building, the best mechanism is an inspector, whereas for a hot water system a suitable mechanism is a thermometer.

7.5 EVALUATE CONDITIONS AND DETECT PROBLEMS (O.3)

The $IDEF_0$ diagram of O.3 is shown in Figure 7.6. Brief descriptions of the subfunctions follow.

Evaluate Information Against Standards (O.31): This is the phase in which the information is reviewed and compared with the critical or expected performance values. It also includes the determination of whether or not there is a problem.

Locate and Identify Problems (O.32): Find out where the problem is and determine what the problem is.

Notify Problem Solving Mechanism (O.33): Once a problem is located and identified, a mechanism is notified for developing a solution or even implementing it. The mechanism may be an operator, a device, or even the user.

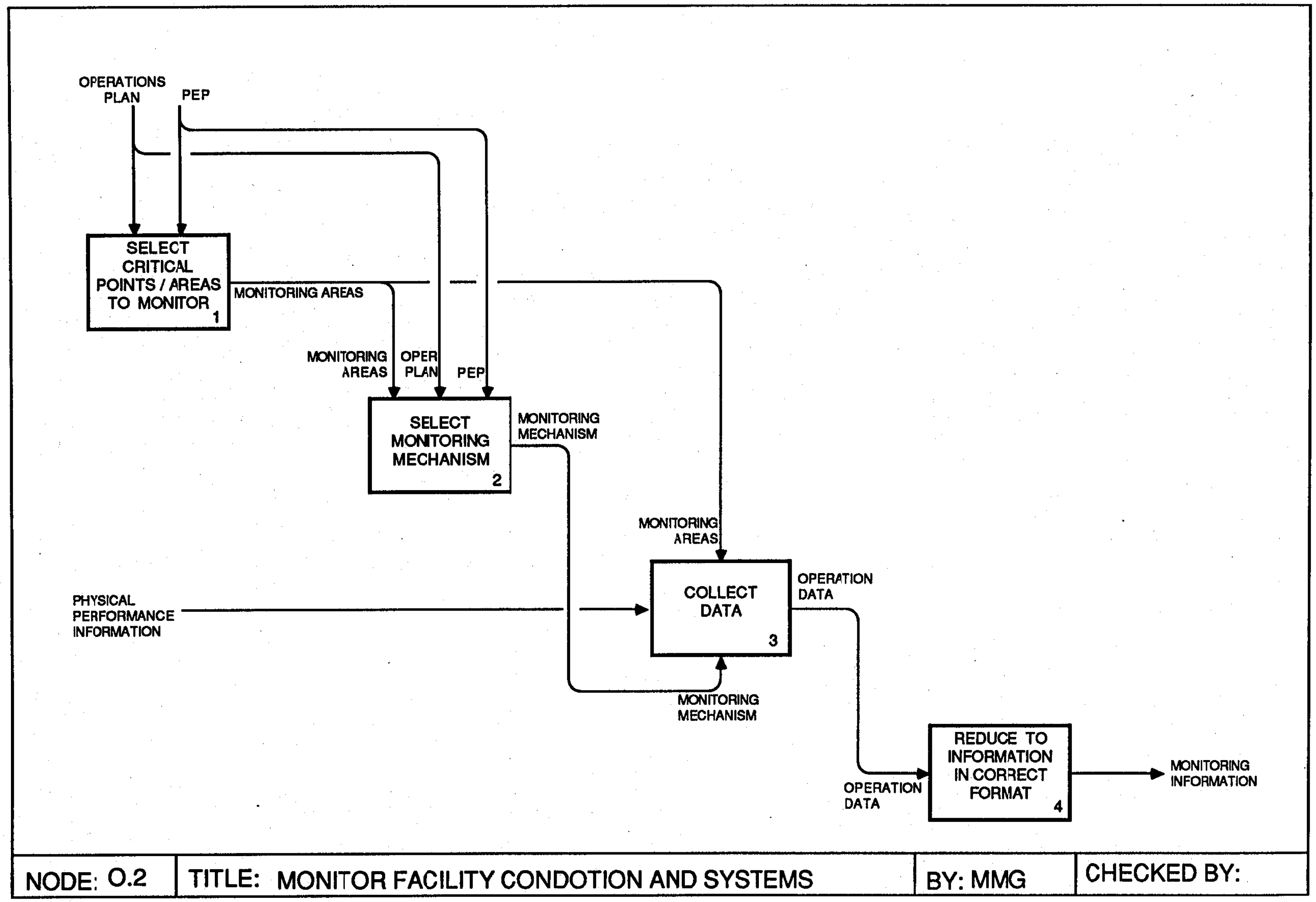


Figure 7.5: Monitor Facility Condition and Systems

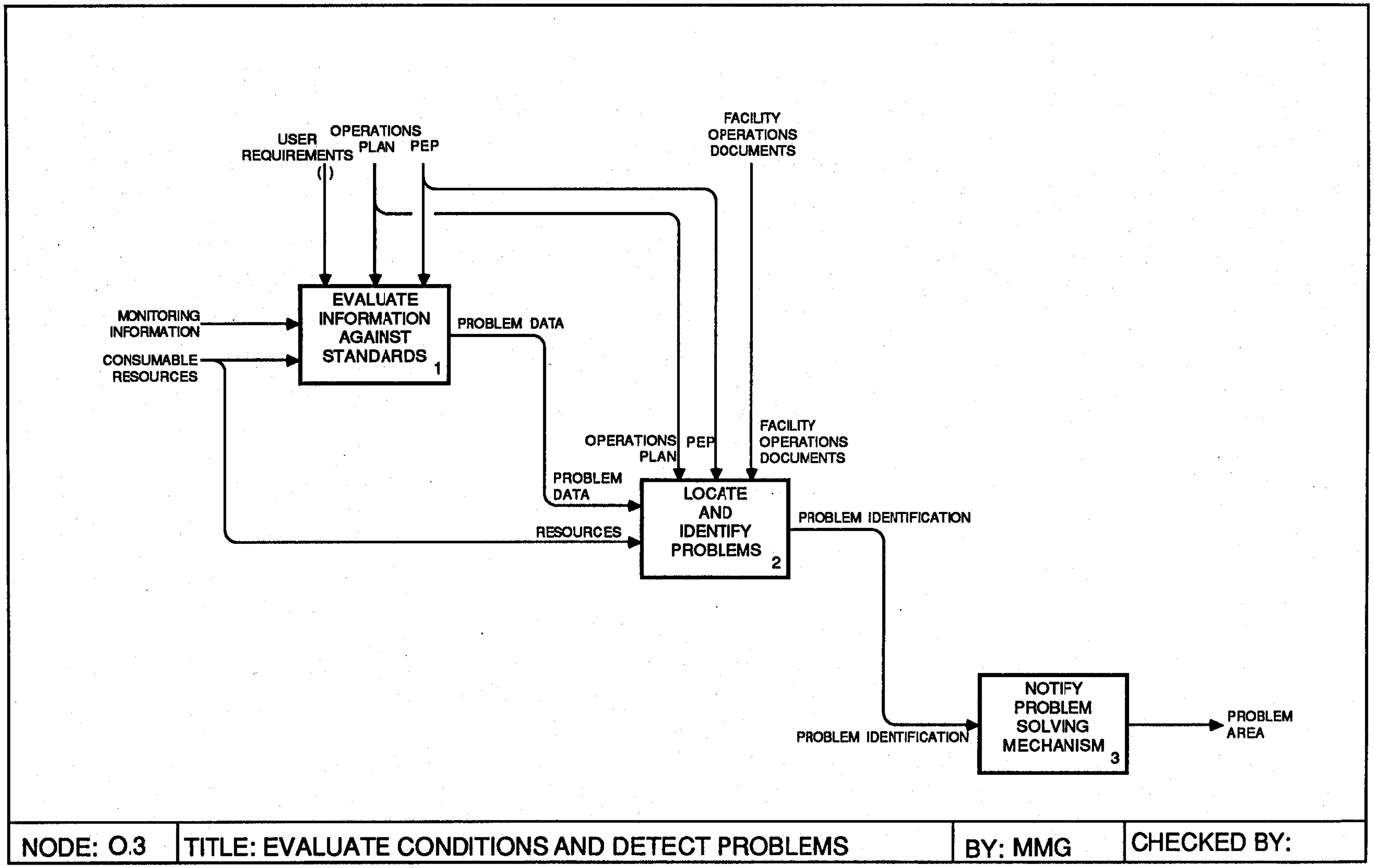


Figure 7.6: Evaluate Conditions and Detect Problems

User requirements and standards have the main influences on defining the environment to be maintained in a facility. There are also tolerances to which these requirements can be extended. This function determines whether or not the actual status of the operations is within the tolerance limits of the desired standards or user requirements. If necessary, it locates and identifies the problem, and notifies a mechanism to find a solution.

7.6 DEVELOP SOLUTIONS (O.4)

The $IDEF_0$ diagram of O.4 is shown in Figure 7.7. Brief descriptions of the subfunctions follow.

Understand the Problem (O.41): Understand the problem area and generate the necessary information to develop solutions.

Determine Necessary Information and Skills (O.42): Determine the information and skills needed to solve a problem.

Assemble Necessary Information and Skills (O.43): Collect/ put together the information and skills needed to solve a problem.

Develop/Design Solutions (O.44): Design a technical solution for a problem.

Analyze Implications (O.45): Analyze the aspects of the problem solving plan which are not directly related to the operations and maintenance of the facility, such as business operations, disturbances, availability, etc.

Present Alternatives (O.46): After a plan is developed, it is communicated to a selecting mechanism as a set of alternatives.

The following notes supplement the above explanations:

1. A full understanding of the problem is necessary in order to develop effective solutions.
2. The implications of the technical solution (cost, disruptions, availability, codes, etc.) should not be overlooked.
3. A good presentation of the alternatives will provide a good understanding of the problem and the solution.
4. The way that the presentation is made may affect the selection.

7.7 SELECT PLAN OF ACTION (O.5)

The $IDEF_0$ diagram of O.5 is shown in Figure 7.8. Brief descriptions of the subfunctions follow.

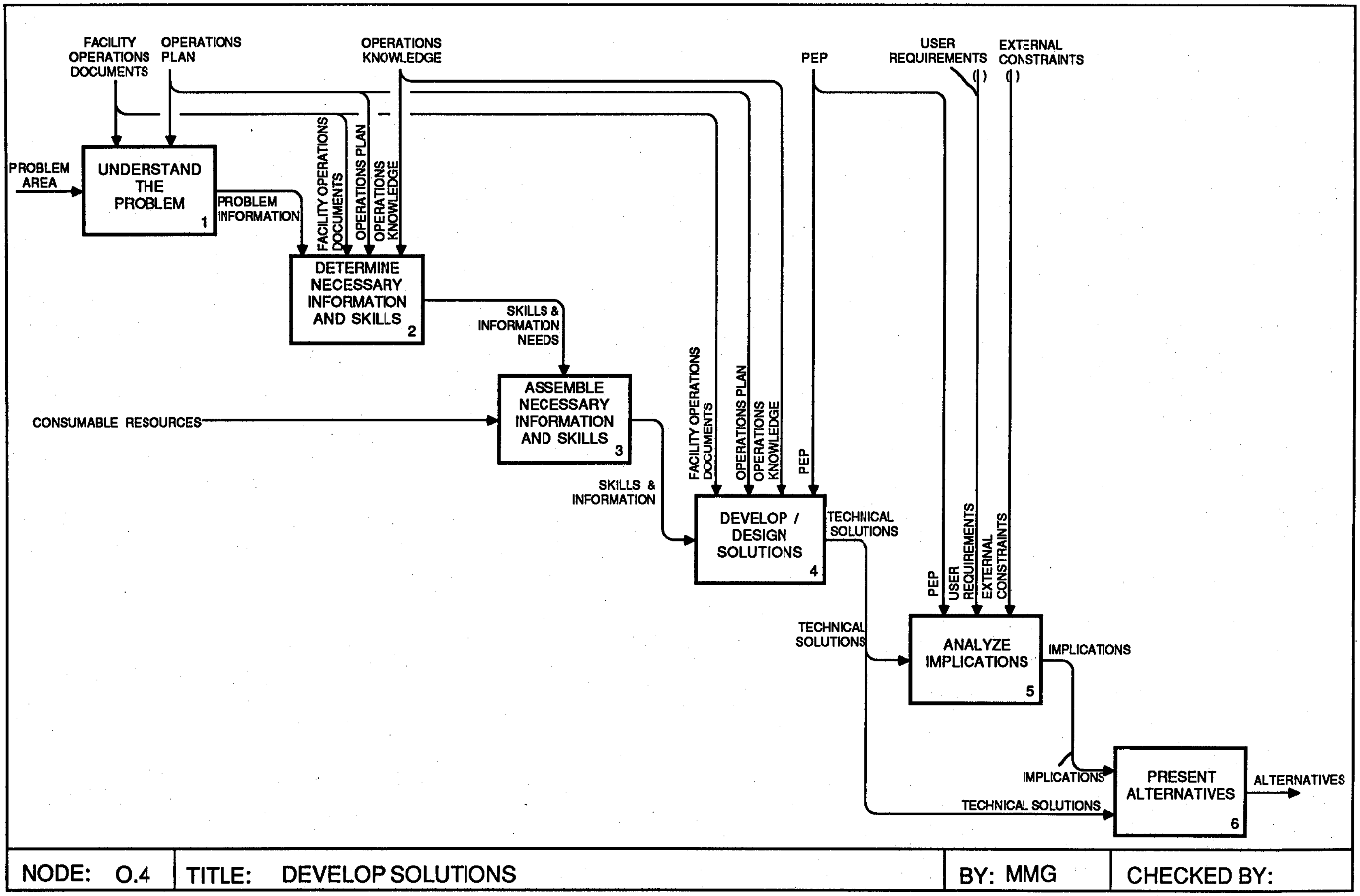
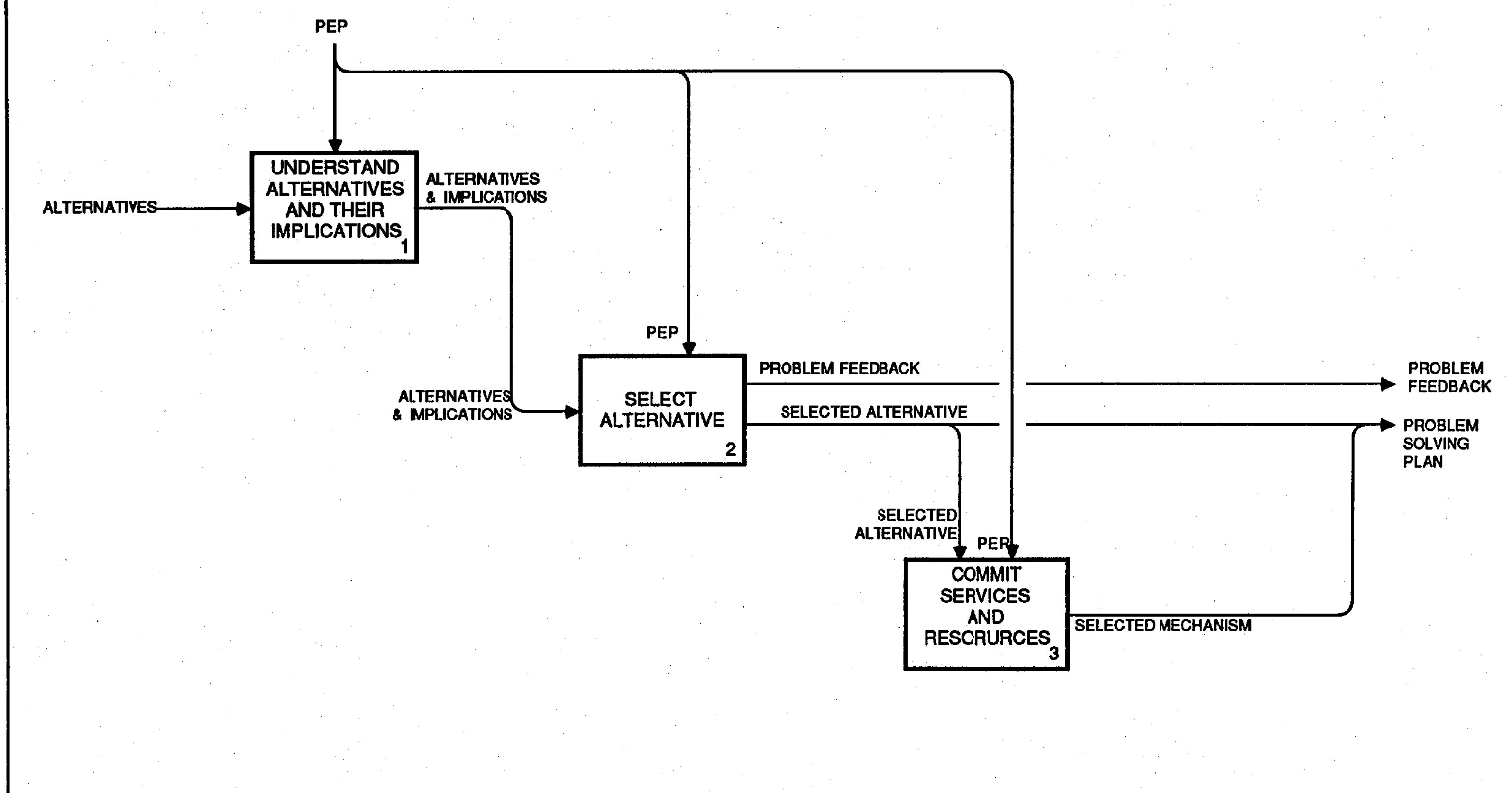


Figure 7.7: Develop Solutions



NODE: O.5	TITLE: SELECT PLAN OF ACTION	BY: MMG	CHECKED BY:

Figure 7.8: Select Plan of Action

Understand Alternatives and Their Implications (O.51): Understand the alternative problem solving plans and their implications in order to make the most suitable selection.

Select Alternative (O.52): Consider the direct consequences of the suggested alternative plans and their indirect impacts/implications, and select alternative(s).

Commit Services and Resources (O.53): Allocate the people, materials, equipment, contractor, etc. to implement the selected plan.

The following notes supplement the above explanations:

1. In the case that none of the alternatives are suitable for the problem, there is a feedback (referred to as "problem feedback") for new alternatives to be developed.
2. A full understanding of the alternatives and their implications is essential for selecting the best solution.
3. Selection of a plan can be subjective. The preference of the selecting mechanism may be different form that of the developing mechanism.

7.8 IMPLEMENT PLAN (O.6)

The $IDEF_0$ diagram of O.6 is shown in Figure 7.9. Brief descriptions of the subfunctions follow.

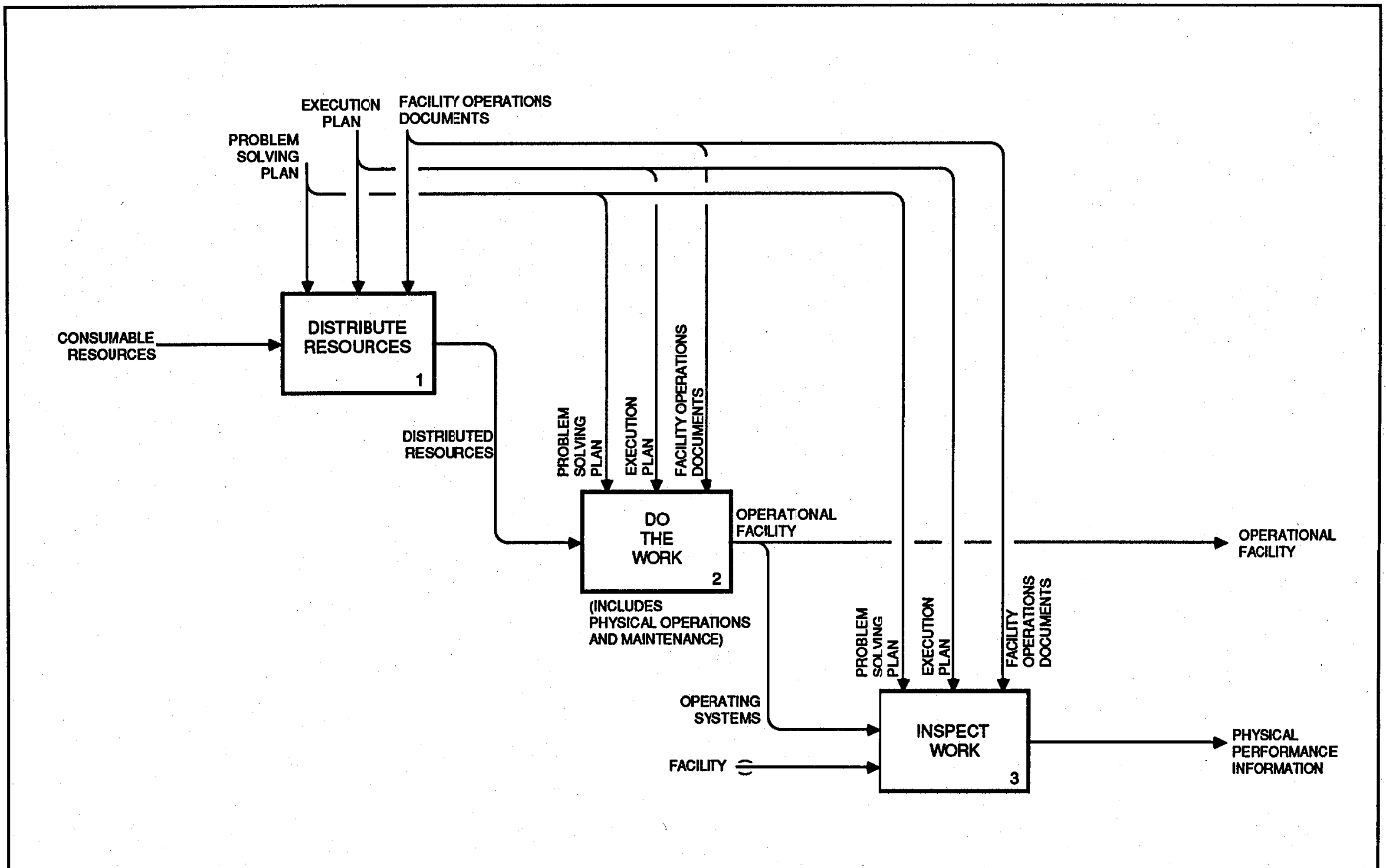
Distribute Resources (O.61): Giving the resources necessary to carry out the designated operations or maintenance work, to the mechanism performing it.

Do the Work (O.62): The actual implementation of the physical work, i.e. turning on/off switches, replacing or repairing parts, cleaning, etc.

Inspect Work (O.63): Includes the inspection of the maintenance; the checking of whether or not the work was done properly, or whether or not the implemented plan was an appropriate one.

The following notes supplement the above explanations:

1. The term plan refers to both the initial "execution plan" and the "problem solving plan" which is reactive to a breakdown, malfunction, etc..
2. "Inspect Work" should not be confused with the inspection which is a mechanism for monitoring the systems (O.2).
3. The "Physical Performance Information" is an input to O.21 for continuous monitoring, and to O.11 (Review Data) to be used as historical information for planning.
4. O.61 distributes the resources which are provided by the O.1 function (Manage Operations). The distribution is done according to the plans, and resource requirements of different activities.



NODE: O.6	TITLE: IMPLEMENT PLAN	BY: MMG	CHECKED BY:

Figure 7.9: Implement Plan

7.9 DISCUSSION AND SUMMARY

These diagrams depict generic functions required to operate a facility. Two major points to be highlighted are as follows:

1. The $IDEF_0$ diagram is time independent. The functions do not have to follow this specific order. Depending on the type of the facility and the point in time in which the process is being observed, any one of the six boxes in the diagram can be the starting point.

2. In many cases functions O.2 through O.5 (and even O.6) can occur simultaneously, or some of the functions in the chain can be skipped. An Automated system is an example to such a case: When a certain space in a facility gets relatively cold, the cold air can activate a thermostat which is set on a temperature range according to certain requirements or codes. This can operate a heating unit until the space reaches the desired temperature, and heating is stopped again by the thermostat.

The functions required to operate a facility have been defined. This is the last section of the model to be decomposed. The next chapter concludes the report.

CHAPTER 8

CONCLUSIONS

This report has presented a model of the essential functions required to provide a facility from the viewpoint of the user. The model defines the tasks involved in managing, planning, designing, constructing, and operating a facility and describes the flow of information between these processes. The model consists of interrelated diagrams, function definitions, and a glossary. The model's evolution and its validation using data from 22 building sites was discussed.

Using this model, the various project participants can understand which factors influence different tasks, and how their activities relate to the project as a whole. The model also improves the owner's understanding of the necessity for efficient flow of project information within the management process as well as between management and the other functions required for providing a facility.

8.1 BENEFITS OF THE MODEL

The model has numerous opportunities for implementation offering many potential benefits to the construction project owner and the other participants. Some of these opportunities are:

1. The model can be used in analyzing current project management procedures for improvement. A similar (As-Is) model of current operations should first be constructed. This actual model can then be compared with the ideal model. Such comparison will offer many opportunities for improvements and can serve as a tool for integration.

2. The functions in the model must all be performed for a project to be completed. This framework is useful for defining task boundaries and responsibilities in structuring contracts, thus eliminating duplication or omission of assigning responsibility for activities to the various contractors.

3. The model can be used to improve the communication between the owner's team members and between the owner and other project participants.

4. The model can serve as the basis for designing a facility information system. This may be implemented using a facility data base that contains selected facility information including those produced by the planning, design, construction and operation functions. Such a data base would serve project management in managing the on-going planning, design and construction as well as in managing future facility modification projects. The data base would also provide the information needed to operate and maintain the facility.

5. The model can be used for teaching purposes. It can be used to demonstrate the significance and the context of each activity, and how the owner and other project participants may influence the flow of the overall project.

6. The model can be used to determine which key decisions will be required, when these decisions should be made, and what information will be needed to support these decisions. The model can also be used to highlight the implications of the lack of timely decisions, information or other resources.

In summary, the model will serve as the single mechanism to unite the scheduling, budgeting, contractual, organizational and other tools used to represent the project as a model. However, it does not attempt to freeze any variable, such as time, or cost relationships. On its own, it is conceptual and generic. When used in conjunction with these other tools, it can be very powerful.

8.2 LIMITATIONS OF THE MODEL

Three of the model's limitations are:

1. It does not assign values or priorities to tasks. Thus, it shows each task as having an equal value to the project, rather than its actual importance.

2. It shows no sense of time nor does it show task sequence relationships (The $IDEF_0$ methodology describes a process as a series of functions tied together with a number of inputs, outputs, and constraints; no time concept is introduced). In many areas of the construction process, timing of tasks and information has a high impact on the project success.

3. The modeling diagrams are very complex - an accurate indication of today's construction process. A more simple method for executing construction projects must be defined using the models, then implemented in the field.

Nevertheless, these limitations can be overcome by using other models in conjunction with this model. For example, the model can be cross referenced to identify key activities on a schedule network (e.g., CPM) and key cost budget items, thus providing a collection of tools for the user. This model then complements and fits with current tools used in the industry.

8.3 FUTURE RESEARCH

Some issues which were faced during this research require solution in future research. These are:

1. The processes required to provide a facility and the resulting information flows need to be simplified.

2. An information system to support the provision of a facility must be designed. This information system should include process, product and resource information. The model is the starting point for this facility data base.
3. An effort is needed to relate this model to other project management tools such as CPM schedules and budgets and provide an integrated decision support tool.
4. The elements defined on the arrows in the model need further development. Qualitative and probabilistic measures of performance must be provided. In addition, hey can be decomposed into information elements at further levels of detail using the terminology accepted in the industry today.

8.4 CONCLUSION

This study has developed the first comprehensive process model of the functions required to provide a facility. Technical Reports 2 through 7 provide details and case studies to support these models. The Investigators believe that the original intent of the subject project has been met and exceeded. The authors hope that you find this work of use and plan to use it as a cornerstone for the development of an information architecture to integrate the entire manage, plan, design, construct and operate processes.

Appendix A

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Appendix B

GLOSSARY OF TERMS

Accepted Resources: Resources which have been inspected and approved as meeting the specified quality and quantity (e.g., inspected for damage from transport). This is typically verified with a signed receipt of goods note.

Acquired Resources: Resources which have been delivered to the site, but have yet to be accepted.

Acquisition Information: Detailed information on the physical condition of the required site, its size, location, purchase/lease price, etc.

Alternate Plans: Alternate options for meeting user's need for facilities such as: buy, modify, expand or build.

Alternative Construction Plans: Several strategies (primarily concerning methods, estimate, and schedule information) which will be analyzed to select an optimum construction plan.

Alternative Work Methods: Possible techniques or construction processes which could be implemented to build the facility (e.g., formwork designs, selected equipment, selected work techniques).

Alternatives: Plans developed for solving an operations-related problem.

Alternatives and Implications: Plans developed for solving an operations-related problem and its implications such as impact on business, work schedule disruptions, etc., fully understood by the selecting mechanism.

Approval/ Inspection Plan: The selected approval/ inspection plan which dictates the manner in which materials, equipment, or a particular portion of work is examined to see that it conforms to the conditions originally imposed (i.e. quality assessment and quality control). The conformance might relate to specifications, codes, etc., which may be required in order to qualify the item inspected as completed work.

Approved Work: Elements of systems in the facility which have been inspected and are deemed ready for start-up and turn over.

Availability of Sites: This relates to how soon and how easily a site can be acquired. When there are more than one alternative site, availability becomes an important issue for the owner and its business.

Available Resources: The personnel, computer technology, time, space, equipment, materials, energy, funds, etc., available to the project.

Bid and Construction Documents and Criteria: The formal documents, drawings, specifications, instructions, limitations, procedures, and criteria for bidding and constructing the facility. These represent the best information available that conveys the nature of the facility and parts thereof to be built. They include bid documents, scope of work, working drawings, limitations of cost and schedule, and quality criteria as available.

Business Market Conditions: These are the characteristics of the environment in which the owner's business exists. They will indirectly affect the decision of the owner about the recognition of the need for a facility. The facility will potentially improve the owner's business market share.

Candidate Sites Information: A description of the site's attributes such as topography, size, location and soil characteristics.

Codes: Rules and regulations prescribed by organizations defining standard practices, procedures, methods, and performance criteria for facilities (i.e. zoning ordinances, building codes, etc.).

Codes and Regulations: Statutory requirements imposed by various governmental bodies. These requirements can cover safety, environmental, operating systems, and other building codes as imposed by local authorities.

Completed Work Unit: Completed elements of the facility which have not been tested or started-up.

Concept Information: General information about the various concepts collected during their preparation and development. This often includes information in the areas of conceptual cost data, preliminary comparison information, etc.

Constructability Information: The information used to integrate the construction experience on the project into the earlier design phases to optimize the provision of the facility.

Construction Execution Plan: The selected construction plan which defines the way the construction will be performed. This plan includes budgets, schedule goals, approved shop drawings, work methods, quality objectives, safety plan, etc.

Construction Management Team: The subset of the construction team which is responsible for planning and controlling the construction of the facility (e.g., estimators, schedulers, methods planners).

Construction Market Conditions: As the need for a facility is recognized, the construction market conditions such as availability of contractors, availability of materials, costs, construction type trends, etc. become significant.

Construction Market Information: Information about the availability, quality and cost of resources (e.g., labor force, material), and service organizations (e.g., designers, contractors, construction managers, material vendors). This may include information about on-going and future projects that may influence the competition for the subject project.

Construction Performance Evaluation: An owner's evaluation of services provided by the constructor.

Construction Plan: A working document including the methods plan, estimate, schedule, material take-off, etc. that defines the goals and means for the construction of the facility.

Construction Planners: The individuals who are responsible for material take-offs, schedules, methods plans, and start-up plans that govern the construction of a facility.

Construction Team: All parties who will participate in the construction of the facility.

Constructor Proposed Scope Changes: Recommendations from the construction team which might improve the design of the facility or simplify the construction work (e.g., value engineering proposals).

Constructor Submittals: Correspondence from the construction team to the owner and designer confirming the details of the design, material selection, equipment selection, etc. Examples include catalog cuts, color samples, shop drawings, and fabrication drawings.

Consumable Resources: A subset of 'Resources' - materials and energy that is directly consumed during the operations of a facility.

Contract: Legal document between two parties used to arrange for services to be performed and to establish the business relationship.

Contract Changes: Changes, made in response to requests from the management, planning, design, or operating team, affecting a particular portion of work relating to a facility (i.e. performance and facility characteristics) that require modifications or enhancements to a contract. The modifications may relate to scope of work, time of performance due to ambiguities, restrictions, codes, revisions, errors, omissions, equipment, materials or unforseen problems, etc.

Contract Information: Information used to clarify and supplement the scope of work, costs, requirements, etc., that is needed to understand contracts in their full context.

Contract Interpretation: All contract evaluations to clarify contractual responsibilities of parties engaged in the work.

Contract Plan: Information relating to the type of contract required for contractors/ vendors/ agents.

Contract Requirements: The scope of work as described by the legal agreement between parties involved in the construction of the facility. Formal approved change orders become part of the contract requirements.

Contracting Plan: An owner's approach to service procurement that specifies selected contract types (e.g., lump sum, reimbursable), contracting method (e.g., competitive bidding, negotiated) and project delivery strategy, e.g., fast track, design-build or traditional approach.

Contracting Procedures: (A subset of "Owner's Constraints") Owner's standard rules that control the management of contracts, e.g., contractor selection, contract types and clauses.

Contractor/ Vendor/ Agent: Any party, hired by the owner entity to provide services, resources or personnel to complete the facility.

Coordinated Schemes: Any scheme(s) which have been successfully coordinated, checked, and reviewed. These schemes go on to further development and integration before evaluation and selection as feasible schematics.

Coordinated, Compatible Concepts: Any concept(s) which have been successfully coordinated, checked, and reviewed. At this point, all are still "in the running" for selection as feasible concepts.

Coordination Information: Information acquired during the coordination and checking of the design(s). It is especially useful in the determination of the need for any redesign.

Cost Estimate: The initial quantification of the expenses for the construction project. It is used to evaluate the funding requirements and to conduct financial analyses.

Criteria For Qualification: All pertinent factors that influence contractor/ vendor/ agent selection (e.g. past experience, financial stability, etc.).

Current Industry Standards and Practices: General knowledge, accepted principles, and standard requirements imposed by the practicing design industry.

Current/Future Operational Conditions: The requirements of the the owner from the facility regarding its compatibility with the users' needs as well as the facility's intended purpose(s).

Daily Approval Plan: Instructions defining the methods, order, and criteria for checking the physically completed items.

Daily Distribution Plan: Instructions explaining the means and methods for transporting resources to the appropriate locations throughout the site (e.g., instructions to the crane operator).

Daily Plan: Instructions explaining the methods and means for accomplishing the work. This includes the daily distribution plan, daily work plan, daily approval plan, and start-up plan.

Daily Progress Information: The feedback from the completion of the work which will be analyzed to aid in planning the next day's work and also determine if changes to the daily plan or construction execution plan are needed.

Daily Work Plan: Instructions describing the means, methods, and priorities for completing the physical work.

Data Needs: A design team member's needs for certain data (this party is denoted as a user). These needs help dictate what data is to be gathered and what data can be disregarded in a particular instance.

Data Storage Requirements: The requirements of the design team on how the data is to be stored.

Delivery Information: Feedback concerning the receipt of resources.

Delivery Schedule: Projected timetable for the shipment and receipt on site of resources.

Design: The product of the "Design" function that includes design documents (i.e., drawings, specifications and design calculations) and other undocumented information such as as concepts and assumptions evolved throughout the design process.

Design and Construction Feedback: The information regarding the status of the actual design or construction (if the project has to be re-planned during its later stages, or if part of it is still being planned while the design and/or the construction of other parts are already in process).

Design Contract: Legal document between the owner and the designer, used to constitute the design services to be performed and to establish the business relationship.

Design Criteria: Tools used to audit the quality of the design output. They describe the proposed facility, e.g., its image, flexibility, expansibility, and operability. They also include functional description of the facility components (spaces, structural elements, HVAC system, etc.), and the relationships between those components.

Design Data: This is a general term covering any raw data collected through research, interviews with the owner, questionnaires, checklists, etc. during the design process. It is often used by other functions of the design process after having been synthesized into design info.

Design Development Package: Initial documentation of the "final" design including completed discipline drawings (often diagrammatic), preliminary specifications, detailed cost estimates/budgets, etc.

Design Execution Information: Information concerning design execution which is compared to the original plan and used to assess the status of the project and the appropriateness of the design execution plan.

Design Execution Plan: A plan which sets the method, schedule, budget, and quality of the design to be performed.

Design Information: Information used by the various functions in the design process. It is derived from the design data generated in other functions, e.g., room sizes from drawings for heat load calculations, windows from schedules and drawings for lighting design, etc.

Design Performance Evaluation: An owner's evaluation of design services.

Design Plan: The resource acquisition plan, design execution plan, and documentation plan that govern the design of the facility.

Design Planning Information: Information, specific to the project, acquired from the owner, used in setting the type and scope of work to be performed.

Design Team: Design team assembled by the owner to perform the desired design. This team can include representatives of the constructor, owner, and facilities management agency.

Designability Information: The information used to integrate the design experience on the project into the earlier planning phase to optimize the provision of a facility.

Detailed Design: The design at the stage where it is ready for final documentation and to be sent to the other parties concerned. The design is often "frozen" at this point.

Detailed Design (Drawings): The drawings of the design development package representing the finalized detailed design.

Detailed Design (Preliminary Specs): The specifications (i.e., tailored master specs) of the design development package representing the finalized detailed design.

Detailed Design Information: Information collected during the development of the preliminary drawings, specs, etc. including information on costs, schedules, final design review results, etc.

Detailed User's Needs: The requirements for maintaining an efficient working/ functioning environment in a facility, as viewed not at the company/ owner level, but at the user level.

Distributed Resources: Resources given to the mechanisms which implement the selected plans materials and equipment which have been transported to the appropriate work areas throughout the site.

Distribution Priorities: Instructions defining the criticality of the need for resources in aspects of the work (e.g., priorities for the crane operator).

Distribution Progress Information: Feedback (work status and problems) concerning the movement of resources around the site.

Documentation Performance Information: Information concerning documentation which is compared to the original expectations and is used to assess the status of the project and the appropriateness of the documentation plan.

Documents and Contracts: All information generated in the form of documents and contracts, that is used for guiding and governing delivery of a facility. This also includes records that are kept after completion of a facility (i.e. correspondence files, specifications, drawings, data sheets, as-built drawings, weld records, and a completion manual, etc.).

Economic Feasibility Information: Information describing the financial aspects of the project including cost / benefit analysis, project financing plan and project cash flow.

Economy: The current condition of the construction and financial markets which, in turn, determines the availability of constructors, resource suppliers, building permits, money, etc.

Environment: The physical conditions beyond the control of the project participants that affect the ability of the project team to provide the facility (e.g., weather, strikes, natural disasters).

Environmental Project Impact Information: This term refers to all information pertaining to the interaction between the proposed facility and the environment (both physical and non-physical).

Estimate Information: Data describing the anticipated costs of alternative plans.

Evaluated Performance Information: Performance information after it is reviewed and evaluated for possible use in planning the operations.

Evaluation Criteria: Design parameters, project objectives, experience, etc. upon which the evaluations, judgments, and selections of the design(s) are partially based.

Execution Plan: The approach and manner in which management and operation of the facility will be performed. This plan includes field verifications, construction and maintenance schedules, instructions, expediting, procedure reviews, periodic performance reports, etc.

Existing Facilities Evaluation: Owner / user's facilities evaluation for compatibility with current and future use.

Expected Level of Performance: The standard against which the performance reports will be evaluated to determine if the progress is adequate and if the contract requirements are being fulfilled.

External Constraints: Parameters and variables in the environment that will hinder, limit or impact on providing a facility and are beyond the control of all project participants. These include weather, codes, economy, technology, resources, politics, etc.

Facility Champion: The individual who initiates the idea, commits and mobilizes the funds and resources required to get the facility developed, and leads in establishing a project team.

Facility Construction Experience: The improved ability of the participants that construct the facility to construct similar or related facilities in the future.

Facility Construction Knowledge: The information and knowledge that results from constructing the facility and the related experience that can be used in the future (e.g., lessons learned and improved abilities for the next job).

Facility Design Experience: The improved ability of the participants that design the facility to design similar or related facilities in the future.

Facility Idea: The initial thought that recognizes the need for a facility, and its description at the highest level of abstraction.

Facility Information: A collection of all information generated throughout the process of providing the facility.

Facility Management Knowledge: The information and know-how gained from managing the facility and the knowledge that can be applied to future facilities to be built (i.e. a database of cost information, procedures, and resource needs).

Facility Management Plan: The resource acquisition, execution, monitoring, and contract plans used as controlling plans in the governing of the overall project. Another element of the plan are all changes and directives made to the facility management plan (i.e. contracts and documents).

Facility Management Work Scope: This serves to function as the initial information elements and parameters that define the facility, as well as the participants (owner's organization) needed to provide the facility.

Facility Operations Documents: The documents handed over to the facility managers to enable them to operate and maintain the facility.

Facility Planning Experience: The improved ability of the participants that plan the facility to plan similar or related facilities in the future.

Facility Planning Knowledge: The information and the knowledge that results from planning for the facility, which are not included as formally communicated documents (PEP and Program), but are resident in other media, e.g. project files, project participants' memories.

Facility Planning Information: Information acquired through the work scope information and contract negotiation processes used in the establishment of the type and scope of the work to be performed. Elements of facility planning information contain contract needs, resource needs, procurement strategy, etc. (i.e. design information, specifications, and resource/ service information requirements).

Facility Team: Assignment of project members to the plan/ design/ construct/ operate subactivities in order to provide a facility. For the facility management process this includes a management and procurement team.

Facility: The completed building and site, including all installed equipment.

Feasibility Feedback: (A subset of 'Feasibility Information') Information based on various feasibility studies, which can be of significant consideration when recognizing and understanding the needs for a facility and the possible alternatives.

Feasibility Information: Information pertaining to project economical, technical and environmental feasibility.

Feasibility Study Information: (A subset of 'Feasibility Information') The part of the feasibility study product which is used in developing the project execution plan.

Feasibility Study Team: Group of individuals who analyze the technical, economical, and environmental aspects of the project feasibility.

Feasible Concepts: The concepts selected and approved for further development and refinement.

Feasible Schematics: The schema selected and approved for continued development and refinement.

Field Experience: The combined skills and knowledge of the field labor team.

Field Labor Team: The subset of the construction team which is responsible for constructing and turning over the facility.

Financial Plan: The owner's best approach to project funding. The financial plan establishes source(s) of funding (i.e., internal, borrowed) and project life cycle cash flow.

Financial Resources: Means of acquiring the necessary funding for the construction project. Major financial resources are banks and insurance companies.

Functional Limitations: Limits imposed upon the design which originate from the proposed operation of the facility and/or its constituent parts.

General Programming Information: All the elements of information which describe the proposed facility. These are used for developing the design criteria and communicating the overall information to the designers and the contractors.

Government Regulations: Statutory requirements imposed by various governmental bodies (e.g., mandatory inspections, building codes, OSHA safety requirements, EPA requirements).

Historical Data: Database of costs incurred and resources used in completing the work to construct the facility.

Identified Repair Needs: Information describing the need for repair and maintenance of particular resources.

Identified Work Location: The exact physical location for a component of the facility (e.g., chalk lines defining the corner of a wall).

Impact on Environment: This includes all influences on the environment associated with the process of providing the facility, such as physical (e.g., pollution, noise) and non-physical impacts (e.g., economic loss/profit impact on project participants).

Impact on/of Infrastructure Information: This includes the impact of the facility on the conditions of the infrastructure as well as the impact of the infrastructure conditions and limitations on the facility.

Implications: The non-technical aspects of a plan which must be considered during the implementation, such as impact on business, work schedule disruptions, availability issues, etc.

Incomplete Documents: Drawings and/or specifications lacking in some information. Discovered during the document reviews.

Incorrect Information: Information which has been judged by the user as incorrect, incomplete, or unhelpful.

Infeasible, Unapproved Concepts: Any concepts which were not approved by the owner and/or other parties due to their lacking or misrepresenting some information or not meeting the needs of the owner/user, project objectives, and/or design parameters.

Information Needs: The needs of the user for specific information in a specific format which initiates the retrieval of data from its storage medium.

Information Request: Initial requisition for additional information which was incomplete or missing and therefore affected the accuracy of design. This often initiates the preliminary studies.

Inspection Plan: The selected inspection plan for required quality assessment/ control by the project field inspectors.

Inspection Records Information: Feedback describing the performance of the testing and checking of the completed work (e.g., a failed inspection).

Inspections: Formal determinations of the ability of the work to meet specifications and code requirements (e.g., reviews of the work by code officials).

Integrated Schematics Package: The coordinated, integrated schematic(s) typically consisting of the design in preliminary drawings and outline specifications. This package is evaluated based upon the evaluation criteria and other information.

Internal Capabilities/ Resources: Internal resources provided by the owner to the facility team. This may include engineering office space, employee services, supplies, utilities, computer software/ hardware, machinery, transportation, manufacturing, equipment, etc.

Inventory Information: Data concerning the quantity and or location of stored resources at a particular time.

Items in Need of Repair: Resources for which a repair or maintenance need has been identified.

Maintained Resources: Resources which have been repaired or maintained and are ready to become part of the available inventory.

Maintenance Information: Feedback concerning the progress in maintaining and repairing the resources. This includes projections of when resources will be repaired and usable.

Maintenance Program: A subset of the resource acquisition plan which establishes standard procedures for the upkeep of resources, most importantly the construction equipment.

Management Proposed Changes: Modifications to the scope of work, cost or time allowed to perform work due to ambiguities, restrictions, codes, revisions, changes, or unforseen problems, etc.

Management Team: Company personnel, consultants, contractors, and other people who are identified as being capable of performing a portion of the work required to take the project from its inception to its completion. Essentially this team involves all parties who will participate in the management of a facility.

Material Takeoff: Identified types and quantities of resources needed to execute the construction plan.

Methods Knowledge: Expertise or experience in construction methods gained through constructing other facilities, attending seminars, reading industry literature, acquiring experienced people, etc.

Mobilized Site: A site that has the facilities to support construction work (e.g., tool storage, job trailer, access road, safety equipment).

Monitoring Areas: Areas which are selected to best represent different sections of the facility for monitoring purposes.

Monitoring Information: Performance information which is monitored and put into right format for evaluation.

Monitoring Mechanism: The mechanism/system which is selected to carry out/assist in the monitoring process. This can be an automated system, an inspection team, the user, etc.

Monitoring Plan: Performance criteria plan for controlling and troubleshooting areas to be monitored for compliance by the facility participants. This includes both monetary and technical compliance.

Needs: All requirements assessed to be pertinent in the make-up of a facility.

New Data: Raw data which has yet to be stored, updated, or otherwise altered from its initial condition

Non-Physical Impact Information: Information describing the influence of providing the facility on the community (employment, local business, population, etc.).

On-Hand Resources: Resources which are in-stock or easily accessible and available to be allocated.

Operability Information: The information used to integrate the facilities management expertise on the operations into the earlier construction phases to optimize the provision of the facility.

Operating Systems: All the systems in the facility (environmental, architectural, transportation, communication, etc.)

Operation Data: Performance information after it is collected by a monitoring mechanism.

Operational Facility: A facility that satisfies the needs of the user; i.e. meets its intended purpose.

Operations Documents: The formal documents, drawings, specifications, instructions, limitations, procedures and criteria for managing, operating, and maintaining the facility. These include as built drawings, final test reports, system operating guides, equipment operating and maintenance guides, etc.

Operations Experience: The improved ability of the participants that manage the facility to manage similar or related facilities in the future.

Operations Information: Information about how the facility is being operated.

Operations Knowledge (OK): The information and knowledge that results from operating the facility that is not included as formally communicated documents, but is resident in other media, e.g. project files, project files, project participants memories.

Operations Planning Knowledge: The information and knowledge that results from planning the operations of the facility, and the related experience that can be used in the future.

Operations Resource Needs: Information about the manpower, materials, equipment, space, etc. which are necessary for the operations plan to be carried out.

Operations Team: All personnel who are assigned responsibilities, and all tools and equipment which are used by them, for the operating a facility.

Opinions, Facts, and Information: The set of information elements which include details about the scope of work and the design criteria.

Optimization Information: The information used to integrate expertise of participants in providing the facility. This includes designability, constructability, operability, and maintainability information.

Owner Supplied Resources: Internal resources provided by the owner to the facility team player. This may include engineering office space, employee services, supplies, water, electricity, computer software, etc.

Owner's Budget and Schedule: The financial plan or the fund expected to be set aside for providing the facility, and the time allocated or the required date for the facility to function.

Owner's Constraints: Constraints set by the owner organization and are subject to owner's influence such as owner's strategic and operational plans.

Owner's Needs: The main elements (in terms of function, form, economy, and time of facility) desired by the owner which will suit his/ her needs for a facility.

Owner's Purchasing Policy: This includes the owner's managerial decisions relating to the governing strategies and procedures for resource acquisition.

Owner's Standards: Specifications describing the owner's needs in terms of quality, procedures, or codes that exceed minimal regulatory standards.

Owner's Strategic Plans: Long range objectives and general approaches of the owner used to meet company or project goals. These include preliminary schedules, facility manager's long term requirements and owner's priorities for time, cost, quality and safety.

Owner/Designer Requests: Informal change orders or directions from the designer and owner which may alter the plans or require the replanning of the work (e.g., a request to allow a potential client to tour the job site).

Parameters: Design limits, guidelines, and requirements which give direction to the design and design process (e.g., overall cost limits, quality control guidelines, time/scheduling requirements).

Partially Consumed Resources: Materials and equipment that are leftover after performing a portion of the work (e.g., tools and supplies that can be reused).

Past Facility Construction Knowledge: Expertise possessed by company personnel, consultant knowledge, etc.

Performance Feedback: Information on the performance of the facility team in using the resources to achieve the goals, including both formal and constructive changes that need to be made to the contract(s).

Performance Information Needs and Criteria: A subset of the construction execution plan that identifies the data which should be gathered in order to track the progress of the job or satisfy the requirements of the contract.

Performance Information: Information/ feedback about 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 (e.g. time, money, quality, and other performance factors). It includes information for the delivery of the facility (i.e. cost, financing, value engineering, contract work scope, contract packaging and scheduling, changes, claims, backcharges, inventory, resource acquisition information, resource distribution information, etc.). This information includes methods of performance.

Performance Reports: Organized and communicated data describing the performance of the work which will be analyzed to determine if the work is progressing according to plan or if replanning is necessary.

Performance Requirements: All criteria, predicated by the work scope information, found to be of critical relevance in the execution of providing a facility. These may be milestones, witness and hold points, budgetary conformance, aesthetic qualities, etc. Essentially, this involves information on all necessary and essential achievements that need to be made throughout execution of the facility life cycle.

Physical Performance Information: Information about 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.

Planning Execution Plan: A plan that sets the methods, schedule, budget for the facility / project planning function.

Planning Feedback: Information about the project execution plan which can be used for studying the technical feasibility of parts of the project.

Planning Parameters: A well-defined work scope and planning goals which set the strategy and guidelines for planning including the required level of detail and accuracy of the plan. The planning parameters also include decisions that have been made regarding methods, costs, and schedule which narrow the possibilities to be considered when planning.

Planning Team: A team assembled by the owner to plan for the project. This team may include representatives of the owner, the user, operation and maintenance entity and planning professionals.

Plans and Specifications: The formal media for communication of the design. These include the architectural, structural, mechanical, electrical, and plumbing drawings, and the accompanying narrative description of the specific details of the design and selected materials.

Plans: A collective term used to label the product of the planning function. It covers the information used to guide the work and to keep the overall goal of providing an operational facility which meets the requirements of the owner. It comprises the program and the project execution plan.

Possible Concepts: All concepts developed in the various disciplines which have yet to be coordinated with each other.

Possible Schemes: All schema developed for the various systems as they are before any formal coordination and checking.

Post-Construction Documents: Vendor suggested maintenance procedures in the form of manuals; documents prepared by the constructor which explain operations and maintenance procedures (as required by the contract); edited construction drawings which represent exactly what was built.

Post-Construction Information: All information generated, introduced or modified by the construction function such as as-built documents, shop drawings and O&M manuals.

Post-Design Document Package: Material including drawings, specs, bidding documents, etc. and any material required by reviewing agencies before final approval by the owner and other parties.

Post-Design Documents: The written documentation comprising bid & construction documents and operations & maintenance documents.

Post-Design Drawings: The final drawings including all plans, details, sections, elevations, schedules, system sizings, etc.

Post-Design Specs: The final specifications with any bid and/or contract documents required.

Potential Agents/ Contractors: All screened individuals, be they agents or contractors, who are deemed capable of providing a particular service required for obtaining a facility.

Potential Contractors: Contractors identified by the management team as being capable of performing a portion of the work.

Potential Vendors: Vendors identified by the management team as being capable of performing a portion of the work.

Prepared Information: Information which has been developed from the data and is ready to be delivered to the user in their specified format.

Prepared Resources: Distributed resources that have been processed or worked on to get them into their final form for use in performing the work (e.g., mortar).

Problem Area: Complete information about the location and the type of problem that is detected during the monitoring (O.2) and the evaluation (O.3) phases.

Problem Data: Information which is used for locating and identifying a problem once its existence is detected.

Problem Feedback: Information Stating that none of the alternative plans are suitable to be selected.

Problem Identification: Complete information about the location and the type of problem that is detected during the monitoring (O.2) and the evaluation (O.3) phases before it is communicated to a problem solving mechanism.

Problem Information: The problem area as it is understood by the problem solving mechanism.

Problem Solving Plan: Selected alternative(s) and mechanism(s) which are developed to solve the operations-related problem.

Process Information: Information defining characteristics of the work in progress (e.g. material flows, crew sizes, methods, sequences, etc.).

Procurement Team: The subset of the construction team which is responsible for providing the resources required to build the facility.

Productivity Data: Database of information gathered from past work which can be used to predict the duration of activities.

Program: A document that describes owner/user's requirements comprising spatial, operational/ functional aspects, and criteria for the designer to meet. The program as a document is used to define the proposed facility to the design and management teams.

Programming Team: The group of individuals and the equipment that carry out the programming function.

Progress Information: Work performance information which may require revisions to the construction execution plan.

Project Execution Plan (PEP): Owner's plan for procuring all resources and services that are required to provide and manage the facility. A PEP includes schedules, contracting strategy, milestones, budgets, value engineering cost incentives, review/ approval points, authorities and responsibilities delegated, allocation of resources, inspection and notification requirements, specifications, drawings, instructions, and limitations.

Project Information: Details concerning the designed facility which are discovered through sources other than the contract documents, such as: communications with the owner or designer, site investigations, consultant advice, etc.

Project Management Procedures: (A subset of "Owner's Constraints") Owner's standard rules that provide guidelines for managing the construction project.

Project Objectives: The general goals of the project including establishment of reliability requirements, desired attributes of the facility, clarification of the scope of design, and determination of regulatory agencies requirements.

Project Participants' Constraints: The parameters / limitations imposed by project participants, e.g. schedule, budget, risk level.

Project Plan: Owner's selected approach to providing the facility. This includes overall project budget and master schedule with established major milestones.

Proposals: All offers, propositions, requests or advances received by a project participant. The proposals are in the form of documents usually containing a bid price, scope of work, and definition of capabilities, prepared by qualified parties.

Purchase Orders: Written documents that define and prescribe all the agreements, promises, and provisions relating to procurement of resources (i.e. time of delivery, insurance, shipping, packaging, taxes, payment terms, etc.)

Qualified Parties: The contractors, consultants, company personnel, and other people who are identified as being capable of performing a portion of the work.

Quality Standards: Criteria defining desired properties of project resources.

Recalled Data: Data which has been retrieved from storage in order to be synthesized into useful design information.

Redesign: Reworking of the design after being judged unsatisfactory for some reason.

Requests for Bid Information: All data requiring further work scope definition.

Requests for Bidding Information: Feedback from the parties preparing proposals asking for clarifications to the work scope or for additional project information.

Requests for Clarification: All data pertaining to instructions to bidders, the bid proposal form, etc. requiring refinement or interpretation.

Requisitions: Formal requests or orders made for required resources.

Resource Acquisition Information: Feedback information relating to inventory, acquisition, inspection, distribution and availability of resources.

Resource Acquisition Plan: A subset of the execution plan including: site layout plan, material takeoff, quality standards, storage procedures, maintenance program, and schedule.

Resource Acquisition Plan: A subset of the execution plan which explains the approach, time and manner in which resources will be acquired. This plan includes the policies (i.e. budget and quality) and strategies/ sequence for which all resources are acquired (i.e. wholesale, purchases of bulk quantities, rental fee limits, long lead items, etc.) and the effective scheduling of those resources.

Resource Availability: The quality, quantity, and accessibility of resources to support the functions within the facility.

Resource Requirements: This information defines all resources that are deemed by the management team to be necessary for completing portions of the work needed to provide a facility.

Resources Accepted: Acquired resources which have passed inspection to ensure they have met the specified quantity and quality requirements.

Resources: This term includes all resources provided for the facility by all participants (building materials; time and man-hours; energy; money, furnishings, supplies, utilities, etc).

Results: Data and information from simulations, reviews, etc. including information in the areas of value engineering analysis, design and technical quality reviews, and the like.

Safety Standards: The accepted practices designed to preserve human life and prevent injury of the project participants and the general public. These are specified through methods and performance standards.

Schedule Information: Data defining the anticipated duration of activities.

Schedule: Identified planned starts, finishes, float times, interrelationships, and associated resource needs for activities in the construction plan.

Schematics Information: Information on the standard systems schemes (i.e., concerning space requirements, systems configurations, etc.)

Scope and Need Requirements: Establishes a complete breakdown of all work requirements encompassed for providing a facility. This includes the financial, personnel, material and equipment factors necessary for obtaining a completed facility.

Scope Requirements: Essentials of the scope of the project as prepared for the programming of the facility.

Selected Alternative: A subset of 'Problem Solving Plan' - the plan which is developed and selected to solve the operations-related problem.

Selected Constructor: The constructor chosen from the qualified parties with whom an agreement will be made to perform the defined scope of the work as a member of the construction team.

Selected Contractor/ Vendor/ Agent (C/V/A): The contractor/ vendor/ agent chosen from the qualified parties with whom an agreement will be made to perform the defined scope of a particular portion of the work.

Selected Mechanism: The people, equipment, contractors, etc. that will implement the plan.

Service Requirements: All services provided by project personnel, determined to be necessary in providing a facility. The period for which the services are required covers the time from a projects inception all the way to its operation stage.

Site Analysis: (A subset of "Site Information") Elements of the study which covers the topographic and geological conditions of the site, its present and future value, accessibility of materials and equipment to the site, etc.

Site Criteria: A selection tool that sets recommended facility site characteristics such as geographical location, accessibility, traffic load, site physical conditions, cost, surrounding environment, utilities etc.

Site Evaluation and Conditions: The end product of the review of the candidate sites usually in the form of one selected site and its general attributes (size, price, availability, etc.)

Site Information: A description of the site's attributes such as topography, size, location and soil characteristics.

Site Investigation Funding: The capital which is required for executing the site investigation.

Site Layout Plan: The strategy for operating the mobilized site throughout the project including identified locations for the temporary facilities and utilities, laydown areas, parking areas, trash bins, etc.

Site: The physical location of the land on which the facility is to be constructed.

Siting Requirements: Essentials of the site conditions as required for the programming of the facility.

Skills and Information Needs: Information on the required knowledge, people, devices that can help develop a solution.

Skills and Information: The required knowledge, people, devices that can help develop a solution.

Spec Information: Information gathered during the development of the specifications (i.e., what is or is not included, the level of detail of the specs, decisions concerning vendors, material substitutions, etc.)

Staffing Plan: Strategies for acquiring the services of in-house staff, subcontractors, consultants, etc.

Start-up Plan: Instructions consisting primarily of procedures, events, and schedules which identify how and when the facility's systems will be tested and approved.

Storage Procedures: A plan for stock-piling resources, inspecting resources, and tracking the inventory.

Stored Data: Raw data which has been placed in storage in some medium such as computer memory or files.

Strategic Plans: The subset of owner's overall constraints, which includes his business limitations and plans.

Studies Results: Data and information from the studies performed including information on spatial relations, site use and layouts, circulation and flow volumes, and the like.

Submittal Approval: Acceptance of materials selections, equipment selections, design details, etc. (i.e. catalog cuts and shop drawing approvals) proposed by the contractor.

Submittal Feedback: Responses to the construction team from the owner and designer concerning material selection, equipment selection, design details, etc. (e.g., catalog cut and shop drawing approvals).

Systems Information: Information concerning details, building materials selection, systems equipment selection and layouts, etc.

Systems Schematics Information: Information from each system including preliminary sizing and/or sizing criteria, initial large equipment selections and locations, preliminary mechanical/electrical systems loads, etc.

Technical Availability Information: Data pertaining to the accessibility and the serviceability of the technical details of the project.

Technical Feasibility Information: Information describing the technical aspects of the project including the technical availability of resources and technology, technical properties of the project, and the physical execution feasibility of the project.

Technical Properties: Essential attributes of the project which relate to the technical aspects of the construction.

Technical Solutions: The part of a designed alternative which considers only the technical aspect of a problem. These technical solutions, together with its other implications (business aspects, availability, work disruptions, etc., become the alternative plans for solving the problem.

Turnover Information: Feedback concerning the current progress in starting-up and handing over the facility.

Unapproved Detailed Design: A detailed design which was not approved by the owner and/or other parties due to it lacking or misrepresenting some information or it not meeting the needs of the owner/user, project objectives, and/or design parameters.

Unapproved Documents: Documents (drawings, specifications, bid documents, etc.) which were not approved by the owner and/or other parties due to their lacking or misrepresenting some information or not meeting the needs of the owner/user, project objectives, and/or design parameters.

Unapproved Parameters: Any design parameters which were not approved by the owner and/or other parties due to their lacking or misrepresenting some information or not meeting the needs of the owner/user, project objectives, and/or design parameters.

Unapproved Schematics: Any schematic design which was not approved by the owner and/or other parties due to it lacking or misrepresenting some information or it not meeting the needs of the owner/user, project objectives, and/or design parameters.

User Operational Plans: Plans describing current/future user's operations (e.g., Business Calendar, operations expansion plans)

User Requirements: The current/future needs and standards (usually governed by codes , sets of physical and psychological values) which define the desired environment and the effectiveness of a facility.

User's Delivery Requirements: Requirements from the user as to when, where, and how the prepared information is transmitted/delivered.

User's Format Requirements: Requirements from the user as to the specific format of the final design information.

User's Needs and Requirements: The needs of the user pertaining to the type, style, format, quantity, quality, etc. of data and/or information required.

User's Needs: Description of the user's functional and environmental requirements from the facility.

User: A member of the design team (used in function D.6)

Waste: Residue from materials and resources used in the building process which need to be discarded (e.g., trash).

Work Progress Information: Feedback defining the status of portions of the physical work.

Work Scope Information: The subdivision of work into contract/ subcontract packages and the sequencing of their information. This defines the scope, the complete design information, and the due consideration for project schedule purposes.

Work Space: An area designated to the craftsmen for performing a portion of the work (e.g., assembled scaffolding, a cleared floor area).

Working Plans: Establishment of initial work plan methods/ techniques/ objectives/ policies of the owner's organization -- that guide the execution of project administration (i.e. description of approval process, accounting of bills, communication and reporting, procurement factors, financial factors, ground rules for changes, etc.). In other words this serves to function as procedural control plans and work coordination.