IFC BASED INTEGRATED CONSTRUCTION MANAGEMENT PROCESSES

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ABSTRACT

In the last few years, the modelling of generalized AEC processes becomes a central issue in supporting network-based coordination among project participants. However, even though various solutions have been proposed, a general approach based on an acknowledged model is still missing. In order to address this gap and to represent the integration of product and process information for the interoperability of the involved actors and tools, based on the complementary views complying with the IFC product model, (1) a process integration methodology and based on that (2) two integrated process models are presented in this paper. The implemented methodology brings different views and aspects together such as application systems, quality management procedures, organizational units and procurement systems. The main objective is defined as, to integrate product and process information in a generic process model, so that interoperability over a broad spectrum of applications is facilitated.

Keywords: Construction Management Processes, Software Interoperability, Concurrent Engineering, Industry Foundation Classes (IFC)

1. INTRODUCTION

Specific requirements within the distributed nature of the construction industry provide the rationale for setting up the basic principles. Most critical success factors for efficient construction management can be best achieved through the concise electronic and network-based collaboration among ad hoc participants.

This requires the specification of integrated process structures as well as the definition of information resources involved. A resource also known as actor, performer or process participant is an entity that is assigned to a function and is requested in runtime to perform work in order to complete the objective of this activity (Zur Muehlen 2004). In order to represent all different type of entities taking part in a process sequence, there is a need for a model which presents all resources in an appropriate format. In this case, van der Aalst et al. (2003) conducted the Resource Meta Model by which consists of a UML class diagram and a corresponding XML rendition for the specification of process resources. Recker et al. (2005) analyzed a representational analysis with a focus on Business Process Modeling Notation 1.0. Green et al. (2005) analyzed event-driven process chain notation using the Bunge-Wand-Weber (BWW) model, and different modeling standards for enterprise system interoperability, to determine their ontological completeness and clarity. zur Muehlen et al. (2009) conducted a BWW representational analysis for several different languages particularly relevant to compliance management.

However, because of its complex nature, a process integration methodology in the construction management domain is still missing. Thereby the generic representation of different but complementary views, such as application systems, quality management procedures and processes, the organizational data and application methods based on IFC in a single process model has not been addressed.

In this context, in order to fulfill this gap (1) a new process integration methodology and based on that (2) two integrated process models are proposed in this research. This allows for coherent integration of

product and process information, helping to achieve the interoperability of the involved actors and tools in collaborative project environments.

2. BACKGROUND

The start point for process management solutions can be found in the early 70's with the office automation prototypes (Zisman et al. 1977) which generally consider the automation of human-centric processes. Recent developments in the area of web services choreography have discounted the organizational aspect of workflow solution and focus exclusively on the coordination of control flow structures (zur Muehlen 2004). Furthermore, the proposed standards such as WSCI (a subset of BPML), (Arkin et al. 2002), WSCL (Banerji et al. 2002) and BPEL4WS (Curbera et al. 2004) do not contain any notion of human activity performers. Instead, they focus on the technical coordination of inter-enterprise processes with limited or no human intervention. While some initiatives focus on the automation of mainly technical processes, such as the automated data exchange between different applications, some vendors stress the organizational aspect of their solutions (Orlawska et al. 2003).
However, in order to enhance, harmonize and eventually standardize the process patterns and to support technical coordination with human intervention, a process integration methodology that complies with domain specific views and aspects is required.
In this context, for ontological clarity in the construction management domain, several requirements should be considered. Keller et al. (2003) identified these requirements as;

1. Analyze the underlining technical and organizational aspects,
2. Design a workflow language,
3. Identify the context parameters,
4. Improve domain specific process patterns.

3. APPROACH

The precise representation of relations among the functions, events and resources through the definition of associated attributes and properties is of great importance in obtaining process accuracy.This can be achieved through a process integration methodology with considering technical and organizational aspects, a modelling framework, and the definition of process patterns as envisaged in the previous research.
In order to comply with these requirements in our case;

1. The technical aspects are analyzed based on the software integration requirements,
2. A modelling framework is developed with ARIS - ceEPC model in order to obtain integrated process structures,
3. The context parameters and organizational aspects are defined according to ISO9001 Quality Management procedures and processes and,
4. The process patterns are identified with the developed process Life-cycle Model.

The methodology implemented in this research focuses exemplarily for the development of integrated processes for the Bidding Preparation Phase. The associated requirements for software integration, organizational data and process patterns are defined based on the state-of-the-art analysis of Construction General Life Cycle Model of American Institute of Architects (AIA 2011).
The ARIS method of Extended Event-driven Process Chain (eEPC) is chosen for the definition of the generalized Construction Management Model namely Organizational Management Process (OMP).
The OMP represents different views. In order to structure the OMP a new Life-cycle Model is developed to combine different views in one single generic process structure.
Thereby the OMP brings together (1) the set of interrelated processes based on ISO9001 Quality Management System, (2) application methods determined by different type of procurement systems, (3) the organizational data, and (4) the technical aspects. The set of interrelated processes are structured in such a way that one of the processes takes the role of the main process while the others are supporting processes.
Based on the OMP, the complementary IT Management Process is developed. The IT Management Process represents the integration of design, resource planning and scheduling domain information which facilitates to map process resources and IFC classes.

In order to comply with IFC, it is sub-structured in three sequenced and interconnected processes namely;

1. IT Management Design Process,
2. IT Management BOQ Process and
3. IT Management Scheduling Process.

This provides the basis for formalizing the IFC Views and represents related resources to identify IFC Extensions.

In order to support completeness, a mapping structure between these two process models and IFC is maintained. The interrelationship is controlled by instantiating scenarios based on different procurement systems.

4. THE TECHNICAL ASPECTS BASED ON SOFTWARE INTEGRATION REQUIREMENTS

Integration means to form, coordinate, or blend something into a functioning or unified whole by ending existing segregation (Meriam-Webster 2002). From operational point of view, integration provides an ability to system components to work together in a coherent way for the solution of complex tasks.

The conceptual design of a process application regarding to software interoperability requires the definition of integration requirements. Zur Muehlen (2004) identifies these as (1) Internal and (2) External integration requirements.

Internal integration requirements are specified as;

1. The resource integration that is required by the process system to keep track of the participants available for the activity assignment,
2. The data integration that makes process relevant data accessible to process structure thereby connecting the system to databases used by external application systems,
3. The application integration that describes the ability of the process system to invoke external application systems during the control of a process and,
4. The security integration which relates to the use of existing authentication and authorization mechanisms through the workflow system, such as single-sign-on and role based access control mechanisms.

On that basis, in our case, the internal integration requirements and associated technical aspects are addressed with considering the;

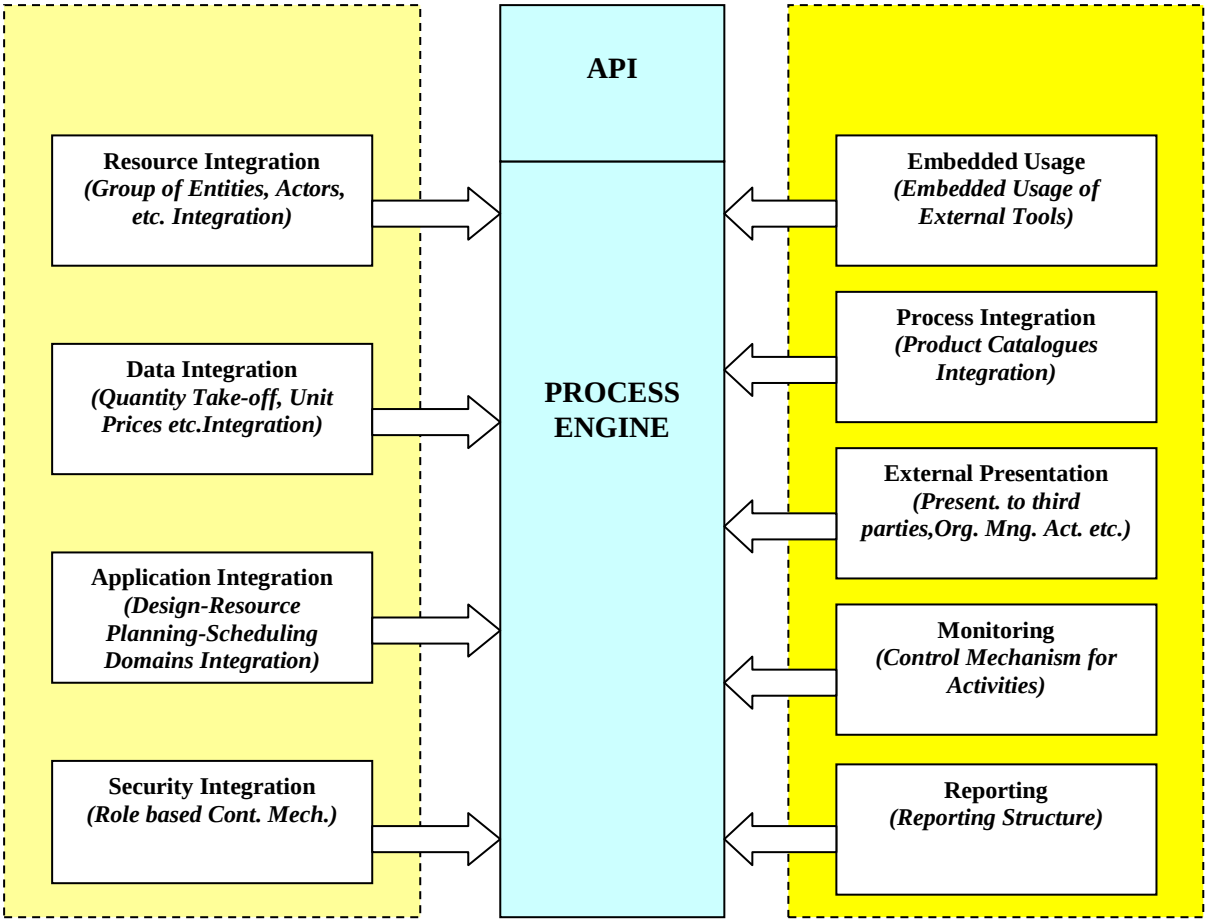
1. The resource integration which is provided by newly defined organizational units such as group of entities, actors etc. specific to construction management domain that are directly involve in the process,
2. The data integration which is obtained through defining the required data specifically used used by these organizational units,
3. The application integration which is supported through the design, resource planning and scheduling domains' integration and,
4. The security integration that refers to role based control granted to organizational units.

External applications are required to call the services of a workflow engine from outside, invoking workflow instances, querying the status of activity instances or handling resource assignments through external systems.

In our case, the external requirements and technical aspects are addressed as;

1. The embedded usage that comprises embedded use of external systems such as product catalogues, external databases etc.,
2. The process integration that reflects the integration of a process belongs to an external source,
3. The external presentation which covers the representation of the system capabilities such as status of work flow instances,
4. The monitoring which defines a control mechanism in order to control process activities and,
5. The reporting that comprises report of audit trail information by external applications.

In this context, internal and external integration requirements and associated technical aspects are addressed in a graphical notation as illustrated in Figure 1 from an internal and external perspective.



Source: Modified from Zur Muehlen, (2004)

Figure 1: The Technical Aspects based on Software Integration Requirements

However, in spite of defining the technical aspects that may lead to an integrated management, there is no single way to organize an enterprise in an expected granularity as Galbraith (1973) expressed in his contingency theory. The effecting factors in this case can be defined as application methods, client demands, market requirements, etc. that may represent differences due to various conditions. Never the less, to manage fragmented structures and to formalize optimal processes, there is a need for well-defined resources that facilitate management activities. Furthermore, to combine various types of views such as procurement system requirements, services, procedures etc., which are prerequisite for completing different aspects in a generic process structure, a modelling methodology is required. On that basis to blend all these aspects to form generic process structure, a Life-cycle Model is proposed in this research.

5. THE LIFE-CYCLE MODEL FOR INTEGRATED PROCESSES

In order to develop integrated process patterns and to define a process formalization structure a new Life Cycle Model is implemented to formalize the OMP, based on Zur Muehlen's (2004) process life cycle approach as illustrated in Figure 2.

ISO9001 Quality Management (QM) procedures and processes, technical aspects, procurement system requirements are brought together in this structure thereby exposing an integrated model that meets the envisaged interoperability.

The formalization starts with (1) the initial analysis of the Bidding Preparation Phase of the Construction General Life Cycle Model of AIA (with specific focus on the technical aspects based on software integration requirements, organizational data and process patterns), associated QM procedures and processes, and the Procurement Systems. This phase is followed by (2) a process design phase, during which the overall process structure is engineered, the resulting process model is

designed, the resources involved and the mapping methodology is decided. This includes the modelling of organizational units. In the third phase (3) the designed processes are implemented. In our case, ARIS-ceEPC model is used to formalize process sequences. The main process is defined according to QM`s Bidding Preparation Process (M) which is identified under customer relation main procedure. The supporting processes such as job development (S1), design coordination (S2) processes etc., are also defined and used partially within the Bidding Preparation Process (M) in order to obtain an integrated generic process structure. This new structure is named as 'Organizational Management Process' as mentioned in the previous sections. Internal process participants (which are part of the process-enabled organization) are notified through their work lists. The related application systems are defined based on software integration requirements. Afterwards, they are attached to process sequence in order to formalize IT management processes and the mapping structure. After implementation of the work flow, (4) established processes are checked to see whether they support generic integration comprising seamless information flow within the processes. The formalized resource consistencies are controlled and the mapping structure is scrutinized in this regard. The processes, resources and mapping structure are (5) evaluated in the next phase. The required improvements are suggested and they are designed and implemented again according to these suggestions.

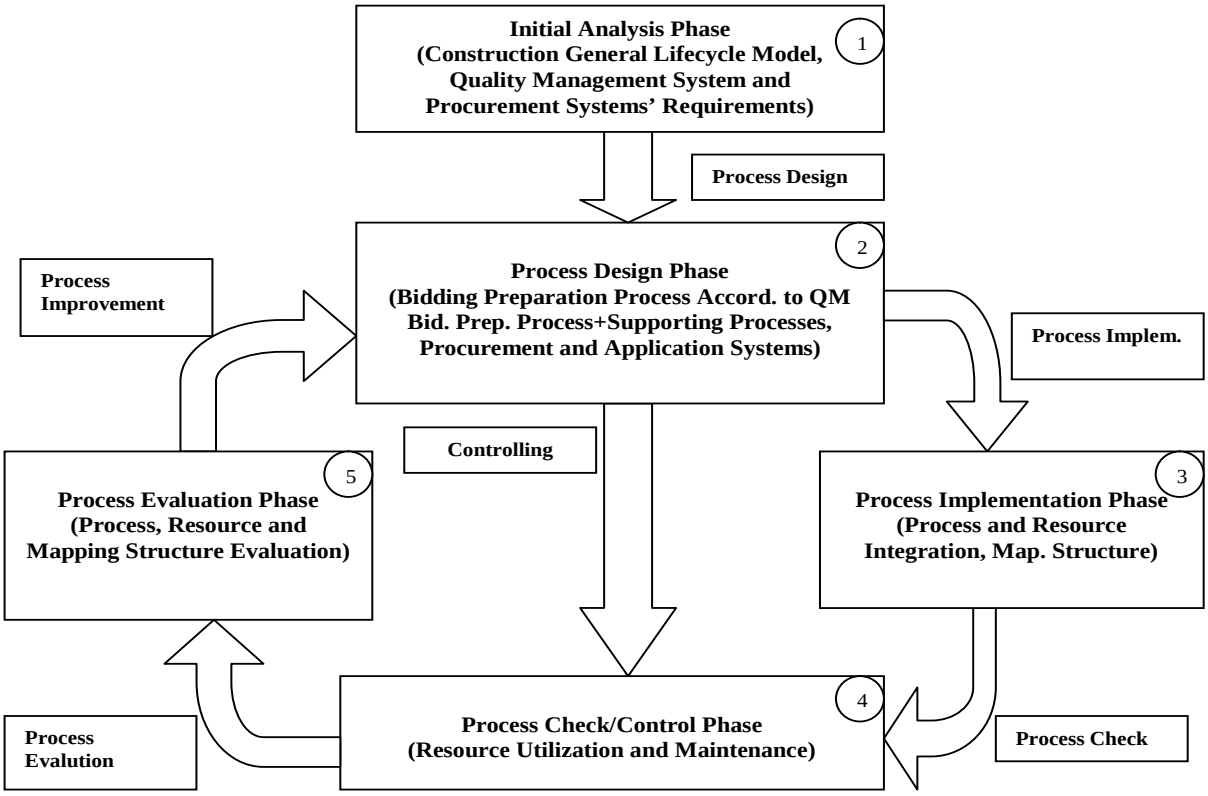


Figure 2: The Life Cycle Model for Organizational Management Process

6. THE MAIN AND SUPPORTING PROCESSES BASED ON ISO9001 QUALITY MANAGEMENT SYSTEM

To support QM requirements and to provide a generic structure, the OMP is designed based on the Bidding Preparation Process (M) which is accepted as the main process. It is extended with seven supporting processes, procurement system and software integration requirements and application systems based on the Bidding Preparation Phase definition of AIA. The supporting processes are used partially within the main process to fulfil the required integration. In this case, the process models are structured with considering the basics given below.

Bidding Preparation Process - Main Process (M)

Bidding preparation process represents the way of obtaining tender documents and preliminary evaluation. Moreover, it comprises country/region visits and the preparation of the related reports,

determining the responsibilities, working on the project specifications, providing the basic data, obtaining price quotations, review and presentation of the bid, tender follow-up, performing of contract and the contract revisions.

Supporting Processes

The following processes interact and hence supporting the main process.

Job Development Process (S1)

Job development process considers pursuing business/project opportunities and examines job development system and sources of information. Conformity research and review of pre-qualification conditions are also undertaken at this stage.

Design Coordination Process (S2)

Design Coordination process commissions a responsible project design manager who possesses design preparation experience. This process pursues drawings review, distribution of drawings and as built detailing.

Defining of Project Organization and Management Planning Process (S3)

Defining the project Organization and Management Planning process provides project organizational structures and scopes of the job and the responsibilities. Project organization manual, organization notification, content of "Project Master Plan" are also considered as the main items. According to obtained information, "Quality Plan" is also formalized in this process.

Human Resources (S4)

Human Resources process represents the way of new employee requests and preparations of the requested qualifications. Moreover, it comprises preparation of the work descriptions, notification and data collection, review of applications, employment, personnel placement, personnel documents, orientation and reporting.

Work Program Scheduling and Follow-up Process (S5)

Work Program Scheduling and Follow-up process comprises preparing of tender and the target work schedule, updating of work program during project progress, and comparing the planned work schedule with the existing situation on jobsite.

Purchasing Process (S6)

Purchasing process defines basic data such as project data, purchasing schedule, budget and cash flow data, approval of material request, all related specifications, tests and guaranties during the procurement process. The preliminary studies such as market research, marketing survey for subcontractors, selection of choices about material is also required.

Subcontractor Management Process (S7)

Subcontractor management process identifies job items (product/service) in subcontractors' scope, quotations and reviews, and contract agreement with subcontractor. It formalizes performing and control/monitoring activities, reporting, finishing activities and handing over. Subcontractor performance is pursued in this process.

7. THE MODELING FRAMEWORK

The overall modelling framework is established based on the ARIS-eEPC modelling method. The eEPC enables holistic consideration of functions, events and resources in their inter-relationship. However in order to design an interoperable software solution and to configure management processes and to support mapping between different but interrelated data based on the requirements of the procurement systems, organizational units and application systems, require extensions. In this context each function, each event and the related resources are complemented by a notation.

The new model is named as "complemented eEPC" (ceEPC) model. Thereby the common functions, events, actors and objects that are provided both in Organizational and IT Management Processes are identified in a logical mechanism. This greatly helps to obtain a mapping structure between interrelated data and functional definitions.

Furthermore, this enables the management of all processes in a collaborative way and contributes so that organization units are better informed.

A ceEPC describes processes by creating a chronological sequence of functions, events, and their logical interdependencies using logical connectors, and related performing actors and services as given in Figure 3.

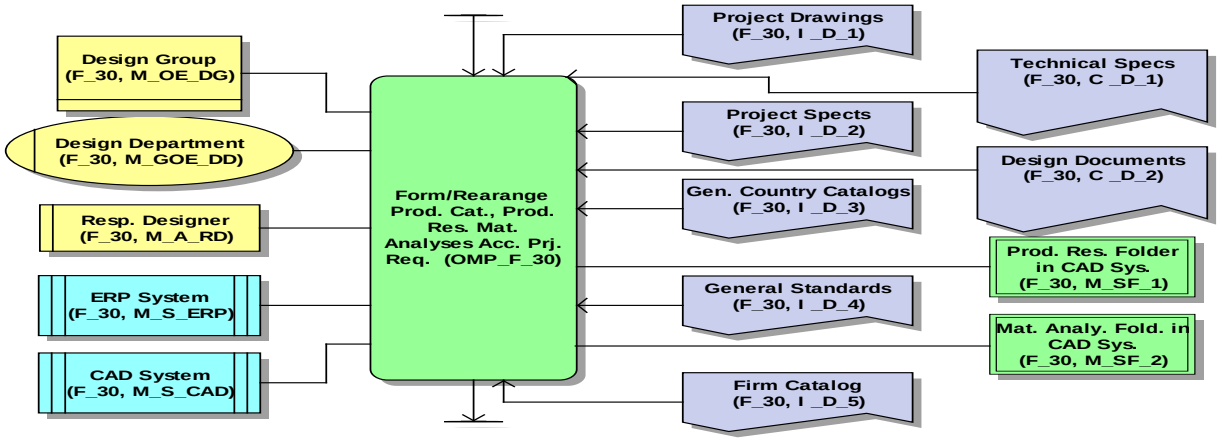


Figure 3: ceEPC Model Structure (A cut-out example of OMP)

In the envisaged ceEPC structure, several types of resources are formalized as: organizational entities, group of organizational entities, actors etc., as given below.

- Organizational entities are the main milestones of the organizational structure of an enterprise. It symbolizes an entity such as: main contractor, client etc. in a process. The participants of organizational entities are commissioned to perform the related activities as granted authorities.
- Group of organizational entities form organizational units, such as departments (permanent units) or project teams (temporary units). It is formed of company participants in terms of actors, in order to support unique aspect of a process.
- Actors are the formal organizational positions granted to organizations' participants. They are commissioned to posses the required work within group of organizational entities.
- Services are used to support activities. These services can be classified based on design, resource planning and scheduling domains. They facilitate the process and support integration with company actors. In our ceEPC model, design domain is represented by the CAD system, resource planning domain is represented by the ERP system and scheduling domain is represented with the Scheduling System.
- System folders comprise the data which is exposed by services. This data can be used by actors and other services, in order to work out related tasks.
- Documents are direct resources, which are used to complete related tasks such as forms, reports, etc.
- System interfaces solve seamless data flow by supporting integration between different systems. The main idea is to obtain seamless integration in order to obtain complete data.

In this research, due to lack of existing models' capabilities such as limitations for 'will-be' processes as it is seen in IDEF0, or lack of representation of all process participants within a process sequence as it was observed in UML activity diagrams etc., and after several attempts in this context, ceEPC model is developed in order to represent all associated resources for a generic process implementation.

8. ORGANIZATIONAL AND IT MANAGEMENT PROCESSES

The whole OMP is formed of 3 organizational entities namely main contractor, client, design group, 9 different groups of organizational entities such as bidding department, procurement department, finance department, etc., 14 different actors such as bidding manager, responsible designer, procurement manager, etc., and 117 sequenced functions and events, 135 different documents and 3 interconnected software systems. Furthermore 7 supporting management processes are referenced and used partially as envisaged in the previous sections

In this paper the generic representation for OMP is given in Figure 4 which composed of three columns as Column 1 - Application Systems, Column 2 - IT Management Processes and Column 3 - Main and Supporting Processes. The QM processes are represented in column three under the main and supporting processes. They are realized in a generic sequence. The IT systems are illustrated under the first column, under application systems and mapped with the envisaged processes according to the

application sequence. The second column represents IT management processes. This includes the application sequence of the involved IT tools, their relations to processes, performing actors and their general systemic interrelations.The ITMP represent the QM System processes and application systems integration. This approach facilitates the observation of common functions, events, resources and objects which are used in the IFC View Definitions.

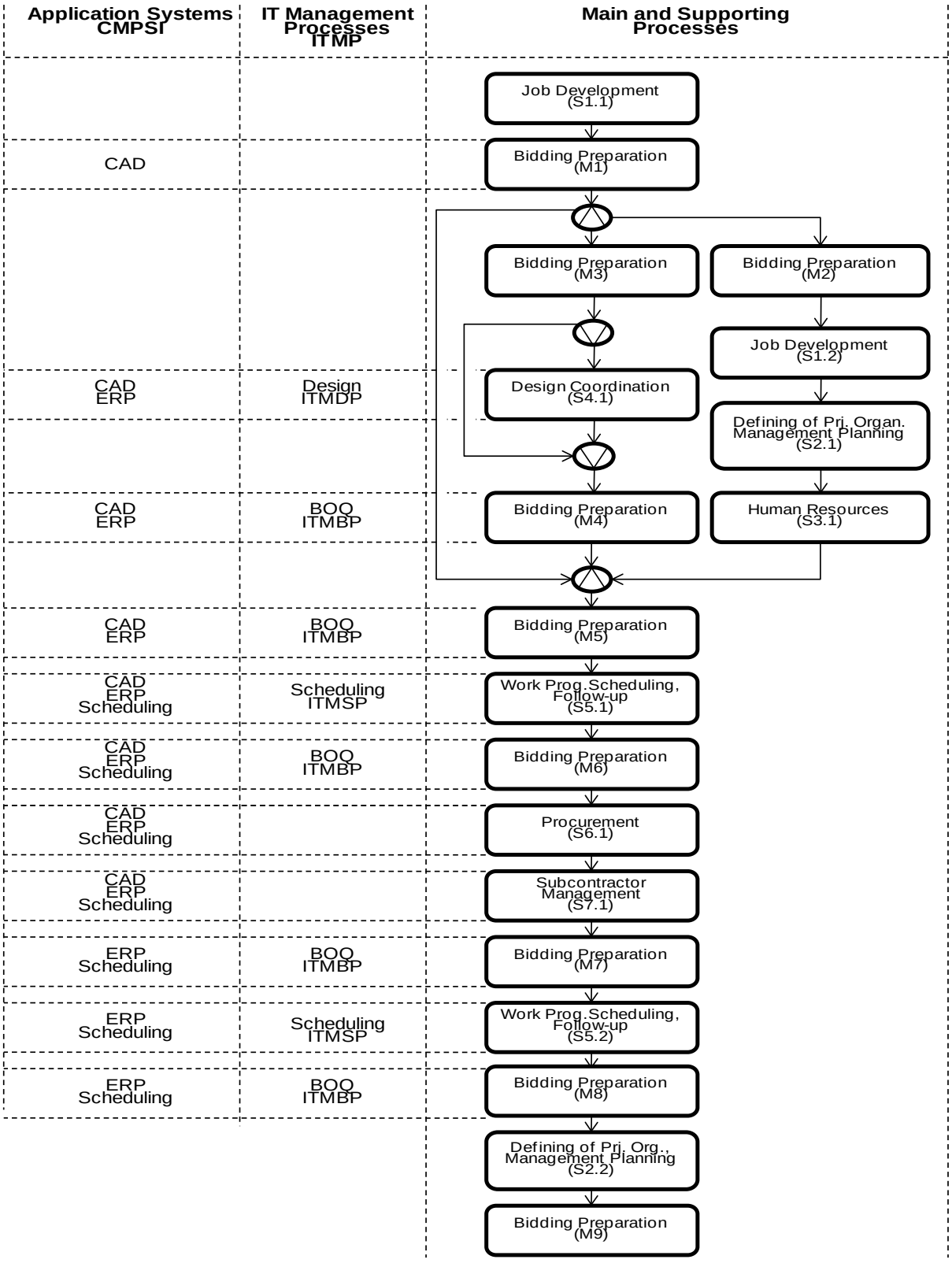


Figure 4: Generic Representation of OMP

9. SUMMARY AND CONCLUSIONS

In this research the principal process definitions 1) the Organizational Management and (2) the IT Management Processes are developed based on the Bidding Preparation Phase of the Construction General Lifecycle Model of AIA. The main aim of the suggested approach is to enable handling various types of information coherently, including product, process and management data to formalize a conceptual framework and to reach an integrated structure. In order to provide this, the Organizational Management Process is developed with the implemented Lifecycle Model for the Processes, which brings different views together in one single process structure. Subsequently, IT Management Processes are described in accordance with the CAD-ERP-Scheduling interoperability needs according to Software Interoperability and Organizational Management Processes. The ceEPC Model is used to establish the overall framework. This helps greatly to design and interoperable software solution and to configure business and technical management functions. Moreover, it can be used to formalize the mappings between the different but interrelated data and functional definitions.
According to the defined process activities, resources can be mapped with the required IFC objects or, where necessary, these resources can provide new entities within an IFC model extension for the Construction Management. The methodology shown at the example of Bidding Preparations can be applied to any of the other phases of Construction General Lifecycle Model.

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