THE CONSTRUCTION MANAGEMENT PHASES FOR SOFTWARE INTEROPERABILITY

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ABSTRACT

Interoperability of the heterogeneous applications used in the domain of construction management can be best achieved by using generalized and standardized representations of the required data, thereby enabling faster and better management and decision-making in the construction process. This can be achieved by merging the organizational context and the information involved. The developed Construction Management Phases namely (1) Design, (2) Bidding Preparation, (3) Planning & Construction, (4) Projects Payments, (5) Evaluation of the Outcome and Feedback in this paper represents software integration with regard to design, resource planning and scheduling in the Construction General Life Cycle Model Phases, and is dedicated to the Construction Company view. This new approach composed of five integrated phases is named as “Construction Management Phases for Software Interoperability” (CMPSI). The phase representations are provided in IDEFØ modelling method. This representation facilitates the revelation of Construction Management Resources that are used for the implementation of IFC Views. The CMPSI is developed as a framework model that is capable of representing diverse targets of different software involved in the integration process. Therefore, a mechanism, by which the systematic and consistent interfacing of the envisaged systems supported, is obtained. The generalisation within the structure allows flexible application. This is achieved at a variety of strategic levels across a variety of projects using combinations of software in an interoperable structure.

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

1. INTRODUCTION

Along with the increased realization of construction projects in virtual enterprises comprised of physically distributed specialist teams, a growing interest in the introduction of advanced production methodologies and the use of Information Technology (IT solutions) can be widely observed.
Currently, in all countries there exist solutions integrating design, resource planning and scheduling domains. Quite often general-purpose light-weight tools such as Microsoft Project (MS) are integrated with specialized in-house developments and/or more powerful Computer Aided Design (CAD) and Resource Planning (ERP) Systems. There are also, design to cost developments offered by single software vendors (such as Vico USA, Nemetschek Germany, etc.) which provide more or less comprehensively the required functionality in the construction management domain. The major advantage of such solutions is in the combined use of construction site databases and head quarter’s databases which leads to the following benefits (1) improved project/cost control, (2) reduced operation costs, (3) increased work efficiency of the site personnel, (4) decreased dependency of key personnel on the process, (5) quick response to change in the construction environment, business operations and market conditions.
However, whilst such systems offer the above mentioned advantages, they lack generality in terms of data and process interoperability. Thus construction processes are defined in terms of the capabilities of the used applications and not on the basis of generalized industry requirements. Similarly integration of product, process and cost information is based on the specific internal models of the used systems and not on a standardized data model. This significantly decreases flexibility, the information ex-

change between systems, multi-stakeholder collaboration and last but not least, inter-enterprise cooperation and knowledge transfer. In spite of its potential, the upcoming common project models, such as the Industry Foundation Classes (IFC) are practically not used for construction management purposes.
In order to address these issues, the work in this paper is grounded on the interoperability problems of the existing systems, the integration of construction phases and the information exchange primarily within the design, resource planning and scheduling domain based on IFCs. The main objective is defined as, to generalize construction management phases, so that interoperability over a broad spectrum of applications is facilitated.

2. BACKGROUND

A phase demonstrates a temporal period before a transition and designates the sequential and connected activities during that period.
There are variable ways to name and partition the phases of construction project's lifetime. Gielingh (1988) proposed the lifecycle according to its major transition points. The periods of time, between these transition points are referred to as phases. Eastman (1988) adapted his classification according to this model but mostly concentrated on the periods of time between phases.
The initiatives such as CALS developed standards for electronic data interchange, electronic technical documentation, and guidelines for the improvement of construction life cycle; IRMA defined generic relationships between products (results), activities, resources and participants in the building processes addressing construction phases; GPP developed the framework of common definitions, documents and procedures to provide seamless integration between project participants; the projects like eConstruct developed semantics that support electronic business communication about construction products, resources, work methods and regulations; OSMOS specifically concerned defining of work practices, processes, techniques, tools and technical infrastructure, and the IukBau which developed and demonstrated novel methods for context sensitive information access on construction sites, can be identified as the major interferences in this context.
However, the standard phase definitions for Construction General Lifecycle and the goal of lossless, incremental data flow through construction phases, through standards such as IFC and STEP have not been achieved.
In order to determine standard approaches to construction general lifecycle, to find a solution to seamless data flow between construction management phases and IT domains based on IFC, and to provide a process oriented information modelling methodology, an integration method, encompassing the product and process information exchange within application domains in the Construction General Life Cycle Model Phases is required. Thereby, the relevancy of the information resources, which are provided in the phase definitions, can be mapped to IFC classes.

3. APPROACH

The newly introduced Construction Management Phases for Software Interoperability (CMPSI) is dedicated to Software Interoperability. It is defined based on state-of-the-art analysis of Construction General Lifecycle Model of American Institute of Architects (2009).
The development aim of CMPSI is to identify the necessary data and to provide them in a generic form so that various types of IT domains can use them in an integrated way for Construction Management purposes. This data can be used to realize object-oriented data structures and enable the examination of the basics for seamless and coordinated work environments.
The CMPSI is described by using IDEFØ, which is a widely accepted effective modelling method. It obtains a detailing mechanism in terms of decomposition of high-level processes to sub-defined activities of the general model. The structure is composed of basic elements namely function, input, output, control and mechanism to describe process activities in a logical way.
A function is represented in a function model as a 'rectangular box' graphic diagram and the interfaces to or from the function can be identified as 'arrows' entering or leaving the box. To express functions, activities should be followed by other activities in terms of sequential functions, with the interface arrows. There are four basic arrows can be identified, as input, output, control and mechanism. Basically input has a label that describes information used by the function, the 'output' describes information delivered by the function, the control is related with the constraints on the functions, and

the ‘mechanism’ can be identified as an actor, a database or software in the formed structure. The basic diagram of CMPSI in IDEFØ modelling method is shown in Figure 1.

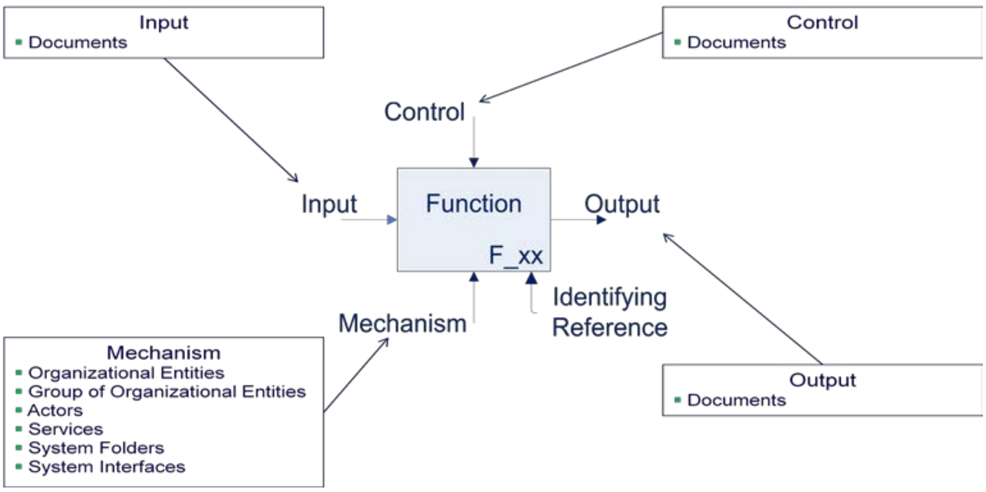

Figure 1: Basic Diagram of IDEFØ Modelling Method

4. THE CONSTRUCTION MANAGEMENT PHASES FOR SOFTWARE INTEROPERABILITY

In this research to provide a systematic approach to the integrated design of products and their related processes, and to take into consideration the economic and technical aspects that can affect these during their lifecycle from software integration point of view, the CMPSI is developed which is deduced from the Construction General Lifecycle Model of American Institute of Architects (2009).
American Institute of Architects (AIA) defines construction lifecycle in six sequenced phases. These are named as: (1) Feasibility, (2) Design, (3) Bidding Preparations, (4) Construction, (5) Contract Closeout, (6) Operation & Management. These phases are defined from a general perspective.
In this research, in order to narrow the scope, the Construction Management Phases are represented from the contactor point of view as:

- Design,
- Bidding Preparation,
- Planning & Construction,
- Project Payments,
- Evaluation of the Outcome and Feedback.

The mapping between Construction Phases of AIA and the proposed phases is represented as:

AIA Phases	**Proposed Phases - CMPSI**
Feasibility	→ Out of Scope
Design	→ Design Phase
Bidding Preparation	→ Bidding Preparation Phase
Construction	→ Planning & Construction Phase
	→ Project Payment Phase
Contract Close-out	→ Evaluation and Feedback Phase
Operation & Management	→ Out of Scope

Figure 2 represents the phase sequence.

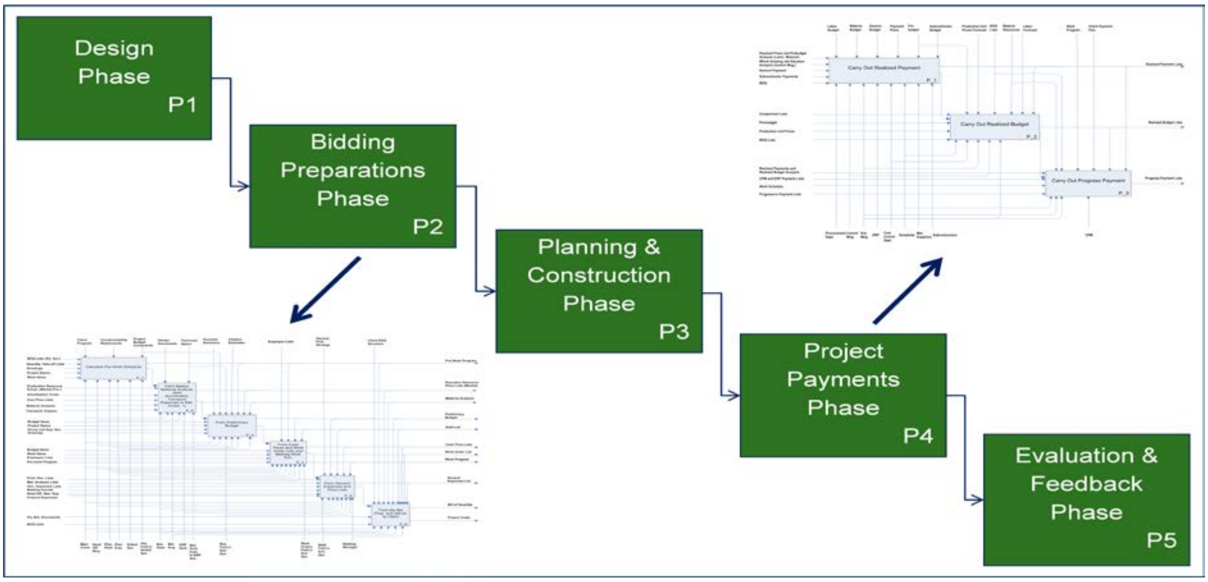

Figure 2: Construction Management Phases for Software Interoperability

Figure 3 represents the partial definition of Bidding Preparation Phase based on IDEFØ and in this paper only the Design Phase is shown in IDEFØ to represent the complexity and interaction of all resources, which are involved in the process.

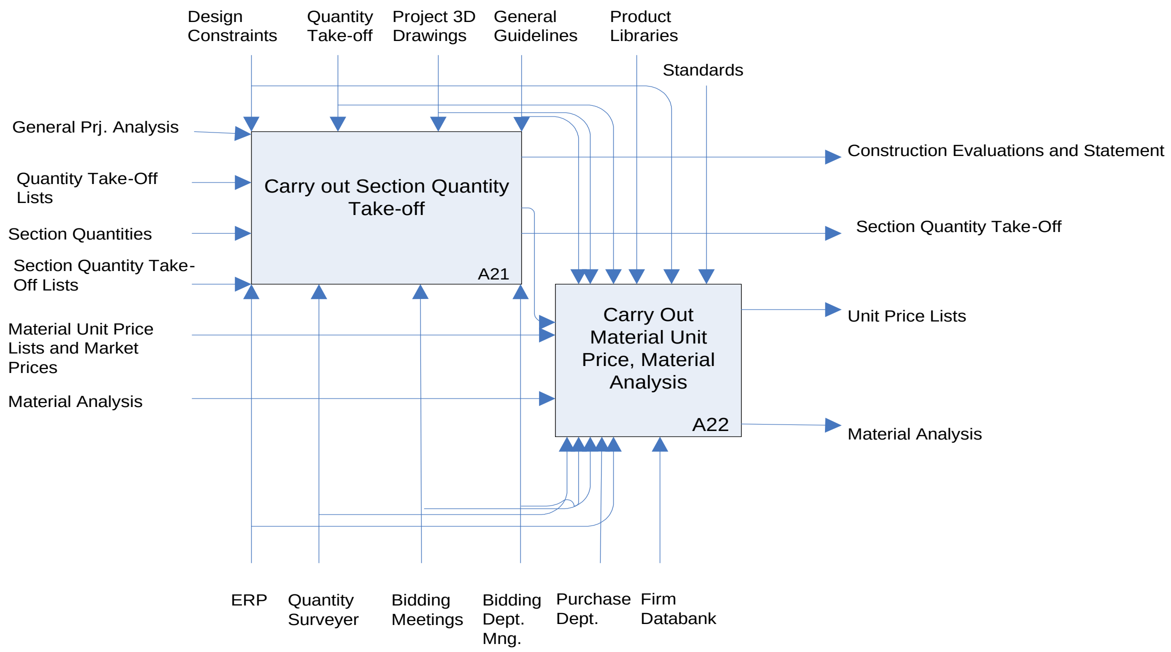

Figure 3: Partial Definition of Bidding Preparation Phase

In construction companies, monitoring the project progress and the monetary situation is important to see potential detrimental occurrences. This should consist of examining the situation to decide on necessary actions, in order to overcome the existing problems during project progress. Moreover, the creation of links to accountancy is widely required. Therefore the new phase \`Project Payment Phase\` is proposed and detailed in our approach.

Furthermore, the associated statements are provided, as in the following:

These phase definitions may vary for different countries, but the basic principles are the same. In all stages specific databases and algorithms are used. All these databases must keep the information about their function and content in suitable structures and algorithms so that they can be further re-used by the other stages when required.

According to the given model the functions based on software interoperability should be supported in the proposed integrated Construction Management model. These are also to be covered by the whole life cycle model of a building. In this broad scope, various types of information entities have to be considered in their interrelationship:

1. The information about the constructed facilities, construction products, processes, documents and regulations,
2. The information about the model itself including the information representation (databases), the information processes and the components of the environment such as servers, and clients,
3. The “information about the information” including concepts like ownership, access control and versioning.

Design Phase

Design Phase is the initial phase which comprises the general analysis and design activities of the project. Conventionally, regarding to AIA, Design Phase is composed of (1) pre-design, (2) site analysis, (3) schematic design, (4) design development (5) construction documents (6) bidding and negotiation (7) construction contract administration.

Although these functions are generally identified as given above, a system that comprises the general management skills, existing CAD applications, information exchange and relevancy to IFC product model, requires a new model designed according to best practices.

To see all attributes regarding this approach, the system is appropriately structured in IDEFØ as given in Figure 4. The associated five functions are explained in the following paragraphs.

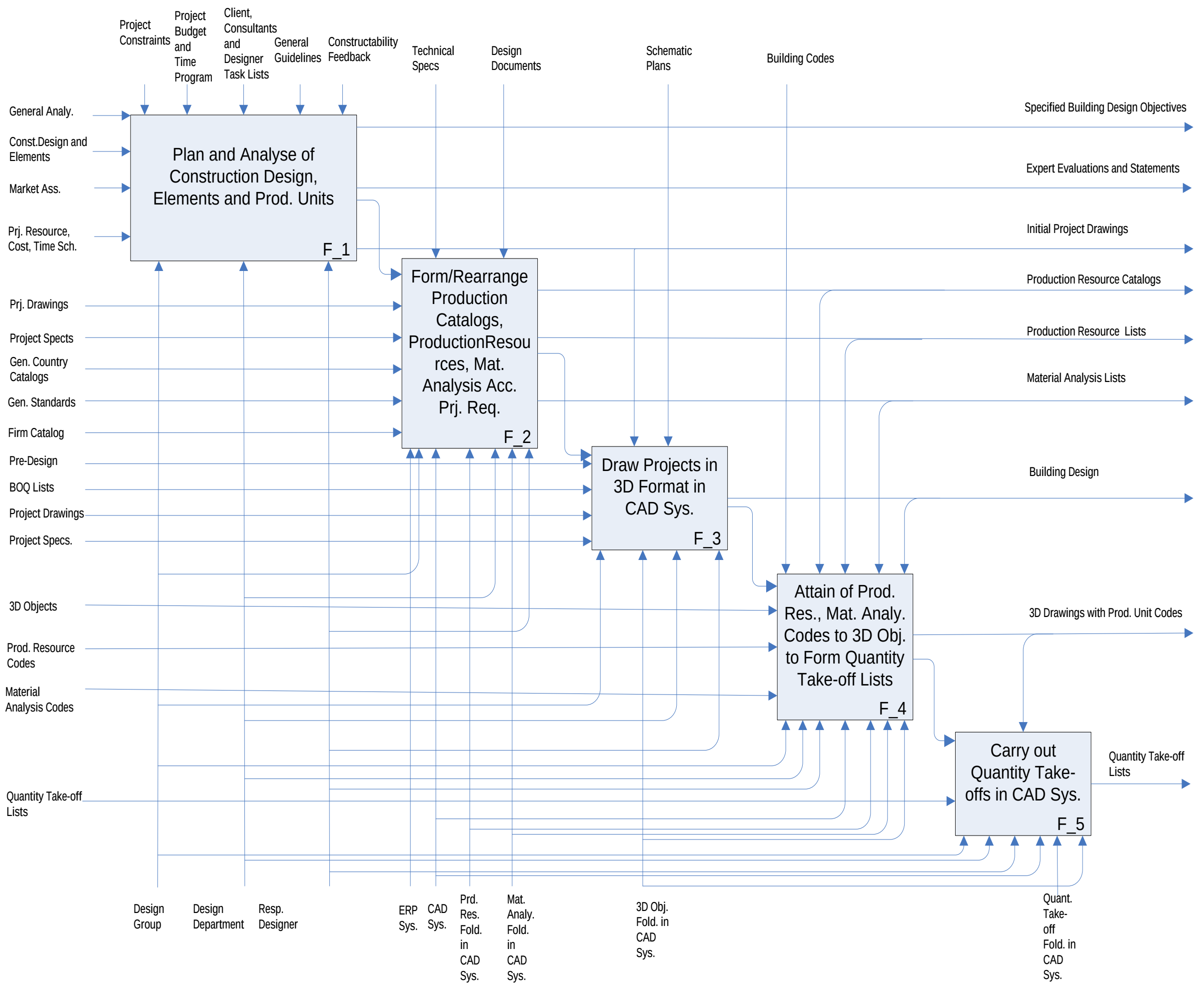

Figure 4: Design Phase, CMPSI – P1

F_1: Plan and Analyse Construction Design, Elements and Materials

This function considers some of the feasibility activities such as identifying the project requirements, construction constraints, market assessments, etc. Construction design can be completed according to project constraints, project budget, and general guidelines. Moreover, several organizational entities and actors are taken part such as design group, design departments and designer to fulfil these requirements.

F_2: Form / Rearrange Production Catalogues, Production Resources and Material Analysis According to Project Requirements

This function is the milestone of the proposed management structure. For managing all the activities, a product catalogue composed of production resources with their IDs and prices has to be identified. These catalogues can be national, international or firm’s private catalogues. The information exchange, based on the production resources, can be managed with these IDs.

F_3: Draw Projects in 3D Format in CAD System

The drawing process is composed of architectural, structural, HVAC drawings and the installation schemes, which provide the database of the initial processes of the project. These schemes and drawings are the inputs for the technical applications defining the construction details, the quantity take-offs and the section lists. Quantity take-offs and the section lists can be achieved with the help of reliable CAD tools like AutoCad, Allplan, Graphisoft etc. The 3D drawings can be used as the initial information of the other phases.

F_4: Attain Production Resource and Material Analysis Codes to 3D Objects to form Quantity Take-off Lists

The production resource codes in terms of IDs can be taken from national / international product catalogues / libraries according to identified production resources. These production resource codes can be attained to 3D drawings in order to reach Quantity take-offs. These also can be used in each phase of the envisaged model to formalize production resource prices, material analysis, BOQ lists, scheduling activities, cost analysis and procurement etc.

F_5: Carry out Quantity Take-offs in CAD System

3D drawings allow the visualization of a project three dimensionally. These drawings generally support production resource codes format which can be used in other stages of the construction management process. In the envisaged model, this is done by use of design domain in terms of CAD systems which have the ability to form 3D drawings which can report the quantity take-offs in suitable forms

Bidding Preparation Phase

The Bidding Preparation Phase is generally composed of controlling design documents, checking quantity take-offs, formalizations of pre-work program, estimations of direct cost etc. In our case, the Bidding Preparation Phase is represented in six functions namely (1) form pre-work schedule, (2) form market material analysis, (3) form preliminary budget, (4) form cash flows and work order lists, (5) form general expenses, (6) form construction BOQ.

In the Bidding Preparation Phase, after the quantity surveying is finished, cost estimations can be established. These estimations are typically prepared on the basis of the construction diagrams and technical specifications. In this context, a proposal should be prepared based on the cost estimation and conforming to the owners’ requirements. Quantity take-offs should be checked, recalculated and classified. Based on the production analysis, production unit prices are calculated, and market values are formed. At the same time, the effect of inflation, the budget and cash flow tables have to be considered with regard to a pre-work schedule. This requires integrated work throughout the company. One group performs the quantity surveying and creates the quantity take-off database, another group undertakes market research and creates the production unit price database, a third group performs the construction cost analysis with respect to the company standards, and a fourth one prepares the work schedule and creates the budget and cash flow tables. These databases have to be inter-related. Each data produced in one group is needed by another group, i.e. highly cooperative work is required.

Hence, an approach using integrated construction management tools is required which can support bi-directional information exchange between the application domains.

F_1: Calculate Pre-work Schedule
Pre-work Schedule is formalized using relevant scheduling systems and by considering project activities, client requests and project situation. The activities can be structured according to sections which are formed in the design phase.

F_2: Form Market Material Analyses (Add Amortization, Transport Expenses to Material Analyses)
According to product catalogues used in the design phase, the production resource price lists, and material analysis can be formed based on the market prices. This item changes existing catalogue prices with the market prices and so updates the costs of the procurement items.

F_3: Form Preliminary Budget
Preliminary budget can be settled according to: material analysis, human resources, procurement decisions, prices, and the project pre-work schedule. It facilitates the forecasting of project budget situation and the formation of project cash flows.

F_4: Form Cash Flows, Work Order Lists and Bidding Work Schedule
In this function, cash flows are formalized based on the budget items. Additionally the work order lists are constituted based on the work items and employee lists. The cash flows and employee numbers facilitate to reach pre-defined project expenses. Furthermore, Bidding Work Schedules can be formalized in this context.

F_5: Form General Expenses and Price Lists
According to firm general strategy indirect costs, general expenses, mobilization and financial expenditures and price lists are planned and formed in this function. These are used as the main input of the general expenses for BOQ preparations.

F_6: Form the Bid Proposal and Deliver to Client
The Bid Proposal is formed according to a combination of the given items: Project Bid Documents, BOQ Lists and Structure, Production Resource Price Lists, Material Analysis, Preliminary Budget, Staff List, Cash Flow List, Work Order List, Work Program and General Expenses List.

Planning & Construction Phase

Conventionally, the Construction Phase is composed of functions such as construction document checks, defining of construction units, establishing of activity sequences, initial construction schedule, establishing of procurement plans etc. In this context, the planning and construction processes are combined and Planning & Construction Phase is constituted in order to support integration between planning and construction activities to facilitate a flexible management structure.
It is composed of sequential processes such as: schedule work program, carrying out budget and cash flows, carrying out material requirement lists, carrying out material buying and payment plans etc.

F_1: Use BOQ, Material Analysis, Work Orders
Scheduling Programs (Primavera, Suretrak etc.) can be used to schedule and to allocate resources. To achieve that, activities should be defined with (1) The quantities of their resources and, (2) Monetary values of these resources. These items can be received from the bidding preparation phase as BOQ and material analysis information. These are the main inputs to formalize the budget and cash flows of the construction project. Also the work orders are used to define the labour, which can be connected with the project schedule.

F_2: Schedule Work Program
The project schedule activities can be formalized according to BOQ lists and can be detailed according to materials which can be used within the project progress.

The activity periods should be calculated according to material, labour and site conditions. The pre-work schedule can be used as a baseline for the work schedule.

F_3: Carry Out Budget Cash Flows

Pre-budget can be formed according to income and expenses which are already determined in the proposal. The income is related to the production and the sales price of the production on the construction process. The distribution of the production over time is determined in the work schedule. The material requirement, which is also determined in the work schedule, is the budget expense and can be retrieved and reported periodically. To calculate the real budget, the resource costs of the activities, the estimation of the inflation, and the sales prices of the productions are required in this context.

F_4: Carry Out Material Requirement Lists

It is important to have a decision about material purchasing. It should be known which material is going to be used, when and in what amount. The material requirement lists the amount and work program, received from scheduling programs which support material purchase decisions, so that a payment plan can be easily created. Also the client's requests and standards have to be taken into consideration before purchasing.

F_5: Carry Out Material Buying and Payment Plans

As it is defined, a material buying plan is connected with the material requirement lists. The materials can be procured according to a time schedule. The site management can arrange their program according to this time schedule and can procure the related materials. The payment plans can be formed according to project schedule related with the material buying plans.

F_6: Plan Work Orders

In construction practice, most projects are easily managed according to scheduling programs by continuously consulting the work orders. Such work orders can be reported automatically every morning. They provide the lists of tasks to be performed during the day by any unit or technical personnel, and they can be reported easily.

F_7: Execute the Job on Jobsite

The items that are examined under project, cost and period have the dimensions of quantity, money and time and can be formed using data evaluation programs based on arithmetical algorithms. The job on jobsite can be executed by using reliable systems in this context.

Project Payments Phase

In most approaches, construction phase is defined according to jobsite processes. But due to increasing competitions in all fields and decreasing profit margins detailed budgets are required. In this regard, the project payments phase is formed under three basic functions namely carry out realized payment, carry out realized budget, carry out progress payment to see the detailed money transactions between the project partners in terms of client, main contractors, material suppliers, subcontractors etc.

F_1: Carry out Realized Payment

The creation of realized payments depends not only on the estimated budgets and the demands of the construction site but also the demands of the headquarters management. From headquarters point of view, all projects are considered as a whole, and the payment plan is organized depending on the degree of importance. The realized payment can be structured according to payment plans and pre-budget, whole existing job situations, general payment and BOQ lists in this regard.

F_2: Carry out Realized Budget
The real budget is formed according to headquarter management decisions and site requirements. It can be structured according to pre-budget, production unit prices, BOQ lists, which are determined in the bidding preparation phase. However, it is hardly possible to compare the planned budget, the required budget and the real budget and to inform the management about these.

F_3: Carry out Progress Payments
Progress payments can be identified as partial payments for accomplished work phases. The realized payments, realized budget analysis, payment lists and work schedule are the inputs of progress payments. The work schedule can also be used as the source database of the progress payment reports. Using a reliable scheduling program supports the realization of production amounts, i.e. the portion of the construction completed within a certain period.

Evaluation & Feedback Phase

It is important to evaluate the project situation in order to see the problems and their effects. A project evaluation structure can facilitate further actions to prevent problems in terms of money and time logs. Our approach is separated into six main functions to follow up the existing situation of the project, namely; carry out invoices, carry out stock control, carry out material costs, carry out payroll, carry out labour costs, carry out profit & loss status. According to the outcomes of these functions, profit and detriment situations can be seen and the required actions can be taken before project completion.

F_1: Carry out Invoices
The invoices reflect the actual situation of the project progress. It is important to realize the invoice list of each construction item. It is used to control the project costs in terms of monitoring the material on the jobsite and related labour. The basic components to formalize invoices are the payment lists, according to completed project activities.

F_2: Carry out Stock Control
Following the real stock movements enables the determination of the production units' costs in those analyses and supports the tracking of purchases and material amounts more precisely. The main inputs are invoices. This facilitates comparisons between present project situations and planned ones.

F_3: Carry out Production Resources' Costs
The cost of each construction item is defined in the agreement. The invoice lists facilitate the follow-up of the existing use of production units on jobsite. The determination of the real costs of the resources reveals the real values of the production analysis as estimated in the proposal. This can be used as a comparison criterion to see the situation at the end of the project.

F_4: Carry out Payroll
One problem of the existing in the construction sector is identifying the real labour force on jobsite. This information is the basic component of the material analysis in terms of identifying the real cost of the construction activities. If tallying can be followed-up in an appropriate form, i.e. which worker worked for what construction item on which day, this information can be used for the bidding preparation phase.

F_5: Carry out Labour Costs
Employee payments are an important part of the project overall costs. According to payroll and tally lists, labour costs can be calculated. It is used as a baseline for material analysis, comparison of the existing situation and for the new proposals.

F_6: Carry out Profit & Loss Status

According to outcomes of the given actions above: invoice lists, stock lists, material and labour costs, payroll lists, construction conditions can be matched between the proposal and the existing close-up. This comparison clearly shows the profit or loss during the construction.

Feedback Phase

The information which is gained from the project should be entered in a database system for future proposals. In each project, recording the new findings ensures a strong basis, for future proposals and decisions of the company. It enables the users to conveniently access various types of information such as material analyses, production unit/resource prices, technical specifications, method statements, scheduling aspects, budget, stock, payroll, profit and loss records.

The Construction Management Phases for Software Interoperability is a framework model which is capable of representing diverse targets of different software involved in an interoperable process. Therefore a mechanism, by which the systematic and consistent interfacing of the envisaged software systems supported, can be facilitated. The generalisation within the structure allows flexible application. This is achieved at a variety of strategic levels across a variety of scales of projects using combinations of software in an interoperable structure. The main aim underlying this approach is to find a standardized structure for managing processes and building products, and to develop partial models which are essential for software interoperability.

5. CONCLUSIONS

In this research, in order to realize interoperability over a broad spectrum, the application domains and their interactions within the construction management phases are provided, and named as ‘Construction Management Phases for Software Interoperability’, (CMPSI) model. The related phases are represented with IDEFØ function modelling method based on the Construction Phases of AIA. The CMPSI model is capable of representing information resources which required by different software domains involved in the interoperable process. Hence the generic data which can be used to obtain object-oriented data structures can be supported.

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