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RESEARCH ARTICLE

Process Description Languages in Construction Logistics

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Abstract
During the construction processes, many problems might arise, at present the symptomatic treatment is the common practice. Besides, the literature offers a wide choice of business process description languages. This paper presents the modern principles and the description languages are used in the construction's logistics processes. The most commonly used process description methods in the construction industry are the simple flow charts and Gantt diagrams. In our days, the Last Planner System (LPS) has a wide application range in the construction processes. The mostly used standardized process description language in the construction processes is the IDEF0 (Integrated DEFinition for function modelling, version 0). The hybrid model is also promising, which combines the scheduling, the BPMN (Business Process Model Notation) charts and IDEF0 method. Finally, by a comparison, a proposal has been developed, which gives a good basis to describe the logistics processes of construction.

Keywords
logistics, construction, process description languages

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1 Introduction

Hypothesis: The process description languages used in the business may be useful in the logistics processes of construction too. The planning, the organization, the direction and the control of the logistics processes in construction might be more efficient (e.g. time, cost, resource allocation) if these formal languages are applied.

First of all, it should be noted that the above hypothesis is not at all obvious. At the beginning of our research, it has been felt, and then it has been already proved through the literature review that the use of process description languages in the handling of construction processes are scattered. Despite the opportunities and the high number of these languages, it has been found simple flowcharts and only a few process descriptions, which are based on standardized rules.

During the construction processes, many problems might arise, which should be addressed already in the planning phase. In our days, the symptomatic treatment is the common practice; but:

- it does not provide predictability;
- the possible branching's and actions are not defined clearly;
- there are no clear areas of responsibility;
- to mention only the most important failures.

The obvious solution would be for process control, to handle the main sources of faults and to give a correct list of what to do during the construction process. The process description languages may be useful not only in the standardization but also help to avoid losses. The delays and the increased costs can be reduced, in case we use these description languages.

The main goal is to give an overview of the commonly used process description languages in the field of construction processes, in addition, one-sub goal is to give recommendations to improve the current methods, consider the constraints and requirements. It is important to note, that the main research area is connected with the organisational and control processes, there are not handled the physical processes of the constructions.

2 Basics of construction process description

The most commonly used process description methods in the construction industry are the simple flow charts and Gantt diagrams. In our days, the Last Planner System has a wide application range in the construction processes. The next part presents the major revealed original researches and applications in connection with the above-mentioned fields.

The Last Planner System (LPS) is a planning, monitoring and control system that follows lean construction principles such as just-in-time (JIT) delivery, value stream mapping (VSM) and pull scheduling (also known as reverse phase scheduling). Principles of LPS (Fernandez-Solis et al., 2013):

- plan in greater detail as you get closer to doing the work;
- produce plans collaboratively with those who will do the work;
- reveal and remove constraints on planned tasks as a team;
- make and secure reliable promises;
- learn from breakdowns.

Functions of LPS:

- collaborative planning;
- making ready;
- constraints identification and removal;
- task breakdown;
- operations design;
- releasing;
- committing;
- learning.

Components of LPS:

- phase scheduling;
- look ahead planning (LAP);
- constraint analysis;
- weekly work planning (WWP) or commitment planning;
- daily huddle meetings;
- first run studies;
- percentage plan complete (PPC);
- reasons for non-compliance and feedback loop;
- five-whys – root cause analysis.

The prime reason behind the application of LPS is making plans and workflow more reliable, moreover, improving productivity and quality. The main benefits of LPS implementation are the reduced cost and time of project delivery and greater collaboration between the project members. In addition, there are substantial challenges while applying LPS such as lack of leadership, resistance to change, lack of training, lack of experience and knowledge.

In addition, there are also other methods, such as it can be shown in (Slorup, 2014) that the resource-based Line-of-Balance can be successfully implemented as the main scheduling tool of a large construction company if there is an easy-to-use software tool to support the implementation. The paper proposes a software tool, with which:

- the quality of schedules can be checked;
- the schedule risks can be analysed;
- the project flow can be systematically controlled;
- and control actions can be graphically evaluated and optimized.

Moreover, the study (Li et al., 2012) develops a non-unit based algorithm for planning and scheduling of repetitive projects. In contrast to the traditional view of repetitive projects as many repetitive production units, a non-unit based repetitive project takes the view that the project is repetitive in activities. A non-unit based repetitive project has the following characteristics:

- the operations of activities in an activity group are similar but not the same;
- the work logical relationships are more generalized;
- there is no hard logic relationship between activities in the same activity group;
- various working crews can be employed in each activity group;
- cost and time for routing the various resource crews among production units (Ficzere et al., 2013) are considered.

Constraint modelling is a necessary step in construction planning. Paper (Chua and Nguyen, 2014) presents a scheduling tool called integrated production scheduler (IPS) to handle the non-precedence constraints in supply chain and information flow. The IPS has three main objectives to be fulfilled:

- the first is to promote work plan reliability;
- the second is to increase resource utilization and throughput based on the estimated resource profile;
- the third is to maintain a stable workflow through reducing uncertainties in the supply chain and information flow.

To further facilitate reliable planning, a set of schedule buffers is established to help manage the constraints. Specifically, the working buffer and the shielding buffer ensure quality assignments by removing resource conflicts and supply chain uncertainties. The pulling buffer and the screening buffer increase availabilities of resource and information by managing the delivery issues in advance. With the proposed schedule buffer management, it is feasible to enhance the reliability of look-ahead plans and consequently achieve lean process management.

Variability significantly degrades the project performance. Two types of variability may affect in a construction schedule, namely, task duration and the availability of resource and information prerequisites. The variability of task duration could delay project completion; however, the effect of resource and information availability/unavailability on construction schedule needs to be depicted. Paper (Nguyen and Chua, 2012) presents a simulation model which allows studying the effect of resource and information related variability to a construction schedule. Comparisons are made to illustrate the impact of each type of variability as well as the combination of both types of variability. The results suggest that both types of variability should be minimized in order to achieve a reliable work plan which is important to reduce project delays and schedule changes.

The concept of (Ballard and Tommelein, 2012) is relatively straightforward: define the design process (with the help of IDEF0) from a generic model and produce an integrated project plan by DSM (Dependency Structure Matrix) analysis; then schedule and control design production with look ahead and weekly work plans by assigning design activities as the required information and resources become available. Design is thus planned and managed based on the generation of information with realistic and achievable task setting. The effects of change can be managed by further matrix analysis and process reliability monitored by measurement of PPC (Percent of Plan Completed).

Study (Tezel et al., 2015) proposes some guidelines for managing physical flows in construction sites. It proposes that such flows must be made transparent by collecting data and using modelling tools. This means that the flows of people, equipment, and materials must be explicitly and systematically managed as part of the production planning and control process. A number of typical decisions concerning physical flows have been identified for each hierarchical decision-making level.

Besides, paper (Ballard and Tommelein, 2012) presents a three-tiered model, allowing users to specify the site layout, the physical flow, as well as the process flow. The three layers are integrated with one another so that layout data (e.g., distances) can be used in process simulation. The depiction of the physical flow helps a user locate possible bottlenecks and interference problems. Path crossings can also be captured in the simulation model. The linkage (between the layout, the physical model, the process model, and the simulation) provides an output that is key to quantifying the quality of one layout alternative over another.

In addition, work (Han et al., 2012) discusses the use of the Construction Process Analysis (CPA) technique as an appropriate tool for lean management in construction. Results indicate that for highly repetitive processes such as steel erection, CPA is effective at identifying and quantifying waste.

Research (Bogdani et al., 2012) aims at the application of a planning technique that permits flow processes to be represented through plan state sequences. Based on a careful description of activities, it may be possible to manage an interface analysis and to outline explicitly the complex frame of constraints put backward by every activity sequence. The objective is to support the contractors and the construction managers at the planning stage, paying attention to risk factors influencing the quality and constructability performances. In this paper can be shown IDEF0 diagrams too.

3 IDEF0 diagrams in construction process description: top-down modelling

The most common used standardized process description language in the construction process is the IDEF0 diagram. Apart from the above-mentioned applications, there is a wide range of further uses in the field of construction processes.

In paper (Cempel and Mikulik, 2013) it is modelled the overall construction process systematically creating a generic state-of-the-art IDEF0 model that covers the design and construction of a building project from the conception of the project in a client's mind to its completion for handover and use. This study mentions six top levels of IDEF0 diagrams:

- client's work process model;
- architectural design process model;
- structural design process model;
- building services design process model;
- geotechnical design process model;
- and production design process model.

In addition, this study gives detailed lists of activities and flows of construction processes. This is a good example to create construction process IDEF0 diagram.

Study (Tserng et al., 2010) proposes the concept of IDEF0 modelling methods and provides a prototype used for designing construction knowledge management systems. This IDEF0 diagram shows five top levels of construction knowledge management:

- knowledge acquisition;
- knowledge extraction;
- knowledge storage;
- knowledge sharing;
- knowledge update.

These each has an additional five-five sub-levels.

Moreover, research (Björk and Samuelson, 2013) presents the role of information technology in construction processes. A model of the information and material activities which together constitute the construction process is presented, using the IDEF0 activity modelling methodology. The information process contains:

- person to person communication;
- creation of new information;
- information search and retrieval;
- making information available.

The material activities of construction process:

- factory production;
- transportation and storage;
- on-site construction.

Over and above, in the paper (Yang and Kao, 2012), the method of IDEF0 is used to portray the contents of a management information system for schedule delay analysis. The content of an IDEF0 graph for delay analysis:

- developing the as-built schedule;
- identifying the delay amount and responsibility for each delay event;
- comparing the as-built and as-planned schedule.

Sometimes, the IDEF0 method is in association with other process description methods. Research (Rezgui et al., 2010) uses IDEF0 and UML (Unified Modelling Language) to develop the electronic document management of construction processes. IDEF0 is responsible for overall process description: activities and information flow between the activities. It can be found in UML the detailed description of procedures, rules and messaging.

Furthermore, a study (Cempel and Mikulik, 2013) presents the generic construction process modelling method (GEPM) which has been developed to overcome the deficiencies of the existing methods, such as scheduling, IDEF0, and simple flow methods. GEPM has borrowed some features from the above methods and thus, users can interact with a GEPM model through partial models or views that represent scheduling, IDEF0, and simple flow.

Figure 1, Fig. 2 and Fig. 3 show three levels of construction, namely:

- implementation of construction (A0 – main level);
- offer building implementation (A1 – sublevel of A0);
- formulate tender (A13 – sublevel of A1).

Explanatory purposes, the basic symbols of an IDEF0 diagram (the detailed documentation of IDEF0 can be seen on the IDEF website – www.idef.com):

- boxes (e.g. A1, …, A5): processes;
- blue lines: inputs and outputs;
- green lines: mechanisms;
- red lines: controls.

The main steps of implementation (Fig. 1):

- offer building implementation (A1);
- prepare for production (A2);
- control production during construction (A3);
- build (A4);
- hand over the building (A5).

As an example, in Fig. 2 can be shown the sub-level of offer building implementation (A1), with the following steps:

- process invitation for tender (A11);
- implement cost accounting (A12);
- formulate tender (A13).

Going further down, in Fig. 3 can be shown the sub-level of formulating tender (A13), with the following steps:

- set tender price and terms (A131);
- draw tender documents (A132);
- compile and approve tenders (A133);
- submit tender (A134).

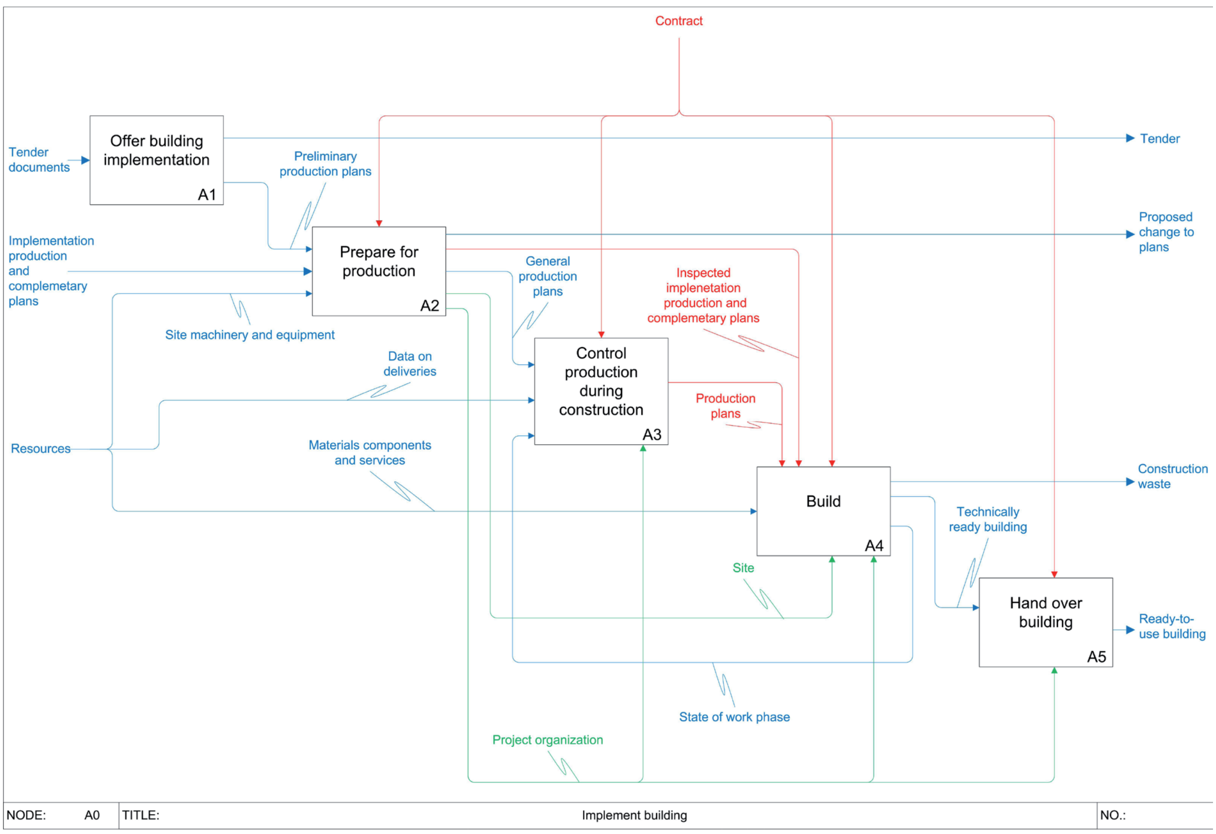

Fig. 1 Implementation of construction (A0) in IDEF0 (own edition)

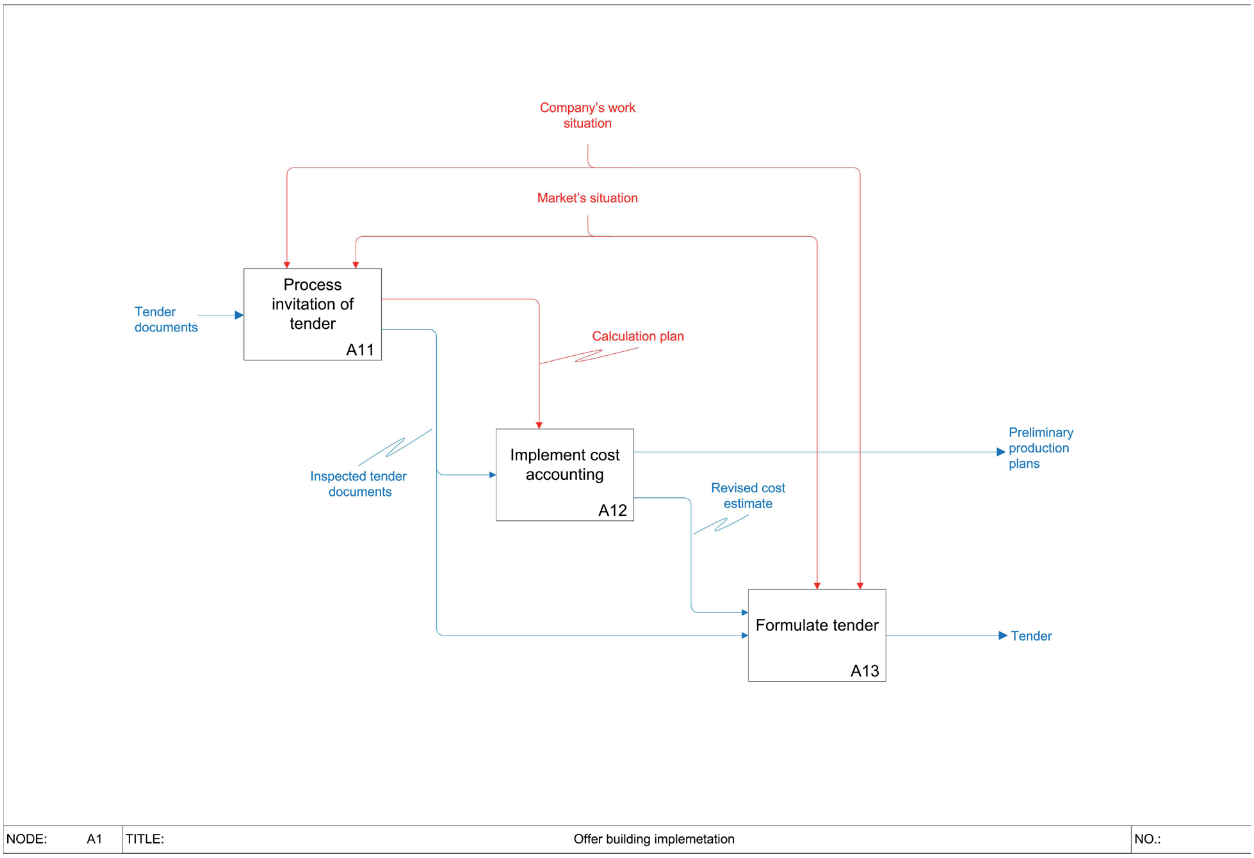

Fig. 2 Offer building implementation (A1) in IDEF0 (own edition)

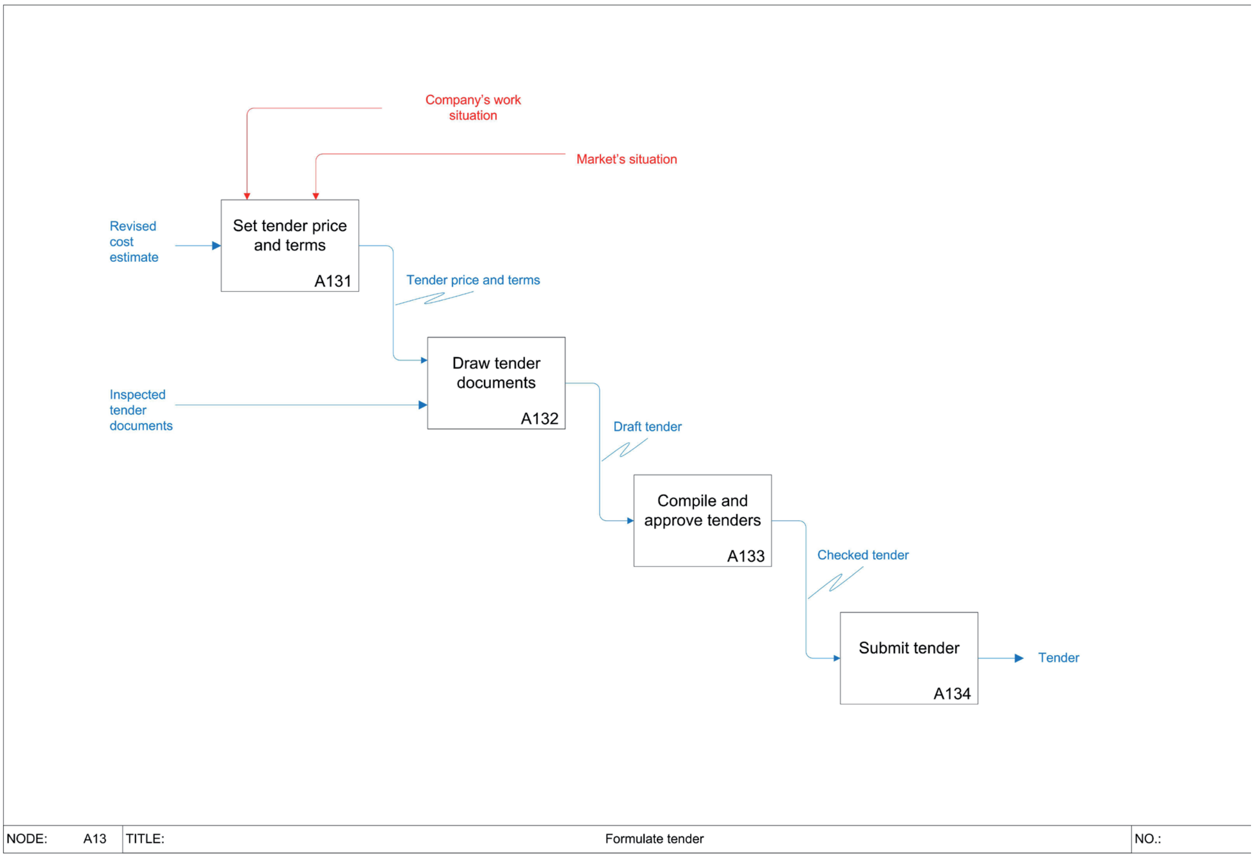

Fig. 3 Formulate tender (A13) in IDEF0 (own edition)

IDEF0 is best for top-down modelling, an excellent tool for the entire process overview. IDEF0 is not primarily suitable for detailed process description. Therefore, a language must be found, which best for low-level process step modelling.

4 BPMN, EPC, (Petri Net, UML): low-level modelling

Paper (Cheng et al., 2011) presents a Petri Net model of a concrete placing operation. Moreover, it establishes that Petri Nets may be useful in the high-fidelity modelling of automated construction operations.

UML is highly expressive and rich in notations and can support successfully the concept modelling of the construction information system. Paper (Rezgui et al., 2010) also mentions an application of UML. The modelling of the OPDT (on-site project document) system by UML for construction processes is recommended because the various aspects of the construction information system can be precisely visualized, specified and documented.

Cheng et al. (2010) demonstrates the modelling of construction supply chains using the Supply Chain Operations Reference (SCOR) framework developed by the Supply Chain Council (SCC). The SCOR modelling framework provides a structured and systematic way to model and disaggregate a supply chain from conceptual representation to process element specification. The SCOR framework is commonly used by corporations for strategic planning of their supply chains. This paper further presents a model-based service oriented framework that leverages the SCOR models for performance monitoring of construction supply chains. The SCOR models are represented in BPMN standard.

BPMN is a highly recommended process description method, due to its support and other applications (e.g. in logistics). As an example, Fig. 4 and Fig. 5 show two parts of a construction tender process in BPMN. Explanatory purposes, the basic symbols of a BPMN diagram (the detailed documentation of BPMN can be seen on the OMG website – www.omg.org):

- circles: events (start, end, other: e.g. in Fig. 5 a message event can be seen);
- boxes: activities;
- piece of papers: data objects (e.g. input or output data);
- gateways: control the sequence flow (e.g. in Fig. 5 parallel and complex gateways can be seen);
- solid line: sequence flow;
- dotted line: link data objects with activities.

It is worth comparing IDEF0 and BPMN (Fig. 3 and Fig. 4 show A13 sub-process in different languages). A13 could be the border between the overview (IDEF0) and the detailed

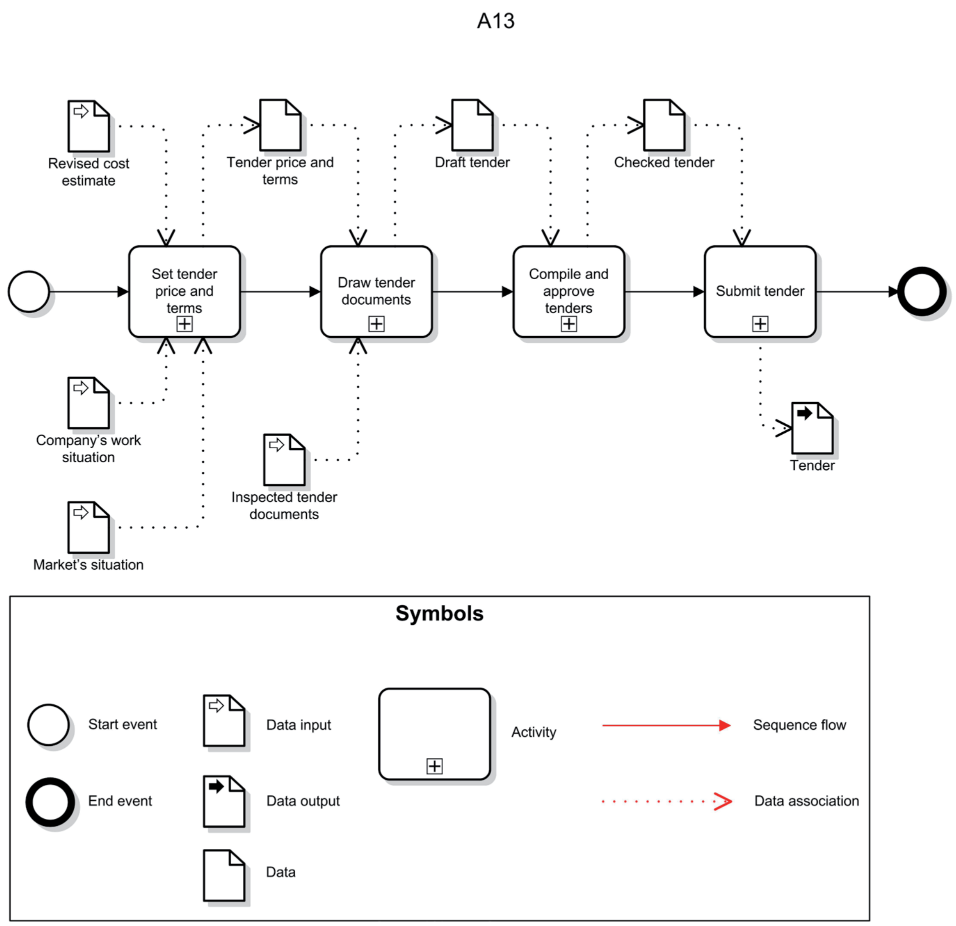

Fig. 4 One part (A13 – formulate tender) of a construction tender process in BPMN (own edition)

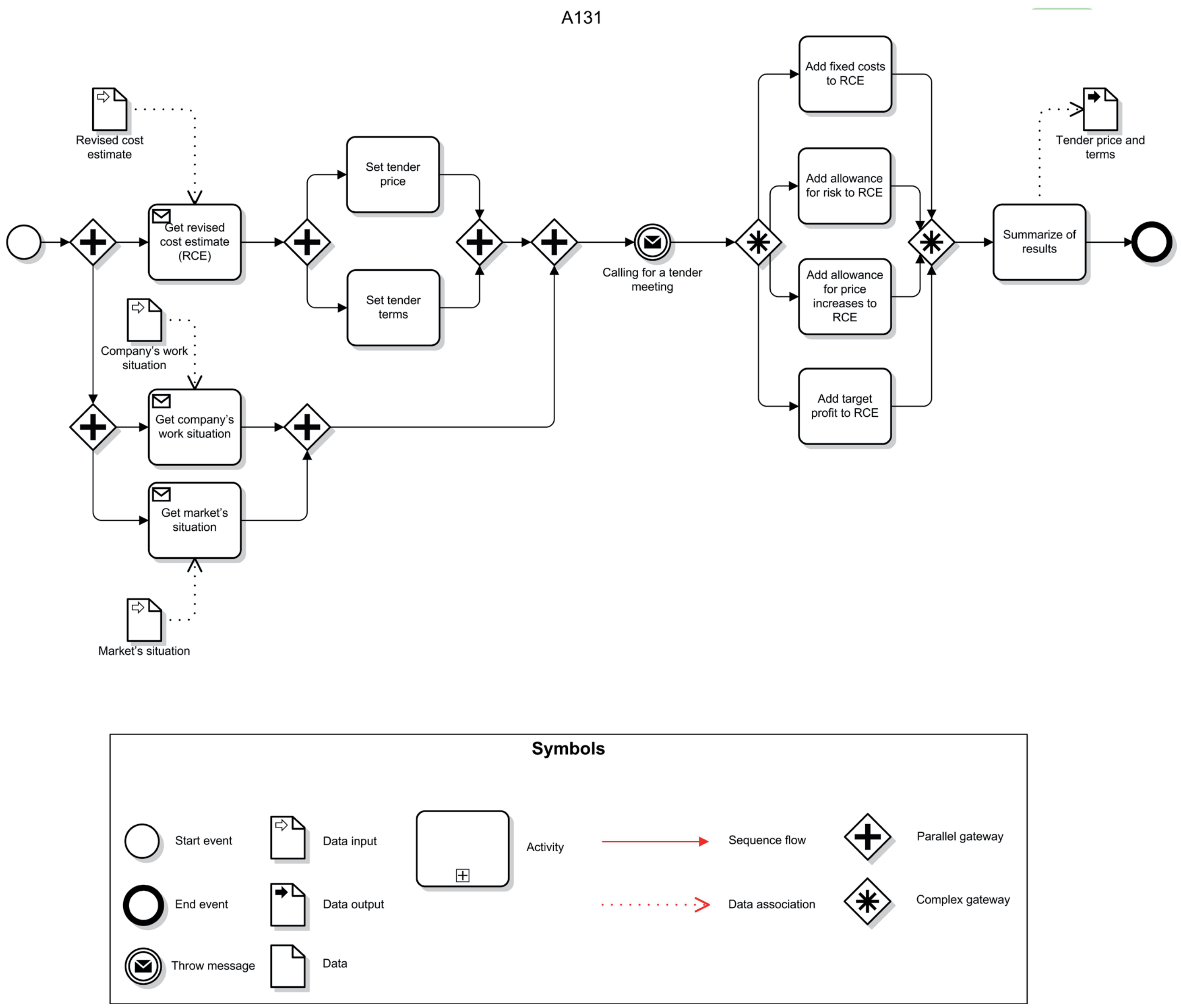

Fig. 5 One subpart (A131 – set tender price and terms) of a construction tender process in BPMN (own work)

view (BPMN). The main advantages of BPMN can be shown in Fig. 5: branches and control events are well represented, unlike in IDEF0.

Figure 6 shows one part (A131 – set tender price and terms) of a construction tender process in EPC (Event Process Chain):

- green boxes (rounded rectangle): functions;
- red boxes (hexagon): events;
- logical connectors: and (∧), or (∨), xor (X).

Compare this process in BPMN (Fig. 5) and EPC (Fig. 6), EPC has a larger flow chart and limited toolbar, so BPMN more effective and it allows a more detailed description. Moreover, in an EPC diagram a function must be followed by an event, so the process description will be unnecessarily large.

The main functions of A131 (set tender price and terms, Fig. 5. and Fig. 6.):

- get: revised cost estimate (RCE), company's work situation, market's situation;
- set: tender price, tender terms;
- calling for a tender meeting;
- add: fixed costs to RCE, allowance for risk to RCE, allowance for price increases to RCE, target profit to RCE
- summarize of results.

5 Hybrid model: top-down and low-level modelling

The basic idea: combine the advantages of each process description method, because there isn't a perfect method for all specific purposes. The IDEF0 notation is best used for top-down modelling, starting with the top processes and breaking down to the appropriate level, to understand the whole process structure. These models are used to get a

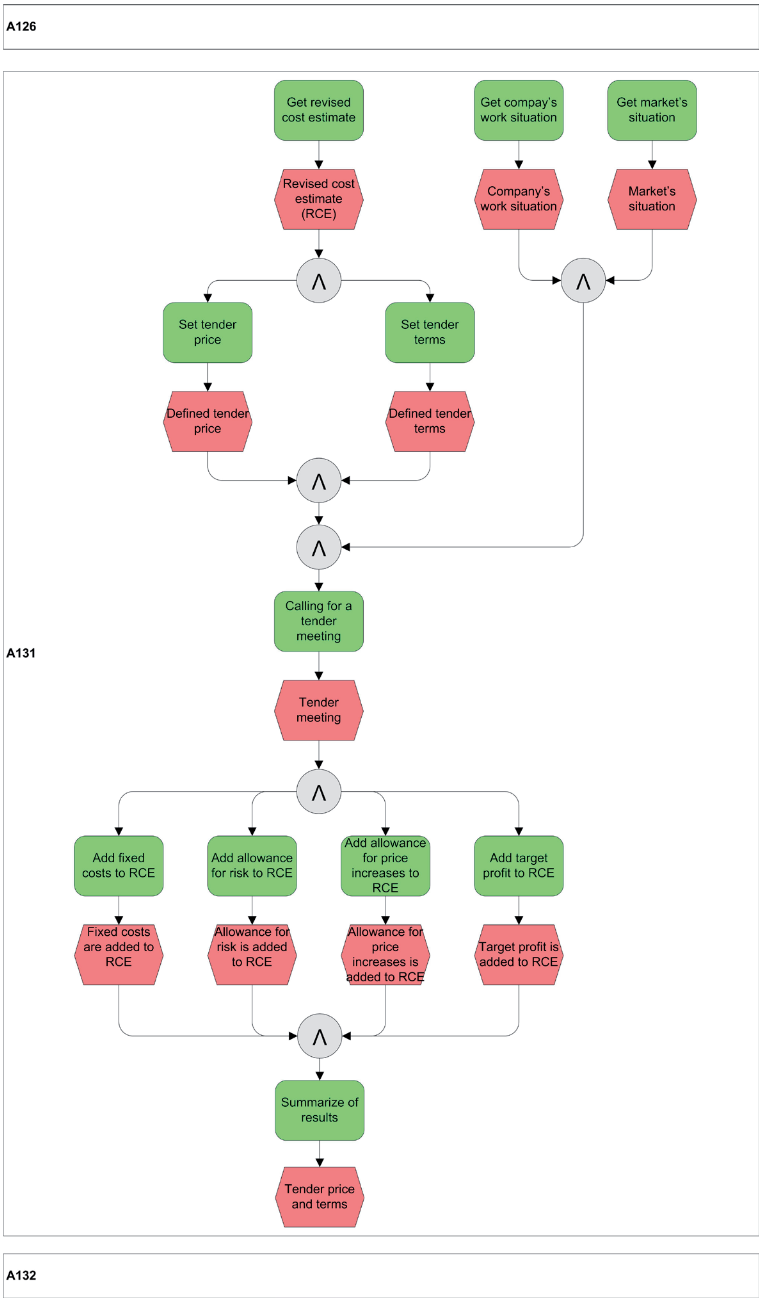

Fig. 6 Set tender price and terms (A131) in EPC (own edition)

common understanding of the process structure and are also used as a specification of how the enterprise processes should be. On the leaf level, it may be best practice to model with an EPC or BPMN notation. BPMN notation is best used for low-level process step modelling (e.g. time handling, exception handling, documentation, responsibilities). This is a detailed level where you start to know the flows, roles, applications, documents etc. involved. Another very important aspect is the connection with lower-level languages (BPEL – Business Process Execution Language), such as BPMN. Table 1 presents the main conclusions in connection with the emerged process description languages (the best solutions get "+").

As an example of potential hybrid application, research at the Department of Material Handling and Logistics Systems in Budapest is aimed to help logistics processes at the construction industry. The work reported in (Bohács et al., 2014) has been developed in the framework of the project "Development of construction processes from logistical and informatical aspects". This research is part of a project (KTIA-AIK-12-1-2013-0009) financed by the National Development Agency of Hungary. This project concentrates on the logistics aspects, where the organization of the material flow is an important task.

As another example, during logistic system development and integration, the system approach and the top-down modelling are also indispensable (Fedorko et al., 2015; Husakova, 2015) So, the hybrid modelling also shows promise as a transportation system modelling tool.

Thus, the hybrid model (Fig. 7) is necessary, which combine the advantages of the certain process description languages. In a hybrid model, IDEF0 is proposed for the process overview,

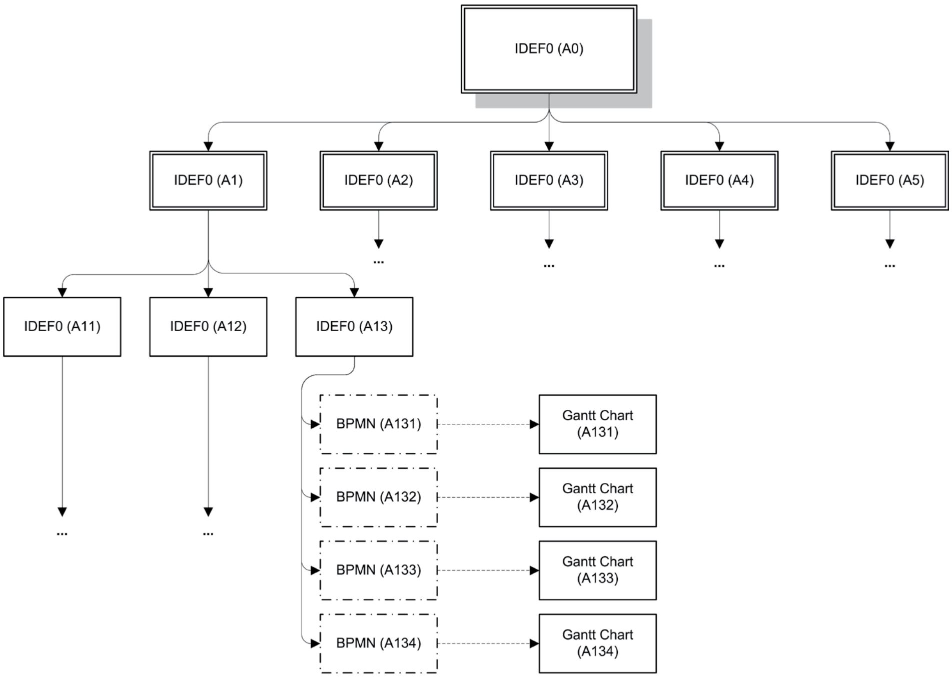

Fig. 7 One possible structure of hybrid logistics process modelling (own edition)

Table 1 Comparison of the emerged process description languages (own edition)

Aspects/Languages	IDEF0	BPMN	EPC
Clearly defined standards	+	+	+
Understanding the global structure	+		
Detailed process description		+	
Transparent *responsibilities*		+	
Branches and decision points		+	
Time handling (e.g. waiting)		+	
Managing *regulatory* events		+	
Detailed related *information* flow		+	
Simplicity (preparation, understanding)			+
Contact with *lower-level languages* (e.g. BPEL)		+	
Graphical display	+	+	+
Software support	+	+	+
Current application in *logistics* process description	+	+	+
Current application in *construction* process description	+	+	

BPMN is recommended for the detailed process description. The role of the Gantt chart is characterizing the time dimension, based on BPMN.

6 Conclusions

Based on the literature review, the most commonly used principle is the Last Planner System and the most commonly used process description methods are the simple flow chart and Gant diagram. Moreover, there are some mentions about formalized process description languages, principally IDEF0, occasionally UML and BPMN. The GEPM model is also promising, which combine the scheduling, the flow charts and IDEF0 method.

Based on the literature, the IDEF0 is best for top-down modelling, and from a certain level, BPMN is best for low-level modelling. Therefore, it is necessary the use of hybrid models from the helicopter view (IDEF0) to the movement's level process description (BPMN). BPMN is probably the best option for the detailed process description, it has a wide toolbar and modelling options.

The main topics of further research are refining features and choosing the most suitable process description languages to handle the construction processes. The hybrid approach may give an excellent base for this.

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