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RULE BASED EXPANSION OF STANDARD CONSTRUCTION PROCESSES

H. -J. Bargstädt *, **R. S. Tarigan**

* *Institute for Construction Engineering and Management*
Bauhaus-Universität Weimar
Marienstrasse 7a, 99423 Weimar
E-mail: hans-joachim.bargstaedt@uni-weimar.de

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Abstract. *The paper introduces a systematic construction management approach, supporting expansion of a specified construction process, both automatically and semi-automatically. Throughout the whole design process, many requirements must be taken into account in order to fulfil demands defined by clients. In implementing those demands into a design concept up to the execution plan, constraints such as site conditions, building code, and legal framework are to be considered. However, complete information, which is needed to make a sound decision, is not yet acquired in the early phase. Decisions are traditionally taken based on experience and assumptions. Due to a vast number of appropriate available solutions, particularly in building projects, it is necessary to make those decisions traceable. This is important in order to be able to reconstruct considerations and assumptions taken, should there be any changes in the future project's objectives.*

The research will be carried out by means of building information modelling, where rules deriving from standard logics of construction management knowledge will be applied. The knowledge comprises a comprehensive interaction amongst bidding process, cost-estimation, construction site preparation as well as specific project logistics – which are usually still separately considered. By means of these rules, favourable decision taking regarding prefabrication and in-situ implementation can be justified. Modifications depending on the available information within current design stage will consistently be traceable.

1 INTRODUCTION

The objective of this research is to demonstrate theoretical possibilities in order to provide detailed specification supporting decisions making in construction projects. It is particularly concerning issues that have not been determined by clients and therefore designers and contractors are completely in charge at free disposal as contracting parties. Background of the research is based in the well-established facts in construction project, that thorough requirements are hardly specified by clients. In contrast, designers are often required to provide alternative solutions in a swift manner. In this case, decisions taken by expert designers are based on a long-term experience, the reasoning behind them are however often cannot continuously be traced by other parties. This leads mainly to problems during design and construction stage, since changes in such long period are unavoidable. Those changes often occur in terms of objective function of the project regarding quality, cost and schedule. Changes emerge furthermore within project constrain, in the design and the work preparation as well as during execution when responding the dynamic of site. Following this, on one hand contractors are hardly able to reconstruct considerations taken by designers during the design process. On the other hand, the lack of complete information typically requires the designers to utilize assumption as a temporary feasible solution. In this case, decisions taken by designer are traditionally based on partial knowledge as illustrated in Figure 1.

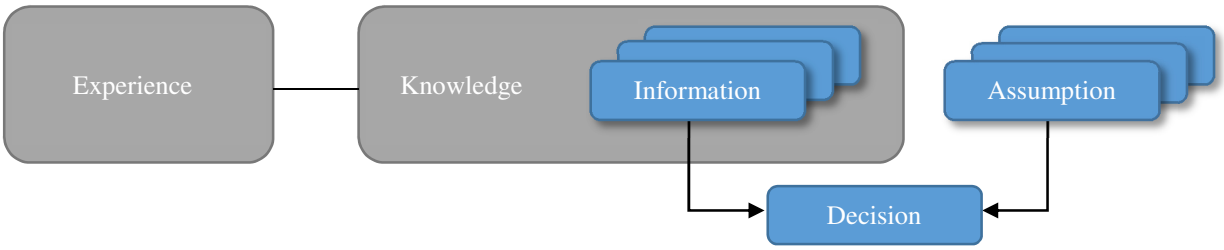

Figure 1: Decisions are traditionally taken based on experience and assumptions.

This paper is going to be compiled as follow: Section 2 will describe basic approach to classify construction management knowledge in regards to construction project delivery type and functional requirements of buildings. Hence Building Information Modelling (BIM) as current possible tool in transferring the knowledge will be proposed. Section 3 will present the concept of rules in expanding construction processes due to standard logic of construction management knowledge. Section 4 will expose examples on how simple construction management knowledge can be represented by means of additional information embedded within the BIM-design tool. Section 5 will draw conclusion and future works.

2 CLASSIFICATION OF CONSTRUCTION MANAGEMENT KNOWLEDGE

The main concern of how to enable traceability of the decisions taken during the early design process is to make the road map of a standard construction process accessible, where construction management knowledge is represented. This knowledge will be classified at different level of granularities, in order to support flexibility when choosing decision path through all different project stages. This is necessary, reflecting the facts that numerous execution alternatives exist, particularly in building construction projects. Hence, decisions and other alternatives should be kept available in transparent manner as a guideline through all different project phases. Furthermore the design elaborating process in such complex construction project is not carried

out sequentially from feasibility study up to execution planning anymore. It is common that during the early design phases, clients and designers have already had specific ideas regarding construction details. Those ideas are however hardly to be transformed in a traditional sequential service structure of architects and engineers, e.g. in Germany called "HOAI" [1] and in USA called "AIA" [2], where only the lowermost performance profile at each design stage is defined.

2.1 Construction Project Delivery Types

The inappropriate type of construction project delivery typically causes an expensive modification of the design and construction process. This fact requires therefore a consideration of project delivery type in early design stage. Hence, clients decide in which project stage contractors should have been involved, in order to engage construction management knowledge. In referring to this decision, designers should be aware of the consequent risks, since designers are not only liable for delivering design performance but also for warranting result to be brought of each design stage. In regards to HOAI, Table 1 illustrates several common types of project delivery [3][4], that make use of different design phase as working basis for contractors. In a traditional design process, designers for example prepare construction documents along with execution drawing; however this method is particularly suitable only for project delivery type number 1, since designers are solely liable for the constructability of the design. Contractor undertakes risks that only based on its own design such as in project delivery type number 4, 5 and 6. Problems occur traditionally at type 2 and 3, where contractors typically can neither rely on design nor on detailed specification provided by clients. The challenge of each project delivery type is how to coordinate interfaces throughout the design processes to be consistently traceable at the time of handover of the design to contractors.

Nr.	Procurement Method	Specification	Contractor Business Type	Working Basis
1	Design Bid Build	Detailed	Single Contractor	Phase 5
2	Design Bid Build	Detailed	General Contractor	Phase 5
3	Design Bid Build	Detailed	Partial General Contractor	Phase 5
4	Design Build	Functional	General Contractor	Phase 3, 4
5	Design Build	Functional	Partial General Contractor	Phase 3, 4
6	Design Build	Functional	Contractor led Design Build	Phase 1, 2

Table 1: HOAI-based working basis for contractor in several types of project delivery.

2.2 Functional Requirements of Buildings

Decision taken according to aforementioned type of project delivery is closely related to demand and desire of clients to be actively involved within design and construction phase. The more clients desire to undertake control of the project, the less designers and contractors are in charge at free disposal as contracting parties. This fact indicates the relevance of building typology, which is implied by its functional requirements. Should projects be procured through functional specification, it is important to consider prestigious aspect of the building, since then clients hardly influence the design anymore. In regards to HOAI, building typology is in general defined through several criteria and reference samples, for which demands on architects involved are described. Those criteria range from buildings that require minimal demands on the architect's performance up to buildings that indicate extreme difficulties of the design process. Buildings which make minimal demands on the architect's performance, for example multi-storey car parks, will be suitable for a design build procurement method. For such buildings with stringent requirements and complex interrelation like concert halls, detailed specification is legally needed.

2.3 Application of Building Information Modelling (BIM)

According to National Building Information Model Standard Project Committee [5], Building Information Modelling (BIM) is "*a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition*". An application of BIM in context of construction management modelling is facilitated by so called parametric modelling, which refers to the relationship among all elements in a project model that enable change simultaneously and can be controlled both automatically by system and semi automatically by user. Moreover process integration can be enhanced through BIM, since parametric objects serve as knowledge container that can be used continuously throughout the design and construction stage.

3 RULES TO EXPAND CONSTRUCTION PROCESSES

In expanding construction processes, constrains arise from each type of project delivery types are firstly and foremost to be systematically identified. In order to make those constrains accessible to be considered by designers during design processes, information templates should be placed within semantic description. Hence construction management modelling serves as working templates, where designers and contractors can feed in knowledge. Rules that embedded in a logical formulas will control the automatic and semi-automatic expansion of the processes. A "what-if-scenario" will be applied. In regards to terms of contract, some decisions paths that are taken along with expansion possibilities cannot be reversed.

Furthermore patterns during construction process should be captured, in order to understand the semantic amongst trade work activities during construction process and subsequently be integrated within Building Information Model. Process patterns for example have been identified when generating a work plan schedule, so that some tasks can be automatically linked together as a work sequence, through rules. Those patterns refer to logical dependencies amongst the tasks such as technological constraints and available resources. However, there are dependence amongst some tasks, for example in a specific site condition, which should only be semi-automatically decided by authorized person [6].

Further approach in order to determine pattern of construction process can already be adopted. In infrastructure projects, working sequence is specifically defined by technological constraints amongst activities of machine and equipment. In building construction projects, particularly finishing trade works, constraints consist of rather on how to prioritize and organize tasks. That what is here known as soft constraints can be handled through weighting certain strategies of each trades work [7]. In combination with various dependency of logistic components, infinite number of strategies can be developed [8]. A more reliable decision support system in executing trades works is characterized by considering the multi-layer constraints [9], where working space and weather condition are additionally included. How to deal with all of those constraints is a representation of construction management knowledge, which can be used to trace decision that supposedly will be taken by contactor in the future.

A consideration of dynamic condition of the construction process in the early design process enables designer to compress specifically vast numbers of design solutions. The complexity of production site during construction process will be hence controllable. When designers understand how the works will be executed, that is to say the language of contractors, the intended

purpose of the building project as well as the proposed standard level of architecture, which represent the demand of clients, can be clearly articulated. Aforementioned considerations are even more crucial in order to procure building projects precisely in regards to meeting technical and quality requirements.

4 EXAMPLE

A simple demonstration of a parametric modelling of window type will be carried out by utilizing a BIM-geometric tool. Window`s utilization in a building is closely related to the type of façade that either opted by client, since they have already been used by or during previous projects; or selected by designer that has already had preferred supplier for the building products in the proposed design. During the design elaboration process, several considerations of the construction process are taken. For example the function of the façade, whether the load of the building is to be borne with it or not; that means the decision taken is simply either punctuated façade or non-punctuated façade. When load is not to be borne, further façade types such as post and rail façade, element façade, curtain wall, etc. are possible to be used. Additional construction aspect that needs to be considered is the side of assembly, whether the mounting process takes place from outside or inside of the building. This aspect will lead either to the requirement of the auxiliary component such as scaffolding or the machinery required such as forklift and crane.

When a punctuated façade is opted for, position and size of the wall opening are significant points for the windows to be mounted. Since loads are to be borne in this case and depending on the wall material, steel reinforcement in concrete wall for instance should be considered. It means there are constraints to be implied in regards to the wall opening in the course of windows design process. Following simple modelling demonstrates the relationship of those elements. Supposed that windows in a punctuated façade should be positioned at least 300 mm from the edge of the wall. The distance between windows should not be less than 600 mm. The height of the sill will additionally be determined as 1100 mm, when presumably that the wall is designed for an office function. For window type size 1100 mm x 1100 mm, a minimum wide space of the wall required is 2000 mm as illustrated Figure 2. These constraints will be applied as preconfigured parameters of a wall opening in a window class as illustrated in Figure 3.

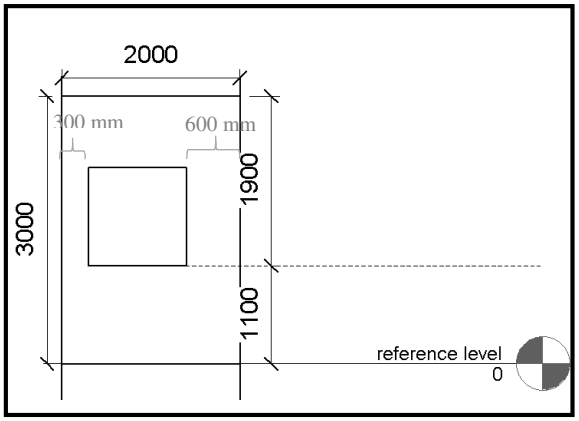

Figure 2: A window family consists of a 2000 mm wide wall and an opening inserted

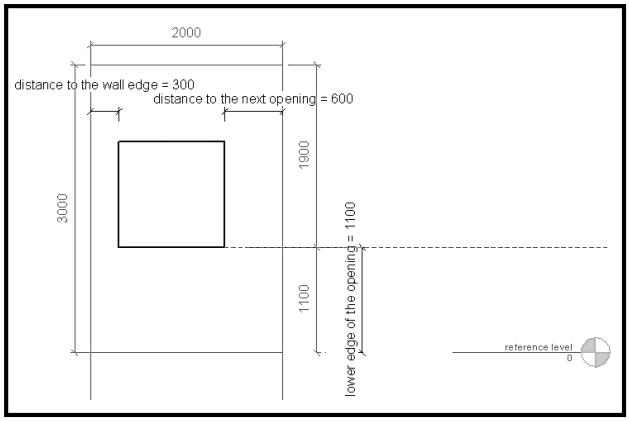

Figure 3: Distances of the opening in the wall-element are preconfigured as parameters

Moreover the wall opening can serve as a placeholder for subsequent detailing of the window. When standard details of some building elements are already acquainted in the early design stage,

it is possible to embed those details within model elements and treat them in several modes of view. In regards to HOAI and AIA, those different modes of building elements are available to be retrieved in every design stage to guide clients during design elaboration process.

5 CONCLUSION AND FUTURE WORKS

Well-structured and reasonable information is a basis of all reliable construction knowledge. A transformation of organized information into knowledge however can only be ensured by means of semantic description. Hence, to provide construction management knowledge as templates accessible for the design process, the corresponding logic and its parameters of construction management have to be aggregated in an appropriate semantic. This paper proposes a construction management modelling method, which will assist designers during the design process by integrating several construction process knowhow in building information model. The possibilities to expand construction processes through the modelling method are defined typically by constrains arise from construction project delivery type and functional requirements of the building. By using a simple geometric example it is demonstrated that several construction management parameters can be embedded in early design stage. This will be starting point for the future works to develop the construction management modelling method. It would hence to be expected, that those parameters and their interfaces are going to establish a logical consequence of the functionality, construction and form.

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