Effect of Subcontracting on Construction Scheduling

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Abstract: - The right sequence of construction works and their positioning in time-schedule are unavoidable prerequisites for a high-quality construction process. Often a prepared schedule has serious problems in ignoring the necessary technological sequence of works or, if the technological order is correct, due to a lack of flexibility in case of any unpredicted changes. The necessity of planning the construction process according to various limitations and changes, technological correlations and resources provides a challenge to create a model that would allow preparing flexible schedules for construction tasks. Such a model should take into account the conditions, limitations and possibility of changes for specific construction sites on a case-by-case basis, and thus planning correctly the share of subcontracting. The paper discusses the possibilities for preparing a construction schedule and the effect of subcontracting within it. Also, the initial conditions and parameters of the simulation model for evaluation of different management strategies are determined.

Key-Words: - job sequence, scheduling, subcontracting, simulation model

1 Introduction

Scheduling the construction process demands clear formulation of the desired output and good knowledge of building technology in order to provide the optimal task sequence necessary for achieving the planned duration and quality requirements. As a rule, the construction process is managed by methods of project management due to the project-based nature of construction [1, 2]. The arrangement of the combination and sequence of tasks should enable the production of high-quality buildings, erected within strict time and resources constraints. Thus, Hendrickson [2] differentiates three categories to which special attention should be paid: initial prerequisites for construction, quality of the construction process, and quality of the completed constructions.

This paper concentrates on discussing the construction process and understanding the functioning mechanism of this process in order to find ways to improve it. The focus is on general construction works performed on building sites. It does not include the construction of roads, streets, utility networks, highways, bridges, etc. The paper provides an overview of on-going research in the Department of Building Production of the Tallinn University of Technology (TUT), directed towards establishing a simulation model for evaluation of different management strategies from the point of view of determining the share of subcontracted works within a construction project. The simulation model enables the rehearsal and assessment of different management strategies in the lab in order to increase the awareness of the project participants, and thus improve the quality of construction as on-site decisions become more flexible with regard to the management of processes. The term “technology”, as used in construction, means the processing of initial objects in a certain way, in order to produce a desired output; and organising construction works means implementing the chosen management solution on the construction site. We absolutely agree with Howell and Ballard [3] that no solution can be considered to be the only right one in construction; there is always a range of possible alternatives, positioned on a wide spatial scale, but solutions are assessed by projecting them onto a specific situation. The advantages of one solution can outweigh the disadvantages of another and the results of risk assessment can cause an otherwise good solution to be dropped from the set of suitable alternatives. This is why simulation modelling might give the best answers depending on the interests of parties involved.

2 Factors influencing the scheduling of construction works

The usual initial conditions, on the basis of which the planning of construction activities are started, are detailed plans, results of environmental and construction surveys, construction design, building permits, and the construction contract with its annexes [4]. Aspects having a very important role in planning the construction process include the expectations and requirements of the owners, consultants, and other parties related to the construction activities. Very often the client sets time limits and directions, e.g. intermediate milestones, and this influences the schedule of tasks. On the other hand, the choice of technology alternatives is affected by the activities of the supply sector, e.g. the possible supply schedule, deadlines dictated by suppliers, realistic times for manufacturing the necessary precast elements, etc. Other factors influencing the time scheduling are seasonal limitations, financial requirements, conditions of construction site, geological circumstances, the dendrological situation, etc. The schedule of tasks is also affected by initial conditions related to the construction market (availability of labour resources, materials, information, etc.). A construction schedule is limited by an insufficient or inadequately estimated construction duration, lack of resources, lack of information, poor knowledge of building technology, unsuitable materials, changes in the market and financial situation, legal limitations, etc. [5, 6]. The simulation model would allow the determination of the probability and intensity of initial, influencing or limiting factors by using the relevant evaluation system.

2.1 Impact of contracting method on task planning

According to statistics, the contracting method utilised has a significant effect on the establishing, functioning and changing of construction schedules. According to Estonian building statistics [7] the usual contracting methods in the Estonian construction market are illustrated in Figure 1.

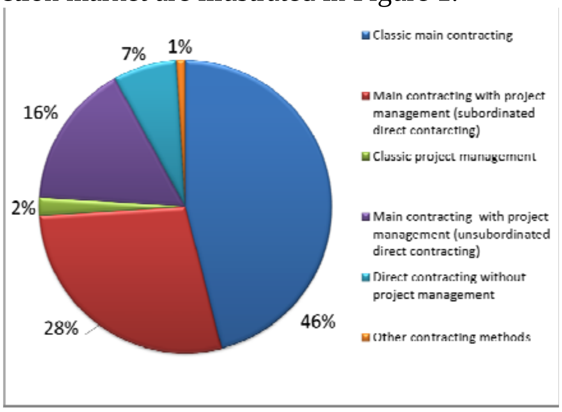

Fig.1 Distribution of contracting methods in Estonian construction market

The analysis of the set of construction sites has also yielded the main proportions of use of subcontracting. Every contracting method has a differentiable effect on the establishing of the construction schedule; the model deals with determining and mapping these effects. There are several general methods that are commonly used and embedded in commercial project management solutions: the Gantt chart and the Critical Path Method (CPM). A similar method to CPM, the Program Evaluation and Review Technique (PERT), provides a probabilistic approach to scheduling. However, the CPM and PERT methods do not consider the resource constraints in planning in advance. This usually makes the produced schedule unreasonable. A Critical Chain Scheduling (CCS) method aggregates and concentrates safety in the form of buffers that are used in protecting project target dates from variation in schedule performance, and in maintaining focus on the 'critical' activities [8]. In case of main contracting, the main method of preparing construction schedules is the CPM and the performance of critical path tasks with own resources [2]. In the case of main contracting with subordinated management, the preferred method of preparing schedules seems to be the CCS (in addition to critical element monitoring, task overview control etc.). Methods of simulation modelling also allow the inclusion of buffer objects (projects with no time limits) in order to provide an even workload [9].

2.2 The impact of site arrangement on construction scheduling

The establishing of construction schedules is significantly influenced by the decision-makers' awareness of the methods of performing tasks and their skills in implementing those methods in a justified manner. The common scheduling method of construction works for more complex constructions involves dividing the buildings into horizontal and/or vertical working zones and dividing the group of tasks into clearly distinguishable work sections which can be performed as a unified integrated unit. Within these arbitrary zones, the tasks are then organised according to the linear, parallel or articulated method. In the first case, the processes follow each other in a simple progression; in the second case, parallel resource sets are used; and in the third case, the resource sets are exchanged between the work zones in a calculated manner. In the latter case, the scheduling also includes combining and timing activities, in order to achieve a synchronicity of continually moving construction flows. For example, repetitive projects such as multi-story building allow working with rhythmic planning [10]. Hinze [11] examines mainly two methods of resource allocation: the series method and the parallel method, but actually, real processes in construction require more complex approaches to respond to various special demands, including economic considerations. Thus the linear scheduling may not be appropriate under any conditions.

2.3 Impact of technological sequence on construction tasks

The technological sequence of construction processes plays an important role in the composition of possible time schedules. A technological sequence is considered to be a sequence of works ordered according to their nature and characteristics; this must not be confused with the sequence of tasks stated in the planned schedule [12]. Correlations are determined by studying the draft plan of works, their descriptions and articulated structural list. A technological sequence of works may be a sequence of either absolute or complementary correlations. A calculation of the sequence involves choosing between various alternative technologies, increasing the flexibility of schedules in order to diminish the risks. Bertelsen and Koskela also find that "*…what we seek is a tool assisting project management in assessing the risks at the outset of the project and before it turns chaotic, and in pinpointing the sources of such risks*" [13]. Inappropriate, planned technological sequence is one of the greatest hazards. There are few known results for optimal sequencing of systems to minimize setup costs or setup times. One of the reasons for this is the complexity of the problem [14]. Also, the implementation of unplanned schedule compression is common in the construction environment [15]. Complementary correlations between tasks are, for example, external connections, conditional correlations and hidden correlations. Proper planning and implementation of site tasks is possible only if the correlations between tasks have been taken into account correctly from the beginning of sequencing and scheduling, and if the secondary correlations of tasks are possible to reassess so that corrections can be made in the task schedule if necessary. The model to be established in the course of this study will make this easier in the future.

The most commonly used techniques for setting the technological correlations between works are the articulated list of works with a line graph on one hand, and the review of their assessment with a network graph on the other hand. With both of these approaches, a visual image of the technological correlations is established, which is then combined with a data representation. It is most important to establish an image that provides the preparer with information about both the absolute correlations and the secondary correlations. In order to display the complementary relationships, it is necessary to articulate the list of tasks in such a way that it would reflect all significant markers of the nature, components and properties of the tasks. The best approach to achieve adequate determining correlations and to complete the initial task-sequence procedure is using pre-articulated task lists or standards [16]. On the other hand, preliminary work lists cannot be specified further without knowing the nature of their components. There is no method that would allow the preparation of a distribution list without knowing the contents of construction works. The absolute correlations between construction works allow the preparation of only a coarse, inflexible and rigid model. The complementary correlations allow specifying the model further and changing it to suit the current needs. The most important aspects of an articulated list of works are the correct level of detail and the necessary comprehensiveness of the list. As indicated by the study and various sources [16], [17], it is impossible to create articulated lists of tasks via the method of a step-by-step approach and instead the method of moving from the whole to detail on the basis of classification of types must be used. With further articulation, the list is made suitable for determining correlations, and primary and secondary correlations are identified. The optimal number of records depends on the nature of the works and construction site, and takes into account the borders of work zones. There is a special term – reengineering - related with process treatment when interferences occur within the project schedule. We do not agree with Kwak *et al*, stating that „*… in rough terms, about 20% of any reengineering project is analytical and strategic planning, and the other 80% is implementation details*“[18].

2.4 Impact of labour demands, time norms and time limits

The scheduling of construction works is significantly influenced by the time limits which may result from normative-computational, empirical or declarative factors. In all cases, the preparation of the schedule is very much affected by the adequacy of the initial data and also by how realistic the forecasts are made. If no actual construction activities have been performed yet, then only preliminary forecasts of labour demand and time demand can be used. As the construction activities progress, the actual data collected from the process can, and should be used in a certain way [19]. The financing schedules are usually already prepared at the beginning of the construction activities, thus any deviation from forecasts brings along changes in financing. This study looks at the possibility of improving the usability of the normative databases and reducing the over- and underassessment of risks. For this, the content of the time norms used as a basis of the calculations must be classified and their applicability verified (for example by chronometrical measurement).

3 The role of subcontracting in the construction process

Subcontracting is used in construction primarily for performing specific, pre-determined types of construction works. Traditionally such firms act as trade sub-contractors to a general contractor [20]. The advantage of subcontracting is that the party performing a task is specialised in that particular type of construction task. This creates the advantage of the subcontractor’s competence and legal readiness for performing the relevant work section and to take responsibility for the warranties related thereto. It is characteristic for subcontracting that the subcontractor is always subordinated to the management and supervision by the main contractor and the main contractor is essentially the party ordering the performance of tasks from that subcontractor [21], [22]. Subcontracting must not be confused with employment or direct contracting. Subcontracting or restrictions on its use change the structure and flexibility of the construction schedule; the use of subcontracting can also be restricted by the main contractor’s wish to perform profitable or critical tasks with its own labour [23]. Applying sub-contractors in real processes is related with cost-planning in pre-phases and there is possible over- or underplanning. It seems that multiple layers of sub-contracting add enormously to the overall construction budget but the use of sub-contractors varies appreciably [24]. In its later stages, this study will also discuss the effects of subcontracting on the task schedule. For example, it has turned out that the use of subcontracting significantly improves the possibility of reassessing the technological sequences of tasks with certain parameters, thus improving the flexibility of the schedule. Correct assessment is very important, as it allows continual updating of the schedule of construction tasks and avoiding the inclusion of processes with excessively high risk levels from the start.

3.1 Preparing the model for evaluation of the effect of subcontracting

In the field of construction, models can be divided into 2 main groups: models with the purpose of preparing management solutions, where optimum time schedules are established against particular techno-economic parameters, and models for studying the productive and economic performance in which the simulation experiments enable the examination of the interaction between the parameters of modelled processes [25]. In object-oriented modeling, large and complex problems are decomposed and modeled as a set of objects [26]. This study discusses the first type of model, i.e. time-scheduling in order to find the best management strategy from a subcontracting viewpoint. In all cases, first the typology of the observed constructions is identified (as per categories based on functional and/or structural identifiers [25], and then the main list of tasks is determined for each of them on the basis of the type of constructions. Technological absolute correlations of the tasks included in the construction processes are set from the first-level articulated lists, which are then mapped as a network graph differentiating the start and end, duration, and other parameters of each individual task. The initial categorisation and classification of correlations is a necessary prerequisite for the follow-up work. Thereafter, the lists and graphs are extended, secondary correlations are identified, and the effects of the initial prerequisites and conditions on the technological sequence are determined. Mapping the effects to a matrix table shows the intensity of the effects and the interrelations between them. The model provides a visually perceivable image of the network of correlations and provides the possibility to calculate the parameters of construction schedules for every combination of initial and limiting conditions. It would also enable decision-making with regard to involving subcontractors or choosing between alternative technologies. For example, according to [3] coordination between organizations or crews is primarily controlled from a central plan that establishes sequence and determines when an activity will start. This model integrates basic factors that affect scheduling in different construction projects: construction work classification and description, initial conditions, limits and constraints, the impact of contracting method, the impact of the site arrangement method, the impact of technological sequence, labour and subcontracting demands, time norms and limits, etc. Simulation modelling also enables the management of buffers and recast job sequences. The principle outline of the simulation model is presented in Figure 2.

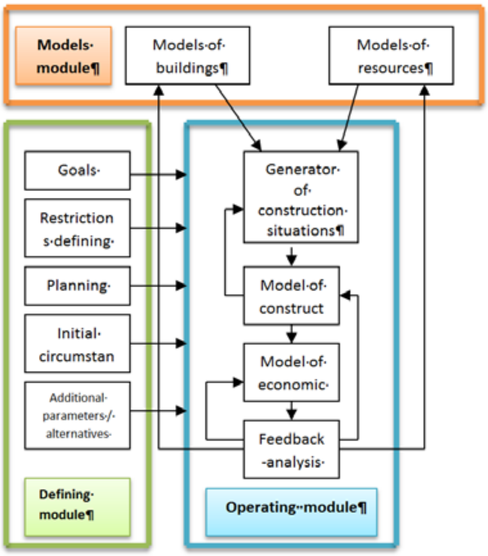

Figure 2. Principle outline of the model

4 Conclusions

The strategies of managing subcontracting depend on the initial and limiting conditions of the construction works, on the contracting method, the method of organising the works, the correct assessment of the technological correlations and labour demands and on the preparation of the construction schedule according to that. When assessing the appropriateness of the time schedule either under subcontracting or with the resources of the main contractor, the first step is to verify whether the planned schedule conforms to the requirements of the technological absolute correlations, and to assess the effectiveness of the method for the organisation of tasks, the adequacy of the time limits, etc. After that, it becomes possible to identify the effects of the initial conditions of performing the construction tasks, the dynamic conditions, the technological dynamic correlations, etc. on the schedule of tasks via modelling and to use that information for optimising the schedule. This paper provides initial information for the development of the simulation model, and enables the focussing on the development of the model's components and interoperability in the subsequent stages of the study.

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