CALCULATION OF THE CONSTRUCTION TIME- SYSTEMATIC MANAGEMENT OF PROJECT UNCERTAINTIES IN RUSH PROJECTS IN MAKKAH

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Abstract

New fast track construction projects worth more than $100 billion are being implemented in Makkah to improve services being rendered to millions of pilgrims who come for Hajj and Umrah. The new development projects in Makkah, including largest expansion of the Grand Mosque. The time factor has become increasingly as an outstanding requirement on this construction projects. In the present work, the question "acceleration of construction projects" is moved in the center. Consequently, innovative structures, procedures and techniques are required for a time-oriented project management; consistently and purposefully focus on the reduction of process time and not to shrink back from entirely new, unfamiliar processes. so recommendations for the efficient management of construction projects always need to be developed taking into account the specific objectives and framework. This article discusses also the deterministic method, the simplified stochastic method and the application of the Monte-Carlo simulation as a stochastic method. With increasing of level of detail of the information content of the project and increases the calculation effort with the result that the range of the construction time decreases, thus the accuracy increases. Based on this range, finally the construction time of the building as well as the part times for the individual construction phases are determined.

Keywords – *Construction industry, Risk management, Construction Projects, project uncertainties, fast track projects, construction time, project management*

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1. INTRODUCTION

The construction time is an essential indicator of the project success, as both the construction cost and quality are significantly affected by the construction period. The construction time is usually given from the client. The construction time should be respected by the contractors or their subcontractors subsequently. The client has to manage those conditions as part of his contractual obligations that ensure the compliance of the construction time. New fast track construction projects worth more than $100 billion are being implemented in Mecca to improve services being rendered to millions of pilgrims who come for Hajj and Umrah. The new development projects in Mecca, including largest expansion of the Grand Mosque. An important requirement for a fast track construction project is the stability in the project and the project environment. To calculate the construction time, quantities and performance rates are required. If the project is being considered as a whole, for example, the gross volume of the building or tunnel length in the transport infrastructure is used for the quantity calculation. The quantities are calculated from the plans. The precision of the calculation of quantities depends on the considered phase of the project and the associated level of detailing. In early project phases, the calculation of quantities can be specified only in larger ranges. From these uncertainties and due to the fact that the nature and scope of activities and the range of the activity performance cannot be accurately described or identified, it is also possible to estimate the production factors only within a range. These uncertainties in earlier stages of the project are higher than in later ones. Based on the level of information, trying possible combinations of the production factors will be developed in order to get approaches for the production performance. With the production performance, on the one hand the client can close on the construction time and on the other hand the bidders or contractors subsequent to the required use of production factors.

2. AIMS OF THE STUDY

If you can determine the specific project requirements highly efficient procedures only as a function, so recommendations for the efficient management of construction projects always need to be developed taking into account the specific objectives and framework.

In the present work, the question "acceleration of construction projects" is moved in the center. This is because the demand structures and needs in the real estate market are changing faster and faster. A short planning and execution time is becoming increasingly clearer to an outstanding performance feature of construction projects. Expected and more often in the future a particularly short duration even become a decisive factor in the choice of the project team.

The acceleration is even from the construction perspective an interesting challenge, but it is neither an exclusively technical problem nor a matter of scheduling. The acceleration of construction processes is primarily an organizational and "group dynamics" challenge for the management. It must never be based on the setting, but everything as before, but a bit faster.

If the short duration of a project is based only on Pressure so suffers both the psyche of all interested parties and the quality of the work. Consequently, innovative structures, procedures and techniques are required for a time-oriented project management; consistently and purposefully focus on the reduction of process time and not to shrink back from entirely new, unfamiliar processes.

3. THE TIME FACTOR AS A CHALLENGE FOR THE CONSTRUCTION PROJECT MANAGEMENT

In recent years, the time factor has become increasingly as an outstanding requirement on a construction project. This is due to an attitude change towards the real estate and due to a tougher economic environment. A construction must more often not only cheap and functional, but also can be offered to the tenant or buyer as soon as possible. Particularly in the commercial and industrial sector buildings are also becoming less as long-term investments and more and more considered as a commodity. If "time to market" is the decisive criterion, so long-term construction processes cannot be accepted. Industrial construction projects often have a compulsory given time limit - and often to be available only for a certain period of time.

3.1 Restrictions in the Fast-Track Construction Process

Although the factor still so clearly moved in the foreground, but all other relevant objectives of the work must lie within a common or usual objectives scope. A high speed may not be acquired through poor quality or unduly high costs. The investment in a plant or in an investment property is only useful if the construction costs stay within a reasonable budget and the functionality is fully guaranteed.

3.2 Acceleration as an Organizational Problem

Suitable tools and the required basic knowledge of the project management are a prerequisite, they bring alone but no acceleration of the construction process. Also the constructional engineering provides today many approaches for speeding up the construction work, but their effectiveness begins only at an advanced stage of the long construction process. If they are also not included in the early stages of the project in the planning, so they only develop a minimal effect. In contrast, when considered as whole project cycle time period from the decision of the implementation of a building till its commissioning, so often the early decisions and concepts of the customer, the authorization phases or the pre-engineering project will be the more time-consuming sections. With the acceleration of construction projects is then rather more an organizational than a technical problem. The determination of the basic organizational principles take places, together with many other dominant elements, even in the earliest stages of the project through the client.

4. PRAGMATIC ACCELERATION AND TACTICS INNOVATIVE TIME MANAGEMENT

The problem of a very tight schedule is not new for the construction practices. It is confronted with a demand for a very fast implementation of projects and usually reacts with the following tactics.

- **"False shortening" of the operation duration**
  When scheduling of construction projects is not infrequently assumed from luxuriantly designed schedules. A first reaction of the urging of the client to an acceleration is now to reduce the long-term operation durations. However, it is not a real time reduction, but only to the reduction of unnecessary time reserves.

- **Acceleration through consistent project management**
  Since in many project planning, not the same attention comes up to time-related aspects as the cost or the functionality, a first acceleration can be achieved by the intensification of scheduling and monitoring. By increasing use of techniques of scheduling, an optimization is obtained. However, only negligence can be prevented and deadlines are met more easily. With these measures, neither innovative methods nor organizational changes are involved.

- **Project acceleration by streamlining and concentration**
  In the context of known project processes, a change can take place in the priorities of the Costs and the design of the deadlines. Under our clear prioritization of the period falls easier on all parties, the streamlining of all activities and deadline focus formation. Backed by a strong, competent project management, with emphasis forms the corresponding priorities in the formulation of guidelines, priorities set by current decisions and allocation of resources and (out) and a rigorous, advanced project controlling operates, a substantial acceleration can be achieved.

- **Minimum project duration by massive use of resources (crash projects)**
  Already, the construction industry is in a position under exceptional conditions to cause massive acceleration. This is usually done by the extraordinary use of resources, and by the application of special authority and an extraordinary motivation impact for all involved. However, this type of acceleration has its price. Other activities will be postponed or left undone, and the project team is under a non constant to be maintained pressure. This approach should therefore remain an exception.

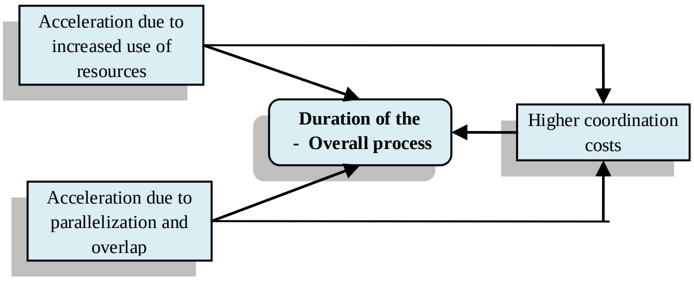

Fig.1. Duration of the process as a function of increased resource utilization and parallelization on the one hand and increasing coordination effort on the other hand

The parallelization of sub-processes offers as well as the higher simultaneous use of resources an enormous acceleration potential. But there is a significantly greater coordination and communication requirements, which in turn can cause loss of time.

5. PRINCIPLES FOR THE ACCELERATION OF CONSTRUCTION PROJECTS

The duration of an overall process is determined by the processing time, the waiting time between the individual processing steps and the time sequence of individual sub-processes. The easiest way is to shorten the processing time. This can be done through the use of additional resources or technical tools, but predominantly through the use of know-how. The waiting times between processing cycles can be traced back to missing information or to a suboptimal organizational structure. To their reduction especially the interactions between the involved subsystems or processes are optimized. For each information flow and every interaction takes time and increases the risk of waiting times. The largest accelerating effect can be achieved by clever variations in the sequence of the individual sub-processes of an overall process. Corresponding sequence patterns can be aimed on the elimination of individual sub-processes, their overlapping or simultaneous processing, but also to the "redundant" problematic part machining processes.

Accelerating action on these three levels (processing time, reduced wait times or less interactions and variation in the sequence of sub-processes) are always interrelated relationships. Therefore, a key objective in the organizational design must be the reduction of interactions and dependencies by decomposition. It creates the prerequisite for rational to edit individual packages can be formed and can be connected in parallel processes efficiently.

5.1 Time Effectively Process Elements

The traditional project management focuses on the optimization of specified sequences by the use of traditional processing techniques of scheduling. It begins with an optimal use of resources and the elimination of non-value added time periods. In an innovative time management, however, are all basic possibilities of action of interest that have an influence on the duration of the overall process. This can be derived from the following schematic illustration of a sequential workflow in the industry.

In construction projects, exist the same approaches for acceleration:

- *Reduction in the processing time*: The processing time depends on the human, technical and professional capacity. Management has influence through the planning and the supply of the necessary resources and the selection of appropriate technical tools.
- *Reduction of waiting- or lay-time between the processing steps*: between the individual work steps, it always comes back to lay time. This may due to lack of capacity (for seamless further processing) or
- Be caused from the available information. You will face the classic management especially with efficient scheduling and resource planning. A higher-level organizational approach seeks, however, after the reduction of dependencies or interactions between individual processing steps.
- *The sequence of sub-processes*: In a conventional approach, the individual steps are processed sequentially. The nested, parallel or early implementation of processes represents a time-effective alternative to the sequential processing.

6. DETERMINANTS OF FAST-TRACK PROJECT

The speed of construction projects is predetermined in the earliest stages of the project by the customer. He is responsible for ensuring that the truly dominant performance determinants are taken into account as early as the project start. The ability of the co-operation of the overall system. The rapid construction project is the result of many individual measures, but finally the performance of an optimally functioning, highly productive overall system.

The most important approaches:

- *The ability of the co-operation of the overall system:* The rapid construction project is the result of many individual measures, but finally the performance of an optimally functioning, highly productive overall system.
- *The complexity of the structure:* the simpler the building and the construction process are structured, the greater the acceleration potential.
- *The collaboration between the client and the contractor:* the purposeful work on all parties to a clearly defined end state toward the faster the project proceeds. Uncertainties and changes in the requirements slow down the project by a variety of information gaps, additional clarifications and multiple repetition of work already undertaken.

7. RELATIONSHIP BETWEEN COMPLEXITY AND PROJECT DURATION

The more parties involved in a project, the more complicated the construction tasks to be solved, and the more objectives or possible developments (high dynamic range) to be taken into consideration, the more difficult it is the design of objective-based, efficient and above all fast project process. There is a direct relationship between the complexity of a project and its duration. So take for example, many projects longer than necessary, or get out of hand,

- By the "construction" of unnecessary dependencies in the task and the project organization, for example by emphasizing claims of secondary importance, unnecessary complexity is established.
- High flexibility and late decisions are sought by many clients and parties involved in the project have to work in unsafe or variable objects.
- The project organizations by escalating functional differentiation and Long information paths are unnecessarily bloated. Through many dependencies decisions are delayed and responsibilities “diluted".

8. RECOMMENDATIONS FOR THE ACCELERATION OF CONSTRUCTION PROJECTS

The acceleration of construction projects is primarily a question of the organization. The project management must always be oriented from the first phases of the project in hand, through an appropriate design of the project and project organization to get all activities with a high speed.
Thus, the contribution constructional and technical measures cannot be negated, These will bring their accelerating effect but only in the later stages of the project and only if appropriate conditions have been created previously.

9. BASES FOR THE CALCULATION OF CONSTRUCTION TIME FOR THE EXECUTION STAGE

The number of parameters for the calculation of the construction period depends on the project phase. Some few values are needed for rough construction period inquiries more hundred values for the calculations for detailed considerations are depending on consideration depth required.

The calculation equations are represented and described for duration, performance and complete cost value in the following which are required for a rough calculation in the phase's building shell. These calculation equations form the base for all further methods of calculation. As production quantity cubic meters of reinforced concrete will be used.

The presented calculation methods do not replace detailed considerations for the calculation of construction time and construction costs.

10. METHODS

10.1 Deterministic Approach

The length of the construction time has essential influence on the construction and very well also on the planning process. At ‚normal‘ construction time, where the limits don't have to be exceeded for economic use of the factors of production, these factors still can be planned optimally. The shorter the construction time, the higher also is the demands to the planning process. By the project management for a short construction time, it must be considered, for example, how is the lack, because it is not installable, cranes can be compensated by other means of transport or other construction method.

As a rule, too short construction Times are provided for construction projects with regard to productive use of the factors of production. However, long lead times contrast for competitions and the planning with the short construction times.

10.1.1 Calculation of the duration of the Reinforced Concrete Works

The duration is calculated in the deterministic approach as a scalar quantity. For each calculation passage scalar quantity for each parameter will be used. As input parameters for the calculation, for example, base values are used. Basing on these base values in terms of opportunity and risk assessment, the final values are determined for the calculation passage.

For Eq. 1 with the average values for the quantity of concrete BT_M [m³] and performance L_{STB} [m³/d] the duration D_{STB} [d] is calculated.

$$D_{STB} = \frac{BT_M}{L_{STB}} \tag{1}$$

To the consideration of disturbances in the calculation, a buffer $PUS_{TB,Z}$ [%] should be included which leads to the following equation.

$$D_{STB,PU} = D_{STB} * \left(1 + \frac{PU_{STB,Z}}{100}\right) \tag{2}$$

The amount of buffer depends on the complexity of the construction and the number of construction stages in winter. From our experiences it has shown that the buffer is between 5 and 15%. In 'normal' construction time the buffer should be at 5% and at least at 15% for a very short construction time.

The buffer takes into account, for example, additional performance or project unawareness

10.1.2 Daily Performance of the Reinforced Concrete Works

The average daily performance for the reinforced concrete work L_{STB} [m³/d] is calculated according to to Eq. 3 In the numerator it result in multiplying the number of workers AK_{STB} [Std/h] with the daily working AZ_{STB} [h/d] the daily labor hours.

The denominator is the total cost value AW_{STB} [Std/m³] for the reinforced concrete work.

$$L_{STB} = \frac{AK_{STB} * AZ_{STB}}{AW_{STB}} \tag{3}$$

In Figure 1 are shown decisive influences on performance. This serves as an exemplary presentation of a qualitative assessment of risks and opportunities portfolio.

The average performance can be calculated for the entire construction or individual structural components. Depending on the level of detail of the project and the project stage, typically rise the accuracy of the input variables and thus the calculation result.

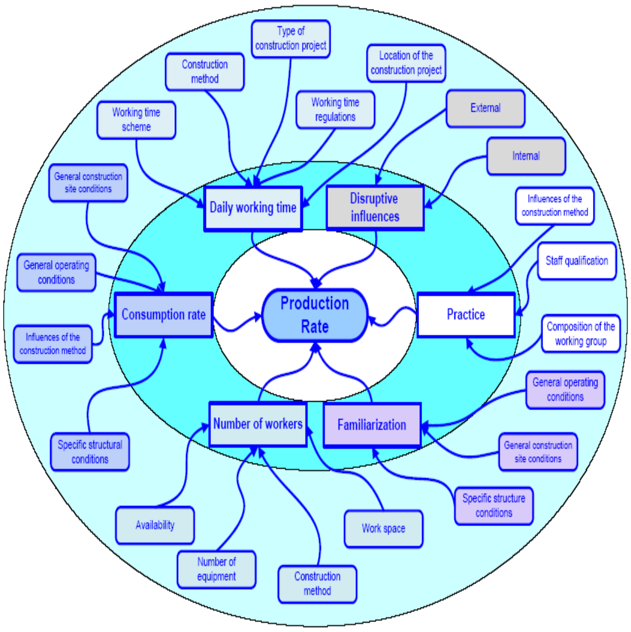

Fig 1: key influences on performance [Hofstadler]

10.2 Simplified Stochastic Approach

For the simplified stochastic calculation method also deterministic calculation rules are to develop. However, for the calculation operation is not one value per parameter required, but three values. In addition, three values must be chosen for the probability of occurrence.

10.2.1 Flexible Method

For the respective input values in the calculation equations respectively three values are used, namely a minimum value, a most frequent value and a maximum value. These values are multiplied by the respective, subjectively defined probability of occurrence. By adding the three products you get the subjectively most probable value

For the probability of occurrence ($P_{EW,i}$) applies::

$$\sum p_{EW,i} = 1 \tag{4}$$

10.2.2 PERT-Method

The PERT method assumes a fixed distribution type, the BETA-distribution. In the PERT method three input values to calculate the desired value is required. The counters are the minimum and maximum value, unweighted and weighted with 4 common value used. The three values are added together and the weighted average the weighted mean average value formed from this.

$$Duration = \frac{1*\text{Optimistic value} + 4*\text{frequent value} + 1*\text{pessimistic value}}{6} \tag{5}$$

In addition to this balanced approach, there are two asymmetric approaches. Werner argues in his dissertation, an optimistic and pessimistic calculation equation.

In the optimistic calculation, the weighted value higher than the optimistic and pessimistic, the calculation is done according to Eq. 6

$$Duration = \frac{2*\text{Optimistic value} + 3*\text{frequent value} + 1*\text{pessimistic value}}{6} \tag{6}$$

On the other hand, it is by the pessimistic analysis the pessimistic value is evaluated with a higher value. The calculation is performed according to Eq. 8

$$Duration = \frac{1*\text{Optimistic value} + 3*\text{frequent value} + 2*\text{pessimistic value}}{6} \tag{7}$$

10.3 Monte-Carlo Simulation

The Monte Carlo method, for example, allows the calculation of the probability distribution for the construction time. In an arbitrary number of iterations generates a software program (in this case @ RISK) for the input values random values, which are used in each pre-defined probability density functions, and combines them for a given calculation rule (the calculation equations of the deterministic method), the distribution function of the results.

- The input parameters are:
- fluctuation margin

- The most probable value (if possible according to the selected distribution function)
- Distribution functions

For the stochastic calculation method, individual selected parameters are proved with a distribution function (e.g. flow chart for calculating the construction time shown in Figure 3). The distribution functions are chosen so that they come closest to reality. Since for the individual parameters still there are not clear characteristic distribution functions, asymmetric triangles will be used here. For each parameter in the flow chart shown values, respectively values are given for the optimistic and pessimistic value and the most probable value.

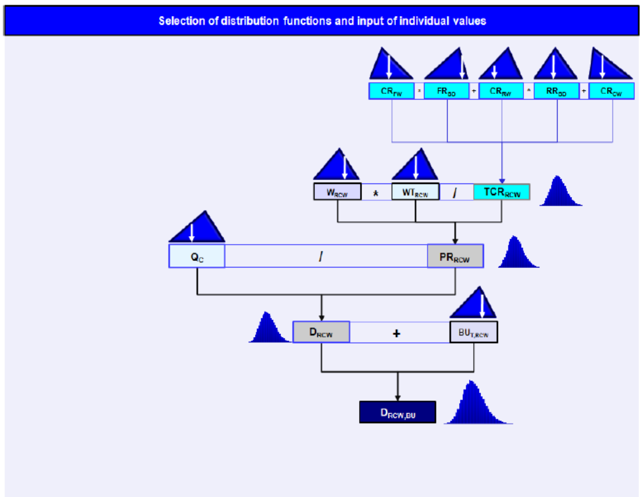

Fig 2: Calculation mode for the Monte-Carlo simulation [Hofstadler]

The values are determined in consideration of the construction management and construction-specific boundary conditions. As a basis for the values, for example, internal company records or data from the literature (e.g. working time guidelines for building superstructures) are used. For example, if the total value of expenditure considered and asymmetric triangular distributions is used, a most probable value will be specified by the cost values for shuttering work, reinforcement and concreting. Based on these values, the opportunities and risks in the course of a situation analysis will be evaluated, which means it is used to determine to what extent these values fall below or could be exceeded.

By including of considerations of probability in the calculations, a significant improvement in the decision-making is possible. Due to the used range and distribution functions, probability distributions are presented according to selected number of iterations for the required results. For the calculation shown in Figure mode is as a result of the total cost value (AW_{STB}) the daily performance ($L_{STB,\ WS}$), a period with no buffer ($D_{STB,\ WS}$) and the duration with buffer ($D_{STB,\ WS,\ PU}$) respectively output a probability distribution. For the calculation mode shown in Figure 6 is as a result of the total cost value (A_{WSTB}) ,the daily performance ($L_{STB,WS}$), a duration without buffer ($D_{STB,WS}$) and the duration including buffer ($D_{STB,WS,PU}$) each has a probability distribution output.

11. CONCLUSION& RECOMMENDATIONS

The general recommendation relating to the organization must be theoretically that all processes in the project must be organized, that the individual sub-processes should be executed as quickly as possible, that there will be no lay- or waiting-times between the individual processing steps, and that as many sub-processes can be parallel implemented.

However, construction projects are complex systems in which all works closely interlocked and run in a tight network of dependencies. From project to project and even from one project to the next phase, the tasks, work priorities and relationships in the system will change. The task of the project management is always defrenciated - and especially with the demand for acceleration - specifically customized solutions must be adapted.

To calculate the construction time, production volumes on the one hand and the production performance on the other hand are required for rough considerations. If the entire project is split into sub-systems, the relationships between the systems (e.g., building shell construction, Construction development, construction Engineering) should be defined. In addition to the uncertainties in the calculation of the partial times for each system now also the uncertainties must be recorded in the relationships and to be evaluated.

Here for each project, the opportunities and risks need to be reviewed. As a starting point here are the experiences from past projects that are only useful if the resulting data can be transparently analyzed. First base values can be determined, based on the chances- and risk assessment, optimistic and pessimistic values are determined.

The preparation of the deterministic calculation rule forms the basis for the stochastic methods. If the stochastic calculation methods systematically and dutifully applied, their results form a good basis for the interpretation of output and ultimately for decision making.

Further studies for the characteristics of distribution functions for cost values and construction parameters (such as formwork ratio, reinforcement ratio) can be performed. The effects of correlations between the input variables are also examined for their relevance. The results will to be published.

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