

Application of project management tools in construction phases to optimize the impact on quality, cost, and time: A case study

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Abstract. This work deals with the disturbed construction process, evaluated using the parameters cost, time, and quality. The aim is to transfer the actual situation of the disturbed construction process into a structured construction process. In this context, the possibility of data analysis and the associated creation of a resilient initial situation is demonstrated. One factor, time, is classified into a measurability with the possibilities of Gantt and Lean Construction Management. A representation of the monetary situation is the determination of additional costs. Here, the best case and worst case are presented and evaluated. The execution of the quality requires the comparison with the fictitious, planning quality defaults at project initiation and the now under consideration of the default costs and dates possible degree of fulfilment. The realization at the considered object has the following initial situation. Construction delay approx. 1 year, delta costs approx. 250 million euros, quality approaches were revised and partly reduced. This was the base for the creation of a schedule. The milestones from the Gantt schedule were incorporated into the system for the Lean Construction system. The monitoring between the milestones or intermediate goals was measured in the target-actual comparison.

1 Introduction

Research and further development of building materials, construction methods, and control systems lead to a complex overall view of construction projects. Procedures that are transferred from the planning representation to the digital realization show this development [1]. Creating a detailed representation of the construction object in 3-D format at an early stage allows you to gain knowledge all the sooner. Experts in individual fields will be able to take into account more quickly the way that different parts of the project influence each other. A distinction is made between construction projects that run through a regular undisturbed process from project start up to commissioning and construction projects that are no longer part of a regular process.

When considering the disrupted construction process, options for collecting data on the current situation are presented. In the form of a design freeze, the services that have not yet been carried out are recorded on the respective floor plans based on the service lists and addenda. Another way to record data is on-site inspection. All recognizable services that have

not yet been carried out by the various trades are recorded. The aim is to create an overview in comparison with the existing planning or a 3D model with tasks, assignment of responsibilities and execution and the setting of dates for the start and end of execution. The to-do list is the basis for evaluating the individual specifications for costs, time and qualities to be created. If the individual consideration of the parameters costs, time and quality leads to a negative result, the effects on the non-negative results are examined in a complex manner. A representation with the implementation goals specified in the construction project represents the basis for the target-actual comparison and shows the delta to implementation goals that were not achieved as planned. The realization goal here refers to the implementation of the construction task in the construction process. The actual situation found shows that the implementation of the complex consideration of the three parameters was not consistently controlled and monitored in the construction process phase, which resulted in an unstructured construction process. As a result, necessary resources were used inefficiently in one or all three parameters. The chosen research method is the evaluation of data from a realization on site based on literature research.

2 Basic information and the process for restarting an ongoing construction project that was disrupted

The way in which individual parameters are considered in the planning and implementation phase has a major influence on the subsequent execution phases. If one of the parameters is limited by specifications, the impact on the other two parameters must be examined. If, for example, the time factor is limited because tenancy agreements have already been concluded with the new users at the start of project implementation, this can lead to higher cost. It is fundamentally important to determine whether the given framework conditions of the mentioned parameters can be considered to be limited or agile.

The influence of this determination is defined in the subsequent phases of the project by the three parameters [2, 3] called the iron triangle. According to [4], these parameters are among the most common project-level performance metrics in construction, along with client satisfaction, rentability, and work safety.

Iron triangle parameters: Cost – Time – Quality

If the project implementation is considered to be realistic, the subsequent process must be structured. This involves creating a schedule, which can be done by using a Gantt schedule. A time schedule of the planning is classified as one of the achievements of the pre-investment phase; own procedures are represented by means of activities in content and time windows. Set milestones are entered as intermediate goals, as seen in Figure 1.

The division of the milestones is broken down into several domains:

- Scheduling the planning. When does which plan have to be available as a released planning for execution on the construction site.
- Executions in the construction process. When must which performance, building component, construction phase be available for trades in the planned execution quality.
- Overarching scheduling project control. Start of inspection of the individual trades, shown in the inspection schedule. Tinning the process for commissioning and handing over the technical trades to the operator. Transfer of the finished building to the client.

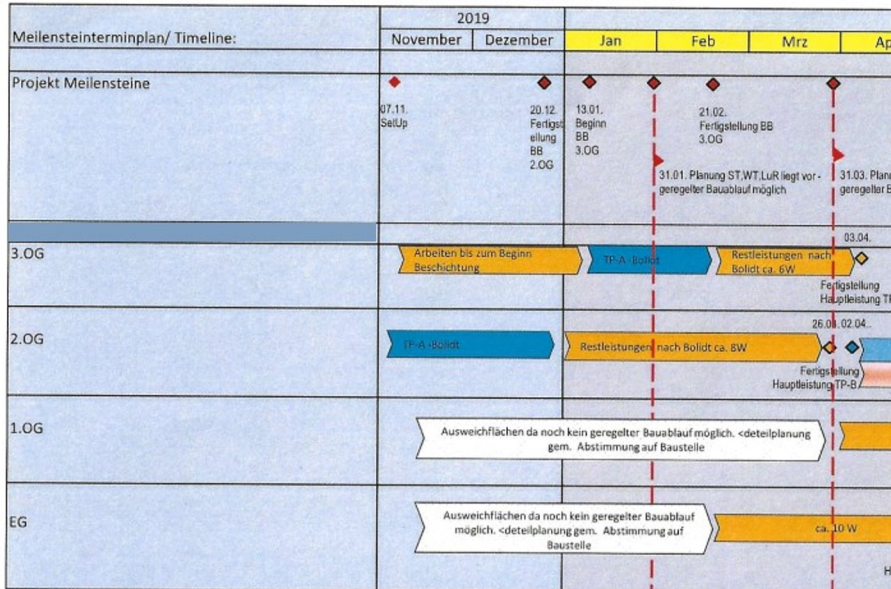


Fig. 1. Section of the milestone schedule.

The construction project under consideration shows that all phases of construction were indeed present in the realization. A schedule based on a Gantt schedule, representing the activities, was available. Based on this schedule, a lean schedule was created using the Lean Construction Management [5, 6] method as seen in Figure 2. This was introduced into the project as the only binding schedule. The stability parameters were determined by the personnel and material parameters.

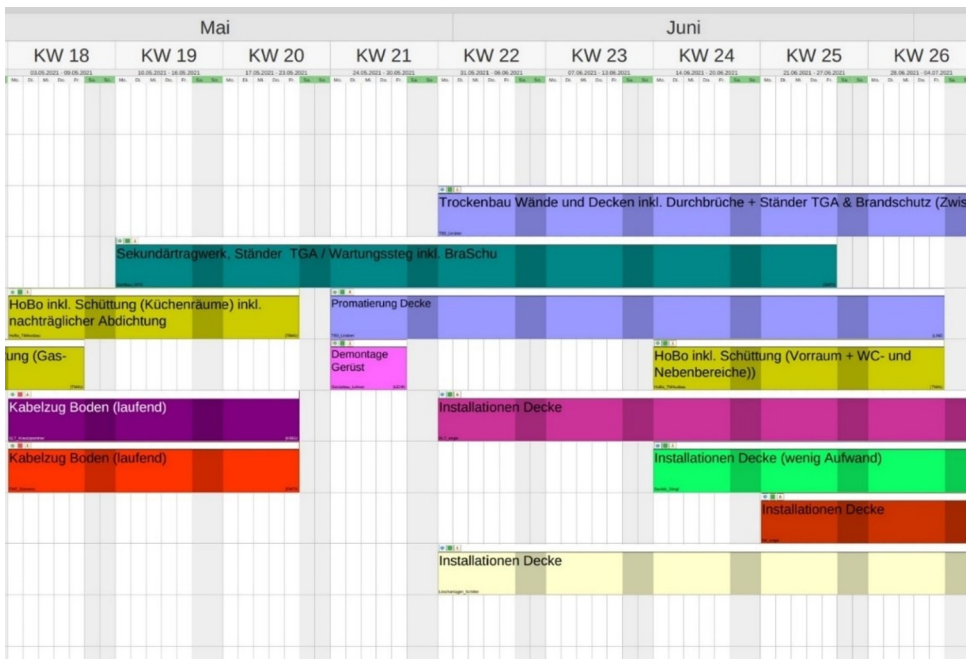


Fig. 2. Section of the Lean Construction Management schedule for the object under consideration.

2.1 Presentation of the actual situation and the management tool for controlling the project

The first inspection of the construction site revealed the following picture. Building material from the various trades was available in abundance on the construction site. The material had to be stored in the building on the construction site because the site equipment area was too small. This first visual impression revealed two weaknesses: lack of staff or lack of planning. When the staffing was examined, it became clear that the staffing was adjusted to the amount of service provision possible on site.

A process of elimination showed that the required planning was not available for the upcoming construction work. Further investigations revealed the following performance picture of the construction site:

- There was a lack of planning, or the planning was not available at the required level of detail.

The lack of planning was determined using design freeze for planning, as shown in Figure 3. Commissioned services, and a performance delta, were recorded through the target/actual comparison of the above-mentioned performance picture of the construction side, for the target status. The purpose of a design freeze in the current situation is to determine the respective status of performance. The negative delta determined in this process flows into the further planning processes [7].

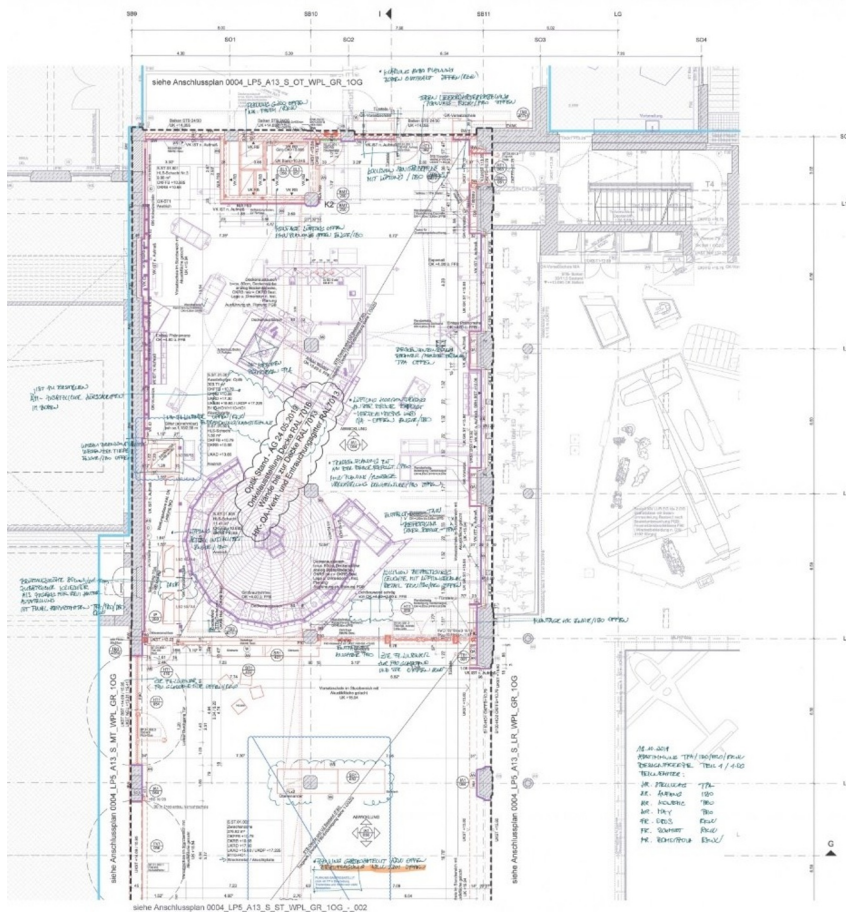


Fig. 3. Design freeze example from the object under consideration.

The data collected from the design freeze have been summarized in a to-do list and assigned to the trades. In addition, this list specifies schedule requirements for the respective subjects and degree of completion, as shown in Figure 4.

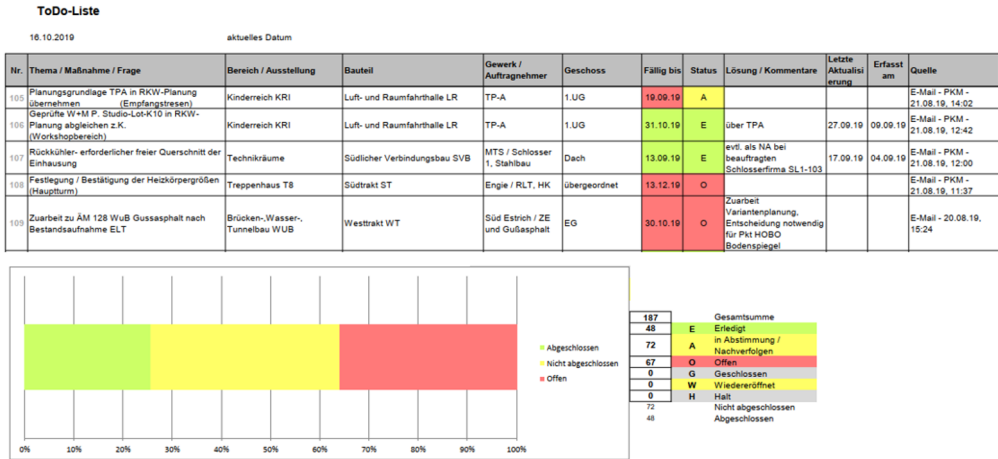


Fig. 4. To-do-List and degree of completion showed in green as done, in yellow as in doing, in red as not completed yet.

From the evaluation of the degree of completion can be seen that from 187 planning contents only 48 were done, 72 were in processing and 67 still to be processed.

- The construction site was managed by the executing companies.

By creating the to-do list and the schedule requirements, the planning content was newly broken down and the capacities for the construction site recalculated. As a result, the executing companies have been withdrawn from the control of the construction site. A manpower requirement for the project was forecast. As shown in the Fig 5

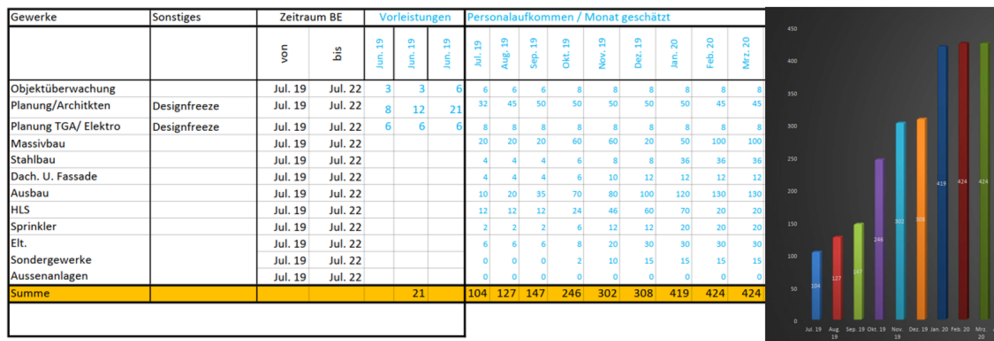


Fig. 5. Estimated manpower requirement.

With the collected data, the situation of planning is displayed based on the increasing manpower requirements and the increase in the manpower of the executing companies is adapted to the planning [8]. It shows the manpower in the respective schedule. Based on the design freeze phase and data collected from the construction side, the performance on the construction project with 104 manpower, started July 2019, was forecast up to a continuous execution on the construction project with approx. 420 manpower until March 2020.

- The existing schedule, which was introduced as binding, did not correspond to the state of the construction site.

The individual construction work on the construction site was described in a lean construction management. As shown in Figure 6.

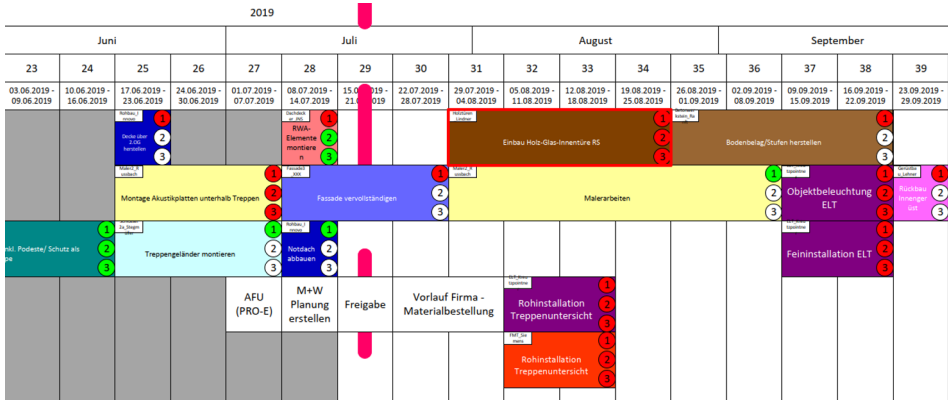


Fig. 6. Lean Construction Management .

The individual processes of the construction works are shown with stability criteria. 1 stands for planning, 2 stands for manpower and 3 stands for building materials of the executing companies. The assigned color to the stability criteria red, white, green is the degree of performance.

- The delay of the construction site to the planned completion date is approximately 1 year.

In the bar diagram of the Gantt schedule, as shown in Figure 7 the entire course of the construction project in the target-actual comparison is shown. The vertical yellow line represents the status of consideration by July 2019, the first vertical red line shows the early planned first completion date. The second red vertical line shows the newly planned completion date and thus the existing construction delay of approx. 1 year.



Fig. 7. The bar diagram of the Gantt schedule.

3 Project performance and its measurements

Performance in the project must be measurable. The specification of a precisely defined goal is the basis for performance measurement. Subgoals and milestones are determined in the scope of performance and time. Measurement of performance requires a measurement method and determination of areas that will be the subject of performance measurement [9, 10, 11]. Performance measurement for the achievement of the goal presupposes that there are one or more methods for the definition of the partial and the final goal. The more reliable these are, the higher the degree of fulfilment of the target expectation [12].

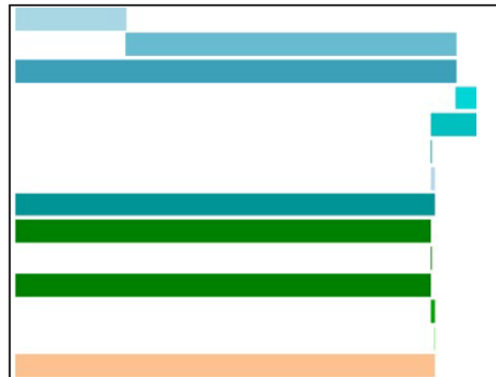
Several methods are used on the construction project to measure the project performance. The performance in the project execution is in summary monitored with the Gantt method in the target-actual comparison. See also Chapter 2.1. The construction work is detailed divided

into individual work packages with the Management System of Lean Construction [13, 14] and monitored with a percentage level of performance. In the project, Lean Site Management [15] was used as a control tool for process planning in the execution phase of the project. The focus here is on the overall optimal process for all participants with the greatest possible added value with regard to the building to be constructed. For the successful introduction of the system, active cooperation is necessary from all involved companies. The system consists of the following elements: overall process analysis and overall understanding [16].

Another method of measurement of performance is cost tracking. On the basis of the services invoiced through executing companies for the work performed on the construction site, is reconciled. The performing companies draw up an invoice for the services performed on the construction site. This is done with the respective measurement of the construction work for the invoicing and is compared with the services provided on the construction site. The cost tracking method shows the main performance and the additional performance of an executing company. Monitoring takes place between overall performance and executed performance. As shown in Figure 8. The increase in the main performance of shown trade in Figure 8 is 299%.

Overview

Main order amount	2,069,104.02	100.00%
Additional order	6,199,532.91	299.62%
Level of order	8,268,636.93	399.62%
Additional costs charged	422,043.00	
Additional costs expected	-884,033.62	
Changes in quantities	0.00	
Costs still available	59,120.90	2.86%
Subtotal	7,865,767.21	380.15%
Status of billings	7,804,885.90	
Price index	0.00	
Status of billings	7,804,885.90	377.21%
Outstanding payment	60,881.31	
Valorisation	0.00	0.00%
Order forecast	7,865,767.21	380.15%



Accruals	5,796,663.19	100.00%
Accruals claimed	5,737,542.29	98.98%
Accruals available	59,120.90	1.02%

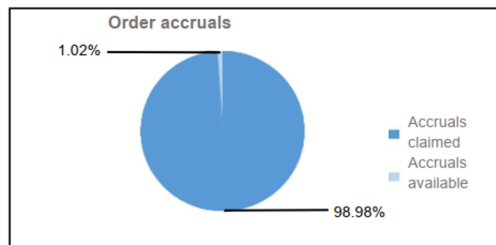


Fig. 8. Cost tracking for one trade.

The overall increases in all trades, the additional effort of man power, see Figure X, as well as the extension of the schedule to additional one year, have led to the additional costs of 250 million euros based on this reliable data.

An accompanying method is literature research. In literature research, the focus of the search is placed on the expansion of knowledge in construction technology, construction methods, control options, and measurement methods.

4 Conclusion

The overall performance must be monitored consistently and in detail. The increase in knowledge is the possibility of executing a performance between set milestones in an agile system such as Lean Construction Management. Announced fixed schedule are not always able to react to all short-term delays occurring in the construction process. The insight gained from this approach is that a control system in this case Lean Construction Management is needed, which incorporates knowledge that was gained from the construction process into the monitoring system. A concurrent performance measurement takes place, as shown in Section 3 based on a degree of performance in percentage.

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