Photo Documentation of Site Observation (06.04.2020)

In order to validate the potential of a process improvement in the field of interest of this thesis, an actual construction site is observed with the goal to identify drawbacks and waste in current practice regarding the management of TCIs.
Using a participant observation role allows to observe current practice regarding TCIs (Saunders et al. 2016) and includes both own experience and the experience of the project participants regarding the research selection for verification purposes. The semi-structured interview with the construction professionals is regarded in chapter 5.1.1 while this photo documentation will reflect the observation which was conducted during the site visit. The photos represent the situation on site and will be used to identify current practices and how the proposed solution might improve these situations.

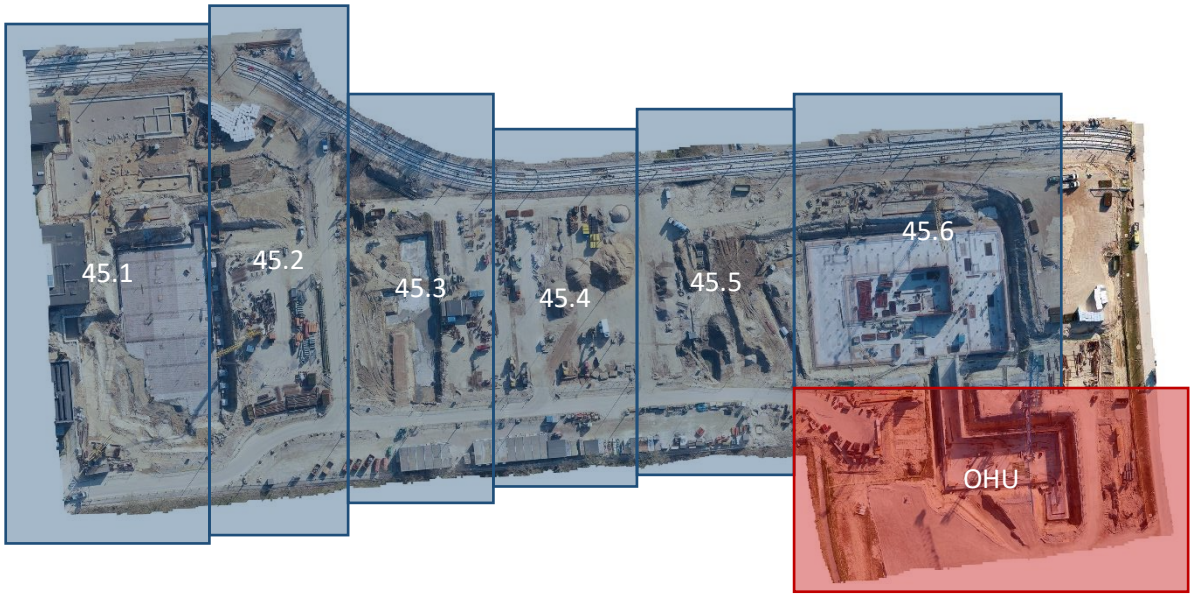

Figure 1: Construction site drone picture with different locations

N.	Photos	Comments
		Site facilities are located on a strip, where no construction will happen. There is enough space available to provide site facilities at this location for the entire construction project. In general, the site facilities are well planned and there is a site layout which specifies the bigger installations on site as cranes, container, etc. **Potential**: TCIs that are not directly related to the construction activities, as office container, might be calculated with the total quantities of the building and the schedule information.
1	Site facilities near the entrance of the construction site	

N.	Photos	Comments
		Different standard forms, that are rented from a supplier are located at the storage area. **Potential**: An updated and detailed utilization plan of the formwork might enable a more "just-in-time" delivery as well as a dynamic planning and lean management from delivery overutilization to the return of TCIs. This will benefit all parties involved in the TCI-cycle for a construction site.
2	Storage area of formwork that is currently not used	
		Single form laying around which might block the access to other items at the storage area. **Potential**: Using location-based scheduling as a principle of planning would enable to specify specific storage areas for the TCIs that are not in use. These storage areas depend on the time and location of the next utilization. The information can be distributed to the relevant workers, as all information is accessible.
3	Single form laying on the floor, blocking useful storage area	
		This picture shows the ongoing construction of the concrete walls in the basement. Formwork is used to support this activity. In the front, electric cables are placed in an earth route to enable electrical service on site. **Potential**: With the proposed solution, the construction manager would at all times have transparent knowledge about what types and quantities of formwork is used in which location of the construction site.
4	View to the construction of basement walls with electric cabling in the front	
		Metal plates are used to create a temporary road that enables transportation on site. Signage-posts are used to mark the way. Next to the road, a neglected form was noticed. **Potential**: TCIs, related to on-site transportation can be part of the solution as long as there is a site-layout model, enabling a relation of TCIs to a model object. There would not be a neglected item on site and IoT-tracking of TCIs would further improve the transparency.
5	Temporary construction road using metal plates and way signage	

N.	Photos	Comments
		Different building material and TCIs are located on the foundation. The quantity of the located forms should fit the need for constructing the walls. There shouldn't be too few and to many forms to still be able to provide sufficient support for the construction activities but not blocking the limited space and costing rent. **Potential**: Quantities are available on a detailed level for each activity, enabling a lean management of the items on site.
6	Basement foundation with ongoing casting of in-situ concrete walls	
		Installed formwork that supports the construction of a basement wall. Secondary formwork parts as push-pull props, walers, couplers, etc. are clearly visible. **Potential**: Secondary formwork parts can be calculated for each construction activity with a simple estimation that is based on the panel quantities and sizes.
7	Formwork installation for basement walls	
		Several temporary construction items are laying around, near an ascent from the excavation area. It is assumed that the storage area is not official and there might not be a record or documentation of the location of the shown items. **Potential**: If TCIs are planned with time and location information throughout the construction project, one will always have knowledge where the items are supposed to be.
8	Temporary construction items on site	
		A foundation reinforcement is placed at basement level. Formwork elements are stored temporarily on the reinforcement and it is unclear where the forms belong to. **Potential**: A construction manager can easily compare the planned quantities of TCIs with what is installed on site, identifying missing parts. Having IoT-tracking of these items will also allow to locate the required items for each construction activity if not stored properly.
9	Formwork elements laying on foundation reinforcement	

N.	Photos	Comments
		Several temporary construction items are laying around a storage area. These small storage areas allow a lean storage of TCIs near the location where they are used next. With current practice, it is however unclear, if the stored elements are sufficient for the upcoming tasks. **Potential**: Specifying decentralized and dynamic storage areas on site allows to store the TCIs where they are easily accessible for the next utilization without blocking other construction processes on site.
10	Storage area for different items	

Concluding Comments

The observed construction site of the new SDU SUND project is generally managed and planned well, especially regarding site facilities as container offices and main storage area near the entrance of the site. Furthermore, all machines as cranes and lifting platforms are in place and intact.

However, there have been issues with planning TCIs on site as they were not considered in the initial plan and budget. Fences for separating construction roads and walkways were not planned and budgeting of other TCIs is only estimated as a part of the total construction costs but never broken down to a more detailed level. This is also reflected by the photo documentation, which shows several items that are just laying around the construction site, blocking access paths or causing safety hazards for the construction workers. This little attention regarding TCIs is a common practice for several construction sites.

The proposed solution in this thesis is taking this issue into account and tries to automate the planning, management and monitoring of TCIs on site by linking them to the existing building model and project schedule. For formwork, scaffolding and supporting beams, the relation between the TCIs and building objects is obvious but also TCIs as road signage, safety fencing or metal plates can be included in the solution as long as there is a site layout model available. Based on this model and the respective schedule information, the number of TCIs which are needed to support a specific phase of construction activity can be calculated with an algorithm and then linked to the model elements. With this approach, the developed algorithm can be applied to almost all construction projects as the way of calculating TCIs is the same, either based on best practice or specified in commonly used standards.

The conducted observation of the construction site, on the one hand, presented an already well managed and modern construction site, but nevertheless revealed space for improvements regarding the planning and management of TCIs. On the other hand, the assumption was verified, whether the project fits as a case study to test the proposed solution. The developed prototype solution focuses on planning and management of formwork and hence, the main requirement for that is the utilization of formwork. As shown in the photo documentation, this is the case at the SDU SUND project in Odense. The case study will then reveal the real potential of the solution by allowing a comparison between the practice without and with the proposed solution.