LOGISTICS AND LAYOUT PLANNING OF CONSTRUCTION EQUIPMENT ON A VR-MULTI-TOUCH-TABLET

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ABSTRACT: *Significantly more complex building projects and strong international competition create a significant cost pressure in the industry. To improve the efficiency of planning and implementation of construction work, digital methods from the stationary industry shall be transferred, adjusted and extended to the construction industry. Many construction sites are currently being planned in 2D and by experience. With 2D it is nearly impossible or really difficult to visualize 3D collisions. In order to withstand the pressure of costs, planning only by experience is not enough. The logistics planning on the construction site and in particular the material flow planning is often determined at the start of construction. The very late planning of the logistics leads to mistakes and increased costs. Many unnecessary rearrangements or the search of already supplied materials, are the result. This increases the time needed and leads to higher costs. A integrated logistics planning on the site will be developed in this project through the use of digital methods. Several planners arrange the logistics of the construction site with the various phases using a multi-touch table. The screen visualizes a 2D top view. All necessary items are selected from an object library and placed on the layout with the touch of a finger. Subsequently, there objects are validated by planning algorithms. The objects obtain source-sink and time/date information. This allows to show and evaluate the material flow. Bottlenecks can be made visible. On another screen the construction with all his objects are shown in 3D. This tool will bring everyone who is involved in the logistical planning to one table. With the digital tools it is possible to evaluate and show errors or information in real time.*

KEYWORDS: *layout planning, virtual reality, collision, multi-touch table*

1. PRESENTATION OF THE PROBLEM

Nowadays the construction process is subject to enormous demands concerning costs and completion times. Significantly more complex building projects and strong international competition create a significant cost pressure in the industry. The construction industry can only fulfill these demands by improving the quality of processes regarding the keeping of deadlines and cost security.

To improve the efficiency of planning and implementation of construction work, digital methods from the stationary industry shall be transferred, adjusted and extended to the construction industry. The applied methods in stationary industry of the digital factory (Kühn, 2006) shall serve as a model to overcome the complex basic conditions of current construction projects in future. The latter are basically made up of

- The construction and creation of unique items,
- The dependency on climatic conditions,
- The strong fragmentation of the industry during the completion of construction,
- The distinct segmentation along the process chain as well as
- The reluctant usage of modern information and communication technologies (Günthner, 2011).

The use of innovative digital technologies supports the planning of logistical processes. By considering these fringe conditions, it is necessary to determine the layout from aspects of material flow and thus in future conduct construction processes more effectively and cost-efficiently.

Usually each construction site is subject to different conditions, the production sequences vary and the local conditions are different from project to project (unique construction). This demands an intensive, detailed planning. However, in reality the logistics and more specifically the planning of material flow is poorly done and determined close to the beginning of construction (Bauer, 2007). Due to the immediateness and poor methods this 2D plan based approach tends to lead to non-transparency and mistakes in the later process. There is no digital validation or verification of planning process taking into consideration the specific fringe conditions at the construction site. Digital methods based on intelligent, three-dimensional objects can support those responsible for planning and increase the planning performance. Furthermore, it is necessary to portray the different construction phases and their dynamic fringe conditions and deduce corresponding suitable measures for the planning of supply and material flow.

Compared with the stationary industry the construction industry is very fragmented, a significant majority of the companies are in the group of SMEs and in this case small enterprises (Bauer, 2007). As a consequence, all processes are conducted by different companies, especially in the case of large construction sites. The lack of consistency leads to insufficient transparency in the process and in the worst of cases to different levels of planning. A central model for the planning of supply and material flow ensures a consistent communication of all participating – away from a plan on paper to a digital 3D model.

Up to now digital methods are only used very restrictedly in the construction process, a completely digital construction site is far off from standard practice. A prescient planning of the logistical process chain is only very rarely applied (Langhammer, 2009). Even though the potential of a construction logistic encompassing the entire construction process was already recognized, there is a lack of methods and instruments of how the construction logistics can be integrated in the inter-company execution process of orders according to current knowledge (Krauß, 2005). Nevertheless single tools are capturing the market, as 2D CAD or model building no longer suffices for the demands of current construction processes and the necessary flexibility.

By the aggregation of the logistics planning and a centralized supply of information of the participants in a digital 3D model, different scenarios can be compared and a corresponding layout can be constructed for every step in construction. Despite constricted space conditions in inner-city areas, the project costs can thus be significantly lowered by an efficient material flow based on a well-planned layout (Hofstadler, 2007). Mutual dependencies and influences of the single elements of material flow become understandable and an integral planning is enabled.

錯誤! 找不到參照來源。 shows possible reduction of costs resulting from consequently planned and executed construction logistics

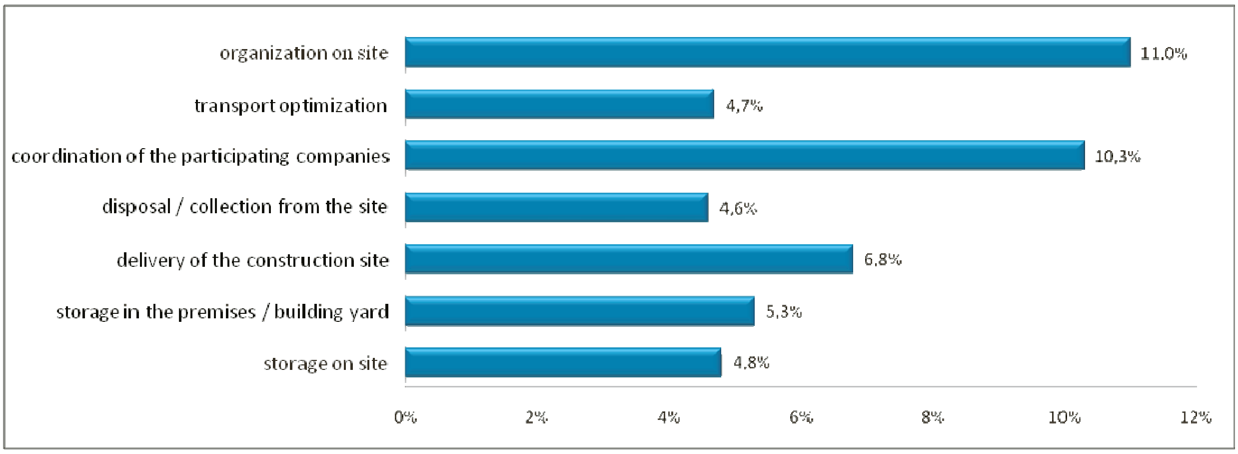

Fig. 1: Potential reductions of costs by construction logistics (Günthner, 2008)

The main goal is a practice-oriented planning instrument which allows the determination of layout and the equipment of the construction site for the entire running time of the project and is only changed if needed. A suitable approach for cross-company processes supports the preparation of work and enables a cross-company planning during the execution. Intelligent development algorithms guarantee a qualified logistics planning by evaluating equipment-related parameters with reference to the current planning step and logistical weak points are revealed prematurely. The different phases of construction can be portrayed clearly and single supply processes can also be analyzed during the execution. Thus the dynamic surrounding of the construction site and the principles “construction means transport” and “construction means communication” (Deml, 2008) can be taken into consideration.

2. CONCEPT

Within the research project LogPlan Bau an approach is developed for the transparent planning of different objects on a construction site. The topic of the paper is to have a collision-free and lean logistics for the supply of construction sites. Function units such as storage areas or transport routes, large appliances and their working rooms as well as static elements (container) shall be planned cheaply. The subgoals of LogPlan Bau can be deduced:

- Development of planning algorithms to support the planner during the interpretation and conception of the corresponding construction steps
- Creation of a general 4D model of the object of planning objective during all phases of construction.
- Use of an intuitively usable planning tablet combined with the spatial representation of a VR system.

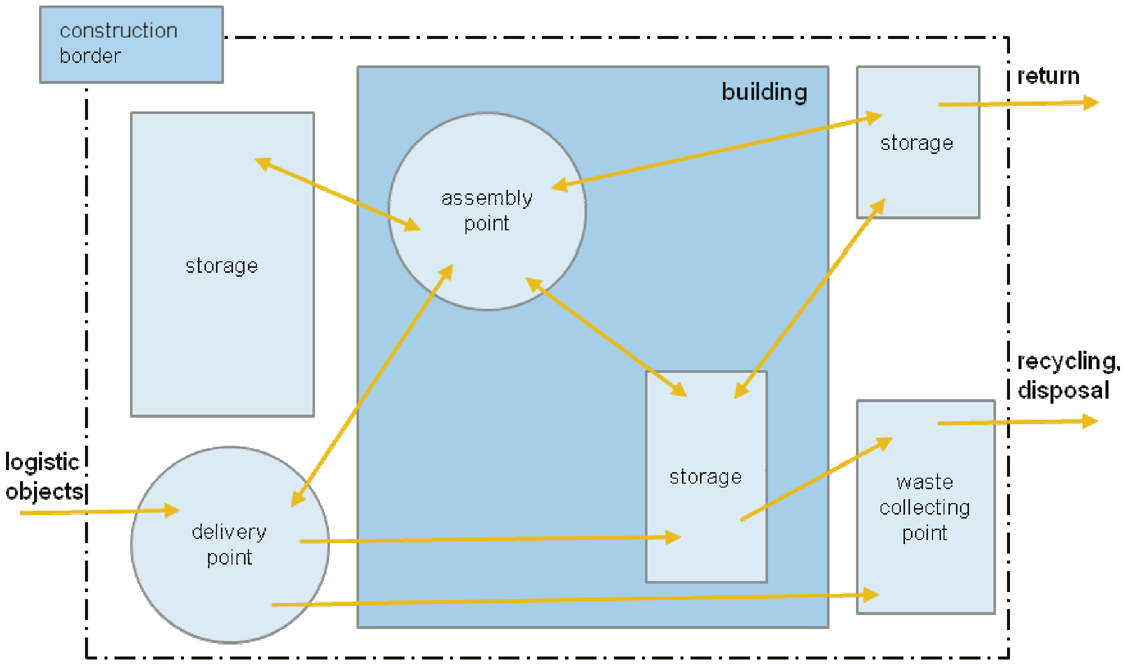

Fig. 2: Different object on site with dependencies

The result should be a full-functioning demonstrator, which creates an innovative possibility for all phases of construction to equip construction sites plan-based and depicts the dynamics of construction sites spatially and temporally.

Beside the development and the build-up of a function pattern, the creation of a consistent planning method is decisive. A central approach is to be developed which anticipates the material flow processes at the construction site as well as logistical processes for supply and disposal cross-company (see Fig. 2Fig. 3:). Computer-aided planning algorithms additionally guarantee a sensible planning of the single resources.

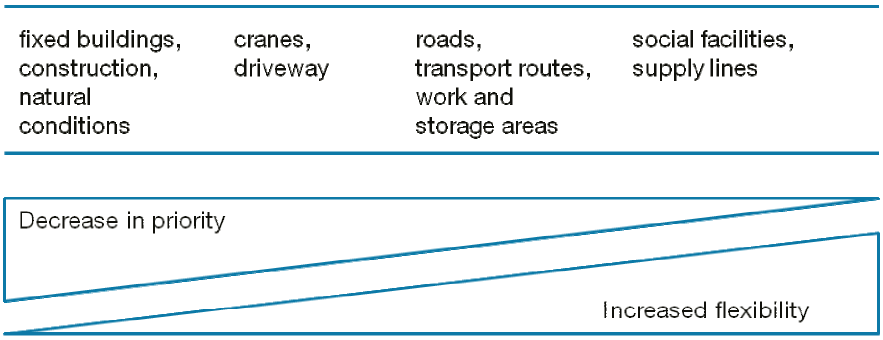

Fig. 3: Priority and flexibility as possible influence quantities of planning methods

The approach and development algorithms help the person responsible for planning by suggesting a sequence for the shaping of the material flow processes and possible mistakes in planning are caught.

The single elements are aggregated into coarse classes and should be modeled as parametric objects which are summarized in a common library. The parameters (e.g. height, radius) of the general class (in the example: crane) are only determined during use and then checked for validity by the planning algorithms.

The function pattern for the planning and the layout of large construction sites is basically made up of a planning tablet and a VR system. Fig. 4 illustrates the intended setup.

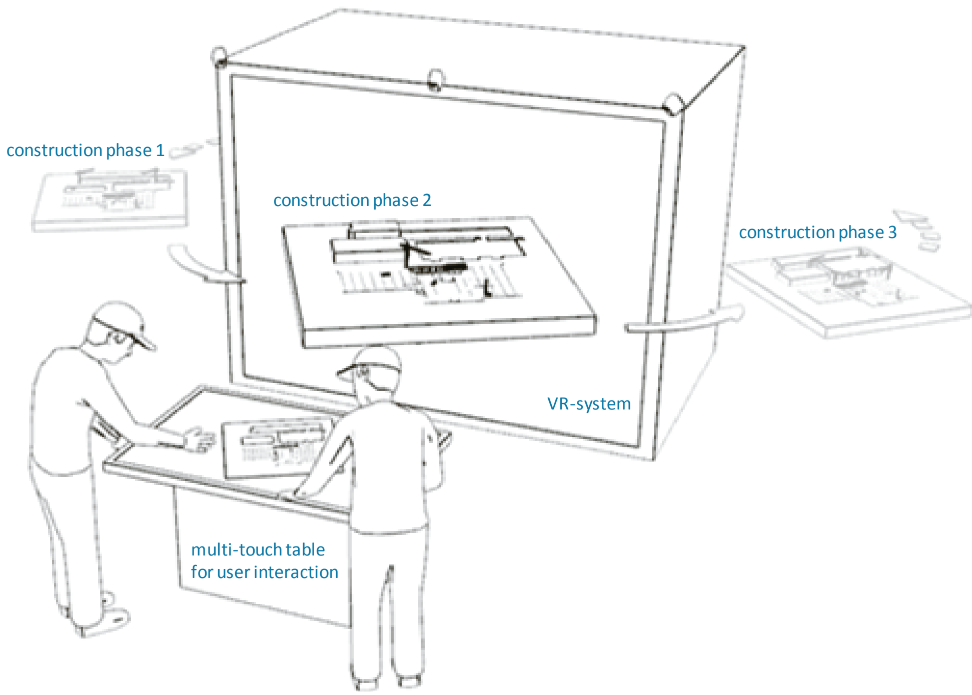

Fig. 4: Functional schematic of the demonstrator

The equipping of the construction site is done on a dynamic 2D plan which is portrayed on the to be developed surface of the planning tablet. Corresponding to the properties of the construction site, the layout can be changed over time so that the different construction phases can be planned using digital models. The blending in of specific resource parameters as well as their dependency chains on the planning tablet enables a safe and efficient construction process. The VR system shows a stereoscopic view of the current planning state, so that the total model for all phases of the project can be evaluated. This way the different phases of construction can be depicted clearly and single supply processes can be checked even during the execution. Mistakes in planning and supply can be identified and spatial geometric collisions can be avoided.

The result of the project is a central tool for the mutual planning of logistic actions and the communication of these between those participating in the project.

Following partial results are amongst them:

- By the transfer into the model area object-orientated components result for the planning of equipment as well as their time-dependent parameters.
- Different deployment scenarios are developed for a systematic evaluation of these components.
- Those responsible are supported by implemented planning algorithms which check the planning effort with reference to logistic and geometrical demands.
- A consistent approach is developed to plan the layout as well as the material flow of large construction sites. A model with several scales allows both rough and detailed planning.
- The equipment elements are assembled to a component library and a parametric, resource specific 3D model is deposited for each.
- A virtual spatial model is created which unites static and temporally dynamic parts. The latter enables the portrayal and planning of different phases of construction.
- For demonstrative purposes as well as for the validation and improvement of the planning system, a function pattern with different configuration levels is put into operation.

On the basis of the results a new method to plan cross-company logistic processes for the construction site are defined and provided. This is based on a universal innovative planning method whose processes small companies can also conduct with regard to a reduction of complexity. For this the logistical supply of construction work is planned at a joint model taking into consideration the mutual influences.

The planning algorithms to be worked out in this research project both for the integrated planning process as well as for the specific (material flow) objects are independent of the system. Therefore it is possible to transfer the newly developed algorithms to other potentially interesting systems. The requirements for such a planning tool are developed systematically and available solutions are investigated for the compliance of these demands. Therefore it is also possible in future to investigate new systems for their usability for the construction industry.

The research project is the first to apply the use of innovative VR technologies in combination with methods from the digital factory to plan the supply of construction sites. By the development or implementation of an innovative man-machine interface, the user shall be supported with information as good as possible at the specific planning action without expecting too much of him with reference to his technical knowledge. Different scenarios can be analyzed realistically and logistical key figures such as e.g. use of area can be gathered. Aside from the feasibility of such a system, especially the high potentials shall be verified.

Users can yield advantages in the communication over different hierarchical levels and specifically over the limits of companies. The mutual work in a virtual environment which enables an intuitive system command and visualizes necessary information sensitizes people of different areas for the task of others or promotes the understanding of problems and creates transparency. The worked out interdisciplinary results of planning can be accessed from the central model at all times and independent of location.

Based on the construction site model the planner at the construction site can access important information based on the already planned construction site model by using augmented reality.

3. CONCEPTS PLANNING TABLE

The planners at the planning table use a software onto which the layout of the construction site can be imported. After the layout is imported, the planer must identify the areas for the building to be constructed as well as border areas of the construction site. This is necessary so that the system knows the areas which can be used for the logical planning of the construction site. In the rough planning, the planer can mark this onto the plan using the touch of his finger.

Next he can determine the construction phases and for each phase of construction chose a different 3D model which depicts the buildings to be constructed in each respective phase of construction. In this step he shall also be able to determine pits and other information on heights.

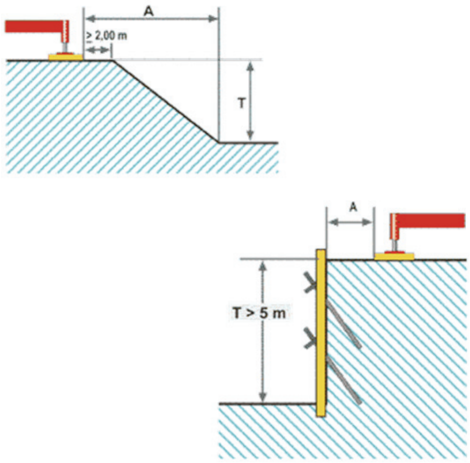

Fig. 6: Distance of a machine to a pit

After the basic information was determined, the actual planning can begin. From an object library sorted according to topics and significance, the single planner or several planners can then select the object, which is necessary, somewhere on the construction layout. When placing the object other data is needed such as measurements, weight or other resource specific parameters, which has to be added by the planner. After inputting the data, it is checked for validity by the planning algorithms. Additionally the system provides information if a device / machine can stand at the spot where the planner has placed it. A simple example of this is if a machine is not placed in a building. The distance of a machine to a pit is also controlled (see Fig. 6). In the case of a distance-pit problem, the system informs the planner that the machine could be too close to a slope and thus must be placed further away. However, it can also provide recommendations that the slope should be enforced. The system only informs the planner, he must still make important decisions himself.

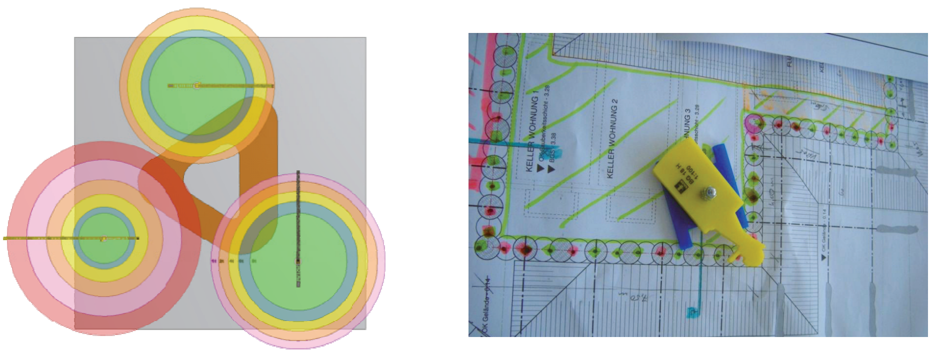

Fig. 7: Field of work of different machines (crane and deep drill) on computer and paper

When placing a machine which has a specific field of work (e.g. cranes) the user can display this field of work. Fig. 7 illustrates this example. However current practice is that a model is used on a plan (see Fig. 7) and this model is then moved and turned manually. It is more precise if this happens digitally like shown in Fig. 7: The cranes have different support structure areas. The visualization of the top view by circles of different colors reveals if a crane can take the load at an important spot (position of material supply, low ground) or if either the location of the low ground must be positioned better or the crane must be set up differently. Furthermore, the tool allows to see the collision of cranes with other cranes and buildings (see Fig. 8).

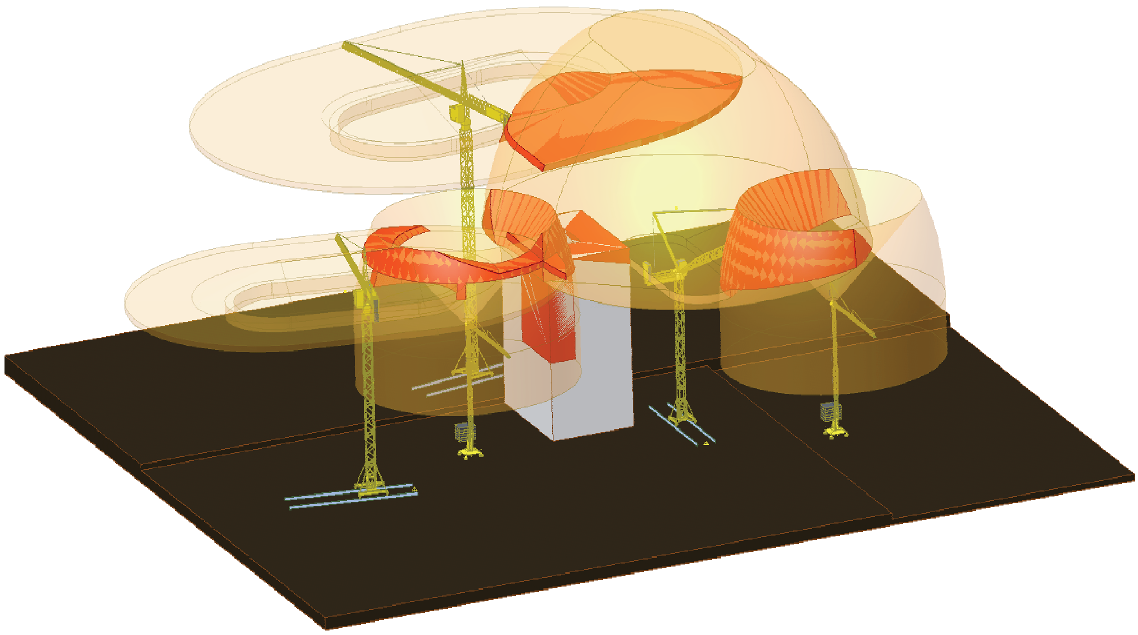

Fig. 8: collisions between different cranes and building

In the course of the project time lots of such information will be collected and visualized through the software.

4. SELECTED HARDWARE

For the concept, different devices were researched and evaluated which could come into question for planning tables. The same was done for the VR system. Due to the demands of a construction site and the desire to not only set up such a planning instrument in an office, but also in a container at a construction site, the following system was acquired:

- Planning table: 46" multitouch frame for a screen which is set up horizontally as a table. It is large enough so that several planners can all work at a table but sufficiently small so that it can be stored in a construction trailer (size x m times xm). The full functionality of the multitouch frame is independent of lighting influences.

Fig. 10: Example of the selected planning tablet

- VR system: 3D television set. Normally large screens or even caves are known as VR systems. However, these are hard to transport or cannot fit into a construction trailer. For this reason, a 3D television was selected for this subsystem. During planning however, the 3D television set is operated in 2D so that the planers must not put on or take off the glasses according to if they look at the 3D television or at the planning table. If the construction site is evaluated in 3D, the planner can decide if he wants to activate 3D mode so he can immerse himself into the 3D world.

Both subsystems each have a computer that communicates with each other via Ethernet. Tablets are used for the AR system. During the project both systems (Android as well as iOS) are tested. Furthermore, the system has a connection to the internet which gives the AR system access to the information of the construction site model which should be blended in by augmented reality.

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