Digital Tower Crane Deployment Planner

Winner of the VDBUM Innovation Prize 2014

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Based on the idea of being able to intuitively plan and manage crane operations in a simple and fast manner, the Institute for Materials Handling, Material Flow, Logistics (fml) at Munich Technical University (TUM) has developed a digital planning tool for tower crane project planning in close cooperation with crane manufacturers and crane operators. In comparison with the previous, very time-consuming and mostly manual crane deployment planning, the tower crane deployment planner (TEP) significantly simplifies and optimises the project planning process, both financially and with regard to the operation progress.

The forward-looking overall concept of this system based on databases uses state-of-the-art software technologies. In its implementation the focus was on performance and running stability, and also on straightforward integration at the customer, user-friendliness and an intuitive approach. The system supports the user in all crane planning stages: from optimum crane selection, to the actual 4D-based process analysis on the virtual site and the handling of transport logistics challenges, up to financial planning components such as cost calculation or bidding and billing. The system is now being used for the first time by different project partners. Thanks to their expertise and by taking all individual requirements into account it has been possible to create a comprehensive and innovative tool suite for practical applications.

To mark its highly innovative character, economic efficiency, high technical standard and practical relevance the TEP tower crane deployment planner was awarded the VDBUM Innovation Prize 2014 at the VDBUM Congress in Kassel.

Crane selection and configuration

The system has a multilingual structure and supports the simultaneous processing of different planning designs by several users. The project representation is divided into two sections: the left-hand section lists all currently assigned cranes in an organised tree structure while the right-hand section shows details of the planning content selected in the project tree. The TEP planner offers the option to activate or deactivate individual cranes; it is thus possible for the user to vary a design by showing different crane constellations and configurations. The lower levels of the project tree correspond to the time phases of a crane or, in the event of a mobile substructure, those of its track system and thus represent the respective erection conditions.

To integrate a further crane into a project the user defines its scheduled installation period using a calendar module that is integrated in the TEP planner and then selects the appropriate configuration from a fleet of available crane types. In this process the user is supported by an extensive system-level search function that makes it possible to identify a tower crane suitable for the specific application or for accomplishing a certain hoisting job, thus restricting the number of search results displayed. The integrated logics of the search function limit the relevant search contents, any mutually exclusive specifications are ruled out beforehand.

After selecting the crane upper structure and substructure comes the definition of the tower composition in the basic configuration of the individual crane, including any accessories, i.e. documentation of its basic structure at the beginning of the erection period. If there are any alterations in the tower structure the planning tool pays attention to the correct pairing of integrated components. The TEP planner appropriately restricts the number of selectable components. This excludes any impermissible tower composition in advance, or such a constellation is identified as such.

Mobile substructures enable the provision of a track system. The track system to be selected for this purpose describes the type of rails and sleepers used as well as the laying method and the maximum permissible spacing.

If required, climbing phases are then defined for the selected crane configuration with the provision of additional time phases and the integration of added tower elements as well as additional equipment. The TEP tool distinguishes between the interior or floor-climbing process and exterior or building-climbing process. Besides selecting appropriate climbing equipment the system also supports the definition of crane attachments or anchoring systems. Any required track system is designed analogous to the implementation of the climbing phases: in the same way, additional track laying phases are provided with the design of further track sections.

If the created crane configuration shows a frequently recurring pattern, the TEP planner can include this configuration in the range of standard cranes, thus ensuring fast access to frequently used configurations. In this way, cranes often used with the same structure do not have to be redesigned every time another project is planned.

Virtual planning of crane transport

With regard to its planning components for transport logistics the TEP planner can define transport convoys including the detailed load orders using a 3D-supported planning environment specially implemented for this purpose. Here the user selects the required transport vehicles corresponding to the scheduled time, differentiated according to arrival and departure.

In a first step the user allocates the items to be loaded to the individual semi-trailers. This is followed by the concrete three-dimensional positioning of the items on the respectively active transport vehicle, similar to the drag and drop method (Fig. 1).

During the entire positioning process the physical simulation module of the engine on which the load order module is based is used. The positioning of the items on the transport vehicles therefore represents a

completely realistic reproduction of the actual behaviour: tilting over edges and sliding on slanted surfaces are simulated in the same way as falling or collisions.

During the virtual loading of a transport vehicle the system observes the permissible loading height, width and length as well as the weight. There is also an automatic determination of the load's centre of gravity or its position in relation to the trailer, based on the partial centres of gravity of all assigned individual components.

With the user-specific load order the application generates loading lists including a graphical overview of the basic loading pattern. In addition to specifying the trailer type, the system displays for each vehicle detailed information concerning the number, designation and the weight of the items to be loaded, and also the overall centre of gravity and the total weight of the load. Taking the 3D models of the trailers configured in the previous planning step as a basis, two-dimensional vertical sections and isometric representations of different views are deducted for visualisation of the proposed load order.

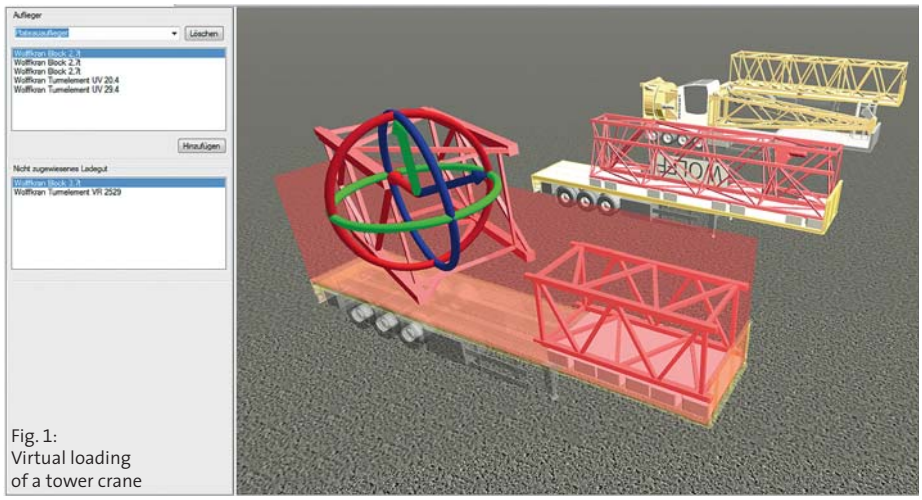

Fig. 1:
Virtual loading
of a tower crane

Increased efficiency in construction crane logistics

Using the given loading lists and load orders as well as the weights and centres of gravity the TEP planning tool allows a comprehensive crane transport logistics planning. These transports can now be organised in a clearer and more structured form, especially for third-party logistics companies. The loadmaster is supported with the provision of detailed loading lists including specifications on the required loading pattern in the form of straightforward illustrations, and besides ensuring an efficient and correct loading process, the correct arrival of all required crane components at the demand point on the worksite is guaranteed at the scheduled time.

There are no more bottlenecks involving waiting periods on the worksite for missing transports, and there is no more piling up of components that have been delivered all at once, instead of a coordinated arrival over a defined time period. Optimised transportation also reduces the number of vehicles in use to a minimum and prevents unnecessary additional trips. The resulting best possible utilisation of each individual object in terms of performance and reduced downtime limits the financial share of crane logistics and can be measured in energy efficiency and environment protection quantities.

3D-based modelling of tower cranes

According to the prepared project the TEP planning tool is able to generate suitable 3D crane models of a uniform design (Fig. 2). Each configuration can be dynamically derived as a detailed true-to-scale model. This is simply done by the user selecting the desired crane and the erection condition to be shown, the system then prepares the 3D model and presents it ready for download. Besides the actual crane, the model can also include the planned track system, if required. In addition to this, the 3D interface displays the lifting capacity curve of the selected crane as well as the maximum work zone in the form of a semi-transparent envelope curve.

The 3D models show and hide the envelope and capacity curves, as required. When displayed these have an adequate level of transparency so that they are only shown as additional information when actuated and do not hinder the actual visualisation of the crane or its integration in a 3D worksite model. The operator can always fully comprehend and assess the scenario, in spite of the displayed envelope and lifting capacity curves.

In order to be able to clearly identify the individual objects within a crane constellation the TEP planning tool can include crane designations awarded in the project. These are optionally used during the 3D export and are indicated next to the model. Furthermore, there is an option to apply advertising signs to the crane model – in this way, company names or logos of planning engineers or contractors, or also crane hiring companies can be integrated. If the main colour of the 3D model prepared deviates from the colours of the actual crane manufacturer, the TEP tool can export individual colour compositions.

When developing the 3D interface special attention was given to compatibility with different planning environments currently used in the construction industry. The crane models are optionally made available in the industry-focused, system neutral jt-format or alternatively in the dwg-format. This makes it possible to integrate TEP generated 3D models in corresponding projects. Various applications of Autodesk, e.g. the planning environment Revit or also the 3D modelling software Inventor as well as the PLM software NX of Siemens (formerly Unigraphics Solutions) are also supported.

Fig. 2:
3D tower crane
modelling using
the tower crane
deployment planner

4D process analyses of construction crane deployment

Using the 3D interface of the TEP planner the user can quickly analyse an optimised crane deployment. This leads to a maximum level of use of each individual crane and a reduction in the number of cranes in operation. Within the applied planning environment the envelope curves of the crane models permit identification of any overlapping of the work zones between the cranes or with their immediate environment on the basis of Boolean operations. This enables the detection of potential collisions in advance and prevents collisions during the actual construction work. Spatial bottlenecks during hoisting processes are displayed and any required slewing limitations can be defined.

The planning engineer also receives visual information regarding possible over-slewing of the cranes and the spacing between their work zones. In particular, it is possible to check the coverage of all required hoisting tasks: due to the semi-transparent formation of the capacity curves integrated in the envelope volumes it is possible to project the curves onto the ground of the worksite. Through visual inspection the planning engineer can now decide whether the respective crane position on the virtual construction site is suitable for accomplishing all hoisting tasks. It is therefore possible to show the lifting behaviour of the cranes in conjunction with their immediate environment/positions that can be reached and the hoisting heights (Fig. 3).

By simply deriving complete three-dimensional models from the previously implemented crane project design different crane combinations and different crane positions can be tried out in the shortest of time in the digital worksite scenario. The models can be easily exchanged and shifted to reach a crane constellation in which the cranes can best interact – also with their direct environment. The exportable global coordinate system of each crane model guarantees an uncomplicated positioning in the 3D worksite model.

Besides the planning and analysis of hoisting and delivery processes, or the definition of the ideal crane positioning in a work progress oriented 3D model, these crane models can also represent the planning company. Thanks to the possibility of a user-specific crane model variation regarding colour and crane designation, and the possible integration of advertising signs that display company names and logos, in a holistic 3D worksite scenario the recognition factor increases significantly. This advertising effect has a particularly positive impact when awarding contracts: visually highlighting the position and presence of the crane deployment planning company.

Potential for the digital tower crane deployment planner (TEP)

The TEP planner permits digital, paper-free tower crane planning while simultaneously reducing financial costs and logistics expenditure. Configurations created at just a few clicks can be used as a flexible basis for a holistic planning concept: optimised crane selection, erection according to construction progress, transport, assembly, 4D process analyses and calculation. It is possible to respond to unpredictable changes during the construction progress with immediate re-planning measures and any extra costs are reduced to the required minimum. Compared to conventional manual project planning the reduced expenditure with the TEP planner and the possibility to try out different variants offer flexibility in planning quality and quantity and ensure process reliability: tower crane deployment can be designed faster and with a more holistic approach, making it possible to handle more projects and also projects of greater complexity. Cranes selected according to the actual hoisting task boast an excellent utilisation level and consequently lead to a more efficient crane operation than is currently the case.

In future, there will be projects with fewer cranes and an exact crane selection corresponding to the assigned tasks. By considering the required coverage of operating radius and lifting capacity as well as possible collisions between cranes or with the direct environment, a 3D-based position analyses can define a suitable crane constellation with the optimum level of utilisation and site location (Fig. 4).

The TEP planner permits project planning in a fast and simple manner allowing contractors to take on projects with complex hoisting tasks. Tenders and invoices as well as technical crane data sheets, package lists or detailed instructions for transport logistics can all be quickly derived from the planner. Crane hirers can respond to inquiries within the shortest of time and can support customers with their expertise; subsequent change requests are easier to handle. Using the TEP tool the available crane fleet can be exploited more efficiently, the deployment of each individual crane takes place in the best possible way in compliance with its individual hoisting performance.

Loading lists and load orders as well as weights and centres of gravity of the load created with the TEP tool make crane logistics more transparent and structured. Clearly defined transport convoys enable efficient loading and arrival of the correct part at the scheduled time. On the worksite this results in a controlled workflow without delays. Optimised transport reduces the number of vehicles in use to the required minimum, thus avoiding unnecessary trips and low-capacity machine utilisation.

The expertise of crane planning engineers remains indispensable. With the support of the TEP planning tool the work of crane planning engineers is more transparent. Redundant, time-consuming procedures such as datasheet searches or the preparation of package lists are omitted. Recurring, work-intensive manual processes

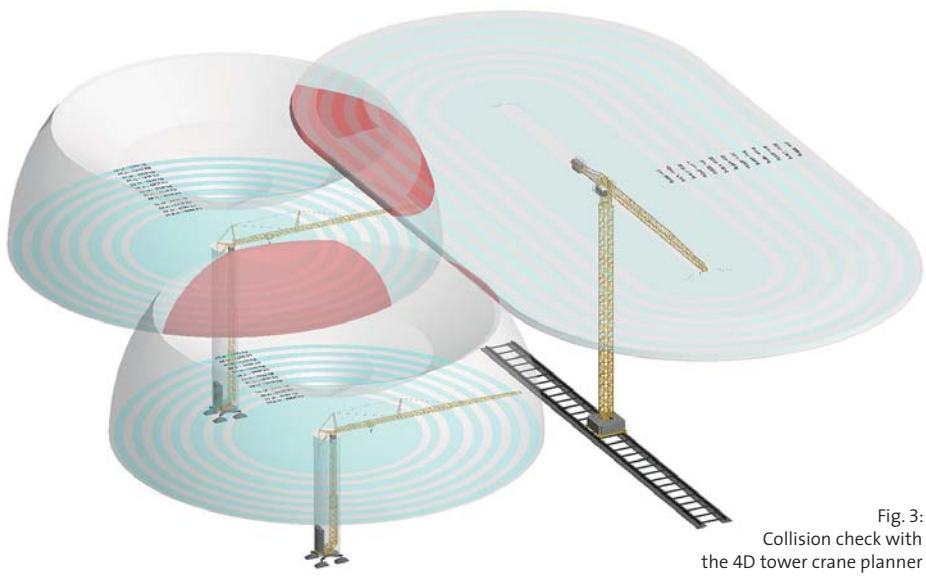

Fig. 3:
Collision check with
the 4D tower crane planner

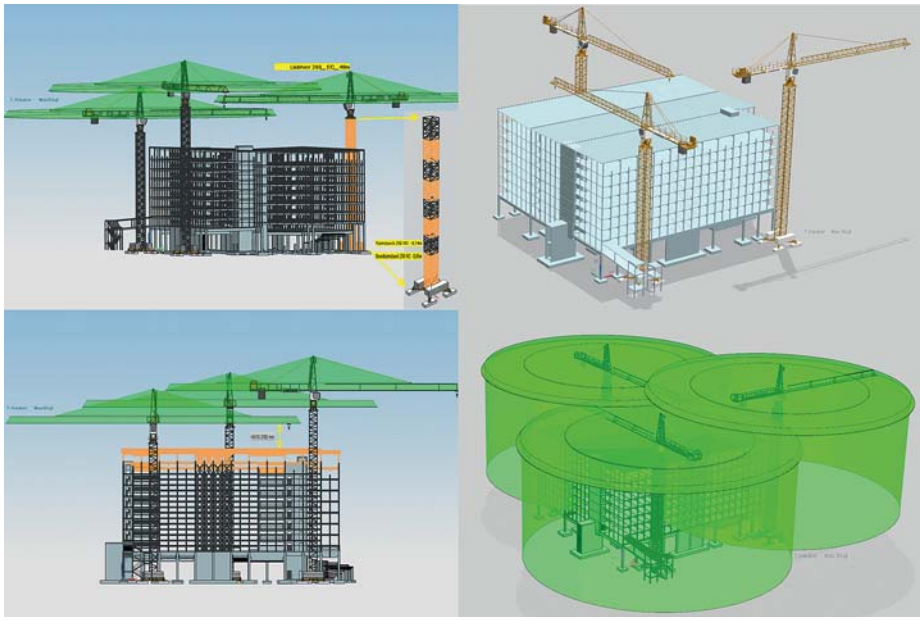

Fig. 4: 4D tower crane planning – practical examples (source: Max Bögl GmbH)

are taken over by the digital planner in an intelligent structured planning framework with central database. The task of the planning engineer is now focused on the core competence of optimising tower crane deployment using a holistic approach.

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