Findings from Evaluation Interviews (Chapter 6)		*red = comment
No.	**Question**	**Interviewee**
0	**TCI management (for Contractor only)**	
0	From your experience, how are temporary construction items e.g. formwork elements planned and managed for construction projects?	
	- Maybe it's obvious but the main the main business model in Denmark here is renting a formwork not buying	**TCI Provider 1**
	- Different on every project --> On small project, just an estimation. On some project where a site model and 4D plan is created, TCIs are considered more in detail - However, TCIs are very important to consider as they affect time, cost and quality of a project --> better planning = reduce waste, have transparency - Many construction manager/ foremen order a lot of formwork elements, to be sure that is will be enough for the project! --> **Security** --> with a more transparent management of these items, insecurities can reduced and thus, the amount of elements on site are reduced to the minimum	**Contractor 1**
	- Over the las 10 years, TCIs have been considered along the BIM-based project delivery to optimize the production and the planning as well as economy regarding the number of items to rent/buy and use on the site. - Example project: Nordea project --> Twice a week a meeting with the construction crews regarding how they should handle the TCIs (material, machines, etc.) on site in a very efficient way so all the crews knew what was available when and where --> Weekly meeting for discussion and update based on dashboard! --> Internal planning system called to combine location based planning from VICO and BIM on the construction site for the planning and management of TCIs	**Contractor 2**
	- In my company, we already plan our projects from the building model, and afterwards we plan the project on site, and then we compare those two elements and make it work together. - Own specialists calculate the TCI requirements for the site model --> What is missing is the process in between from the planning to the site and there the solution presents a good way to bring the required data to the site, enabling a just-in-time delivery and takes into account the progress delays or changes	**Contractor 3**
	- Temporary construction items are only included as an estimate or percentage of the total cost but is often not planned and monitored properly. It is not sure what is there on site, who is using it (booking of tools, machinery), and sometimes they just disappear because they are neither planned nor tracked.	**Consultant 2**
	- Planning of TCIs is still done in a very primitive and manual approach based on Excel data which is extracted form the building volume - Based on this rough estimation, TCIs are ordered from supplier - On site, formwork is getting lost and stolen because of there is no transparency about what items are needed when and where --> As no transparency of what items are needed where, order enough items --> Overstock or Understock on site	**Consultant 3**
	- Current practice: In worst case scenario you just order what you think is needed on site - Sometimes, you considered TCIs in your site management, but most processes still wouldn't give you a precise number and therefore, the stock can be too much or too low, depending on your estimation - During the project, equipment is ordered on short notice as the construction manager further develops the construction plan - Nowadays nobody counts things on site --> If returned to supplier, there must be a standard percentage of maybe 5% which covers the waste (losing or damaging items) --> As PERI said with linking this information to the delivery and stock numbers of the supplier!	**Consultant 4**
	- TCIs are mainly considered in site planning as an estimation, based on the existing building data --> No precise numbers are used and the main driving force of the TCI quantification is to ensure that the schedule can be followed --> Therefore, the approach is to make sure, that there are always enough formwork elements on site, to meet the estimated demand + some buffer --> Leads to a lot of waste in space and rent on the construction site --> Especially elements taking up valuable space on site is heavily impacting the productivity and safety on site - Formwork elements which are currently not used are stored in some corner on site and when the item is needed again, the workers might have forgotten where it is and have to look for it or simply order a new form --> Missing transparency is creating these issues - The better and earlier TCI planning is integrated into a project, the better the site planning can benefit from the transparency regarding TCI utilization and save money and time on site	**Contractor 4**
1	**General Validation of the Solution**	
1	What is your first impression after the presentation of the prototype solution? From your perspective, where do you see the most potential in the proposed solution, integrating TCI planning and management in the existing BIM-based project delivery?	
	- Easy accessible for people who actually use the data --> mobile app for site workers and dashboard for management - Challenge: Difficult to automate the process of formwork planning as it is a quite heavy engine with many complex considerations --> Make an option to manually plan the complex parts of the project as the automatic planning is best for easy wall layouts - Also consider the impact of changes to the system --> address how changes can be implemented in the TCI utilization plan --> Implement changes in an easy way! --> all changes has to be done in the schedule to update the TCI utilization plan!! - A lot of benefits of this tool for the industry - **Main benefit**: Large amount of easily and automatically calculated formwork elements (for big in-situ projects with straight walls and rectangular corners) to plan all tasks in advance and just instruct the workers with the assembly of the already correctly located items - Formwork elements itself are not expensive. But the installation and handling of formwork elements can constitute high costs and are mainly affected by the transparency and available information --> The solution provides transparency for the contractor but also the TCI provider to apply a more lean and efficient management of formwork elements - Information about which items are available at the job site or what is the pool of material available.	**TCI Provider 1**
	- Solution is very interesting and has a lot of potential to increase awareness and transparency of the utilization of TCIs - Interesting to actually use it in a construction project and make the workers actually use it and benefit from it - Construction Management will benefit a lot and gain **control** over the TCI utilization --> Better planning of the site logistics and space management --> Continuous construction flow with a forward-looking and lean approach - Benefits range from reducing waste, gaining more space on site and reducing costs as all in-situ concrete related construction activities can be executed in a more efficient and secure manner - Also environment gains on the solution as only the elements are ordered which are actually needed and waste is highly reduced --> environmentally friendly	**Contractor 1**
	- Interesting solution, but based on a lot of assumptions (cost information, only straight walls) - Need for a process flow where and when is the solution used in a construction site	**Contractor 2**
	- Good first impression - Easy and understandable process --> Main potential with the site integration that people on site will directly use and benefit form the solution and can give their feedback to the project management level - Having transparency which enables just-in-time delivery and a dynamic consideration of TCIs benefits a contractor	**Contractor 3**

Findings from Evaluation Interviews (Chapter 6)		*red = comment
No.	**Question**	**Interviewee**
	- Fascinating solution that tries to solve a real and complex problem in the construction industry with an open standard approach - Extremely usable solution for contractors	**Consultant 2**
	- On the right track with the idea and developed solution - Automatic generation of TCI utilization is targeting a niche in construction which is not yet fully optimized	**Consultant 3**
	- Good first impression and solution looks very promising and nice - Generally scared when something is automated when it comes to quantities --> Really need to be sure, that whatever you extract from the different sources is valid --> possible solutions: 1. Developed standards which the stakeholder have to follow to guarantee the right data 2. Create model checks to verify the model according to the specifications (e.g. clash detection according to the ICT agreement --> Need to establish a verification process of what is extracted from the BIM data (model & schedule) - Generally on a construction site or any production site (also in factory), it is important to know where stuff is --> Solution targets this need and thus provides a great value --> Knowledge about where equipment is lying and how much of it is on site and where it is used next. - It is really showing the potential of integrating data sources in the construction industry which historically has been really poor --> Currently it's a problem of chicken and eggs because people don't structure the data because nobody uses it, so why do it. --> Therefore, there is a risk that the data is not correct and this requires some awareness and quality assurance means to assure the data integrity --> With standardization and generally a higher technology level of the industry, this can be resolved in the future - Lean management is currently not possible because the information is missing. The proposed solution provides this information and therefore, allows to have a lean management --> However, it requires a **change management** in the way people work and this is a fundamental part of the thesis! --> Emphasize in the thesis project that the solution provides the information and potential for lean management, but there is a lot more needed to actually implement a lean management process on the construction sites --> not just technology (emphasize this in the thesis) - Thesis intention should not be to develop an intelligent engine to calculate formwork elements, but rather provide an idea or platform of connecting things (--> be specific about that in the thesis goal)	**Consultant 4**
	- Cool approach to take the standard data from a building model and use it to calculate the quantities of items which are in a relation to the extracted building elements --> Can be applied to many different areas (e.g. sizing of a radiator, thickness of a slab and the division in hollow core elements) --> approach to create a data model to each project and use it for calculations has a big potential - Use of a very generic perspective (data modelling with Linked Data) on a very narrow problem (formwork planning & management)	**Consultant 5**
	- Good first impression of the solution, integrating the available data and going through the entire process but applying it to one specific area (TCI utilization of formwork) and **bringing the BIM data to the construction site !** --> Deeply into the data of construction --> Maybe too deep to where the construction projects are today - Good corner that has not yet been touched and therefore provide value to the industry! - Similar to the process of managing prefabricated elements (certain order, just in time) but including a calculation engine to provide the TCI information	**Consultant 6**
	- Impressed of the holistic scope of the project --> Managed to link all the relevant data (building, schedule and TCI data) into one solution and create a functional and automated process flow to generate the desired result - Sees the need for such a solution in the industry, however, not sure if all the contractors are already ready for this	**Consultant 7**
	- first impression of the proposed solution is that it is a good concept with a lot of potential for further development. It gives the management team as well as the contractor a good idea what TCIs to expect in the upcoming period as well of the expenses which come along.	**Client 1**
	- Good first impression and appreciates the data-driven perspective with using an open data environment and data model to generate value for the construction site - Main benefit would be the saving that are generated by the dynamic stock consideration with reduced items on site leading to less rent and less waste of valuable storage space - The second biggest benefit is the enabling of a lean management due to the transparent TCI utilization plan --> Has to be integrated into site planning	**Contractor 4**
2	What are the benefits of the proposed solution? Can you name the benefits for each of the following stakeholder group? Who else might benefit?	
	Everyone will benefit from it. --> reduction of amount of deliveries to and from the site --> cost savings for everyone (also due to reduction of waste) **1. Client:** - Reliability of the contractors offer, less claims and more transparent construction site, able to follow the schedule without cost and time overruns - Easily apply the solution with different provider and find the best fit/ price for subcontracting a supplier (same for contractor) --> comparison between suppliers with proposed solution **2. Contractor/ CM:** - cost savings due to reduction of waste, more efficient space management on site, more efficient handling of TCIs and less waste of time - citation form contractor at case study site: "Soon I'll be running out of space on the job site to put the formwork. Where shall I put the formwork?" --> If he can plan it better, he could store the forms somewhere else when they are not needed (external stock) and he knows exactly when to bring it back but right now as he does not have the complete overview over the formwork utilization, he needs to have everything available nearby --> taking up a lot of space for storing but also cost and time for handling --> need to move the things around on the crane on limited site often as the construction site evolves --> time and cost increase - Could create a small stock yard for the site to store all elements which are not immediately needed but the contractor would know exactly when which items are needed from where on the stock yard to where on site - proactive consideration of TCIs, less reliability on supplier **3. TCI Provider**: - For supplier, a better planning of the construction site from the contractor always also means a better planning for the supplier - Better and forward-looking planning of the own stock yard --> Less overstock due to transparent information how many elements are needed when on which project - More time for design engineers to focus on the complex and more important formwork constellations on the project - If the solution is used in-house: Easy calculated offer for standard and simple wall structures!	**TCI Provider 1**
	1. Client: - Benefit generally from a better overview and transparency of the project --> Can rely more on the calculation/ offer of the contractor as it is not only based on estimation --> Less extra price claims, finishing on time, less cost overruns 2. Contractor/ CM: - See **above** - Can use it in the bidding phase for formwork supplier to get a first overview of how much formwork would be needed on site to then select a supplier 3. TCI Provider: - See **PERI**	**Contractor 1**
	Not answered	**Contractor 2**
	- Same as PERI - **Client**: Get a better value project with less cost and time overruns --> more reliability	**Contractor 3**

Findings from Evaluation Interviews (Chapter 6)

*red = comment

No.	Question	Interviewee
	1. **Client**: - No direct benefit, but will have more reliability in the estimation of the project both cost and time-wise 2. **Contractor/ CM**: - Cost & Time savings, overview and control over the TCI utilization, potential to optimize the management of TCIs - Active monitoring would further strengthen the solution as elements on site get lost or are used for tasks they are not supposed to be used. 3. T**CI Provide**r: - Could offer the solution as their own service and calculate the TCI needs for their clients (contractor) and therefore can also optimize their own stock and product management - Higher per unit/cost but lower total prize in bid, as a project specific TCI utilization is offered which requires less TCIs - Get more involved in the project and provide a knowledge-based and collaborative service to the contractor	**Consultant 2**
	1. **Client**: - Will get indirect benefit from a better project 2. **Contractor/ CM**: - Solution generates value for the party who pays for the TCIs 3. **TCI Provider**: - Both perspectives that the TCI provider benefits from the better transparency of the contractor to order what is actually needed but also reducing the amount of TCIs needed on site, meaning lower revenues per item for the TCI provider per project	**Consultant 3**
	1. **Client**: - Will get indirect benefit from a better project --> Reducing risk and uncertainty in a project (extremely important!) - Getting a more accurate price from the contractor (from the equipment management budget) - Especially if the solution is further developed to also include scaffolding and safety barriers, the client would benefit from a safer construction site --> but also the consideration of formwork will give the client a safer and more efficient construction project - Client required the project parties to plan the project in a good way and such a solution would guarantee a good site planning - Client could require such a solution in a project if it is available on the market to see early consideration of the TCI planning and site logistics management in pre-design - It also allows to meet safety requirements from authorities in dense areas a NYC, where a scaffolding is required --> Client can assure to meet the safety regulations with actual numbers and also provide the authority with more transparency to ease the project approval process 2. **Contractor/ CM**: - Main benefits of the solution are for the contractor --> Allows optimize the whole production flow and to have a more efficient and lean management process of TCIs --> Cost and time savings due to transparency - Early stage assessment ! --> Right now, a huge amount of money is put aside for the site equipment management because contractor don't have the knowledge of what items are needed when on site (--> Interesting to ask a contractor how much budget they put aside for that in the beginning and how this budget actually matches out when they go into construction) --> There is a huge discrepancy there - Huge potential in improving the site logistics management with this information (either do it internally of employ a third party as Ajos who takes care of that) --> Requires a further development of the solution with site logistic optimization considerations 3. **TCI Provider**: - First mover benefit --> If one provide would offer this automated calculation, he could reduce his costs and therefore provide a cheaper offer	**Consultant 4**
	1. Client: - efficient project as a side effect --> But would also get more security and minimized project risk as he could require the contractor to proof that he has some consideration regarding the work environment on site --> Can provide clear and transparent information with the proposed solution --> Tailor made dashboard for client mindset would also add value to the client **2. Contractor/ CM: - Can automatically get information of the TCI utilization on site and thus, can better plan the site layout and logistics as well as workflows - transparency of the project and optimization of workflows in general** **3. TCI Provider: - More transparency and better collaboration to the projects** **- Can be directly integrated into the project, giving advice for the design and planning as well as calculate the TCI demands** **- As the TCI provider can give a detailed offer based on the building model, the offer is also not only evaluated by the cost per item, but rather by the cost impact on the whole construction project --> Supplier with higher item costs, but a much better workflow and system would end up winning the contract, as the project manager has the transparency to compare different offers on a much higher level of detail (over time and impact on site)**	**Consultant 5**
	- Who will benefit the most generally depends a lot on the business model, who is in control of the data model and who is providing the data for whom 1. **Client**: - Benefits indirectly of the more transparent and reliable construction process --> maybe gets a discount as the contractor can better plan the construction project - More focus on safety on the construction site through the detailed TCI information on a task level 2. **Contractor/ CM**: - Positive impact in the site logistics and layout planning - Lowering the stock and storage demands on site through a more dynamic and just-in-time delivery - Big contractors with the whole production within their organization can overtake the data model from the design team and have then full control over the construction process with all PCIs and TCIs planned and managed through the structured project data --> Close solution for one company only 3. **TCI Provider**: - Can better plan his stock with transparent information from sit - Can integrate his expertise earlier into the project if he takes an active role in this approach	**Consultant 6**
	1. Client: - More certainty that the project is delivered on time - More safety awareness and consideration on site --> Less items and a better planning on site = safe construction site --> client might end up with smaller construction site **2. Contractor/ CM**: - Reduce unnecessarily blocked space on site - Reducing time and costs of TCIs (in different process aspects as rent, logistics, storage, installation, dismantling) - control and transparency about the TCI utilization leads to a better planning and management of the site workflow - Higher certainty that the amount of items on site is sufficient to meet the TCI demand, but the TCI management is also efficient and lean in the same time **3. TCI Provider:** - Depending on the business model, the created value of the solution might interfere with the interests of the TCI provider as they want to maximize the amount of items, they rent out to the construction site --> In contrast to what PERI says! - If solution is used by supplier, they can offer a better and more transparent service to the contractor --> More competitive price as less items have to be used on each project and they don't need to have an overstock in their storage --> Can use saved items on another site or also temporarily exchange items from construction sites as the transparent handling allows it	**Consultant 7**
	- Both contractor and the client management team will benefit from an automatically created TCI plan. For the contractor it can be reminder of what is needed. With the reminder he can do a quick calculation of the quantities just to ensure that the amount provided matches the TCI plan. As for the management team, a TCI plan provides a good indication what to expect and plan the economy in accordance to it.	**Client 1**
	1. Client: - No direct benefits **2. Contractor/ CM:** - Benefits the most from the automatically generated TCI utilization plan providing transparency to better plan the construction site and use a dynamic TCI delivery approach which results in less waste of space and money **3. TCI Provider**: - From the first perspective, do not benefit from the solution as TCI provider generally make a lot of money due to the fact that the contractor does not know his TCI demand on site - On the second perspective, the TCI provider can improve the communication with the contractor who can order the precise amount of TCIs in advance, leading to a better stock planning of the TCI provider who can reduce the amount of formwork elements	**Contractor 4**

Findings from Evaluation Interviews (Chapter 6)		*red = comment
No.	**Question**	**Interviewee**
3	By integrating TCI planning and management into the construction process, the proposed solution aims to improve productivity and safety on site. In what extent do you see this intention fulfilled? What would be required to solve both issues with the proposed solution?	
	- Safety generally as a secondary effect of a better and more transparent planning and management of TCIs - If specific safety measures are applied: (1) all items in the formwork process have to be considered, (2) add direct safety means to increase safety --> SRF with notification, assembly procedure with video or pdf instructions, checklists for each task which TCIs are there and what is missing - Productivity is obvious due to more transparently and lean management of TCIs	**TCI Provider 1**
	- Agreement - **Productivity**: Much more **control** over what to order and when, just-in-time delivery, more space available on site, improved logistic on site - Security that the utilization plan is correct leads to less contingency in estimations, safe cost - Visualizations are important to increase safety --> Model TCIs in site model or use visualizations/ videos to show assembly procedure and risky activities - **Safety**: More space, better handling of site materials (less material flying around) and SRF raises awareness if used correctly and based on experience. Further improvements should be a video or visualization that shows the specific assembly instructions of each activity, a 4D site model that allows the worker to review the digital twin and also allows a safety professional to analyse the process digitally and thus, prevent accidents.	**Contractor 1**
	- Need to conduct case studies on projects to quantify the benefit of how much improved productivity and how much more safety is realized on site with the use of the proposed solution --> **Field work:** Follow a production crew who construct a in-situ wall without the solution and then compare the same process with the support of the proposed solution!	**Contractor 2**
	- Solution has to cope with changes which happen all the time on a construction site --> Now, changes are only based on schedule updating through the progress monitoring. Would be nice to also make the solution write back to the model and update the model to as-built. - When you know your production and can plan ahead, the safety and productivity is increased as well	**Contractor 3**
	- Better planning and transparency automatically improves productivity and safety - More a secondary effect but cost savings can be seen directly - Especially the lean aspect supports the improvement of the productivity on site - With knowledge about what has to be installed where, safety instructions and risk factors can be introduced to the specific tasks to raise the awareness of correct execution of tasks and safety	**Consultant 2**
	- Saving time and money for the contractor and increasing the efficiency on site and therefore also increasing the productivity - SRF + assembly instructions per task are increasing safety	**Consultant 3**
	- Yes - With safety consideration as a SRF and especially assembly instructions for the construction workers, safety is improved on site - Calc Engine can be used to calculate scaffolding and safety barriers and by that highly increase the safety consideration on site --> Especially for contractor, this would provide great value to their responsibility as the consideration is automated --> Also important from a client perspective to have safe sites and provide transparency about the safety considerations! - Productivity improvements are a result of the possibility to better plan and manage the construction site due to the TCI utilization plan and the transparency it provides - Improves productivity if it calculates the right thing --> Data integrity	**Consultant 4**
	Yes, valid assumption	**Consultant 5**
	- Difficult to get a better safety as the construction workers need to use a mobile application --> Giving them insights of each task --> Maybe foreman needs to be in charge to show the workers the assembly instructions for each task! - Safety as a secondary benefit from more transparency on site and a better workflow with less formwork lying around - Productivity improvement due to transparency and better planning and management of the site --> also just-in-time and less stock needs	**Consultant 6**
	- Yes	**Consultant 7**
	Not asked	**Client 1**
	- Productivity absolutely - Safety also, but more as a secondary effect --> If including the assembly instructions and the safety risk factor (mark tasks in green, yellow and red to identify risky tasks!) --> Huge improvement in safety can be generated as less items are lying around the construction site and if the TCI utilization plan is further integrated into the site planning!	**Contractor 4**

Findings from Evaluation Interviews (Chapter 6)		*red = comment
No.	**Question**	**Interviewee**
2	**Improvements/ Further Development**	
4	Would you and how would you use the proposed solution in one of your projects? What further development/ considerations are needed to apply the solution in a real construction project?	
	- Use of the all items in the formwork process to develop a holistic solution --> Corner, Wall endings, platforms, safety guards etc. (Otherwise, contractor won't buy the solution and will just be another tool in the box that he will not use) - Include man hours of each task related to the formwork application --> time and economy --> Try to quantify the benefit of the solution by integrating the tasks which account for the biggest costs (handling of formwork on site and not material costs) - Include curing time for concrete that depends on the geometry and characteristics of the concrete as well as the weather conditions on site - Include cycle plan of the contractor, when which wall will be installed --> Information for planning corner elements and wall endings with waler and plywood) - Focus on the data integration and distribution part in the solution and outsource the TCI calculation (to supplier) - Link the logistics status with the database, to know how many items are actually currently on site and when the next ones are delivered --> What is delivered and what is returned?? --> PERI would use the solution by asking the client (contractor) to use it and therefore get a better planning of the items subject of delivery	**TCI Provider 1**
	- Would use the solution in a small pilot project to test its functionality and to get feedback from the workers who will use it - Using default TCI dataset is good in the beginning to get a first estimation and to compare bids of potential suppliers. --> Gives a quantity without already choosing a supplier. If supplier provide or publish their products, a cost and time comparison of different product solutions can be made easily. - Link the logistics status with the database, to know how many items are actually currently on site and when the next ones are delivered --> use exicute as a communication platform for the supplier? - Dependency/ Reliability to what is planned automatically --> what is planned has to be executed --> little flexibility for the site workers to improvise --> construction workers are used to get a big box of material and then they look what fits and apply it (as playing with a box of Lego) --> if everything is planned, the workers have to follow the plan and the plan ahs to be easily understandable for the workers! - Needs to be open for different BIM modelling and scheduling software - Integration of 2D-calculation, 4D-site modelling, different TCIs - Prototype is good, but is only a first test and had to be further developed by testing in real life and asking persons who would directly benefit from it, for feedback and improvements	**Contractor 1**
	- Focus more on the collaboration aspect from the construction workers with the project manager --> Construction worker will check on checklist if they installed all TCIs for the construction task and PM will get the update on the dashboard - '- Eliminate the number of ideas and uncertainties around the solution and create a connection to reality --> Only a prototype that has to be tested and applied to a small production activity where the real benefits can be quantified --> Small scale on task level: if the solution can't provide benefit to the task, it won't give benefit to the project - Not possible to name any benefits without the proof of functionality of the solution - Need for flexibly change the master plan with the current circumstances on a construction site - Consideration of the technology demand of small contractor --> Can use solution with the help of a consultant! - Consider the balance between optimizing safety and productivity --> Solution only raises the awareness of safety and improves the space management and reduces safety hazards as the construction and logistic processes are transparently planned	**Contractor 2**
	Not answered	**Contractor 3**
	- Yes, but - Solution has to work with all the different software applications and all stakeholder who might not be on the required technology level --> Create ontologies for describing each data source (model, schedule and TCI ontology!) --> Data has to come from different stakeholder (engineers but also supplier) and therefore, must be directly published in the right format or converted - Solution must be extended to cover different data sources in the following three areas: 1. Software applications for the BIM data, 2. multiple TCI types (not only formwork), 3. multiple products from several supplier --> Decision to create a specialized solution or a platform solution that can generate utilization plans for multiple TCIs from multiple data sources - Solution helps to get an automatic planning of TCIs that enable an efficient management of TCIs on site --> Next step would be to optimize the storage and logistic management with the generated data! --> digital integration of an logistic optimization tool - Write back TCI utilization data to schedule and model and try out different scenarios (e.g. with AI) for optimizing the project delivery --> Avoid special formwork elements, reduce amount of formwork sizes, adjust schedule according to TCI information (requirements, availability, etc.)	**Consultant 2**
	- BIM part is making the solution difficult as not all stakeholders who are involved in the process can provide their data digitally - Important to also work with some manual input for providing the information - Need to answer the question how much of the solution can be done without BIM --> Take the target users from the level of technology where they are today --> Flexible solution - Develop a stable and final solution where all shortcomings and uncertainties are considered and eliminated and everything works as expected - Solution focuses mainly on planning part and only provides raw information for a better logistics and storage management of TCIs on side --> Further Development would be to focus more on the logistics planning with the transparency that is provided by the TCI utilization plan	**Consultant 3**

Findings from Evaluation Interviews (Chapter 6)

*red = comment

No.	Question	Interviewee
	- Solution depends on the data integrity of the extracted or received data from the different stakeholder --> For full functionality, require standardization and digitalization in the construction industry --> Use some manual input in the solution for parts which cannot be received automatically - Intermediate step of the solution could be a semi automated linking of the data ad if the data quality is assured, a fully automated process can be applied in the project - Passive progress monitoring requires the construction workers to actively track their work and what items they used via a mobile application --> Requires a change management to implement it on site --> Active tracking with IoT-sensors would allow to actively track the items on site without the need that construction workers have to actively monitor their work - Consider a packaging service from the TCI supplier or Site manager --> With the information of what items are required where on site, a responsible party (also as Ajos) could set up and locate all the items which are needed for each construction activity on the location, where they are needed --> extra service for site logistics manager --> Would allow a lean management with an efficient space utilization and construction flow on site and reduced waste in terms of material, time and space - At TNO in holland, they had this concept of **BIM bots** --> The idea is what you have small tools like your formwork calculation engine. But you could have any kind of tool and it could be PERI to provide a engine for formwork design and it could be the safety barrier provider, to provide an engine for their project expertise --> Fits well into the idea of a Linked Data environment where different stakeholder publish their project input which can be used for improving the project --> e.g. A formwork design and utilization plan can be provided from PERI and the site manager can use this information for developing a lean site & logistics process that also gives feedback to and can optimize the project schedule - No matter how many bots you include in the system architecture, the solution would still work --> Will never create a solution that can do everything, so the more generic the middle part of the solution is, the better it is --> **Data management/ processing** - Would be great to establish an infrastructure for stakeholder integration so they would provide the project with the required input, based on their products - If the solution can also provide feedback to the planner (model and schedule) as well as to the site planner --> optimization of model, schedule and site logistics based on the calculated TCI information --> Full integration in the construction process, creating a lean --> NCC's Efficient Logistics project --> a lot of planning of all the materials that are needed on site (similar consideration!)	**Consultant 4**
	- TCI supplier could act as service provider to the project, getting access to specific data in the data model to calculate their TCI demand for the project and link it to the project data model from where the project manager can use the information to design the site layout and workflow --> Supplier can be included to the project and give their expertise regarding the project planning with some suggestions of changes in the project that would reduce the costs of TCIs (especially handling) and then also easier provide their offer within a functional tender - Solution can be further developed to the planning of the site and logistics management as now, it is only providing the raw data of how much is needed where, but doesn't suggest where it has to be stored before and after use --> assembly instructions would already --> Flow on the construction site to be integrated: Where is the stock, how are the items moved from one part of the construction site to another part --> Shift the transparency not only to what is needed but also to how this will work in sequential order between (local) storage to use and back --> break down the process of applying formwork to the different steps - Integration of the solution into a digital construction site planning (4D)	**Consultant 5**
	- Structured data in the construction projects with data model consideration and standardization how to describe and model the data is required to make it work --> Only few contractor today have control over their data --> But this will 100% evolve in the future --> Otherwise a third party is needed who will modify the data from the stakeholders, so it can be used for the Linked Data environment - Integration of different stakeholder into a project is only possible with the standardization of data	**Consultant 6**
	- Not sure if all contractors are already ready for the solution, as it requires structured BIM data for the whole project --> Solution depends on the input of the different stakeholder in the construction chain and thus requires a certain level of technology of all the stakeholder - Improve the formwork calculation engine with more advanced algorithms and different TCI types - Also open up solution to also add data manually which is not covered and not part of the system --> Fully automatic solution might not be able to cover all geometries and complexity of structures --> If the solution solves 80% of the problem, but it takes 80% to solve the last 20% of the problem, then there is an issue for implementing the solution in real life - Apply the solution in a pilot project and determine and reduce most of the uncertainties and clearly demonstrate the benefit of the solution to convince also the conservative construction industry that this is actually beneficial - Solution is only working with Revit models --> Standardized solutions as ifc-models would be better to reduce the dependency to a software --> Either have a solution that uses standardized data sources (model, schedule) or make the software applications automatically extract the data as Linked Data (in RDF triplets) that the individual generators of the data can publish it directly to the Linked Data project environment	**Consultant 7**
	- Deploy the proposed solution on the project with the considerations of theory and practice, as well as taking bugs into account. Because theory and practice never go hand in hand. As this concept is quite new it needs to be employed in small projects first to see how it goes.	**Client 1**
	- Difficult to implement such a solution in the current industry as it requires an effort regarding change management to change the way people work --> Current practice is very slow and inefficient with information management from the construction site using change orders, etc. A simple information registration from the worker on site in a mobile application would generally improve this information management a lot but it is still not implemented widely --> Using data in construction is a quite new approach and the industry has to adapt to it, in order to fully implement such solutions --> The more visual and easier the solution is to use and understand, the better it can be implemented! As simple as possible to provide the required information - Enhance the impact to design by giving feedback to assess the TCI demand as early as possible in real time when the building is modelled --> e.g. include a real time engine in a modelling software that provides the formwork quantities for each modelled building element as it is modelled, hence, adding the TCI consideration as a new design factor e.g. maximize the number of standardized formwork elements! - Also include slabs, columns, beams in the formwork calculation engine --> catalogue of items will be quite big to create a holistic formwork calculation within one solution - Extend the solution to include also other TCIs! - Further utilize the output of the proposed solution and integrate it into the site planning and lean management process of the construction site --> Using QR-codes to enable this integration as it requires to know, where the items are (e.g. integrating it into IRIS cloud platform)	**Contractor 4**

Findings from Evaluation Interviews (Chapter 6)		*red = comment
No.	**Question**	**Interviewee**
5	**Step 1 - Data Sources & Extraction:** Do you see any obstacles in the way, the BIM-data is now extracted from a project? What modifications are needed to apply this step in a real construction project?	
	- Formwork dataset has to consider all items that are needed in the process of constructing in-situ walls (pouring platforms, wall endings) --> Data has to be complete in order to apply it on a real project! - Revit model has to be modified by contractor in order to model walls as they will be constructed --> Or client already requires the architect to model the building model as it will be constructed	**TCI Provider 1**
	- Open solution that works with multiple BIM software applications or open BIM standards as IFC	**Contractor 1**
	- BIM models are modelled differently and the solution should be able to flexibly handle variances in the BIM model --> Either put it clearly in the ICT agreement how the model must look like or create adjustment possibilities of the solution - Property extraction from the model can be difficult as a wall length is not always the wall length of the real wall --> Solution must extract the right data and must do that for all different software application used in the industry	**Contractor 2**
	Not asked	**Contractor 3**
	- Develop standardized ontologies that describe the different data sources (building model, schedule & TCIs), so that all stakeholder can publish their input in the right format and make it accessible - Include different software applications as data sources in this solution which are used in the industry	**Consultant 2**
	- General contractor is responsible for planning, Arch./ Eng. is responsible for building model - More open/generic (ifc-based) data extraction from the building model --> Not based on software application --> Or simple excel import?? - Focus on more elements than formwork in the TCI ontology --> Where else is a need for a utilization plan? --> Cranes, scaffolding, ladders, supports, etc. - Concept that allows also to use machines and other TCIs with the consideration of how they are provided --> Distinct process of storage and delivery if the items are owned or rented! --> Internal rental store or external rental store	**Consultant 3**
	- Using open API to extract the data would probably be easier to apply the solution in the current industry than Linked Data - Quantity extraction from a building model is risky as it requires a correct model setup --> a more open and standardized (maybe ifc-based) data extraction might solve this issue to reduce the risk of false quantities due to an inaccurate modelling --> also ICT-agreement - Creating standardized ontologies for the supplier data --> Standardized ontology framework for the construction industry. - For scaffolding and other TCIs, maybe more data is needed (load considerations) which has to be integrated as well	**Consultant 4**
	- Solution can also be done with usual data integration and the use of open APIs --> Linked data is one approach to do it and a way of working that opens up the process to different stakeholder who could add their information to the project --> Creation of a standardized approach as you give the suppliers a standardized language (ontologies) to describe their products and as a project manager, you can use this data in combination with all other datasets from the project - Parse model data directly from Revit into RDF triples (not through Dynamo) or even from a standardized model format IFC. --> In the future, you want the BIM authoring tools to directly communicate with the data store of the data model - Automated rule-based checking of the quality of the data sources (in LD via SHACL) to see if the individual data model complies with the requirements --> Could develop a dashboard to report the warnings back to the modeler, so the model gets modified accordingly to ensure the quality of the data sources and the security of the correctness of the output	**Consultant 5**
	- As data in construction projects is not good enough, a party has to adjust or modify the data first (great effort) or establish a QA tool that assesses the data from the stakeholder before it is used for the Linked Data Environment - Integrated solution allows to validate the data which is coming in, but many stakeholder are also restrictive in using integrated solution as they fear that it can automate the whole process	**Consultant 6**
	- Open for other software applications --> More standardized ifc-Approach possible	**Consultant 7**
	Not asked	**Client 1**
	Not asked	**Contractor 4**
6	**Step 2 - Data Management:** Do you see any obstacles in the way, the data from different sources is now stored & managed as Linked Data in a triple store? What are the requirements for a Linked Data environment for a project?	
	- Might be a challenge to introduce Linked Data to the construction industry and require all stakeholder to contribute --> Existing project information sharing environments as byggeweb are already in use and it is difficult to introduce a new solution --> Keep it in one place! Link to byggeweb?? - Implement it in the environments the stakeholder already use --> Get data from Byggeweb for example as the ideal current scenario --> Require all involved parties to publish their work in Linked Data as a future vision (name benefits of linked data!)	**TCI Provider 1**
	Not asked	**Contractor 1**
	Not asked	**Contractor 2**
	Not asked	**Contractor 3**
	- Right approach to use an open data format as Linked Data that can disrupt the industry and improve collaboration - Standardization means are needed to develop a framework in which the stakeholder can publish their project specific input - Right approach to create a flexible platform that pushes the data generation and distribution responsibility towards the supplier and then pulls the required data to create value for the project - For the consideration of creating a commercial product, the Linked Data approach is too futuristic and can be replaced by a simpler API-approach with classic data integration	**Consultant 2**

Findings from Evaluation Interviews (Chapter 6)		*red = comment
No.	**Question**	**Interviewee**
	- Use of Linked data required standardization for data extraction and management based on standard ontologies which are able to describe the full context of the process - Linked Data is only one possibility to use such a solution and Triplets are only a way of specifying objects, its properties and describing their relationships --> So far, only ifc-Ontology is working properly in the construction industry - Difficult to classify such a complex context as the built environment and its project delivery - For a business case, there would be more potential to just use an open API of the data providers without the need to translate everything into RDF language and create Linked Data ontologies - Linked Data challenges: - Safety and privacy of data sharing and also change management and revisions --> Quality assurance process or approval process is needed to make sure the right version of the data is used for providing information for the site logistics --> Only what is approved can be used for this consideration	**Consultant 3**
	Not answered	**Consultant 4**
	Not answered	**Consultant 5**
	- Like the idea of using Linked Data and integrating it in a holistic and functioning approach to the existing process of project delivery --> Keep in mind that some individual interests of stakeholder will be broken by interlinking the data and automatically deriving information --> New roles and responsibilities will arise in the market and we need to go in this direction of getting better data - Need to keep control over the process of what data is used and if the data has the required quality and how the data is processed to get information that benefits the process	**Consultant 6**
	- Team up with TCI supplier and let them use their specialty to calculate the demands of their product in the applied construction project --> Either tailor-make the solution for one specific product only or outsource the calculation engine	**Consultant 7**
	Not asked	**Client 1**
	Not asked	**Contractor 4**
7	**Step 3 - Data Processing & Querying:** Do you see any obstacles in the way, the data is used to provide all needed information to create a TCI utilization plan? What modifications are needed to apply this step in a real construction project?	
	- Outsource calculation of formwork elements for complex structures to specialists from formwork provider --> Link the BIM data to a already existing online calculating program (as PERI Quicksolve) --> only select simple structures (straight walls with 90 degree corners) for applying the solution and let specialists focus on the complex parts and calculate it manually --> Filter options to only select the simple walls and mark the walls thar have to be calculated manually --> Differentiation - Distance developed solution from formwork calculation programs --> Potential lies on the automatic consideration and management of TCIs - Integrate the TCI calculation with the schedule information to consider the working sequence of the walls and include the wall endings. Include detailed information about installation, stripping and dismantling time of each formwork related construction activity - Formwork costs are little, money is spent on man hours and handling effort --> How much time is spent to handle the formwork? Man hours, crane hour, stripping time as a function of the wall geometry, the concrete, the season, the weather --> For how long are the forms in use until they can be reused? Time of formwork in use.	**TCI Provider 1**
	Not asked	**Contractor 1**
	- Must consider a solution for calculating the TCIs for complex structures	**Contractor 2**
	Not asked	**Contractor 3**
	- Would require more services from supplier and other project stakeholder which generate optimization with their specific product for the project and provide the	**Consultant 2**
	- TCI calculation part of the solution should be part of the package! - Make solution more usable for users: 1. User can type in some numbers without the automatic TCI planning 2. Automatic calculation of some TCIs 3. Introduce some visual programming for building the rules for the calculation --> From formwork vendor perspective - 2D consideration	**Consultant 3**
	- Need to be a pretty intelligent calculation engine to cover the whole context of formwork design no matter how complex the structure is - Better to use integration of BIM bots (= stakeholder specific engines that would calculate the TCI demands for the project) and then write the data back to the database --> The more generic the data processing is, the better! - Although such an automatic solution (also with individual TCI engines) can plan standard situations on a construction site, there must still be a possibility to manually plan and change the plan of more complex situations!	**Consultant 4**
	- Great that the solution only works as a data model and doesn't draw elements into Revit as it is not needed and would only overcomplicate the 3D-model --> Task based information about the TCI quantities and reference through the data model to the TCI type information is enough - Supplier who would provide their service to the data model could have a pre validation of the model to check if all the required measures and geometries are existing to generate the TCIs demand	**Consultant 5**
	- A new angle on this could be to use AI that is assessing the geographically modelled building and directly derives the demand for scaffolding of formwork, based on what is modelled in 3D --> Can totally ignore the parameters of the elements and thus, is not dependent on a standardized data structure --> Sees the AI development faster approaching than the holistic standardization of data in the industry - Outsource the calculation engine to the supplier would benefit the supplier as he gets more involved in the project and he can use an advanced engine that only has to calculate one specific product type where he is an expert at --> Both the contractor and TCI provider benefit from the transparency and better plannability	**Consultant 6**
	No answer	**Consultant 7**
	Not asked	**Client 1**
	Not asked	**Contractor 4**

Findings from Evaluation Interviews (Chapter 6)		*red = comment
No.	**Question**	**Interviewee**
8	**Step 4 - Data Visualization & Distribution:** How can the developed TCI utilization data be visualized to create value on a construction site? The proposed solution allows to display the data both in a linked Power BI-Dashboard as well as the application Exicute. Is this approach reaching all parties in a construction project who can benefit from the developed data?	
	- Add assembly procedures in the mobile app - 3D visualization on the app that the construction workers use to show how the elements are assembled - Every client has their own cost for formwork! --> No list price for formwork --> More important to focus on the handling cost of formwork than only on the material or rent price --> Rent is a easily accessible and visual figure as the price for 1 lite of milk, but it actually only makes a really small amount of the process of handling formwork on a construction site (man hour, crane hour, etc.)	**TCI Provider 1**
	- Can still work even though the TCIs are not modelled in a 4D-site model as Dashboard and mobile app reaches all relevant stakeholder with the right information to improve their work - Good to tailor-make the visualization of the data to the needs of the worker who are benefitting from the information --> dashboard for management, app for construction workers - **Exicute workflow**: Worker marks the completion of a task and should then receive information about the next task where to place the formwork elements --> Further receive a checklist of what task are planned today and the next day including TCI quantities and where the TCIs are currently supposed to be located - Screen with dashboard on site would also give a good overview for the construction teams and the foremen to plan the upcoming days	**Contractor 1**
	- Reaches all parties on site --> workers with application and project manager with dashboard --> PMs demand automated dashboards to control the construction site and receive updated information from the workers --> Worker need to provide the data and feedback from site to embrace the communication to the PM - Simplify the solution to only have one platform for the construction worker and the PM --> publish dashboard in exicute platform!	**Contractor 2**
	- BI dashboards on big screen at the construction site works pretty good in my experience --> for project manager and also for regular construction crew meetings to discuss the upcoming tasks and their TCI requirements (see LPS weekly hustle and Daily meetings) - Mobile application for workers is already in use and can be used to inform/remind the worker directly on the TCI requirements for each task	**Contractor 3**
	- Yes, graphical visualization always helps to distribute information in as easy understandable format to the relevant stakeholder, and both presented solutions address the needs of the target persons (project manager and construction worker)	**Consultant 2**
	- Easy for the user to understand and provides the right data to the right stakeholder - further development could be to include an XML output for directly communicating with an ordering system of a supplier - Click on app to automatically request TCIs	**Consultant 3**
	- Addresses all the stakeholder and provides the required information	**Consultant 4**
	- Addresses the stakeholder and provides the information in a usable format - Solution also allows to flexibly modify the dashboard and create a tailor-made dashboard for another stakeholder who requests information	**Consultant 5**
	- Modelling the TCIs and hand out shop-drawings for the construction workers (as IKEA instructions) would help the workers to get an overview of what is needed where and how to install it --> Auto-generated shop drawings - Otherwise, the two data visualization and distribution means are able to deliver the required information to the construction workers - Dashboard can also be extended to reach the TCI provider who can have a dashboard for each construction project, knowing when to deliver which elements	**Consultant 6**
	- Use augmented reality to compare what is planned to what is installed --> E.g. AR at PERI or Pascal --> 3d-modeling of TCIs and integration in the site model --> model has to be aligned to the real life --> also for TCI consideration! --> Combination of AR and the automated planning of the presented solution could be very interesting	**Consultant 7**
	TCI data will be valuable if it contains the development of construction site. In other words, it has to adapt to the changes which occur during the construction process. Location, quantities, start time and end time of the use of TCIs. That way you know exactly what is needed, where it is need, when it is need as well as removing it. In the SDU SUND project, the contractors use Exicute to report the progress and complications, if any occur. As for the owners, they can follow the work progress and compare the actual working progress with the theorical schedule. A dashboard is a great tool to have a complete overview of the project, but it contains a lot of data which may lead to a long loading time.	**Client 1**
	- Reaches both the management and construction workers --> Construction workers are getting used to the utilization of mobile apps to report their work - Visualization of the data should be easy to understand also within a short time --> If passing by, the foreman should directly see which TCIs are needed for which tasks --> Gantt diagram with location information and precise TCI quantities would be sufficient for the foreman --> Developed dashboard however, is good to deliver the more detailed information to the management perspective - Safety Risk Factor can be highlighted in each task in green, yellow and red, identifying the risk level of the task regarding the utilization of the TCIs	**Contractor 4**

Findings from Evaluation Interviews (Chapter 6)

*red = comment

No.	Question		Interviewee
9	The proposed solution is enabling a passive monitoring of TCIs, based on progress information from the construction process. A further development for an active tracking of TCIs is the implementation of IoT-sensors.	What is your opinion about this? Is an active tracking necessary for TCIs on a construction site? If yes, how can this technology be implemented in the system architecture?	
	- Difficult as formwork elements are durable, are constantly exposed to high loads, movements and different materials as concrete and steel --> Difficult to install a sensor that withstands this, high risk of breaking the sensors during construction - Would still be too much of an effort for a formwork supplier --> for some preassembled parts, it is already implemented - Sensors would need to be on every item to ensure usability of the tracking system. Not feasible right now and no company currently does that		**TCI Provider 1**
	- Would be the next step to even more increase the transparency and control over the TCI management --> Not only knowledge where the forms are supposed to be, but where they are actually located --> check the workers, security for management that work is being done as planned - Sensors (if integrated robustly in the elements) can also have much more benefits as they would count the use of a form and how many times it can still be reused before disposal		**Contractor 1**
	Not asked		**Contractor 2**
	- IoT-Sensors are used in the company for monitoring what is built and after it is built --> Monitoring water supply, power supply, ventilation --> Improve construction process because real time data is generated about what is going on site - Cheap, easy to use, cloud based --> Big benefits to keep track of the construction process - No use yet for location based IoT-monitoring --> should be possible in theory though!		**Contractor 3**
	- Should be the next step to not only plan the TCI utilization, but have a tool to actively track the items and compare it to the plan --> Possible and cheap technology to use - Active monitoring would further strengthen the solution as elements on site get lost or are used for tasks they are not supposed to be used. - Quality control of the solution implementation with real-time information what is where		**Consultant 2**
	- Technically possible and fairly easy - Better use case for the further development with more focus on logistic management --> Active tracking for more control in this management - NFC tag for checking in and out of storage area on site - Real time site logistics with location consideration by using an antenna (wireless because... --> AR for site) --> possible but more expensive - for logistics consideration cheap tag on the elements is the better choice - counting items with image recognition --> Recognize the size and type of the items on site --> how many items are used/ on site		**Consultant 3**
	- Active tracking would reduce the responsibility of the workers to track their work manually --> Less risk of human failure --> Now the solution relies a lot on people actually reporting back to the database with the mobile app --> Would allow to create a production flow with a sort of fleet management system (instead of cars, TCIs are managed) - IoT itself also has a lot of challenges and limitations (range, damage, etc.), but can be solved in the future - Would definitely improve the reliability and functionality of the solution especially with items that are reused on site multiple times as formwork --> If a dynamic stock with just-in time delivery is chosen and then the workers cannot find the items and there are not enough spare items on site, you are really doomed --> active tracking would reduce the risk of workers not following the plan		**Consultant 4**
	- Would further foster the integration of the solution to the site management --> Where do you store it and check how does it move --> Controlling unit for active site monitoring to check compliance with the plan - IoT-tracking will come and it is so easy to install sensors to TCIs - Linked Data approach provides a framework to include IoT-data into the existing solution		**Consultant 5**
	- Would provide the construction project with automatic feedback on the process with high detail to control the workflow --> Workers might not want to be tracked? --> Need to see the benefit in a more transparent and better workflow - Active tracking should be possible if the hardware is further improving --> Is a good way to have control over the process and get some information out of the chaos on site - More applicable to surveying and controlling from the project manager - Workers should also get insights and benefit from the active tracking, e.g. if a item is not where it is supposed to be, the worker can locate an item of the same type which is located nearby --> Finding benefits for the ones who are getting control is the key to sell it the solution		**Consultant 6**
	No answer		**Consultant 7**
	Not asked		**Client 1**
	- Instead of IoT-sensors, which send location information of the items to the database, the TCIs can be equipped with QR codes, which a foreman can scan --> Prefers this solution as it already addresses the change management and requires to construction workers to actively report heir work, which eventually will have to be implemented in order to improve the communication from the construction site to the management --> Information of where the scanned item is will be directly communicated with e.g. the crane who then knows where to get the item from and where to move it next --> Transparent information due to active TCI tracking through workers reporting their activities --> Would create knowledge where the items are, where they have to be moved, when they are installed and when they ae ready for dismantling --> Requires an active role of the construction worker, tracking the construction workflow --> change management --> However, is seen more efficient and better than using location-based IoT-sensors, as the workers can add much more information in their reporting than only the location (e.g. issues, delay, damage, etc.) - Another consideration would be to use a video or image recognition which is, in real time, analysing the construction site and identifying the different TCI types that are lying around the construction site and where they are located --> Would also give information of where the items are (based on the type)		**Contractor 4**

Findings from Evaluation Interviews (Chapter 6)		*red = comment
No.	**Question**	**Interviewee**
10	Is the prototype solution easily adjustable to create a holistic TCI planning & management tool, not only for formwork but also for other TCIs as scaffolding, supporting structures or fencing? Where do you see obstacles in that?	
	- Look at PERI path for scaffolding as a similar solution that also considers man hours etc. - Solution can also be applied to precast industry for planning and calculating the demand of PushPullProps (supporting the precast elements until they are self-sustaining) --> Big market in Denmark for precast concrete and need to plan the TCIs in this industry! - Separate the planning from the management aspect of the solution --> planning with advanced online tool of supplier (holistic formwork calculation, 2D consideration, ability to use different products, etc.)	**TCI Provider 1**
	- It is interesting and beneficial to try the solution for different TCIs and have more than one feature of the solution - Should work in theory **- Obstacles:** - Get people to use the solution as implementation is difficult --> need to directly sense and be aware of the benefits to change the behaviour --> Frist talk to contractor on site and get their feedback and implement their needs	**Contractor 1**
	- If the data can be extracted similar to the example with formwork, the solution is possible to adapt to other TCIs - As a recommendation, the planning software ALICE might benefit the solution, as its element instance based scheduling allows to schedule optimization with artificial intelligence based on different demands	**Contractor 2**
	Not asked	**Contractor 3**
	- Is definitely possible and depending on which business model is chosen, the solution can be specialized for the calculation of formwork elements or the generalization of calculating different TCI types	**Consultant 2**
	- Seems like the problem is generic --> Therefore, it should be possible - Have a individual rule system for each type of TCI --> Establish a system which applies a individual calculation method to the specific TCI type	**Consultant 3**
	- Problem of lack of information for an efficient and lean construction site & logistics management can be generalized to all items on site --> gypsum walls, fences, safety barriers, formwork etc. --> Location based integration of construction elements is the key for enabling a better management and the solution is addressing exactly this data integration and linking - For safety barriers, the calculation engine only needs to identify an opening and then it can calculate the items - For other equipment it can be done similar - Solution can also be applied for infrastructure projects (bridges, roads) as the consideration TCIs for site planning and managing is sometimes even more important - Example of NCC in crane optimization which relied on the concrete element in the building model (weight, quantity and location of the items to improve the crane layout on site) - Solution would also make sense only for one isolated solution for optimization one TCI type, or only fencing and safety barriers, but it would be better to include as much TCIs as possible (e.g. using the BIM bot principle --> then there wouldn't be any limitations of such a generic platform solution)	**Consultant 4**
	- Yes, the mindset of the solution to use Linked Data in a project will allow to apply it for many different things. It is just a matter to find a stakeholder, who would benefit from something and then you can add this to your portfolio.	**Consultant 5**
	- Solution can be applied to scaffolding, safety barriers and also supporting structures for prefabricated elements - But machines as cranes are more related to where it is located and how far it can reach --> no direct connection to the building model --> Maybe site model? (Specify where possible crane locations are and plan which items have to me moved over time.	**Consultant 6**
	- Yes - Great possibility to use the solution for other items on site (e.g. steel plates for heavy machinery, staircase where you put on certain carpets, etc.) **--> Scalable solution !** --> formwork only one application area for the solution as it allows to integrate the planning and management of much more items through the data-driven approach	**Consultant 7**
	- Agrees and does not see obstacles, but challenges. It is in important in the planning process that everything is planned thoroughly. The same goes with different scenarios. So basically, the planning process will become more tough as the planner has to take more into considerations.	**Client 1**
	- Can be done	**Contractor 4**

Findings from Evaluation Interviews (Chapter 6)

*red = comment

No.	Question	Interviewee
3	**Business Model**	
11	The ideal future scenario (presentation slide 42) requires an involvement of many different stakeholders in a construction project, to deliver their specific input as linked open data, which will be accessed by a calculation tool. Is this vision realistic in the near future? Why?	
	- **Challenge**: Implementation for the contractors --> for making a change in the industry and sustainably implement the solution, the contractor have to be convinced to take over the solution --> Contractor have the mindset to get a job with a cheap bid (using less people and thus quality) = less planning effort = poor planning - Benefit of the contractor have to be visual --> Now, contractors don't keep track of how much time and resources they spend on TCIs (no comparison possible) --> visualization of the of the improvement of their production and their time and their money --> Comparison between how much time they spend on a conventional project for handling formwork and how much they could save with the proposed solution --> Make pilot project where these measures can be derived (how much does it cost to handle TCIs with and without planning?) - So you would have something to hold it up against, which is maybe not existing. So it would take some time maybe to start with to do some field work of actually tracking how much time do this job site really spend on TCI planning and handling and when they don't plan what does it cost them? Because then you will have something to show them that this you will avoid by doing this. And now I will show you on this project how much money you have saved	**TCI Provider 1**
	- Requirements have to be written in an ICT agreement in order to make every party involved in the project, comply with the requirements - Contractor (as a Design & Built, general contractor) is able to set the requirements and make the subcontractors follow - As client is not always professional, he doesn't know which methods are the best	**Contractor 1**
	Not asked	**Contractor 2**
	- See it as a realistic scenario in a few years - All the data is there and also smaller companies will be able to publish their project input or at least provide the raw data for the engineer to translate it into the Linked Data format - Project delivery should be determined in the ICT agreement and already contain requirements and expertise from the contractor --> For a contractor, it is difficult to demand a specific model quality as the engineers develop the models without the help of a contractor	**Contractor 3**
	- Requires a standardisation process for the required ontologies - BuildingSMART is an institution that will foster the standardisation in this area, but it takes some more time - Industry is definitely aiming towards this scenario	**Consultant 2**
	- Not the linked data, but with an open API the scenario is feasible - Standardizing APIS is exactly the same as in Linked Data - Authentication System	**Consultant 3**
	- Biggest hurdle is to standardize how people name and model things --> If this is in place, the solution and vision could work both with Linked Data and an open API --> For near future, need to integrate possibility to manually put in the data	**Consultant 4**
	- There will be a big question of who is generating and hosting the data graph for the project (consultant, client?) --> Common data environment considerations - Centrally stored data model can be hosted by a client consultant and the different stakeholder would gain access to the parts of the model, they need to provide their service - Now, the proposed data flow is needed as the Linked Data approach is not yet implemented in the industry	**Consultant 5**
	- It is a future vision which needs a lot of effort in standardizing the data which is used in the context of construction --> Very hard to implement a totally open and interlinked solution (risk of not getting the required data quality) as long as there is no 100% clean standard - Need to keep in mind the interests of the different stakeholder, if such a solution wants to be implemented --> Contractor for example, want to benefit from the transparency and control, but do not want to share their information --> e.g. progress information to the client - Consultancy as a service can be offered by the specialized supplier who are consulting the contractor with the utilization of their specific product --> Need to gain access to the data model from the general contractor or a client consultancy --> Supplier can also act as a consultant for early project phases where they can apply their expertise to improve the building design or development of the schedule and site model	**Consultant 6**
	Not asked	**Consultant 7**
	Not asked	**Client 1**
	Not asked	**Contractor 4**
12	Assuming that the proposed solution is offered as a **Consultancy Service**, providing detailed information about the TCI utilization on a construction site. What would be the benefits of this business model? Would you consider paying for this service?	
	- Client: Requires the contractor to use the solution - Contractor: Involve a consultant at the first time to get familiar with the solution and then do it themselves on their responsibility --> Do it in a pilot project and then show benefits from the pilot project to the foremen as a proof of concept --> security that the solution works! --> Foreman often decides to order more formwork based on his experience and estimation --> They have to benefit from the solution! - Less fix cost for the formwork companies because of a better planning of their stock --> might lead to cheaper formwork in general	**TCI Provider 1**
	- Contractor need to have control over the TCI utilization (planning and management) and cannot be fully dependent on a consultant --> sustainable implementation of the solution with forward-looking considerations - Best if it is simple enough that contractor can use it themselves after getting introduced to it in a pilot project with the help of a consultant (e.g. two days a week to get started with the solution) - For small contractor it might be better to outsource the expertise to a consultant	**Contractor 1**
	Not asked	**Contractor 2**
	Not asked	**Contractor 3**

Findings from Evaluation Interviews (Chapter 6)		*red = comment
No.	**Question**	**Interviewee**
	- Could be a service aspect of a site & logistics management which use a data-driven approach to optimize the site logistics management either from a external company as Ajos etc. or directly from the contractor --> Services in the industry tend to be not only software applications but always contains a consultancy effort as well --> With that comes also responsibility in the process success - Depending on the business model is chosen, the solution can be specialized for the calculation of formwork elements or the generalization of calculating different TCI types	**Consultant 2**
	- Software solution with training from the software provider	**Consultant 3**
	- Consultant would have to team up with a contractor to adjust the solution to the needs of the contractor --> A only third party service would no make sense, as the consultancy have to use the items the contractor wants and have to align the solution to the processes of the contractor --> otherwise the solution would provide false certainty that something is fixed but in reality look completely different - Consultancy part is the whole picture --> setting up the linked platform (different for each contractor) - also consultancy service for the TCI provider to develop the calculation engines that can receive the data from the platform, calculate the demand for the specific TCI and write the information back to the platform **Different Business Cases:** - For a contractor who has a design&build contract, as they have the whole value chain (designer, consultants, supplier) under them, they are able to control the data flows and easily implement such a solution --> Consultancy as Exigo could support the implementation at a contractor - Client cannot drive the use of such a solution as they do not have enough impact on the value chain --> Could require such a solution that provides transparency about TCIs on site, though - For TCI provider, it would be difficult as they do not have a contractual relation with the data provider (engineers for the model and schedule) and therefore would rely on something they cannot guarantee --> As the BIM bot principle shows, supplier could be integrated into the solution by outsourcing the calculation engine to the supplier. --> would provide a competitive advantage for the TCI provider	**Consultant 4**
	- It's a matter of generating this dataset that it is rich of useful information from the project --> When it is rich, stakeholder can do an analysis of the model and provide quantities or results based on their specific expertise --> Would be a service that they provide - Consultant or even client would be the entity who would manage the data model and provide access to the project parties --> In the construction phase, this could go on to the turnkey contractor, or the consultant would also provide the service for the construction phase as they have the knowledge and expertise on data management --> New role of a consultant that is responsible of the data model and provides access to it - Distributed nature of the project delivery will be the future when the focus will go more towards the data model and not the software solution --> different stakeholder would provide their information as consultancy-as-a-service for a specific part of the project	**Consultant 5**
	- **Contractor**: If the company owns many skilled people who are able to generate the data and have control over it, the contractor can apply such a solution to automate the planning of the site and optimize the construction site layout and workflows --> If contractor has the skills, he would definitely prefer a complete solution for their own where he can have control --> want to make it their process! - **TCI provider**: If the provider can get access to the data model, he can provide the TCI utilization and logistics as a complete service to the contractor --> Are interested in structured data that they can hook on to with our with a catalogue --> Need to gain access to the data and therefore also gets responsibility and risk! - First approach would be that a consultancy is introducing such a solution to the industry and helps the stakeholder to establish the required technology level - **Next step**: When the stakeholder getting more mature, e.g. a general contractor who is responsible for the control and takes the risk can use the solution on their own --> Need to have access to the data model	**Consultant 6**
	- Be aware of the impact of the solution to the different stakeholder --> might require new roles or make existing roles obsolete --> Consider different interests and perspectives of the stakeholders when exploring a business model	**Consultant 7**
	Not asked	**Client 1**
	- Current solution can have a big market for in-situ walls if it is integrated into the construction site planning and lean management - As contractor benefit the most of the solution, they should implement it within their organization --> First as a consultancy service in a pilot project to quantify and verify its success and then incorporate it as their own solution in their processes - In order to pay money for such a solution, people have to be convinced that they can save money with it --> Quantify the benefits in a pilot project!	**Contractor 4**
13	Assuming that the proposed solution is developed as a holistic **Software Solution**, providing detailed information about the TCI utilization on a construction site. What would be the required further developments of the existing prototype and potential obstacles? What are the benefits of this business model? Would you consider buying this software?	
	- Consultancy is more flexible and stakeholder rather outsource what is not their main responsibility or strength (**in contrast to what says Contractor 1**) --> Contractor fear the risk of dependency towards only one provider (PeriCAD is not used by the clients/ contractors) --> Software solution has to be an open solution that is not only applicable with one provider! --> Although it would be cheaper and more efficient for big contractor to plan their formwork themselves by having two specialized employers, doing it for them --> Big contractors have budgets for each project and hiring a consultant can be put in this budget, but buying a software license would go to another pot of expenses	**TCI Provider 1**
	- Solution must be flexible and simple enough that a contractor with enough resources can use it alone	**Contractor 1**
	Not asked	**Contractor 2**
	Not asked	**Contractor 3**
	- Difficult to offer this as a general solution it requires a lot of effort to make it a functioning product that covers all aspects of toll that enables a lean and integrated TCI planning and management. --> Possible to develop a contractor specific or supplier specific solution to reduce the amount and variability of the data (e.g. focus only on a few products or only one contractor)	**Consultant 2**
	Not asked	**Consultant 3**
	Not asked	**Consultant 4**
	Not asked	**Consultant 5**
	Not asked	**Consultant 6**
	Not asked	**Consultant 7**
	Not asked	**Client 1**
	Not asked	**Contractor 4**