

Measuring the effects of using the IT concept

A research project conducted in cooperation with GenieBelt



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Summary



Figure 1: GenieBelt logo

The purpose of this case study is to describe and measure the effects realised by the parties in a construction project of using the IT concept. The IT tool GenieBelt is a coordination, planning, communication and construction project portfolio tool primarily for use in the execution phase of a construction project. The case is based on two construction projects and a building owner organisation which, together, offer insights into the benefits realised by the client, construction management team and trade contractor when using the IT concept in a construction project.

All empiricism collected in this report comes from two specific construction projects in Copenhagen which have both used the IT concept: the 'Maersk Tower' and the 'Niels Bohr Building'. Moreover, the Danish Defence Estates and Infrastructure Organisation (FES) has contributed empiricism to the analysis.

The IT concept

The IT concept entails using the IT tool GenieBelt, which was primarily used to plan and manage activities carried out at the construction site as well as a construction site data exchange tool and as a construction project portfolio tool. The primary users of the IT concept are the client, the construction management team and the individual trade contractors carrying out activities at construction sites. In this report the IT concept is defined by three elements (see also Figure 2).

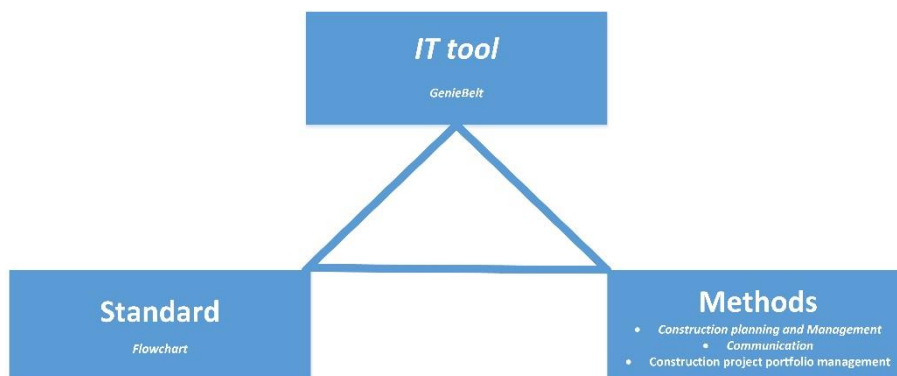


Figure 2: Elements in the IT concept

The effect measurement of the usage of the IT concept is conducted within the context of its usage by respective the building owner, the construction management and the trade contractors. All these companies have contributed with the data analysed in this report.

- **The Maersk Tower**

This construction project is part of the Panum complex (the Faculty of Health and Medical Sciences at the University of Copenhagen),

which has been expanded with new up-to-date laboratory facilities, classrooms, auditoriums, canteen, cycle cellar and a new main entrance. The Maersk Tower has a total of 42,700 new m² of floor-space divided between 15 storeys. The building is 75m tall.

The Danish Building and Property Agency is the client, the University of Copenhagen is the orderer and the tenant, and the Faculty of Health and Medical Sciences is the user of the new Panum complex. The construction project was projected by C. F. Møller (architect), SLA (landscape architect) and Rambøll (engineer), with Sweco and P & Partners as client consultants. The construction project was conducted as a multi-trade contract in which the construction company, Juul & Nielsen, was responsible for construction work.

Juul & Nielsen decided to use the IT concept in their own contract work on the 'Maersk Tower' construction project. In brief, The IT concept was in their context a tool for digital planning and communication of on-site construction activities.

- ***The Niels Bohr Building***

The Niels Bohr Building is a 52,000m² new laboratory and teaching building. The building will be part of the University of Copenhagen Campus North Science City, which houses the majority of the Faculty of Science activities.

The Danish Building and Property Agency is the client, the University of Copenhagen is the orderer and the tenant, and the Faculty of Health and Medical Sciences is the user of the new Panum complex. The construction project was projected by C. F. Møller (architect), SLA (landscape architect) and Rambøll (engineer), with Sweco and P & Partners as client consultants. The construction project was conducted as a multi-trade contract in which the construction company, Juul & Nielsen, was responsible for construction work.

Construction management was performed by the Danish Building and Property Agency together with Degn & Co., represented by production manager Michael Degn. All executing contractors in the project use the IT concept as a planning and communication tool.

- ***The Danish Defence Estates and Infrastructure Organisation (FES)***

FES decided to use the IT concept as a construction project portfolio, planning and communication tool at strategic level (here represented by the senior management in FES) and at tactical level (those responsible for the project at FES as well as those responsible for the project at the suppliers for the construction project with regard to the planning as well as executing contractors).

This analysis does not include empiricism from specific construction projects with FES as the client. Instead the analysis focuses on collecting empiricism from sources representing use of the IT concept by a client's senior management.

Therefore, this effect measurement was pieced together from sources representing the client, construction management team and the executing contractors in several different construction projects, with the 'Maersk Tower' and the 'Niels Bohr Building' as the primary construction projects, and to which FES primarily contributed data regarding the effects of using the IT concept at strategic and tactical levels.

The case

The case in this report is a measurement on the effects of the usage of the IT concept in two construction projects and one building owner organisation respective the building owner, the construction management and the trade contractors from the two construction projects 'Maersk Tower', 'Niels Bohr Building' and the Danish Defence Estates and Infrastructure Organisation.

The measurements are conducted based on three main processes in either the construction projects or/and in the building owner organisation: (1) Managing progress in the construction project portfolio, (2) Management of construction activities and (3) Communication between the construction management team and the trade contractors.

Costs

The costs of a software lease for of the construction project's companies of GenieBelt for a construction project similar to the 'Maersk Tower' and the 'Niels Bohr Building' (each with a budget of just over DKK 1.5 bn.) were calculated at around DKK 650,000 over a period of five months. A number of key costs, implementation costs, education and development of new work processes are however not a part of this analysis. A consequence to this is the cost measured in this report cannot be compared directly with the benefits, which the report documented have been achieved using the IT concept.

Areas of gain

The financial effects of using the IT concept in large construction projects such as the 'Niels Bohr Building' were calculated at about DKK 22 mill. (i.e. corresponding to just below 1,5% of the total budget). This is the total gain achieved by the project client, construction management team and major/trade contractors.

The largest financial gain measured in connection with using the IT concept was from optimisation by the construction management team of production through better coordination of construction activities and by reducing the number of process and installation interruptions, which alone provided a financial gain of just over DKK 14.625 million.

In addition to this were a number of indirect and derived effects. Similarly, there may be unutilised potential from comparing these effects with effects in other cases, as this case only contains randomly selected gains from using the IT concept. Most gains are at construction-project level (see also 'Measurement of the effects'). However, there are also gains at company level for the individual trade contractors.

Conclusion

The main conclusion of the effect measurement of using the IT concept is that, for a relatively minor cost, it is possible to implement and use the tool to manage and coordinate the activities in a construction project, and to manage communication/data collection between the client, construction management team and the individual trade contractors.

The IT concept can be considered as an improvement of a construction-project toolbox with regard to planning/ coordinating activities at the construction site and with regard to handling/streamlining communication, primarily between the construction management team and the trade contractors. However, the concept also offers opportunities to manage project progress for a client with many concurrent construction projects, for example.

Research method

The method used in the research project generally follows the method that has been used in the research project 'Måling af økonomiske gevinster ved DDB' (Vestergaard et al., 2011).

Selection of construction projects

There has been no actual construction project-selection process in which several competing construction projects were screened, although this is part of the practice stipulated by the 'Måling af økonomiske gevinster ved DDB' (measuring financial gains of digital construction) research project. The primary criterion that forms the basis for the two selected construction projects is that they had to be comparable as far as possible, and that it had to be possible to identify the three potential GenieBelt target groups. The two specific construction projects in this study were selected by GenieBelt. Moreover, FES was highlighted as one of GenieBelt's advanced customers at strategic and tactical levels, and therefore FES was also part of the study.

- The Maersk Tower
- The Niels Bohr Building
- The Danish Defence Estates and Infrastructure Organisation (FES)

Data collection

Data collection in the two construction projects as well as in the use of the IT concept by FES was carried out from March 2017 to August 2017. The majority of the data collection for the effect measurement was carried out on the basis of the ongoing 'Niels Bohr Building' project, which, at the time of data collection, was in the execution phase. The actual data collection was mainly carried out through qualitative interviews (in total 10 interviews have been completed). These interviews were subsequently supplemented by information on the use of GenieBelt (info on communication flows etc.), project webs and supplementing telephone interviews by the two construction projects, and by factual information from various websites, such as the Danish Building and Property Agency website.

Measurement of the effects

The measurement of the identified effects, which are a result by using the IT concept in the construction project, is based on the same procedures that has been used in the research project 'Måling af økonomiske gevinster ved DDB' (see also (Vestergaard et al., 2011)).

The developed method is briefly described based on a traditional cost/benefit-analysis that has been adapted to the construction context (e.g. the traditional phases in construction and key construction processes) and by using a discounted cash-flow-technique – in order to calculate the effects' present time financial value.

Effects are defined in this report as respective costs and benefits that have been achieved by using the IT concept in a construction project context (in this case this is defined as parts of the usage of the IT concept in the two construction projects and in the building owner organization). The benefits are categorised by their primary characteristics in four categories as displayed in Figure 3.

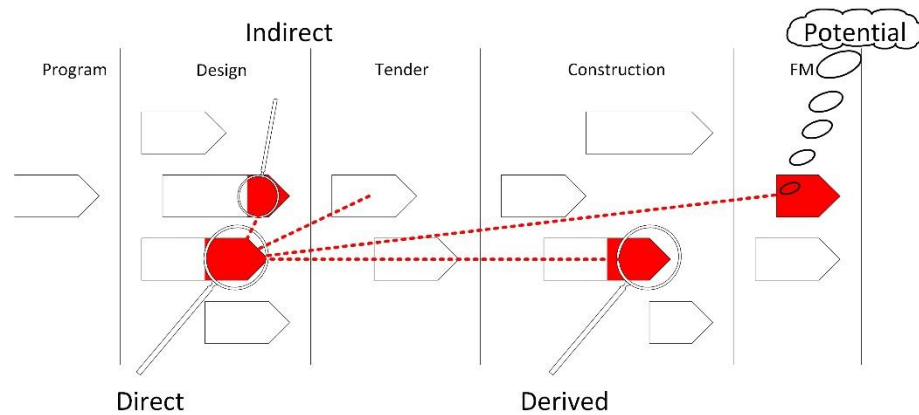


Figure 3: Categories of effects

The categorisation of effects, as displayed in Figure 3, is only used to describe the benefits in the case. This choice is made because the purpose is to highlight the benefits of using IT rather than the measuring the total effect.

Likewise it is relevant to categorise the levels where the effects are realised. A number of possible levels the benefits are realised in is illustrated in Figure 4.

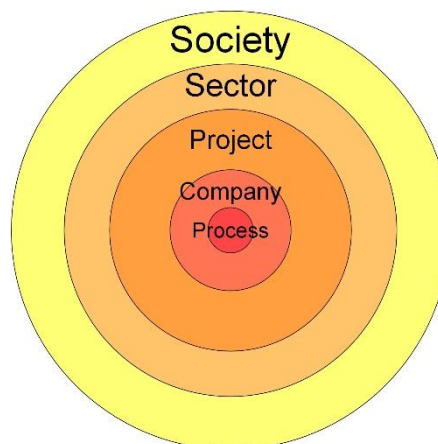


Figure 4: Levels where effects is realised

In this report there has only been identified effects related to the levels Process, Company and Project.

A very central premises for the method is that the results is context-dependant, which means the results cannot be used in other contexts.

The specific premises that the measurements of the economic benefits are based upon are briefly described on p. 36.

Description of the construction projects

The purpose of this case study is to identify and describe a number of the effects achieved by a construction project through applying methods and tools related to the IT concept. The primary point of departure of the case study is the two construction projects: the 'Maersk Tower' and the 'Niels Bohr Building'.



Figure 5: The Maersk Tower, source: C. F. Møller website



Figure 6: The Niels Bohr Building, source: Vilhelm Lauritzen Architects website

Fact about the 'Maersk Tower' construction project

The extension of the Panum complex has been designed with the aim of creating the best possible environment for modern research and teaching. A parallel objective has been to create a building which will stand out as an identity-creating, sculptural linchpin for the entire Panum complex and the university's Nørre Campus (i.e. the North Campus) as a whole. The new complex is also intended to act as the generator of a positive urban development in its immediate neighbourhood and in relation to the entire city.

At fifteen storeys tall, the Maersk Tower will provide the complex with a unifying and dynamic focal point in a clear and readable form. But just as a tree has its root network, the tower rests upon on a series of smaller buildings which contain the common functions: the auditoriums, classrooms, canteen, show lab, conference rooms and book café.

The most striking part of the root network is the extensive science plaza, which will form the new social hub of the complex. The plaza accommodates the main entrance and will serve as the main social meeting-place, linking all functions between the new and the existing Panum complex.

The new Panum complex will have an open and outward-looking appearance, with a transparent ground floor that will help to blur the boundaries between the building and the city. The public will also be invited to visit the top of the tower, where there will be a café, lounge and viewing points.

Between the buildings, new plazas will arise, together with internal garden spaces equipped with alcoves and seating. These will function as an extension of the study rooms and offices, but will also add new green oases to the city. A campus thoroughfare passing through the area, together with pedestrian and cycle paths, will create a vibrant urban park with intimate links to the surrounding city. With its organic forms, the building expresses signal power and innovation, but is also adapted to the existing Panum complex through its colour scheme, rhythm and gravity.

The facade is built up in the form of a grid structure of storey-high window fields that break up the building's large scale.

The project will be pioneering in energy usage, with Denmark's most energy-efficient laboratories, in which waste energy from the ventilation system will be recycled in the overall energy balance of the building to a hitherto unprecedented degree (this description of the construction project was taken from C. F. Møller's website).

Construction organisation/type of cooperation: The project was put out to competitive tendering and C.F. Møller won the project competition together with Rambøll, SLA, Aggebo & Henriksen, Farquharson Gordon, Cenergia and Innovation Lab.

Project period: 2012-2017

Location: The Maersk Building - New Panum, Blegdamsvej 3, 2100 Copenhagen N, Denmark.

Type of building: University building

Size of building: 75m tall (15 storeys) and a 42,700m² extension to Panum. The 42,700m² covers 24,700m² laboratories, offices and shared facilities as well as 18,000m² foyer, canteen, auditoriums, classrooms and technical installations.

Jobs: Not disclosed

Client: The Danish Building and Property Agency

Orderer and tenant: University of Copenhagen

Client consultant: P & Partners and Sweco Denmark

Full-service consultant: C.F. Møller

Architect: C.F. Møller

Landscape architect: SLA

Engineering advisory services: Rambøll

Project management team: H+Arkitekter with EKJ as sub-consultant

Execution: Aggebo & Henriksen, Farquharson Gordon, Cenergia, Innovation Lab, Per Aarsleff A/S, Skælskør Anlægsgartnere A/S, Mogens V. Zeltner A/S, Zurface A/S, Elementmontøren ApS, Hansen & Andersen A/S, Zublin A/S, N. H. Hansen & Søn A/S, Bladt Industries A/S, Waagner-Biro Stahlbau AG, Juul & Nielsen A/S, Tæppeland Erhverv A/S, Malermester Willi Becke ApS, A & C tagdækning ApS, Elindco Byggefirma A/S, L&H Rørbyg A/S, Airteam A/S, Lindpro A/S, Otis A/S, Wicotec Kirkebjerg A/S, Drivhuseffekten ApS, Labflex A/S and Bent Brandt A/S, etc.

Occupational safety and health coordinator: Niras

Total budget: DKK 1,500,000,000 The A.P. Møller Foundation donated DKK 725,000,000.

Average price per m²: DKK 35,129

Case resource persons: Nicolai Ebbensgaard, architectural engineer student, intern at Juul & Nielsen, Michael M. Degn, production coordinator, Degn & Co, Allan Niels, project manager, Bravida



Figure 7: Visualisation of the construction project in context with the building's surroundings. Source: C. F. Møller website.

Facts about the 'Niels Bohr Building' construction project

The Niels Bohr Building will be part of the Faculty of Sciences at the University of Copenhagen and will house teaching and research facilities for physical, chemical, computer science, didactic science and mathematical departments at the University of Copenhagen, as well as including the Niels Bohr Institute itself. The park will be constructed in University Park between Nørrebro and Østerbro, as part of the Nørre Campus Science City.

The building is part of the government investment plan to modernize the university laboratories. It will be built in two stages, one on each side of Jagtvej. Stage 1 will be east of the thoroughfare and cover an area of 36,500 m² in University Park; Stage 2 will be established west of Jagtvej and cover some 15,500 m² on a former commercial estate. A skywalk will link the two stages above Jagtvej. The building was scheduled for occupancy in the summer of 2017.

The jury stated in the report on its deliberations that 'The winning proposal assigns overall areas to researchers, students and staff in a structure that is both rational and flexible and which lends credibility to the desire expressed in the competition programme for spaces for informal meetings, interaction and interdisciplinary cooperation, while enabling well-defined academic identity and absorption.' (project description from Vilhelm Lauritzen Architects website)

Construction organisation/type of cooperation: The project was put out to competitive tendering and a consortium consisting of Rambøll DK/Rambøll UK/Rambøll SE, Colin Gordon & Associates, Vilhelm Lauritzen Architects, Christensen & Co Architects and GHB Landscape Architects won the assignment.

Project period: 2014-2018

Location: The Niels Bohr Building, Jagtvej 128, 2200 Copenhagen N, Denmark.

Type of building: University building

Size of building: 52,000 m²

Jobs: 800 teaching researchers, 260 PhD students, 200 technical and administrative employees and 3,000-4,000 students

Client: The Danish Building and Property Agency

Orderer and tenant: University of Copenhagen

Client consultant: Cowi

Full-service consultant: Rambøll

Architect: Vilhelm Lauritzen Architects, Christensen & Co Architects

Landscape architect: GHB Landscape Architects

Engineering advisory services: Rambøll

Construction management team: Sweco

Execution: Aarsleff (etc.)

Occupational safety and health coordinator: Niras

Total budget: DKK 1,600,000,000

Average price per m²: DKK 30,769

Case resource persons: Michael M. Degn, production coordinator, Degn & Co, Allan Nielsen, project manager, Bravida



Figure 8: Aerial photo of the construction project in context with the building's surroundings. Source: Vilhelm Lauritzen Architects website.

Table 1: Comparison of the two construction projects

	The Maersk Tower	The Niels Bohr Building
Client:	The Danish Building and Property Agency	The Danish Building and Property Agency
Orderer:	University of Copenhagen	University of Copenhagen
Type of building:	University building	University building
Total budget:	DKK 1,500,000,000	DKK 1,600,000,000
Size of project:	42,700m ²	52,000m ²
Average price per m ² :	DKK 35,129	DKK 30,769
Status of IT concept:	The IT concept was used in connection with a software trial period.	The IT concept was used in a conventional manner.
Use of GenieBelt:	The IT concept was used internally by Juul & Nielsen, and several users had access to the IT concept. Users included employees from own production, delivery and execution at the construction site.	The IT concept was used across several enterprises/contractors and each enterprise/contractor was represented by one user. Therefore, users represented different enterprises/contractors, all of which were directly related to the work carried out at the construction site.
IT concept users:	Users were employees related to Juul & Nielsen at operational and tactical levels.	Users were employees related to enterprises at tactical and strategic levels.

Description of the IT concept

Cases primarily represent the use of the IT concept in the execution phase and in connection with closure/hand-over. However, FES uses the IT concept in all phases of construction projects.

Overall, in this case, the following phases/main processes are involved in the IT concept:

- A. Design
- B. Project planning
- C. Tenders/proposals
- D. Preparation for production
- E. Execution
- F. Closure/hand-over (potential)

The IT concept is directly subject to the client requirements of digital construction (Det Digitale Byggeri's bygherrekrav), see Executive Orders no. 118 and 119 (Bygningsstyrelsen, 2013a, Bygningsstyrelsen, 2013b), as both projects have a public client and an estimated contract sum of more than DKK 5 million.

Due to the size of the two construction projects, the aim is to focus on supporting the production at the construction site using a digital tool to plan production and to communicate between the construction site management team and executing production personnel. The use of the IT concept does not ensure compliance with client requirements, however the digital tool can help meet the ambition behind digital construction (Det Digitale Byggeri). Compliance with the client requirements (Bygningsstyrelsen, 2013a, Bygningsstyrelsen, 2013b) has not been examined directly in this report.

The intention of the IT concept is to optimise the planning of construction production by the construction management team and to support exchange of information between the construction management team and the production personnel at the construction site efficiently and simply. Thus the IT concept supports and digitises key work processes related to planning construction production, quality assurance and exchange of information between the construction management team and the on-site production personnel.

1. Digital construction production plan for all executing contractors
2. Project management and coordination of on-site construction activities
3. Exchange of construction activity plans
4. Optimisation of resources and construction activities
5. Collection and exchange of phase reporting at activity level
6. Establishment and collection of quality assurance data/quality assurance documentation at contractor/construction activity level
7. Digital delivery of operation and maintenance documentation

The IT concept is partly within deficiency delivery standard 'U106 Digital mangelinformation' (U106 Digital deficiency information) published by 'bips' in relation to digital construction (Det Digitale Byggeri (bips 2014)), although without specific reference to this.

Software for planning construction production and exchange of information:
The IT tool GenieBelt is a digital tool to optimise construction activities in construction projects and it is a tool to support digital exchange of information between the construction management team and construction personnel from contractors. The tool supports import of Microsoft Project (.mpp) activity plans and schedules, for example.

IT concept initiative

In the 'Maersk Tower' construction project, due to existing strategic cooperation between the major contractor Juul & Nielsen and GenieBelt, Juul & Nielsen decided to implement and use GenieBelt to plan their internal construction production as well as communication between the construction management team and the construction personnel in the on-site trade contract work.

In both construction projects, the tool was primarily used by the construction production management to plan daily construction production, and to a lesser, but not insignificant degree, to exchange information between the on-site construction production personnel. Some of the derived gains from using the IT concept are that individual contractors can better optimise resources with regard to manning day-to-day construction activities, resulting in greater flexibility in the planning of work and better exchange of information between contractors.

The construction production management (i.e. the Danish Building and Property Agency) uses the IT concept to gain a constant overview of production at the construction site with regard to the status of existing construction activities, and to establish the best point of departure for the next construction activities.

By using the IT concept, the project manager/contract managers from the trade contractor (Juul & Nielsen) can gain an overview of the status of current construction activities and establish a basis for decisions regarding allocation of personnel to current on-site construction activities.

Reasons for using a digital tool to plan construction activity and communication:

1. **Resource optimisation:** Improving resource consumption at the construction site relating to manning, machinery and building materials may result in project budget savings which can benefit trade contractors, the construction management team and the client.
2. **Exchange of information:** Information exchange is streamlined by establishing and using a communication platform that directly supports the construction management team's information needs and provides the team with a communication tool targeted at the individual activities on the construction site and reporting by the trade contractors to the construction management team with regard to problem-solving and status of construction activities.
3. **Lower level of conflict on the construction site:** Better planning of day-to-day construction site activities based specifically on updated knowledge about whether the conditions for carrying out the activities are met may result in fewer conflicts between the executing contractors and/or the construction management team.

The parties in the case study

This case study includes many parties/players, and therefore it was necessary to select a limited number as primary players for the case. As the IT concept concentrates on production in a construction project, focus is on the client, construction management team and the trade/major contractor.

Client (FES)

Børge Hansen, project manager

Construction management team (Danish Building and Property Agency)

Michael M. Degn, responsible for construction production, Degn & Co, engaged as consultant to the Danish Building and Property Agency

Trade/major contractors (both 'Maersk Tower' and 'Niels Bohr Building')

Nicolai Ebbensgaard, contract manager, Juul & Nielsen

Allan Nielsen, project manager/contract manager, Bravida Danmark

Case characteristics

The following describes the key characteristics of the case which influence the effects realised from the IT concept. The IT concept is examined within the context of phases involved, main activities supported and the interaction between the players in the construction project.

Phases involved

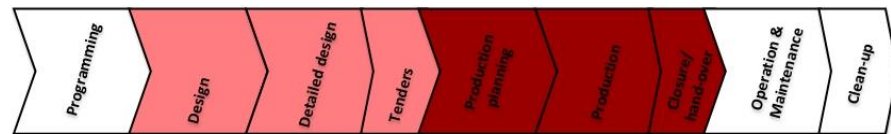


Figure 9: Use of the IT concept in the construction process

The case represents the entire course of the IT concept from the design phase to closure. The IT concept is primarily rooted in the client which commits the executing contractors in the construction project to use the IT concept in the Preparation for production and Production phases in particular. The Design, Planning, Tendering procedure and Closure phases are only slightly involved in the use of the IT concept and have therefore not been included in the study.

The primary players using the IT concept are construction management (primarily Sweco and secondarily the Danish Building and Property Agency), as well as the individual project managers/contract managers from the trade contractors. The IT concept is primarily used as a tool to plan the activities on the construction site and as a tool to communicate between the construction management team and individual executing contractors. It would be recommendable to use GenieBelt in the early design and planning phases, as the Danish Defence Estates and Infrastructure Organisation (FES) does in their construction projects.

No examples of the use of IT concept were demonstrated/mentioned in the Programming, Operation and maintenance and Clean-up phases because a decision to use the IT concept was not made early in the project and the later phases did not hold a potential of use.

What are the main activities involved in the use of the IT concept

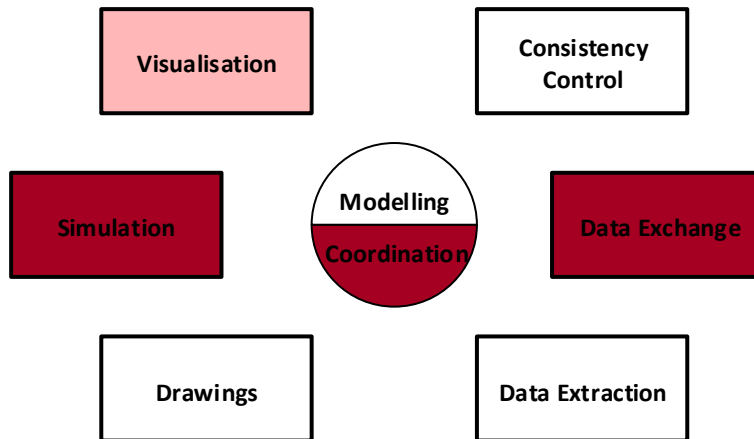


Figure 10: Main activities involved in the IT concept

The following description is primarily based on the construction management team's main activities handled by Sweco and the Danish Building and Property Agency. However, project managers/contract managers at the contractors are involved to a lesser degree in that they regularly provide data concerning the status of their construction activities using the IT concept. The original intention of the figure above was to specify the main activities related to BIM. However, in this context the figure is used to specify the use of the IT concept in relation to the main processes Project management and Communication. The red colour indicates that the IT concept plays an important role in the main activity, whereas the pink colour indicates a less important role.

Coordination is facilitated through support by the IT concept for day-to-day planning of on-site construction activities, thus ensuring optimal utilisation of project resources to achieve progress.

Visualisation is only supported to a lesser degree by the IT concept. Visualisation is not used in this context to show the physical expression of the construction project, but is used to provide a visual overview of construction project activities, represented as a bar diagram.

Simulation of the construction processes shows the order in which the construction activities should ideally be executed to optimise the use of machinery, location, building materials and staff.

Exchange of information with an effect on the status and progress of construction activities, and quality assurance data of relevance for the result of completed construction activities. All drawings and other documents are uploaded on a project web: "Byggeweb". The architect, the engineering consultant, the trade contractors and the client all have access to the project web. Furthermore, the 'Mantis' tool has been used for communication concerning selection of performance operations, etc.

In conclusion, the most important main activities supported by the IT concept are construction activity planning (Simulation) and communication (Exchange). The IT concept supports Visualisation to a lesser extent.

What kind of management relations between the project players are involved when using the IT concept?

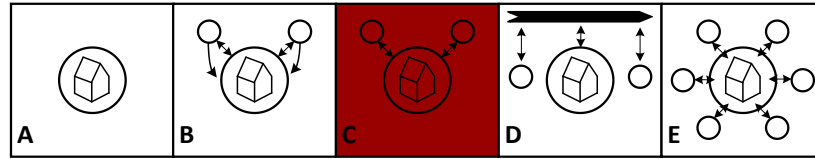


Figure 11: Degree of management relations when using the IT concept in a construction project

Legend:

A: Use of the IT concept by a single contractor. **B:** One-way sharing of the IT concept's construction activity overview. **C:** Two-way sharing of the IT concept. **D:** Overview of construction activities distributed on local server. **E:** Fully integrated activity planning and communication through network.

The case represents a type of management relations corresponding to level C in Figure 11, i.e. two-way sharing of the IT concept. Within each contract, two-way sharing of information is carried out in relation to the central activity overview. However, the construction management team controls the activities included in the contract and the order of these activities, for example. On the other hand, the trade contractors may comment at all levels of the activity overview and may upload phase reports (e.g. percentage of work completed), documentation, etc. with relevance for the individual activities in the activity overview.

In conclusion, the type of management relations and communication in the IT concept follow the building sector's conventional collaboration and hierarchical patterns typically applied in collaborations between the construction management team and individual project managers/contract managers from the individual trade contractors. Comments on production planning are not exchanged across the trade contractors involved, because this part is generally handled/managed solely by the construction management team.

Costs

Below is an estimate of costs associated directly with the use of IT concept. The estimate only includes costs resulting directly from the lease of software (i.e. the cost of GenieBelt); thus, costs of implementation, hardware, training, etc. are not included.

For various reasons, the costs of using the IT concept cannot easily be assessed. Firstly, an IT concept may already be an integrated part of a company's work processes, and it may therefore be difficult to identify the cost associated with a specific project. For example, the Danish Building and Property Agency may already be using the IT concept for several ongoing projects. Secondly, costs and effects are often not managed through general accounting processes when introducing new work methods and routines in companies. The costs will appear indirectly in the companies' financial statements, but they will not be included directly in a benchmarking of new processes. Thirdly, initial costs and operating costs associated with implementation of new work methods, tools, upgrading of skills, etc. are distributed across a large number of projects, and skills upgrades and software investments will have been made and paid for at an earlier point so that they will now be considered as fully depreciated or they will be subject to ongoing depreciation. It is particularly difficult to assess costs when implementing the IT concept in relatively large construction projects due to the large number of companies and employees (upgrading of skills) involved.

Table 2: Cost of software lease (GenieBelt) for the construction project

	GenieBelt Subscription			
	<i>Basis</i>	<i>Standard</i>	<i>Pro</i>	<i>Business</i>
	€ 100	€ 350	€ 750	€ 4,000
Client				1
Client consultant	1		1	
User	1			
Architect		3		
Consulting Engineer	4		1	
Major contractor 1	3		1	
Major contractor 2	1			
Major contractor 3	2		1	
Major contractor 4	Withdrawn			
Major contractor 5	2			
Major contractor 6			1	
Major contractor 7	1			
Major contractor 8	1			
Major contractor 9	1			
Sundry trade contractors	10		1	2
Total cost of software lease per month	≈ DKK 131,365			

The total costs of using the IT concept have not been calculated beside the cost of the services provided by GenieBelt.

Main process 1: Managing progress in the construction project portfolio

General description of the main process

This main process is primarily based on the FES data source. FES uses IT concept as a construction project portfolio management tool, which is the pivot of the first main process.

Because FES handles a large number of construction projects, it needs a digital tool, which provides a simple yet detailed overview of the status of ongoing construction projects and their specific planning and/or construction activities.

FES uses the IT concept to generate status reports on the progress of construction projects in relation to the master time schedules set up for each of the construction projects, and as a communication tool for interaction between FES and its suppliers in individual construction projects.

Through all phases of FES' ongoing construction projects, the respective project managers are responsible for following up on the status of ongoing construction activities in order to be able to continuously identify where action is required to safeguard the progress of the construction projects. Among other things, the IT concept is used to determine the progress of construction activities in relation to the master time schedule throughout the completion of the construction project. This enables management and prioritisation of construction project frameworks, e.g. allocation of resources and adjustment of timeframes etc., and it provides the basis for FES management to make decisions on launching any actions aimed at ensuring the projected progress of FES construction projects.

An important effect area for FES is that, when using as a communication tool between the FES construction project manager and the project/production/contract managers etc. from the individual construction projects, The IT concept supports smooth communication between the parties involved, but also that it provides more comprehensive documentation about what has been decided, when and by whom, if the decisions have implications on the continued progress of the construction project.

Furthermore, it is intended that the IT concept is to be used increasingly as a budget tool together with the FES financial management system, SAP. However, this part of the IT concept has not yet been fully implemented, as work still remains to be done to establish a better digital connection between SAP and the IT concept, and to implement a more accurate and practice-oriented plan and description of how FES employees are to use the IT concept together with SAP in order to ensure efficient support of the work processes concerning budget and bid management.

Sources:

The following descriptions of the benefits of rationalisation are based on an interview with: Børge Hansen, project manager, FES. Furthermore, additional information has been gathered from the internet.

Benefits of rationalisation

The primary benefits of rationalisation in this main process are: 1) recorded benefits (either in DKK, as a percentage or on a scale from A to D, where A is the highest value); 2) type of benefit; and 3) realisor of benefits. The benefits are divided into different types. The direct, indirect, derived and potential effects have been stated by the parties involved in the construction project. For definitions of the types of benefits, see 'Measurement of the effects'.

Direct effects

- Information management: The IT concept as a communication tool for interaction between the client and the construction management team/executing contractors (B, all), BH
The IT concept allows more direct and accurate communication with better documentation between the client and the construction management team as well as each of the executing contractors. Furthermore, it provides full transparency in communication, so that other potential stakeholders can gain full insight into the status or other information related to the construction activities in the project.
- Information management: Reduced administrative burden compared with a traditional construction project, because the IT concept ensures collection of communication data and decisions that affect production on the construction site. (B, client and construction management team) BH
Traditionally, more analogue and/or stand-alone tools are used (e.g. minutes of meetings and email correspondence) to handle administrative tasks and documentation of decisions related to production on the construction site.
- Information management: Use of GenieBelt provides a better status of the client's construction project portfolio. (A, client) BH
Clients are often involved in several active construction projects at the same time. They can use the IT concept to create a simple yet very accurate overview of the current and specific status of their ongoing construction projects (see example in Figure 12). This overview often serves as an important information base for the client's managerial initiatives and decisions.

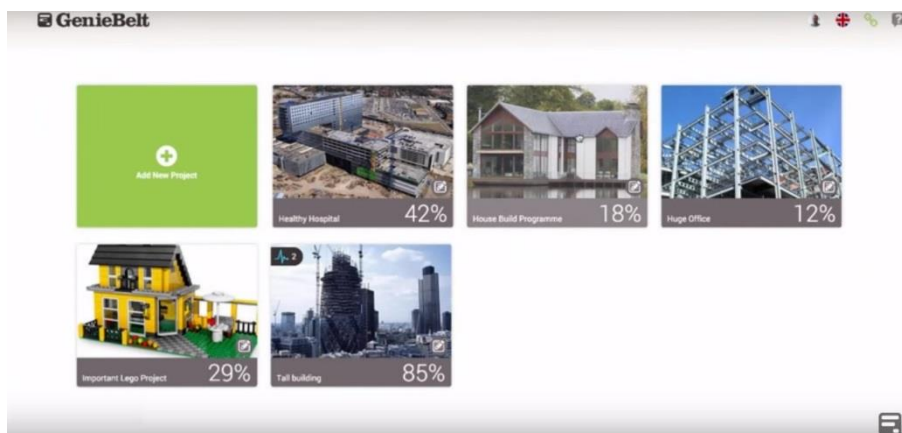


Figure 12: Status overview of the client's construction project portfolio

- Execution: The IT concept makes it easier for FES project managers to compare current phase reports in the IT concept with the invoices forwarded to the client by executing contractors. (B, client and construction management team) BH
By exporting the specific phase reports uploaded to the IT concept,

FES can compare this information with the invoices forwarded by the executing contractors. This ensures that the client only pays for work that has actually been completed, and not for work which has not yet been completed, even if it is stated, e.g. in the master time schedule, that work should have been completed.

- Execution: Invoicing in accordance with progress in construction activities (DKK 3,119 million, client) BH

The client benefits from ensuring that payments to suppliers (including in particular payments to trade contractors) are linked with the actual progress in the construction activities in the project. In a conventionally managed construction project, it is not unusual that trade contractors invoice the client for construction activities which have not yet been completed in order to ensure sufficient liquidity to cover outlays, e.g. to purchase materials etc. in connection with the construction project.

Premises: The financial value of this benefit for this case is measured based on a period 5 months usage of the IT concept with a discount rate on 10%.

Indirect effects

- Tenders/Bids: The IT concept supports FES in work related to tendering procedures for executing contractors. (B, client) BH
FES uses the IT concept to support the procedure of putting the planned construction project up for tender as partial contracts based on tender documents prepared by the project-planning parties; to evaluate the quality of the bids submitted; and to assess whether they comply with the framework conditions on which the tender was based.

Derived effects

No derived effects have been observed, as GenieBelt has not been put to use in any derived processes.

Potential benefits

- Tenders/Bids: By linking the SAP system at FES with the data collected by the IT concept concerning the status of progress in construction activities, in the long term the client will be able to conduct tighter and far more accurate management of cashflows to the executing contractors. (A, client)
FES uses the IT concept to support the procedure of putting the planned construction project up for tender as partial contracts based on tender documents prepared by the project-planning parties; to evaluate the quality of the bids submitted; and to assess whether they comply with the framework conditions on which the tender was based.

IT risk assessment

- General: The IT concept is a very transparent tool, which, in principle, gives everyone access to all information. This involves a greater risk that management decisions are made at higher managerial levels than the level actually responsible for making the right management decisions. (A, client and construction management team) BH
A primary motivation of the IT tool GenieBelt is to achieve high transparency in the representation of data concerning phase reports and communication related to the individual completed/planned construction activities. Consequently, there is a risk of micro-management (managerial interference in decisions at lower management levels), because anyone with access to the IT concept is able to

view the phase reports as well as any communication activities between the different players involved in construction projects. This may potentially lead to inefficiency because it is far easier for decisions made at one management level to be challenged by a higher management level.

Main process 2: Managing construction activities

General description of the main process

In this main process, the construction management team is the most important player, whereas the trade contractors have a secondary role. Primary data collection in connection with this main process is based on the 'Niels Bohr Building'. The actual work processes in this main process were very similar to the processes in a traditionally managed construction project with respect to how the management/decision-making processes in a construction project are performed. The main difference when using the IT concept is that the information base for decisions by the construction management team is better than in a conventionally managed construction project.

In a conventionally managed construction project, much communication and exchange of information takes place through a project web or at coordination meetings, such as construction meetings, period planning meetings and/or meetings with/between foremen. Of course, these meetings will still be necessary, but instead of spending a considerable amount of time to discuss construction activities already completed, the meetings can now focus more on discussing, planning and agreeing on 'to-dos' in relation to future construction activities on the construction site.

The construction management team uses various digital tools to manage construction activities: a project web (the 'Byggeweb' platform, which is used to exchange files), the 'Mantis' tool (platform featuring e.g. a project discussion forum), and the IT concept, the object of the current survey.

Benefits of rationalisation

Direct effects

- Planning/management: More efficient construction project meetings (DKK 0.3 million, construction management team, client, executing contractors) MMD

In a conventionally managed construction project, a considerable amount of the time spent at meetings is used to report on project status and/or construction activities already completed, and to comment on these reports. With the IT concept it is possible to increase the efficiency of all construction project meetings (i.e. construction meetings, period planning meetings and meetings with/between foremen), because all discussions of construction activities already completed can be significantly reduced, so that focus can instead be on future construction activities on the construction site.

Premises: The construction project's meetings are rationalised by 20 min., period planning meetings by 15 min. and foremen-meetings by 20 min. Over a period of 5 months there have been held 20 construction project meetings, 16 period planning meetings and 20 foremen-meetings.

- Execution: Fewer interruptions during the construction process due to better coordination (DKK 14.625 million, construction management team and trade contractors) MMD

This effect measures unexpected interruptions of all construction activity on the construction site, and interruptions between different construction activities by several trade contractors. The IT concept's great transparency and real-time status reports allow the construction management team as well as the trade contractors to optimise the completion of construction activities on the construction site, even if unexpected changes occur in the sequence and/or staffing of construction activities due to changes in the priorities of the construction management team or changes in production terms for the trade contractors involved in the project. The improved access to view the status of construction activities gives the construction management team as well as the trade contractors an opportunity and an incentive to optimise the production flow so that interruptions can be avoided as far as possible.

Premises: There has been registered that the number of process stops has been reduced by 90 stops of varying degrees.
- Execution: Fewer interruptions during the construction process due to fewer errors (DKK 0.647 million, construction management team and trade contractors) MMD

It has been observed that use of the IT concept results in fewer errors, for example construction errors which are costly to remedy. This benefit is achieved because the IT concept provides both the construction management team and the individual trade contractors with better insight into the sequence of construction activities, so that any misconceptions about when work is to be carried out, and by whom, are avoided, thus resulting in fewer construction errors than previously.

Premises: It has been measured that the usage of the IT concept has resulted in savings amounting to five man weeks work pr. month because of fewer errors.

Indirect effects

No indirect effects have been observed in the management of construction activities performed by the construction management team, because IT concept has not had any secondary effects.

Derived effects

- Execution: Better completion of trade contract (DKK 3.626 million, construction management team and trade contractors) MMD

The IT concept provides the construction management team with enhanced knowledge about the current status of construction activities, and this enables the construction management team (in cooperation with the trade contractors involved) to change the sequence of the construction activities and/or their staffing, based on the resources available.

Premises: It has been measured that the use of the IT concept has resulted in a better usage of the construction site resources (primarily man hours) with 275 small and large efficiency gains in the construction site works.

Potential benefits

- Information management: Direct communication (A, construction management team) CB

Traditionally, communication between the construction management

team and individual trade contractors takes place through physical interaction at project meetings or on the construction site. With the IT concept, part of this important communication can become more efficient in the future, and it can take place at the convenience of the individual parties. This leads to increased communication efficiency.

IT risk assessment

No IT risks have been observed.

Main process 3: Communication between the construction management team and the trade contractors

General description of the main process

The third and final main process described takes as its point of departure the trade contractors' use of the IT concept in communication between the construction management team on the construction project and the project managers/contract managers from the individual trade contractors.

Overall, the use of the IT concept is usually based on preparing the production plan (as defined by the project parties and/or the full-service consultant) by means of the Microsoft Project digital tool. The production plan is then converted into a master time schedule and finally set up in the IT concept as a baseline for management of the construction activities by the construction management team. The master time schedule is usually outlined in less detail than is required by the construction management team to manage the construction activities in the project. Therefore, the construction management team prepares a more detailed and consequently more useful production plan which serves as an important basis for communication between the construction management team and the individual trade contractors. Typically, the person responsible for the trade contract (for example the project manager or the contract manager) is in charge of the communication on behalf of the trade contractor.

The IT concept simply implies that the individual trade contractor regularly (usually once a week) updates the trade contractor's activity progress on the construction site by using the IT concept. Furthermore, the trade contractor can immediately upload its phase report/delivery documentation/RFI or similar using the IT concept, when the construction activity encounters problems or it is completed. Based on this information, any stakeholders (for example the construction management team or other trade contractors) can quickly bring their knowledge up to date with respect to progress in construction activities.

Juul & Nielsen: In the 'Maersk Tower' construction project, Juul & Nielsen was responsible for the construction project at a contract sum of DKK 90 million. The contract included installation of:

- 25,000m² of walls of different types
- 1,300 internal doors
- 6,000m² of system walls
- A 75m² spiral staircase as well as the other stairways in the building
- 3,000 internal screens
- 1,500 bicycle stands in the basement

Juul & Nielsen took over the contract in the late summer of 2015, following the bankruptcy of Bruno Hansen Furnitures. The IT concept has been implemented internally across the strategic and the operational levels at Juul & Nielsen. The company's joinery department supplied the furniture part of the contract, and the IT concept has therefore been used as a communication platform between the joinery department outside the construction site, and

the work performed on site. On the construction site, the IT concept was used for work process management, quality assurance and communication.

Bravida. In the 'Niels Bohr Building' construction project, Bravida Danmark is responsible for all electrical installations in the new Niels Bohr Building at Campus North. The total value of the contract is DKK 80 million. The electrical installations contract includes almost all types of electrical work, and it is further complicated because of the many laboratories with highly sensitive equipment.

Sources:

The following descriptions of the benefits of rationalisation are based on interviews with: Michael M. Degn, production manager at the 'Niels Bohr Building', Degn & Co, Claus Brøns Pedersen, production manager assistant at the 'Niels Bohr Building', Nicolai Ebbensgaard, contract manager at the 'Maersk Tower', Juul & Nielsen, and Allan Nielsen, project manager of electrical installations, Bravida Danmark.

Benefits of rationalisation

Direct effects

- Planning/management: More cooperative environment (B, construction management team and trade contractors) MMD

Using the IT concept leads to a more cooperative environment on the construction site, both between the construction management team and the individual trade contractors, and internally between the various trade contractors. The main reason for this is that, by using the IT concept, individual trade contractors gain much better insight into the interdependencies between their respective tasks that affect progress in the construction project. Consequently, the individual trade contractors can achieve a better understanding of the needs and wishes of other trade contractors with respect to completion of onsite construction activities. Overall, the cooperative environment improves as a result of the significantly better mutual understanding between trade contractors of their respective actions and behaviour.

- Information management: Complete audit trail of what has been agreed, provided that the tool is used to adjust activity planning (A, construction management team and trade contractors) NE

Much of the communication between the construction management team and the trade contractors is managed in the IT concept, which has the major advantage that it provides a complete audit trail of all agreements made with regard to deadlines and communication activities between the construction management team and the trade contractor concerning the individual construction activity.

- Information management: Better insight into the division of responsibilities and tasks (B, construction management team and trade contractors) MMD

One of the benefits of the IT concept is that all users can easily see who is responsible for a construction activity and who is executing it. Thereby, users can easily identify whom to contact if they have questions etc. concerning the construction activity in question. In a traditional construction project, it is usually necessary to contact either the project manager or the construction site manager to get hold of this information. This is much more time consuming.

- **Execution: Better and more just-in-time communication with other contractors (C, construction management team and trade contractors) NE**
Communication improves, internally between the trade contractors and between trade contractors and the construction management team, because the IT concept provides for more accurate (activity-specific) and just-in-time communication, as the tool can be used by the relevant builders and workers on site. Traditionally, information is typically exchanged at meetings (construction meetings etc.), through direct dialogue on site, or by means of telephone or email correspondence. This may sometimes result in delays in the construction process due to waiting times.
- **Execution: Better overview of construction activities (A, construction management team and trade contractors) NE**
The IT concept provides a quick overview of construction activities currently in progress on the construction site and of the status of the individual activities, as well as delays in construction activities or future activities to follow ongoing activities. All this information is relevant to gain an overview of the construction project, depending on the focus of interest. In a traditionally managed construction project, it is usually not possible to gain such a quick, yet comprehensive overview of construction activities because this often involves direct dialogue with several players.
- **Human resources: Better utilisation of resources (B, construction management team and trade contractors) NE**
All construction projects involve unexpected changes in on-site production when, for various reasons, changes occur in the underlying preconditions. This often leads to delays in the construction project, but such delays may be avoided if the more comprehensive insight obtained from the IT concept is applied to optimise utilisation of existing resources better than originally planned. This can improve the progress of the construction project.
- **Human resource skills development in connection with coordination of construction activities (C, construction management team and trade contractors) MMD**
Coordination of on-site construction activities is often repeated on the basis of the most recently completed construction project. The IT concept offers the opportunity to view coordination of construction activities in a new way and allows for development of new skills with regard to achieving better coordination of construction activities.

Indirect effects

- **Execution: Flexibility in workflow planning (B, construction management team and trade contractors) NE**
The greater insight into execution of on-site production resulting from the use of the IT concept means that the manager of each trade contract has a little more flexibility when planning and executing construction activities on the construction site. Some of the construction activities performed by trade contractors are highly inflexible due to external conditions such as time pressure, because workers in the next phase have to commence work at a specific time, whereas other construction activities allow flexibility with regard to planning. Overall, the IT concept provides each trade contractor with better insight into the construction activities that allow flexibility with regard to execution (allocation of personnel, materials, machinery,

etc.) and this knowledge can be used to optimise utilisation of the trade contractor's resources.

- Execution: Better project status overview (A, construction management team and trade contractors) NE
Both the individual trade contractors and external stakeholders with an interest in construction production, e.g. the client, inspectors, etc., can be granted viewer access to the IT concept and access to information on the status and progress of construction activities. This may assist them in carrying out their responsibilities in the construction project. The increased insight into the progress of the project and into the challenges and status of individual construction activities leads to more efficient exchange of information concerning the construction project.

Derived effects

- Execution: Faster response from consultant (C, construction management team and trade contractors) NE
Connecting the planning consultants or other associated consultants to the project via the IT concept has resulted in significant reductions in consultants' response times, because each user (in this case the consultants) is notified directly when they are requested to respond to RFIs etc. Previously, this was usually handled either by telephone or email, or at meetings, which led to a long RFI response time.

Potential benefits

No potential benefits have been observed.

IT risk assessment

- Planning/management: Adjusted level of detail in relation to activity planning at contract level (D, construction management team) MMD
At the stage where the master time schedule is input to the IT concept, there is a risk that the level of detail in the specification of construction activities does not match the need to manage the individual trade contracts linked to the construction project. The specification of construction activities may be too general or too detailed, and in either case, the use of the IT concept loses value.

Summary of effect measurement

The results of effect measurements are summarised below.

The summary is based on the following:

- Only benefits and costs recognised by the players involved in the case have been included. The benefits may be calculated financially, or they may be valued qualitatively in relation to the benefits achieved. Ultimately, the qualitative benefits also have financial value, but in the present case, it has not been possible to estimate this value. The case is likely to have other effects as well, which have not been recognised by the participating players.
- In the cost statement concerning the application of the IT concept, only the lease of the software has been included. A more comprehensive analysis of costs associated with using the IT concept for a construction project will identify and value other cost items directly attributable to the use of the IT concept.
- The summary only includes effects deriving from the segment of parties and sub-processes selected in cooperation between the "ØG-DDB" (financial gains of digital construction) project group and the players representing the case. Thus, the total benefits of the case cannot be assessed; only representative benefits of sub-processes.
- The summary is divided into the different main processes. In the tables below, the realised gains are immediately observable that have been realised over a period of 5 months (in the execution stage).
- Potential benefits are not included here, because they are, by definition, not part of the case.

Table 3: Benefits of main process 1

Main process 1: Managing progress in the construction project portfolio						
Sub-processes	Benefit type	Client	Construction management	Trade contractors	Benefit measured in DKK	Benefit level of non-financial effects
The IT concept as a communications tool between the client and the construction management team/executing contractors	Direct					B
Less administrative burden	Direct					B
Better overview of construction project portfolio	Direct					A
Invoicing relative to progress in construction activities	Direct				3.119.093	
Enhanced possibility for managing tenders/bids	Indirect					B
TOTAL benefits measured					3.119.093	High

Table 4: Benefits of main process 2

Main process 2: Management of construction activities						
Sub-process	Benefit type	Client	Construction management	Trade contractors	Benefit measured in DKK	Benefit level of non-financial effects
Greater efficiency in construction project meetings	Direct				303,333	
Fewer interruptions during the construction process due to fewer errors	Direct				647,500	-
Fewer interruptions during the construction process due to better coordination	Direct				14,625,000	-
Enhanced possibility to check phase reporting	Direct				-	A
Better execution of trade contract	Derived				3,626,000	-
TOTAL of benefits measured					19,201,833	High

Table 5: Benefits of main process 3

Main process 3: Communication between the construction management team and the trade contractors						
Sub-processes	Benefit type	Client	Construction management	Trade contractors	Benefit measured in DKK	Benefit level of non-financial effects
More cooperative environment	Direct				-	B
Complete audit trail of what has been agreed	Direct				-	A
Better insight into the division of responsibilities and tasks	Direct				-	B
Faster response from consultant	Derived					C
Better and more just-in-time communication with other contractors	Direct				-	C
Better overview of construction activities in the project	Direct				-	A
Better overview of project status	Indirect				-	A
Better utilisation of resources	Direct				-	B
Skills development in connection with coordination of construction activities	Derived				-	C
Flexibility in workflow planning	Indirect				-	B
TOTAL benefits measured					-	Medium

Description of the effect measurement

The IT concept's effect measurement is divided into costs, benefits and risks. Effects on costs and risks are measured more generically (because the main focus in the report and the method is on the benefits) whereas the measurement of realised benefits is based on three main processes (see also Table 3, **Fejl! Henvisningskilde ikke fundet.** and Table 5).

Each of the three main processes emanates primarily from three central players: the client, the construction management team and the trade contractor, respectively. The consequence of this for effect measurement is that financial benefits have mainly been measurable for main process 2 'Management of construction activities', whereas for the other two processes, the effect has mainly been measured on the basis of qualitative assessments of the size of the benefits.

Two factors in relation to effect measurement have been particularly important for the results achieved. Firstly, the costs are only calculated on the basis of the lease of software. Thus, implementation costs (e.g. acquisition of hardware etc.), costs associated with user training and operating costs are not included in the cost statement. It can be argued, however, that costs related to implementation as well as operation will most likely be fairly low given that the IT concept is a relatively simple online digital tool.

Secondly, it was necessary apply a number of assumptions in order to measure the effects of the financial benefits. The most important assumptions for the financial gains in the calculation of effects are stated in the review below. The effect measurement of the identified benefits are generally based on the most conservative and realistic calculation as possible.

The effect of using the IT concept was calculated over a period of five months (corresponding to the number of months that the Danish Building Research Institute measured the use of the IT concept in the 'Niels Bohr Building' construction project).

The economic benefit by using the IT concept in the main process 1 'Invoicing relative to progress in construction activities' is measured based on equivalent principles as have been used in ØG-DDB's case 'Case 3 BIM hos driftsherre og byg- og driftsherrerådgiver' (Vestergaard et al., 2012), of which the premises is equal to this project's benefit. The interest benefit of this effect is measured based on a period on 5 months using a discount rate on 10%.

When estimating how much the use of GenieBelt (main process 2) has streamlined construction project meetings, the production manager from the 'Niels Bohr Building' project calculated that construction meetings could be streamlined by 20 minutes, period planning meetings by 15 minutes and meetings with/between foremen by 20 minutes. Streamlining these meetings is primarily a result of the fact that no time was spent at the meetings on identifying the status of the ongoing construction activities of the project. Instead the meetings could focus on the next construction activities.

The effect measurement regarding 'Fewer on-site installation stops due to better sharing of information' (main process 2) is based on the fact that the use of the IT concept meant that the construction management team and the individual trade contractors were kept up-to-date with the project, primarily due to better sharing of information on the status of the construction activities and on the challenges regarding the progress of the construction activities. The effect measurement showed that, by using the IT concept, the construction management team could reduce the number of on-site installation stops by 20 installation stops per month.

The most decisive benefit in the 'Fewer process interruptions due to better coordination' (main process 2) effect measurement was more efficient execution of the process due to better coordination between the trade contrac-

tors. The better insight into the actual status of the current construction activities and a better overview of the allocation of resources by the individual trade contractors (primarily building materials and manning) resulted in a reduction in the number of process interruptions by 15 interruptions a month.

Barriers and preconditions for implementation

Discussion of technology

When assessing digital planning, coordination and communication tools, an important factor is how the tool is used, including how the division of responsibilities to draw up plans for contract work and construction activities, as well as to enter status data and RFIs, is defined and executed in practice.

Basically, the technology setup is simple, as the tool is internet-based, and this enables both stationary and mobile access to the tool. The actual tool is accessed either via a browser or via a smartphone app, and this enables the tool to be used both on-site and at the office. This is a practical benefit for the construction management team as well as the individual trade contractors, both of which need to have access to the tool on the construction site to upload documentation material, for example. Moreover, a major benefit is the option to adapt the information content specifically to the user of the tool, for example by filtering out all information that is not specifically targeted to the individual user. By merely using a smartphone, the trade contractor can access the tool and its targeted information. Similarly, the construction management team can access the tool via their work station and this enables more user-friendly management of the tool.

An important point in using the IT concept is that the trade contractor can benefit from using the tool on the actual construction site. For some trade contractors this may go against conventional work practices, in which there is a clear distinction between office work and construction work. This means that GenieBelt becomes an on-site tool in line with a hammer, for example.

Discussion of skills

The IT concept places relatively low demand on the skills of the individual trade contractors. However, the construction management team needs good skills with regard to combining theory and practice, for example in the transition from the master time schedule to the specific construction activity plan. This transition entails division of the construction project into trade contract works and it draws on theoretical and practical knowledge regarding planning, coordination and structuring of the specific construction activities of a project. However, this is not in itself a new skill that the construction management team is required to master. The difference arising from use of the IT concept is the nature of tasks carried out changes, because the IT concept is not only a planning/coordination tool, but also a tool for communication and exchange of information between the construction management team and the individual trade contractor. More specifically, this shift means that what was previously used purely as a planning/coordination tool, primarily for work carried out internally within the specialist group, has now become a tool incorporating also the technical fields of the trade contractors.

A skill which is not related exclusively to the IT concept, but which is important in order to achieve the full value of using the IT concept, is the plan-

ning skill of the construction management team regarding the actual planning of construction activities, as planning, of course, is an important focal point of the tool. Skills are necessary to achieve a good balance between overall activity planning in the construction project and the specific and detailed planning of construction activities – the greater the skills of the construction management team within this field, the greater is the potential for value creation through using the IT concept.

Discussion cooperation and project integration

Both the construction projects studied had a trend-setting construction management team, and this has had a positive influence on the number of efficiency benefits from using the IT concept. An important precondition for achieving the full effect of these benefits is that the understanding and communication between the construction management team and the individual trade contractor in the project are closer than traditionally, and that the construction activity plan is continuously optimised in the context of the individual technical field and the external framework conditions.

Discussion of legislation/service descriptions/fees

The IT concept of this case does not challenge the conventional, phase organisation of a construction project. The IT concept predominantly covers processes within the interface between the construction management team and the individual trade contractor with the possibility of providing the client with a better overview of the status of the progress of the construction project. Generally, there is only a requirement for communication between the construction management team and the trade contractors regarding use of the new planning tool and the increased integration between these parties.

However, an important condition in the use of the IT concept is that the trade contractor is obligated to (perhaps this has been added as a point in the contract between the client and the trade contractor) report back to the construction management team (and any other stakeholders) regularly (at least once a week and at the beginning/end of a construction activity) on the status of their construction activities in the project. The consequence of no status report from the trade contractor will seriously limit the opportunities of gaining the value of the tool, because the status report on progress in the construction project retrieved from the IT concept will not be in accordance with reality.

Conclusion

The overall conclusion is that using the IT concept in a construction project represents opportunities to achieve significant efficiency gains with regard to optimisation of on-site construction production of a project. Similarly, the study has measured benefits for the client. Clients with several simultaneously active projects are particularly likely to benefit from using the IT concept as they gain a better overview and insight into the status of their construction projects.

Optimisation of construction production with better planning

The construction management team benefits greatly from using the IT concept as they gain greater knowledge about the status of the construction activities on the construction site, and are provided with a valuable communication tool which documents and qualifies communication between the construction management team and the trade contractors for the construction project.

A particularly potent aspect of the IT concept is that it provides the construction management team and the trade contractors with better insight into the status of ongoing construction activities, so that the potential options for optimising construction production become more apparent. However, this requires that the construction management team acquire relevant skills that enable optimisation of production planning/coordination.

More efficient construction project meetings

Empirical data has been collected showing that the use of the IT concept offers significant benefits with respect to optimising construction production. Available resources in the construction project are utilised more efficiently by, for example, reducing the number of on-site process/installation interruptions, and by optimising coordination between construction activities by trade contractors.

Streamlined construction project meetings

In addition to achieving better insight into the possibilities for optimising construction production, the use of the IT concept also offers a potential for more efficient project meetings about construction production, mainly because the IT concept makes it possible to focus on future construction activities.

Preconditions for acquiring the benefits

The most important preconditions for benefitting from the use the IT concept are to make all players, whether internal at individual trade contractor level

or at the higher level of all trade contractors in interaction with the construction management team, to make full use of the IT concept, because the positive effect is generated by better insight into the status of construction activities and into the use of the IT concept as a communications platform.

Another important precondition for achieving benefits from using the IT concept is that the construction management team of the construction project or the trade contractors possess skills that enable optimisation of the production in the construction project based on the production conditions arising as the construction project progresses.

Literature

BYGNINGSSTYRELSEN 2013a. Bekendtgørelse om anvendelse af informations- og kommunikationsteknologi (IKT) i alment byggeri. Bygningsstyrelsen.

BYGNINGSSTYRELSEN 2013b. Bekendtgørelse om anvendelse af informations- og kommunikationsteknologi (IKT) i offentligt byggeri. Bygningsstyrelsen.

VESTERGAARD, F., LAMBRECHT, J. F., KARLSHØJ, J., MOURITSEN, J. & HAUCH, P. 2011. Metodemanualen ØG-DDB, casestudiebeskrivelsen. Technical University of Denmark.

VESTERGAARD, F., LAMBRECHT, J. F., KARLSHØJ, J., MOURITSEN, J. & HAUCH, P. 2012. Case 03: BIM hos driftsherre og Byg- og driftsherrerådgiver. Technical University of Denmark.