# Japan-DK Seminar 13/9 2019

*Improvements by Construction Gemba Kaizen and i-Con-struction*

Bertelsen, Niels Haldor

# SBI 2020:13

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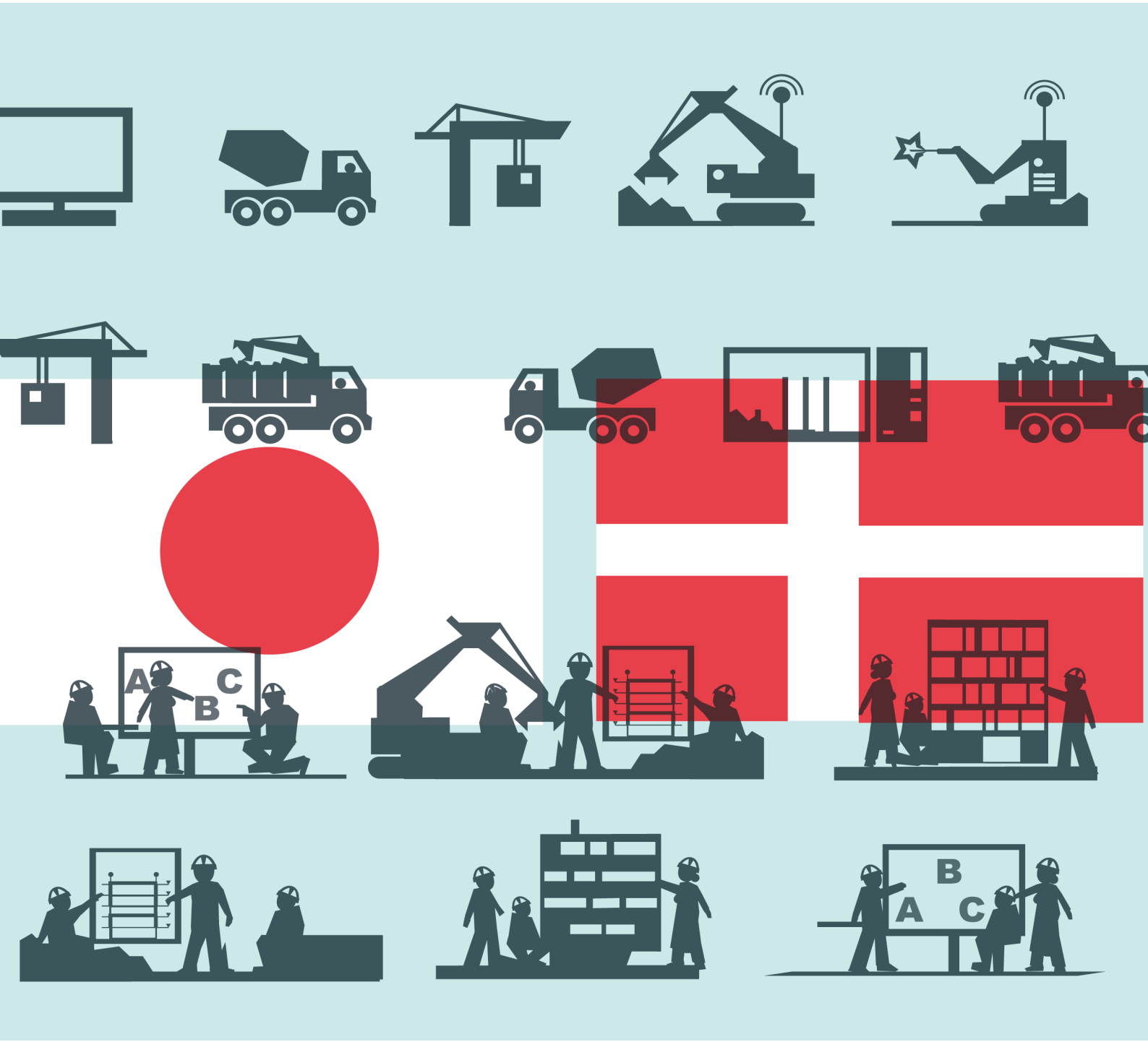
Improvements by Construction Gemba Kaizen
and i-Construction



# JAPAN-DK SEMINAR 13/9 2019

Niels Haldor Bertelsen

SBi 2020:13
Department of the Built Environment, Aalborg University Copenhagen
2020

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# CONTENTS

# PREFACE

The inspirations for this project were the findings from an AAU-Build project on 'Construction Supply Chain Management' for an application of Gemba Kaizen in construction from the Toyota Production System (TPS) and proposals to attain better linkages between research projects, construction practice, and education. On February 26, 2019, the Consulate-General of Japan in New York held a seminar on 'i-Construction as a new stage of construction in Japan' by Professor Kazuyoshi Tateyama of Ritsumeikan University, Japan. The seminar established the background for the cooperation between Ritsumeikan University, Japan, Aalborg University Copenhagen, Denmark, and the Japan-DK seminar on September 13, 2019, in Copenhagen.

We hope the seminar and report inspire the construction sector to fight to solve external and internal challenges in the construction sector. The external challenges include the UN Sustainable Development Goals (SDG), the grassroots aims for climate action, and the intensive push from new technology. The internal challenges in the construction sectors in Japan, Denmark, the European Union, and the United States include facilitating qualified technology, workers, technicians, and managers to fulfil the growing demands for additional, cheaper, better, and sustainable buildings and infrastructures and a better working environment.

AAU-Build thanks Professor, D.Eng. Kazuyoshi Tateyama, Ph.D. Takaaki Yokoyama, and D.Eng. Hiroshi Furuya for the inspiring and constructive presentations and discussions in Copenhagen and New York. We also thank all Danes; you have contributed with presentations and to the dialogue, and a special thank you goes to BLOXHUB, Per Aarsleff A/S, and the Danish Society of Engineers for hosting for the discussion of the four themes.

Department of the Built Environment (BUILD), Aalborg University
Division of Building Technology and Management
April 2020

Ruut Peuhkuri
Research Director

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# SUMMARY AND CONCLUSION OF THE SEMINAR

# 1 SUMMARY AND CONCLUSION OF THE SEMINAR

This Japan-DK seminar, held on September 13, 2019 in Copenhagen, was arranged by BUILD (formerly SBi) at Aalborg University Copenhagen, where 3 Japanese guests and 47 Danes participated. The summary and conclusion in this chapter refer to the following chapters (Chapters 2-6).

**Background, research questions, models, and themes**

The inspiration for this Japan-DK seminar included the findings from a not published AAU-Build project and a seminar on February 26, 2019 in the Consulate-General of Japan in New York by Professor Kazuyoshi Tateyama of Ritsumeikan University, Japan. The seminar purpose was to exchange knowledge, learn from our different cultures, search for solutions to challenges, and improve productivity, quality, and sustainability. As a common framework for the seminar, a discussion was set horizontally between Themes 1 and 3 and vertically between Themes 4 and 2, as illustrated in Figure 1.

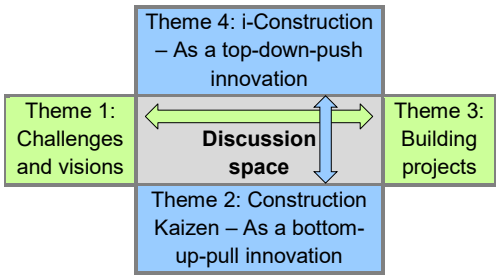



Figure 1. The seminar was divided into four themes forming a common discussion space, where Themes 4 and 2 are examples of top-down-push and bottom-up-pull strategies, respectively.

To inspire the discussions, we raised three research questions in the introduction in Chapter 3 and presented the theme-flow matrix in Figure 2. This again refers to two simple process models (a process matrix in Figure 11 and a list of construction process activities in Figure 12) described in the introduction in Chapter 3. The process matrix describes five steps in the value chain and five levels in the management hierarchy.

The three research questions for the Japan-DK seminar in Copenhagen are:

1. How can construction practice, research, and education implement a national policy for i-Construction, including the aggressive use of ICT in construction as a push strategy?
2. How can the bottom-up pull from Gemba Kaizen and JIT be adapted in construction more widely and contribute to a better pull-push balance with push activities?
3. How can we solve the problem of disseminating research results to education and construction practice with a documented effect on the final building?

| **External requirements and authorities** | | | |
|---|---|---|---|
| **Construction project:** | Challenges and visions | Construction process | Results and building in use |
| ○ Top – the 'paper' world | *Theme 1* | *Theme 4* | |
| ○ Bottom – the real world | | *Theme 2* | *Theme 3* |
| **Research, education and other knowledge activities** | | | |

Figure 2. The theme-flow matrix and learning steps from the seminar. We presented the themes in the summary and conclusion in the order shown by the arrow.

Seminar Themes 1, 2, 3, and 4 were presented in this order, but in this summary and conclusion, we chose to present the four themes in another order similar to the process flow in construction projects, which is a top-down chronology, as shown by the arrow in Figure 2. In this way, we can treat each theme separately and still provide a cohesive conclusion. We also try to put the normal process flow order under pressure to search for a better pull-push balance. This was inspired by the bottom-up pull in Gemba Kaizen, JIT and Soeren Kierkegaard (1843). We here try to make an analysis through a learning process in the opposite direction, as shown by the arrow in Figure 2.

**Theme 1: Challenges and visions for construction**

The construction sectors in Japan and Denmark/EU are fighting for better productivity, technology, workers, and technicians to fulfil the growing demands for additional, cheaper, better, and sustainable buildings and infrastructures. This is expressed in the UN SDG, in the grassroots aims for climate action, and in the promotion for new technology. If we fulfil this, it is important to formulate an acceptable policy for the construction sector, and the challenges and visions must be simple, visible, and applicable to all participants in the value chain. To support the dialogue in the seminar, we referred to the three research questions, the discussion space between the four themes, and two process models (a process matrix and a list of process activities in construction).

In Theme 1 part 2 and Theme 1 part 3 (Themes 1.2 and 1.3), Danish and Japanese presentations cover challenges and visions. See the differences between the two presentations in Table 1. Finally, in Theme 1.4, there was an open dialogue on the reflections on the activities of the site crew, site management, clients and consultants, and training and education. See the keynotes in Chapter 3. Through this, Bertelsen introduced Theme 1 and aimed for a successful seminar and benefits for all.

Table 1. The Danish and Japanese presentations in Themes 1.2 and 1.3 focus on different areas regarding challenges and visions. ICT: Information and communication technology.

| Presentation | Actors | Values | Object | Phase | Activity |
|---|---|---|---|---|---|
| **Danish** | Architects | Quality | Building | Design | Architecture |
| **Japanese** | Engineers | Efficiency | Infrastructure | Construction | ICT |

In Theme 1.2, Espersen described the challenges and visions for construction in Denmark. It is a balance between resource management and value creation explained by a sustainable triple bottom line of benefit and cost. She illustrated the life-cycle value as a gearbox. She expects a changing workload in the design process in the future. The Danish government and the construction industry have addressed global challenges in different initiatives. In the future, there must be a good balance between push and pull. The architects must include this thinking in the idea and design phase, and they are important partners in the discussion between the four themes. Finally, Espersen proposed the following opportunities for business in the built environment:

- Document value creation and wiser uses of resources.
- Always use a life-cycle perspective for finance, design, construction, operation, and recycling.
- Create shared value built on mutual interest and integrate it into the entire value chain.
- Share knowledge of environmental, economic, social performance, and user experiences.

In Theme 1.3, Tateyama described the construction and infrastructure sector in Japan. It is under enormous pressure from climate change, a shrinking construction workforce, and dangerous and low-wage working areas. The Ministry of Land, Infrastructure, and Transport in Japan has formulated a new policy on i-Construction to improve the productivity by aggressively using information and communication technology (ICT), standardising specifications in construction, and balancing orders throughout the year. The ministry aims to attract more young people and females in the sector and to change the sector into a more industrialised, clean, and attractive sector by digitalising and standardising production. In contrast to the Danish presentation, the focus in the Japanese presentation is on infrastructure, the engineering process, ICT, efficiency at the production on site, and productivity improvements.

**Theme 4: Planning the construction process by i-Construction**

In Theme 4, we focus on the development of Building Information Modelling (BIM), ICT, VDC, and i-Construction in Japan and Denmark/EU. The presentations are on the principles and experiences of using digitalisation in design and construction planning, and we discuss it in relation to Facility Management (FM), construction robots, unmanned construction machines, and 3D-printed buildings. We view them as a top-down push from technology and research, which promises better buildings and efficient processes. However, the reality is a limited practical application and an unbalanced bottom-up pull from construction concerning the heavy push from technology. Moreover, we have not seen widespread productivity improvements. Regarding this, Soerensen finished his introduction to Theme 4 with the quote: *'Don't worry folks – artificial intelligence (AI) saves the world*' (James Lovelock). See an overview of the five presentations in Table 2.

Table 2. Categorising presentations in the different parts of Theme 4 on i-Construction, information and communication technology, virtual design and construction, robots, and automation.

| Theme | Actors | Country | Values | Object | Process | Improvement |
|---|---|---|---|---|---|---|
| **4.2** | Consultant | DK | Efficiency | Building | Design & CM | Dissemination |
| **4.3** | Softw. Co. Research | DK | Efficiency In. climate | Commissioning | AI & IoT sensors | Research and practical test |
| **4.4** | Robot Co. | DK | Efficiency | Building | Construction | Dissemination |
| **4.5** | Research Contractor | Japan | Workforce hours & security | Infrastructure | Unmanned machines | First practical test |
| **4.6** | Robot Co. | DK/EU | Efficiency | Building | Production | In the first phase |

*Notes: Co = company; In. climate = indoor or internal climate; Softw. = software; CM = Construction Management; AI = artificial intelligence; IoT = internet of things.*

In Theme 4.2, Kragh described the general development of digitalisation in construction, VDC models applied in the construction and design process, and Location-based Scheduling (LBS) in project management. Virtual Design and Construction (VDC) is becoming a more commonly used tool in main construction and design companies in Denmark, where it links the design and planning in construction more firmly together. In addition, LBS brings top-down and bottom-up planning together, and is a fine supplement to Last Planner System (LPS) and Lean Construction. Gradually, construction companies in Denmark have implemented the principles in project management, but not often for the working teams on site. Both VDC and LPS are illustrated in the presentation by many examples from construction projects in Denmark, and Kragh recommended further dissemination of these in practice.

In Theme 4.3, Blaadal described the visions for the company CXweb, and how they work with big data, AI and the internet of things (IoT). He discussed the degree of implementation of digital technology in the three main phases in construction. In addition, Wolsing followed up by describing the results from an interdisciplinary FM research project, where they have installed and tested IoT sensors in the Technical University of Denmark (DTU) library. From the findings in the DTU library project, it is possible to obtain detailed time series data of building services from low-cost wireless sensors. Moreover, IoT sensors can obtain data regarding the room temperature, carbon dioxide ($CO_2$) concentration, air supply temperatures, heating pipe temperatures, damper operation, on/off status, and light levels. It is possible to automate the demand control of building services and optimise operations using IoT sensors. Prediction using a neural network provided no useful results; however, further investigations could show potential.

In Theme 4.4, Christensen described 'Robot At Work' (RAW), which is a moveable low-weight robot based on a modular rail system in two dimensions. In addition, RAW can be quick to assemble on the construction site with different working tools. The RAW is a new generation of machine that can work with the craftspeople and automatically execute repetitive work. It is a fine link and first step towards a more complicated robot. With simple training, craftsperson can implement RAW in many construction companies. The proposed processes on the actual building parts could be the first example of construction work, where RAW is implemented more widely in the sector. Other kinds of construction work can follow.

In Theme 4.5, Tateyama introduced the development of robots in Japan, which are part of the aggressive use of ICT through precise management. Precise management accepts some unexpected conditions and margins between planning and real conditions. Construction machines with advanced controls are the first step, and unmanned machines with judgement functions are the second step in the direction of robots in construction. In addition, Tateyama also described figures from a white paper from the Japanese government on i-Construction and research projects on construction robots in infrastructure projects and recovery from natural disasters. Moreover, Furuya followed up by presenting the viewpoints from a Japanese contractor point of view. He also showed examples of construction robots and important areas for future work. These include using ICT tools and data, using single automated machines or systems of machines, employing new autonomous methods, and improving the technical skills of engineers. Seen from the Danish viewpoint, it is interesting how structured the Japanese government, research institutions, and private companies describe the development of i-Construction.

In Theme 4.6, Ellinghausen described the principals of the COBOD robot for construction of a 3D-printed building, and he showed other projects of 3D-printed buildings around the world. The 3D-printed building is still in the first phase of invention, there is considerable hype around the first products, and he said, "Purported facts are often fake news". For COBON, substantial technical development still needs to be done, and the business plan must be specified. The focus is on different building parts, such as the foundation, the basic construction, finishing, heating, water, and plumbing. The development still aims to produce a digital printed building that is produced quickly and cheaply and can better fulfil the clients' demands with a lower carbon footprint and better sustainability.

**Theme 2: Improving the construction process by Gemba Kaizen**

In Theme 2, we focus on Gemba Kaizen and continuous improvements in construction sites (e.g. using a bottom-up pull). Moreover, Bertelsen introduced Theme 2 according to the background and purpose (see Theme 1.1 in Chapter 3). Gemba and Kaizen are important

processes in the Toyota Production System (TPS), which are often forgotten in lean and LPS. Gemba (現 場) is the important location in production, and Kaizen (改 善) comprises improvements in continuous steps. In Theme 2, the presentations propose how Gemba Kaizen can be transformed to construction and how far we are in the development in Japan and Denmark/EU. See an overview of the presentations in Table 3.
At the end of Theme 2, there was an open dialogue in four discussion groups about possible reflections from the site crew, site management, clients and consultants, and training and education respectively. See keynotes from the dialogue in Chapter 4.

Table 3. Categorising the four presentations in Theme 2 on Construction Gemba Kaizen and continuous improvements

| Theme | Actors | Country | Values | Object | Process | Improvement |
|---|---|---|---|---|---|---|
| **2.2** | Contractor | DK | Productivity | Building | Kaizen/Lean | Dissemination |
| **2.3** | Research | Japan | Productivity | Infrastruc. | Video inspect. | Field tests |
| **2.4** | Contractor org | DK | Productivity | Building | Innovation | Dissemination |
| **2.5** | ATCM org | DK | Competence | Building | Education | Dissemination |

*Notes: Org = organisation; Infrastruc. – infrastructure; Inspect. = inspection; ATCM = The Association of Architectural Technologists and Construction Managers.*

In Theme 2.2, Frederiksen and Christensen first demonstrated a practical exercise on Gemba Kaizen based on a visit to Japan in 2017. They described the journey of Enemærke & Petersen (EogP) from 2004 to today to implement CGK, lean construction, and other methods to improve productivity. They also provided a short conclusion on how management improved craftsperson productivity in the contractor company EogP. For example, ownership must move from the main leader to the project. Everyone on the teams must be trained to gain synergy and understanding. Understanding and planning the process comes before cost calculation, and we must be ready to invest in the production line and process. On the way to the deadline, we must follow up on previous involvement and learn from the process, and make the results visible to the team. Knowledge sharing is powerful and contributes to a good brand. Moreover, when the experience shows a need for it, we must make a new plan.

In Theme 2.3, Tateyama described how to use video data and drones in the design and inspection of infrastructure and how they work with a work-style reform. He started by concluding, that construction companies in Japan do not use CGK, and that the government has a top-down approach supplemented by a bottom-up pull approach from companies. Video generates a heavy volume of data, which they compress and use to visualise accidents and to educate employees to prevent such accidents. In addition, i-Construction triggers the construction process, which requires new standards, guidelines, and reductions of time spent on site. The reform requires education of more females to work in construction and to use ICT better, and the new skills should fit the individual workers. He presented different examples, including roof construction renovation. He summarised the first three years of i-Construction as follows. Some unique efforts have emerged to improve productivity in construction. Local small and medium-sized enterprises (SMEs) have introduced noteworthy efforts on their issues. The construction industry is evolving now, which could turn construction into a vibrant industry.

In Theme 2.4, Okking described how construction company associations and worker federations have introduced a training programme for motivated companies called SMART. There is a challenge to ‘sell’ the training without external financial support. The focus is on lean in

SMEs and on how to complete the training in the companies. The framework includes company visits, process planning with managers, a two-day SMART course, and a visit two months and an evaluation six months after the course. When the course is running, there is great interest in collaboration and creating practical results. The next step could be practical training on site, including how to prepare company guidelines based on the improvements.

In Theme 2.5, Djaelund described the education of a 3.5-year bachelor's study in architectural technology and construction management (ATCM). Those in ATCM are generalists with a focus on information and communication technology (ICT), building information modelling (BIM), construction management (CM), and other specific competencies required in different parts of the construction industry. They could support implementing CGK in both design and at the construction site, and they can work in all parts of the value chain as managers and co-workers. In the future, a lack of skilled craftspeople is expected and more service and focus on clients and the ability to cooperate and communicate digitally will be needed. Today, the number of those educated in ATCM is bigger than the number of both five-year educated architects and engineers together, and the difference will likely increase. In addition, ATCM can balance the bottom-up and top-down approaches and implement them digitally in projects, as shown in Theme 3. The challenge is whether they still can keep the balance between workers and management.

**Theme 3: Results of the construction project**

In Theme 3, we visit the construction site 'Postgrunden' in Copenhagen with Per Aarsleff A/S as the main contractor. It was a closed session for 17 participants, where Groenlund described the construction project from an open balcony with a fine view over the site and where Thomsen presented the 3D model, VDC, and virtual reality (VR) applied in the project. There was an open and informative dialogue between the participants, and they tried to include the experiences from Themes 1, 2 and Theme 4 into the construction project. The client has put restrictions on an open distribution of the presentations, which narrowed the opportunities to learn from the project and to link it to Themes 1, 2, and 4 in this final report.

Construction projects and practical dissemination in the sector are included in four out of 13 presentations in the seminar. All four have used projects to illustrate the challenges, and some have used projects to document the prototype test, VDC, and Kaizen in practice. The rest of the presentations have very limited relations to practical projects.

**Conclusion and answer the three research questions**

It was beneficial to arrange the seminar in the discussion space between Themes 1, 2, 3, and 4 and to use the example of i-Construction and Gemba Kaizen to demonstrate the balance between top-down push and bottom-up pull. It is difficult for the bottom-up approach from Gemba Kaizen to compete with the top-down approach from i-Construction, which has many visions and a simple form of promotion. However, we lack the supplement of quick development and documented results with a direct effect on practice in Gemba Kaizen, but this has low priority. If the principal of Gemba Kaizen in construction must make a change that is widely implemented with influence in practice, we must focus on it and produce quick, clear, and sustainable results.

The two national presentations in Theme 1 provided the participants with fine overviews over the national policies and activities on i-Construtions and Gemba Kaizen in Japan and Denmark, which supplemented each other. From a Danish point of view, it is interesting to see how structured the Japanese government, research environments, and private construc-

tion companies are in the development of i-Construction. Most the other presentations included an introduction with challenges and visions, but they focused more on a narrow technical area.

Question 1. Implement national policy for i-Construction – Related to Theme 4.
Most of the development in i-Construction, ICT, VDC, robots, and automation is a top-down push from technology and research to improve productivity and reduce labour, but we have not seen the documentation. Theme 4 includes six presentations, which differ substantially regarding how much they are applied in construction projects and how much they are disseminated in the sector. A clear difference exists between the Japanese and Danish approaches. The examples from Japan are more structured and based on the government i-Construction strategy, whereas the Danish examples are more autonomously planned and developed. We could improve the implementation of i-Construction by adding the Gemba Kaizen bottom-up pull approach, and we could add it to the national strategy.

Question 2. Adapt Gemba Kaizen in construction – Related to Theme 2.
Gemba Kaizen at the worker's level in construction is included in three presentations as a bottom-up implementation approach. In addition, 10 presentations showed principles that were critical for implementation of construction Gemba Kaizen at the design and planning level. Seven presentations focused on education and training in the use of diverse methods. They have indicated the needs for education of engineers, project managers, craftspeople, and females and for training in special methods and digital tools to improve small contractor companies and project managers. We must increase research, education, practical tests, and information activities on Gemba Kaizen in construction and include it in the national strategy, if we want to realize its great potential.

Question 3. Disseminating research results to construction practice - Related to Theme 3.
We discuss the dissemination of research to practice in Theme 3 on the construction site visit 'Postgrunden' by Per Aarsleff A/S. All four presentations in Theme 2 argue for better education and learning processes, if we will disseminate Gemba Kaizen wider and deeper in practice. We discuss the absence of a national learning strategy that linked research, education, and learning in construction with documented improvements on the final construction project. It is a process, which we ought to put more effort into in the future, if we wish to accelerate innovation and changes in general in construction.

2

# PROGRAMME, THEMES, AND PARTICIPANTS

# 2 PROGRAMME, THEMES, AND PARTICIPANTS

The construction sectors in Japan and Denmark/EU are fighting for better productivity, technology, workers, and technicians to fulfil the growing demands for additional, cheaper, better and sustainable buildings and infrastructures. The global visions in the 17 UN Sustainable Development Goals (SDG), the grassroots aims for climate action, and new technology have pushed the development in construction. However, are we working towards it, and have we seen essential improvements in building projects?

A Danish study in Construction Supply Chain Management (CSCM) [Bertelsen et alia, 2020b] indicates that we have not seen such improvements. Lean and the Toyota Production System (TPS) indicate that a missing link may exist, where knowledge from Gemba Kaizen and Just-in-Time (JIT) could inspire reaching a better pull-push balance in construction (Gemba 現 場 is the actual place, and Kaizen 改 善 is the improvements).

At a meeting in New York on February 26, 2019, Professor, D.Eng. Kazuyoshi Tateyama from Ritsumeikan University, Japan, and senior researcher Niels Haldor Bertelsen from Aalborg University discussed i-Construction and the challenges. When K. Tateyama with a small Japanese delegation in September 2019 visited Copenhagen, we planned to continue our search for solutions with Danish stakeholders at this Japan-DK seminar.

## Themes, meeting times, and locations

In the programme, the discussions were divided into the following themes to form an encouraging discussion space at the seminar, where Theme 1, 2 and 3 were closed sessions, and Theme 4 was an open session:

- Theme 1: Challenges, visions, and focus areas for construction development in Japan and Denmark/EU to improve productivity and other goals.
- Theme 2: Construction Kaizen, motivation, and small continuous improvements as a bottom-up-pull innovation strategy to improve pull from construction workers.
- Theme 3: A site visit – building projects realise visions and innovation and document the effect on productivity, quality, and other goals.
- Theme 4: i-Construction, new technology, Virtual Design and Construction (VDC), automation, drones, and robots as a top-down-push innovation strategy that pushes construction.

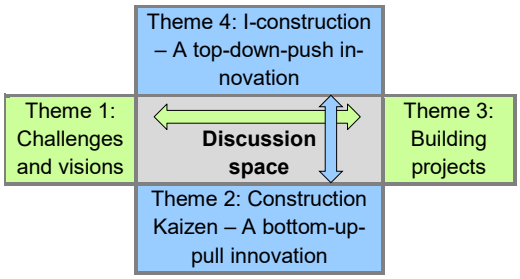



Figure 3. Discussion space at the seminar between the four themes.

**Meeting time**

Friday, September 13, 2019, from 08:00 to 17:00 in Locations A, B, and C.

**Meeting locations**

The seminar was located at the following addresses in the centre of Copenhagen:

A. 08:00-12:30 – Closed session: BLOXHUB, Bryghuspladsen 8, Entrance C, third floor, 1473 Copenhagen K. – Themes 1 and 2.
   https://bloxhub.org/
B. 12:30-14:00 – Closed session: Aarsleff construction site 'Postgrunden', Carsten Niebuhrs Gade 10, 1577 Copenhagen V. – Theme 3
   https://www.aarsleff.com/?ul=1 and http://postgrunden.dk/ in Danish
C. 14:00-17:00 – Open session: IDA house, The Danish Society of Engineers, Kalvebod Brygge 31-33, 1780 Copenhagen V. – Theme 4
   https://ida.dk/om-ida in Danish.

Parking: BLOXHUB or IDA house.

Walking: From A to B is 1.2 km or 15 min, and from B to C is 0.7 km or 8 min.

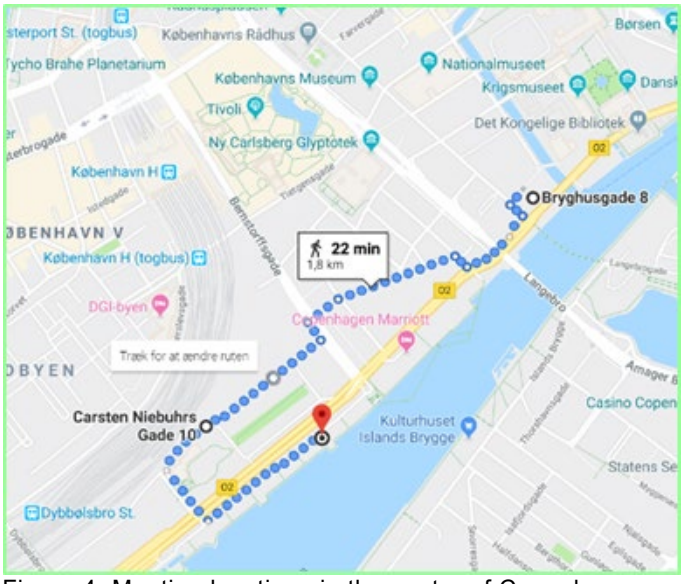


Figure 4. Meeting locations in the centre of Copenhagen.

# Programme for Themes 1 and 2 at Location A

08:00 Check-in, breakfast and networking

**Theme 1. Challenges and visions for construction**

08:30 Welcome and introduction to the seminar

- Welcome to BLOXHUB and Copenhagen
- Introduction and the seminar program
- Challenges and visions in Denmark
- Challenges and visions in Japan
- Discussion of challenges, visions, and focus areas for development in Japan and Denmark

09:30 Reflections and break.

**Theme 2: Construction Kaizen and continuous improvements**

09:50 Introduction to Theme 2

- Kaizen in Toyota as a join practical exercise
- Examples from a construction company in DK
- Utilisation of video data on construction sites in Japan
- Reflection and break
- Continuous improvement training by organisations
- Education in motivation and inter-professionalism
- Reflection and conclusion of construction Kaizen as a bottom-up pull

12:00 Networking and ‘walk and talk’ to ‘Postgrunden’.


Figure 5. Location for Themes 1 and 2.

# Programme for Theme 3 at Location B

**Theme 3. Building project ‘Postgrunden’ by Aarsleff A/S**

12:30 Arrival at the entrance of Carsten Niebuhrs Gade 10

- Sandwich and view of the construction site at the terrace
- Vision, VDC, methods, cooperation, and management
- Discussion of the building project and how to document improvements and the effect of innovation

14:00 Coffee, networking, and ‘walk and talk’ to IDA house.


Figure 6. Location for Theme 3.

# Programme for Theme 4 at Location C

14:00 Check-in, coffee, and networking at IDA house

**Theme 4. i-Construction and new technology**

14:30 Welcome to IDA house

- Introduction and the seminar programme
- VDC, BIM, ICT, and i-Construction in DK
- From i-Construction to FM and commissioning
- Robots and construction site automation in DK
- Break
- Utilisation and challenge of new technology in Japan
- 3D-printed construction and example from North Copenhagen
- Discussion: Development of i-Construction

17:00 Closing, sandwich, and networking.

Figure 7. Location for Theme 4.

**Link to programme and presentations**
https://sbi.dk/japandk

# Japanese guests and seminar participants

**Professor, D.Eng. Kazuyoshi Tateyama**

Professor, D.Eng. Kazuyoshi Tateyama from the College of Science and Engineering is an executive trustee of Ritsumeikan University, Japan. He graduated from Kyoto University with a bachelor's degree in civil engineering and earned his doctoral degree at Kyoto University in 1988. He has taken on the research and development of the rationalisation of construction for many years and has engaged in many committees in governments and academic societies. He is now the chairperson of the committee for construction robotics in the Japan Society of Civil Engineers and Council for Construction Robot Research [Tateyama, K. (2017). *A New Stage of Construction in Japan – i-Construction – Special Contribution.* IPA Newsletter, Volume 2, Issue 2 June 2017].

**Ph.D. Takaaki Yokoyama**

Yokoyama is a lecturer at the College of Science and Engineering in the Department of Environmental Systems Engineering at Ritsumeikan University in Japan. He is an expert on precision construction, soil mechanics, tera-mechanics, and space engineering.

**D.Eng. Hiroshi Furuya**

Furuya is the senior chief engineer at the Technical Research Institute, Obayashi Corporation, in Japan. He is an expert on using Information Communication Technology (ICT) and system development in the construction field, construction robot development, and construction of data model utilisation systems.

**Participants in the four themes**

For Themes 1, 2, 3, and 4 there participated 29, 25, 17, and 40 people respectively.

Table 4. Participants in the four themes. In total, 50 people participated: Three from Japan and 47 from Denmark. 'P' and '#' indicate participants with presentations.

| Name and email Theme | 1 | 2 | 3 | 4 | P |
|---|---|---|---|---|---|
| **Organiser:** | | | | | |
| Niels Haldor Bertelsen (nhb@sbi.aau.dk) | 1 | 1 | 1 | 1 | # |
| **Japanese guests:** | | | | | |
| Kazuyoshi Tateyama (tateyama@se.ritsumei.ac.jf) | 1 | 1 | 1 | 1 | # |
| Takaaki Yokoyama (t-yoko@fc.ritsumei.ac.ja) | 1 | 1 | 1 | 1 | # |
| Hiroshi Furuya (furuya.hiroshi@obayashi.co.ja) | 1 | 1 | 1 | 1 | # |
| **Danish participants:** | | | | | |
| Allan Leegaard (allan.leegaard@batkartellet.dk) | 1 | 1 | 1 | | |
| Andreas Kragh (ankr@niras.dk) | 1 | 1 | 1 | 1 | # |
| Ask Hesselager (ash@danskbyggeri.dk) | 1 | 1 | 1 | 1 | |
| Britt Lynard (brly@aarsleff.com) | 1 | 1 | 1 | | |
| Carl Johan Fokdal Christensen (cjc@bygherreforeningen.dk) | 1 | 1 | | 1 | |
| Casper Arnsbo Poulsen (casper.poulsen@batkartellet.dk) | 1 | 1 | | 1 | |
| Erik Fog Larsen (efl@bygud.dk) | 1 | 1 | | | |
| Henrik Volsing (hevo@aarsleff.com) | 1 | 1 | | | |
| Jakob Groenlund (jag@aarsleff.com) | | | 1 | | # |
| Jan Buur Frederiksen (jbf@eogp.dk) | 1 | 1 | 1 | 1 | # |
| Jette Leth Fejerskov Djælund (jette@kf.dk) | 1 | 1 | | | # |
| Joachim Skovbogaard (jos@bns.dk) | 1 | 1 | 1 | 1 | |
| John Engelstrup (joeng@eogp.dk) | 1 | 1 | | | |
| Keld Ejner Olsen (Keldolsen2@ofir.dk) | 1 | 1 | 1 | 1 | |
| Kirsten Nielsen (kirsten@kf.dk) | 1 | 1 | | | |
| Kjeld Svidt (ks@civil.aau.dk) | 1 | 1 | 1 | 1 | |
| Lars Jess Hansen (ljh@eogp.dk) | 1 | 1 | | | |
| Lene Espersen (le@danskeark.dk) | 1 | | | | # |
| Mads Okking (mo@dhv.dk) | 1 | 1 | 1 | 1 | # |
| Michael Dalsgaard (michael.dalsgaard@3f.dk) | 1 | 1 | 1 | 1 | # |
| Mikael Hygum Thyssen (mit@niras.dk) | 1 | 1 | | 1 | |
| Nikolaj Thomsen (nth@aarsleff.com) | | | 1 | | # |
| Peter Andreas Sattrup (pas@danskeark.dk) | 1 | | | | |
| Soeren Christensen (sci@eogp.dk) | 1 | 1 | | | # |
| Ruut Hannele Peuhkuri (rup@sbi.aau.dk) | 1 | | | | |
| Tim Pat McGinley (timmc@byg.dtu.dk) | 1 | 1 | 1 | | |
| Torben Klitgaard (tkl@bloxhub.org) | 1 | | | | # |
| **Danish participants only in theme 4:** | | | | | |
| Lene Christensen, Ingeniørforeningen, IDA | | | | 1 | # |
| Nils Lykke Soerensen (nls@sbi.aau.dk) | | | | 1 | # |

| Name and email Theme | 1 | 2 | 3 | 4 | P |
|---|---|---|---|---|---|
| Nicki Blaadal-Hansen (nb@cxweb.dk) | | | | 1 | # |
| Marie Bryld Wolsing (marie.wolsing@hotmail.com) | | | | 1 | # |
| Finn Christensen (fc@robotatwork.com) | | | | 1 | # |
| Ole Ellinghausen (ole@cobod.com) | | | | 1 | # |
| Arun Prakash Muthu Naicker Ravichandran, Cowi | | | | 1 | |
| Eleonora Borovic | | | | 1 | |
| Erik Schack Madsen | | | | 1 | |
| Finn Bellstroem Hansen | | | | 1 | |
| Finn Christensen | | | | 1 | |
| Gamal Farah Fanous | | | | 1 | |
| Govinda Prasad | | | | 1 | |
| Holger Koss | | | | 1 | |
| Jakob Lykkebo, Hoffmann A/S | | | | 1 | |
| Jakob Malmskov, CXweb IVS | | | | 1 | |
| Krystian Malada | | | | 1 | |
| Kukkamaaria Tikkamäki | | | | 1 | |
| Lars Lundgaard Lykkebo, Hoffmann A/S | | | | 1 | |
| Lene Christensen, Ingeniørforeningen, IDA | | | | 1 | # |
| Luminita Corduneanu | | | | 1 | |
| Nikolaos Andreas Gkoufas | | | | 1 | |
| Priyanka Kesavan, Cowi A/S | | | | 1 | |
| Renata Klausen | | | | 1 | |
| Susanna Charlotta Van De Graaf | | | | 1 | |
| Susanne Vinther Kjærgaard | | | | 1 | |
| **50 participants in total, divided into four themes as follows:** | **29** | **25** | **17** | **40** | |

3

# THEME 1: CHALLENGES AND VISIONS FOR CONSTRUCTION

# 3 THEME 1: CHALLENGES AND VISIONS FOR CONSTRUCTION

Japan has a growing population of elderly people and a shrinking construction workforce. Globally, there has also been an intensive top-down push on construction from the 17 UN SDGs, from the grassroots aims for climate action, and from new technology, materials, systems, and clients. The construction industry in Japan and Denmark/EU is struggling to attain better productivity, new technology, and qualified workers and technicians to fulfil these growing demands. However, we have generally not yet experienced essential improvements in productivity on building projects. In Theme 1, we discuss different challenges and visions in Japan and Denmark, followed by a discussion of Construction Gemba Kaizen (CGK) as a bottom-up pull solution in Theme 2. They were both closed sessions held on September 13, 2019, from 8:00 to 12:30 at BLOXHUB, Bryghuspladsen 8, 1473 Copenhagen K. In the afternoon, the two first themes were followed up by a site visit for Theme 3 and a discussion about i-Construction, ICT, VDC, robots, and 3D-construction printing in Theme 4.

## Theme 1.1: Programme, background, and introduction

Senior researcher Niels Haldor Bertelsen is from Aalborg University Copenhagen.

**References**

Theme 1-1 Introduction Bertelsen 2019-09-13Niels Haldor Bertelsen (2019). *Japan-DK Seminar Sep. 13, 2019. Construction Kaizen and i-Construction.* Danish Building Research Institute, Aalborg University Cph. 1-7 pages.

Figure 8. Location for Theme 1.

**Theme 1 program at BLOXHUB and introduction**

08:00 Check-in, breakfast and networking
08:30 Welcome and introduction to BLOXHUB by HUB Director T. Klitgaard
08:40 Introduction to Theme 1 by N. H. Bertelsen, AAU Cph.
08:50 Challenges and visions in Denmark by L. Espersen, Danske Ark
09:10 Challenges and visions in Japan by K. Tateyama, Ritsumeikan University
09:30 Reflections in four roundtable discussions and break

**Background, purpose, and discussion space**

On February 26, 2019, Professor Kazuyoshi Tateyama from Ritsumeikan University, Japan presented 'i-Construction as a new stage of construction in Japan' at a seminar in the Consulate-General of Japan in New York. In a following meeting, he and N. H. Bertelsen (from Aalborg University) discussed how to meet these challenges. In September 2019, Tateyama and a small Japanese delegation visited Europe, and at this Japan-DK seminar on September 13 in Copenhagen, we had the opportunity to continue our search for solutions, while guided by the following purpose:

- The seminar aimed to facilitate exchange of knowledge, learn from our different cultures, search for solutions to challenges, and improve productivity, quality, and sustainability.

We divided the seminar into four themes. Theme 1 is about challenges and visions, and it forms a horizontal discussion space with Theme 3 about building projects, where we can test improvements in practice. Theme 2, which is about CGK as an example of a bottom-up pull, forms a vertical discussion space with Theme 4, which is about i-Construction as an example of a top-down push from new technology. The discussion space in the middle can inspire the presentations and discussions in each theme.

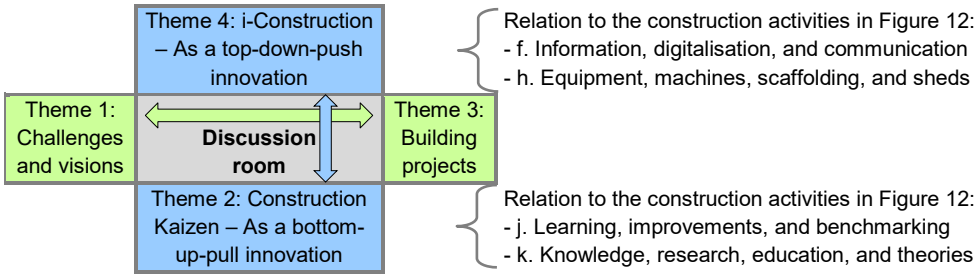



Figure 9. The discussion in the seminar is between the four themes, and the relations to the construction activities in Figure 12 are in the right column.

**Research questions**

The inspiration for the seminar were the meeting in New York with Tateyama and the discussion on how we can solve different challenges in construction processes.

Here we raise a general research question:

- Have we seen improvements in building projects in relation to new challenges, and have we worked towards solving the problems and responding to the challenges?

According to a Danish study in CSCM [Bertelsen et alia, 2020b], we have not finally solved the problems, nor met the challenges. However, the study also indicates that construction Gemba Kaizen (CGK) could be the missing link and could provide a better pull-push balance in the improvement strategy, where Gemba and Kaizen express continuous improvement in the production floor.

When Tateyama and a small Japanese delegation visited Copenhagen in September 2019, we planned to continue our search for a better understanding and solutions together with Danish stakeholders at this Japan-DK seminar. We therefore divided the general question into three specific questions, where the first one is based on the Japanese policy for i-Construction, where the second one is based on the Danish focus on the bottom-up pull from TPS, and where the last one is the common and main question linking to the general question from the New York meeting. The three research questions for the Japan-DK seminar in Copenhagen are:

1. How can construction practice, research, and education implement a national policy for i-Construction, including the aggressive use of ICT in construction as a push strategy?
2. How can the bottom-up pull from Gemba Kaizen and JIT be adapted in construction more widely and contribute to a better pull-push balance with push activities?
3. How can we solve the problem of disseminating research results to education and construction practice with a documented effect on the final building?

We also aim to handle the research questions by applying methods and quotes from philosophers, such as Galileo Galilei, René Descartes, and Soeren Kierkegaard:

- Galileo Galilei stated, through Mr Filippo Salviati from Firenze [Galilei, 1632]:

  *"If you intend to continue studying in that way, then put the term philosophers away and call yourselves historians or memory experts, because people who never philosophize, may not acquire the venerable title of philosopher. Therefore, Mr. Simplicius, now come up with some arguments and evidence, your own or Aristotle's, and not with quotes or pure authority, for our discussions are about the sensory world, not a paper world."*

- René Descartes discussed the method as a philosophical approach with four simple rules [Descartes, 1637]:

  *"1) Accept as true only what is indubitable.*
  *2) Divide every question into manageable parts.*
  *3) Begin with the simplest issues and ascend to the more complex.*
  *4) Review frequently enough to retain the whole argument at once."*

- Soeren Kierkegaard stated [Kierkegaard, 1843]:

  *"Life is understood backwards, but must be lived forwards".*

In the seminar, we presented Themes 1, 2, 3, and 4 in this order for practical reasons. In the execution of a construction project, the order of the main activities normally follows the arrow in Figure 10 as a top-down chronology. In the summary and conclusion of the seminar in Chapter 1, we treat the themes in the same order and follow this process flow to a conclusion. We also analyse the normal execution order and themes concerning the bottom-up-pull strategy in Gemba Kaizen and JIT. In addition, we examine the themes in the opposite direction of the arrow in Figure 10, as philosophers such as Galileo, Descartes, and Kierkegaard have proposed. In this way, we can learn more from the seminar by also thinking about the order of the themes backwards from Themes 3 to 2 and Themes 4 to 1.

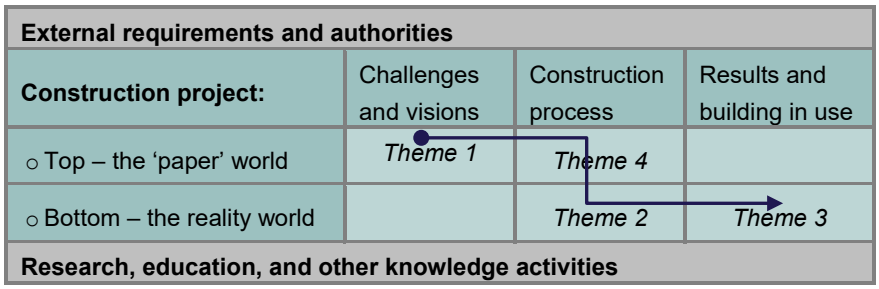



Figure 10. In construction projects, we execute the process in the order shown by the arrow. In the summary and conclusion in Chapter 1, we present the themes in the same order. However, we can learn more from the process that the themes can also be analysed in the opposite direction.

**Introduction to Theme 1: Challenges and visions for construction**

To have a common and targeted development in the construction sector, challenges and visions must be simple, visible, and applicable for the individual participants and the locations in the value chain. In Theme 1, we covered the status of Japan and DK viewpoints of authorities, construction organisations, and innovative clients and companies.

To support the dialogue in the discussion, we referred to two simple process models, a list of construction process activities in Figure 12 and the process matrix in Figure 11, which includes five steps in the value chain and five levels in the management hierarchy. We intended that the discussion space depicted in Figure 9, the research questions above, and the process models would inspire the presentations, participants, and dialogue.

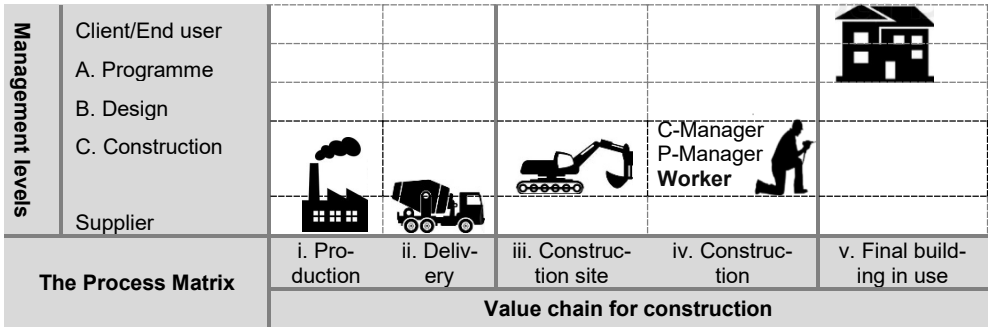



Figure 11. The process matrix consist of the management levels and the construction value chain, where i and ii are the supply, iii and iv are the construction, and v is the building in use. C-Manager is the company manager and P-Manager is the project manager. The figure relates item d (activities) and e (actors) in the list of process activities illustrated in Figure 12.

| | |
|---|---|
| a. External requirements from authorities and others | |
| b. Values, customer requirements, and quality | |
| c. Building, property, and area as physical 'products' | |
| d. Activities, operations, processes, and time | Related to the value chain and management levels described in Figure 11. |
| e. Actors, cooperation, leadership, and work environment | |
| f. Information, digitalisation, and communication | Focus in Theme 4 |
| g. Materials, components, systems, and waste | |
| h. Equipment, machines, scaffolding, and site sheds | Focus in Theme 4 |
| i. Economy, the cost of different parts, and productivity | |
| j. Learning, innovation, and benchmarking | Focus in Theme 2 |
| k. Knowledge, research, education, and theories | Focus in Theme 2 |

Figure 12. Construction process activities developed from TPS, lean, LPS, TDABC, TFV theory, where a and k are the framework, b and c are values and products, d and e are the traditional project controls, and f, g, and h are the flows.

Figure 13. Presentation 7 by Bertelsen: Gallup indicates low employee engagement in jobs globally and that better employee engagement can improve productivity.

## Theme 1.2: Challenges and visions in Denmark

Chief Executive Officer Lene Espersen from the Danish Association of Architectural Firms (Danish: Danske Arkitekt Virksomheder) https://www.danskeark.dk/content/danish-association-architectural-firms. From 2001-11 she was the Minister of Foreign affairs, Legal Affairs and Business; Minister of Finance, Industry and Business Affairs; and Minister of Justice.

**References**

Theme 1-2 Challenges DK Espersen 2019-09-13
Espersen, L. (2019). *Digitalization and value creation – Challenges to research and practice in the built environment*. Danish Association of Architectural Firms, Copenhagen. 23 pages.

**Abstract**

Lene Espersen introduces the Danish Association of Architectural Firms, and how architects today perform in construction projects. She then assesses how authorities, organizations, innovative companies, and research and education collaborate in developing the Danish construction industry. She reviews the development and changes in recent years in the design and construction process in the various life-cycle parts and management levels concerning Figure 11. She illustrates how competitive the Danish construction industry is regarding productivity, quality, architecture, work environment and sustainability or other aspects related to Figure 12. Espersen points out important key points in the discussion between the four themes.

**Presentation**

The presentation [Theme 1-2 Challenges DK Espersen 2019-09-13] is in the following parts (Presentation no.):

- Challenges, ideas, and initiatives (P2-7).
- Examples of architectural design (P8-13).
- Resources and values (P14-16).
- The changing workload in the design process (P17-22).

**Challenges, ideas, and initiatives**

The fundamental challenges are value creation, climate change, fragmented sectors, and lack of data. The Danish government initiated ideas and initiatives in a research programme 2025 [Forsk2025, 2018]. They base the strategy on Denmark as a pioneering country concerning welfare, climate action, and research strategy. Forsk2025 includes heath, green growth, humans and society, and technology and opportunities Figure 14. Green growth, referring to the 17 UN SDGs, will be discussed at the World Congress of Architects, UIA 2023 in Copenhagen.

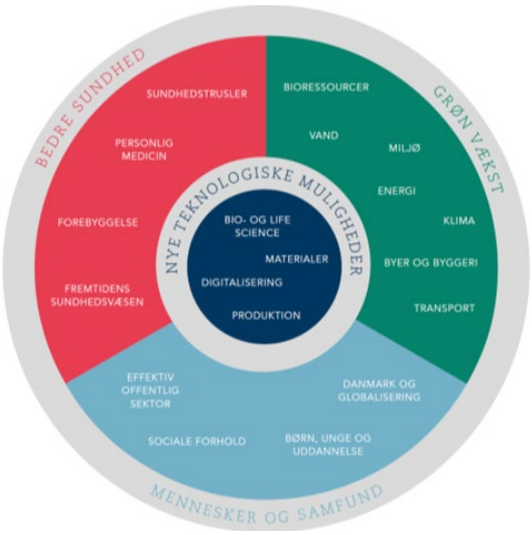



Figure 14. Presentation 5 by Espersen.
Theme 1-2 Challenges DK Espersen 2019-09-13

**Examples of architectural design**

Under the headline ‘What is it worth?’, the following examples are presented:

- Moesgaard in Aarhus by Henning Larsen Architects.
- Jaegers Sports Facility in Copenhagen by Vandkunsten.
- Energy retro-fil of apartments financed by rooftop addiction, Ryesgade 30 in Copenhagen by Krydsrum Arkitekter.
- Renewed park in Sønder Boulevard by SLA.

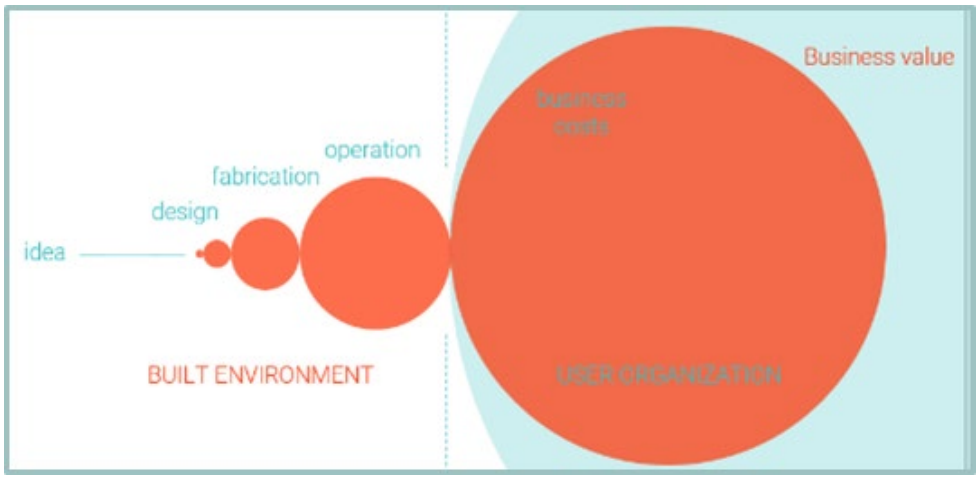



Figure 15. Life-cycle value gearbox from presentation 16 by Espersen.
Theme 1-2 Challenges DK Espersen 2019-09-13

**Resources and values**

The balance between resource management and value creation is explained by a sustainable triple bottom line: benefits (economic, social, and environmental) divided by costs (environmental, social, and economic). The life-cycle value is a gearbox, where a small gear of the idea and design drive bigger and bigger gears of fabrication, construction, and operation of buildings, as illustrated in Figure 15.

**Changing workload in the design process**

From the perspective of the design process, the development of different supporting tools and methods is necessary to measure key performance indicators (KPIs) and estimate and monitor performance in different phases of planning, construction, and building use. The design process must improve the integration of different challenges, tools, and methods and change the workload in the design process. The design process is a high-risk zone for architects while also being a zone for planning great value for the clients, and a revised fee structure and new business models are needed (Figure 16).

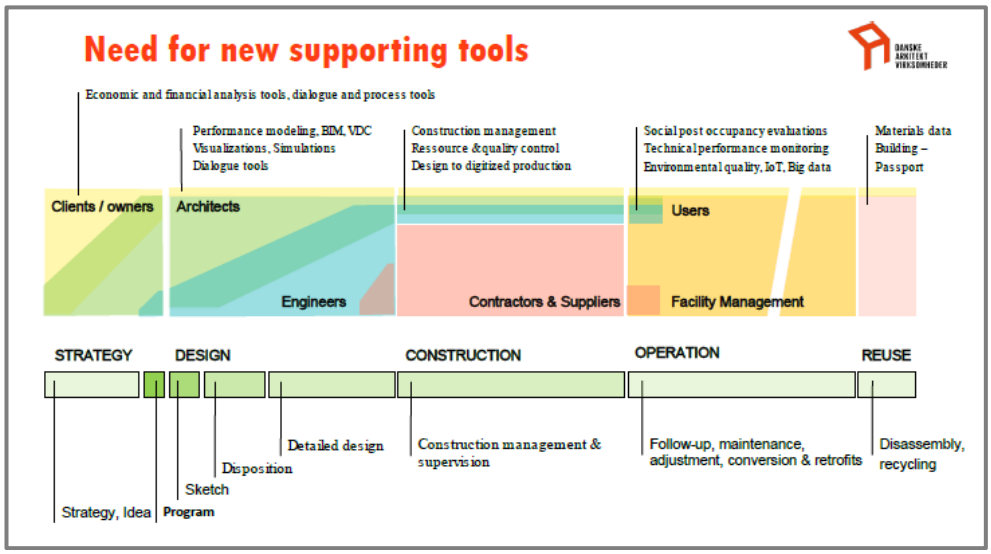



Figure 16. Life cycle, actors, activities, and supporting tools from presentation 21 by Espersen. Theme 1-2 Challenges DK Espersen 2019-09-13

**Reflections**

The Danish government and the construction industry have addressed global challenges and the 17 UN SDGs in various planned initiatives. In Presentations 16 and 21, the push is from the left side and the pull is from the right, and these must be in good balance in the future. It is important that architects include this thinking in the idea and design phases and that it is integrated with the challenges, new tools, and methods to change the workload in the design process. The architects are therefore key partners in the discussion between Themes 1, 2, 3, and 4. The following opportunities have been proposed for the built environment business:

- Document value creation and the wise use of resources.
- Always use a life-cycle perspective for finance, design, construction, operation, and recycling.
- Create shared value, build on mutual interests, and integrate the entire value chain.
- Share knowledge of environmental, economic, and social performance and user experiences.

# Theme 1.3: Challenges and visions in Japan

Professor Kazuyoshi Tateyama is from Ritsumeikan University, Japan.

**References**

Theme 1-3 Challenges Japan Tateyama 2019-09-13

Tateyama, K. (2019). *A New Stage of Construction in Japan i-Construction.* Japan-DK Seminar, Copenhagen, September 13, 2019: Theme 1. Challenges and visions for construction. 13 pages.

**Abstract**

Tateyama explains the challenges facing Japanese society regarding the increasing proportion of elderly people and the declining workforce and how this will influenced the construction industry. This led the Ministry of Land, Infrastructure and Transport to start a new policy of i-Construction, where high wage levels, sufficient holidays, and a safe labour environment are promoted through remarkable improvements in productivity. The ministry established three major steps for such improvements:

- The aggressive use of ICT in construction.
- Standardisation of specifications used in construction to avoid inefficiency caused by single-item production.
- Balancing orders throughout the year, regardless of the season.

Among these steps, advanced construction technology using ICT is expected to play the most important role in realising the final goal. Moreover, Tateyama points out key points in the discussion between the four themes.

**Presentation**

The presentation is in the following parts (Presentation no.):

- The challenges in Japanese society (P2-6).
- The construction sector in Japan (P7-9).
- I-Construction and productivity improvements (P10-12).

**The challenges in Japanese society (P2-6)**

In the next 40 years, a massive change in the Japanese population is expected. The total population is expected to decrease from 127 million in 2020 to 87 million people in 2060 (31 %). In addition, the rate of ageing (people older than 65 years) is expected to increase from 29 % in 2020 to 40 % in 2060, and the working-age population is expected to decrease by 40 % in the same period.

**The challenges in the construction sector (P7-9)**

There has been a change in infrastructure investments. Since 1996, investment in new infrastructure construction has decreased from 70.3 to 40.6 trillion yen, and the investment in maintenance has decreased from 15.9 to 15.8 trillion yen in 2015 (20 years), which increased the rate of maintenance from 16 % to 28 % in the same period. The amount of heavy rain has increased from 160 to 250 hours per year, where heavy rainfall occurs at over 50 mm per hour. This are major challenges in the construction sector, and together the decreased working-age population causes the following challenges:

- A lack of engineers and workers in construction.
- Reduced tax revenue.
- Smaller budgets for public investment.

- Increased complexity and difficulty for maintenance and disaster prevention.
- The inability of the construction sector to provide a stable infrastructure without extensive methods.

At the same time, the construction sector deviates negative from other industries. The construction industry has for example 24 % lower wages, 18 % longer working hours, and 32 % high death rate than all industries (data from 2017).

**I-Construction and productivity improvements (P10-12)**

The Ministry of Land, Infrastructure and Transport formed a new policy on i-Construction, which aims to improve productivity through the following (Figure 17):

- Aggressive use of ICT in construction.
- Standardisation of the specifications.
- Balance of orders throughout a year.
- Improve the hard, dirty and dangerous work through high wage levels, sufficient holidays, and a safe labour environment.
- Implement a drastic development in the construction as in the production industry.

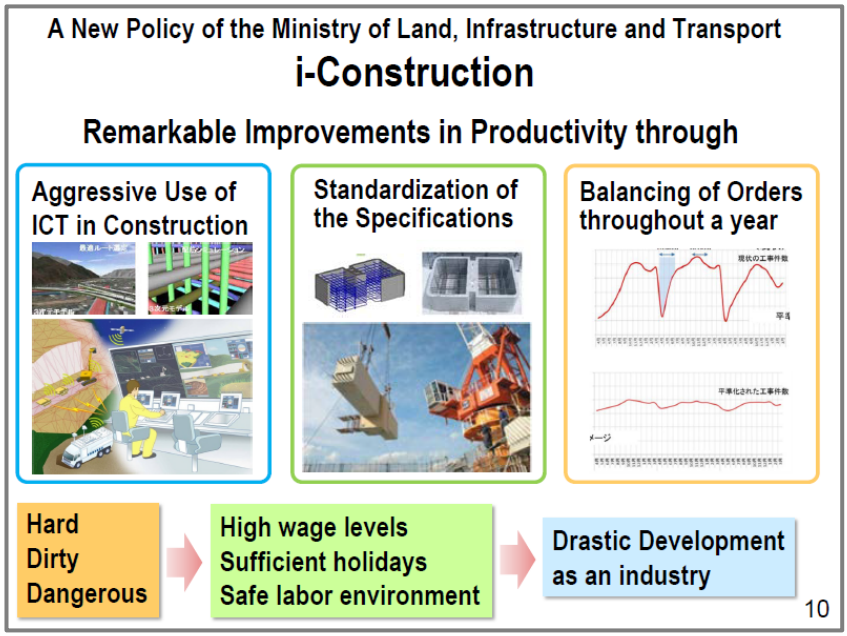



Figure 17. Presentation 10 by Tateyama on three major steps for improvement in Japan.

**Reflections**

The construction and infrastructure sector in Japan are under enormous pressure from climate change, a shrinking construction workforce, and a dangerous and low-wage work area. The solution from the government is to implement an aggressive i-Construction based on ICT and other solutions, which is aimed to improve productivity through drastic developments similar to the production industry. They aim to attract more young people and females. By digitalising and producing standardised production, the government aims to transform the sector into a more industrialised, clean, and attractive sector. In contrast to the Danish presentation, the focus in the Japanese presentation is on infrastructure, the engineering process, ICT, efficiency in production on site, and productivity improvements.

# Theme 1.4: Reflections on challenges and visions

Danish and Japanese presentations focused on different fields (Table 5).

Table 5. Presentation focus by field.

| Presentation | Actors | Values | Object | Phase | Activity |
|---|---|---|---|---|---|
| **Danish** | Architects | Quality | Building | Design | Architecture |
| **Japanese** | Engineers | Efficiency | Infrastructure | Construction | ICT |

*Note: ICT = information and communication technology.*

Based on the introduction and the two presentations on challenges and visions in Denmark and Japan, the participants briefly discussed the presentations and their reflections with the following actor focus and moderators:

- At Table 1, the actor focus was on the 'site crew' with moderator Erik Fog Larsen.
- At Table 2, the actor focus was on 'site management' with moderator Andreas Kragh.
- At Table 3, the actor focus was on 'clients and consultants' with moderator Mikael Hygum Thyssen.
- At Table 4, the actor focus was on 'training and education' with moderator Carl Johan Fokdal Christensen.

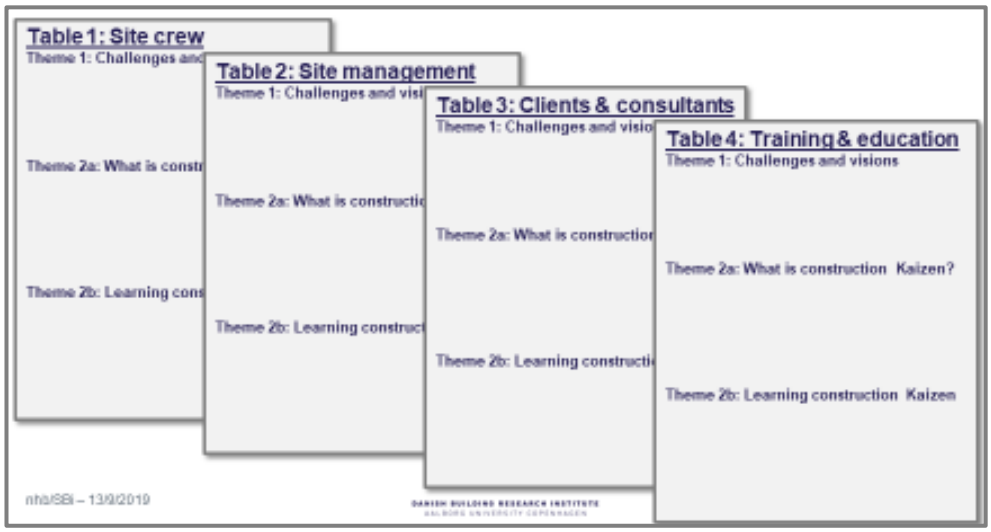



Figure 18. Posters prepared for the roundtable reflections.

In the following outline, the four moderators provided a list of reflection for each table.

**Table 1. Site crew: Reflection on challenges and visions**

- There should be a better relationship between various professional groups.
- Professional and interdisciplinary cooperation should be promoted.

**Table 2. Site management: Reflection on challenges and visions**

- Design as a solution to 'mega' problems.
- Change the value chain – adding resources from other sectors.
- Change the evaluation model and frame condition.
- Designers' contributions: new decision tools, digitalisation, creating shared value and their productivity.
- Change in conditions: capital, labour and 'customer'.
- Change from new building to maintenance of buildings.
- Public initiatives: prefabrication, demand, digitalisation, and automation.

**Table 3. Client and consultants: Reflection on challenges and visions**

The challenges in the industry include the following:

- Sub-optimisation.
- Fragmentation.
- Short-term focus on value creation.
- Lack of productivity.
- Non-attractive work.
- Working-age population decrease.
- Non-professional clients.
- Separate budgets from construction and maintenance can require change in legislation.
- Considerable information is involved in handovers.

Opportunities and visions include the following:

- i-Construction will require increased use of data.
- Standardisation.
- Focus on life-cycle cost.
- Three-bottom line.
- Pull from the end user.
- Share knowledge.

Reflection:

- The construction industry is conservative.
- There is a lack of education for workers.

**Table 4. Training and education: Reflection on challenges and visions**

Challenges in Japan:

- The older population is increasing and building maintenance is increasing, but the budget and taxes are decreasing.
- Climate change is a growing concern.
- Fewer young people are engaged in crafts.

Visions in Japan include the following:

- Information and communication technology (ICT) as an enabler.
- Prefabrication, digitalisation, and 3D.
- Knowledge-driven construction.
- Empowered women with a focus on construction.
- Inform about construction but not as hard, dirty, and dangerous.

The following are challenges in Denmark:

- Short-sighted focus.
- Most buildings for 2030 are already built.
- Focus is on expense not on value.
- No process focus on education.
- Engineers do not learn collaboration.

Visions in DK include the following:

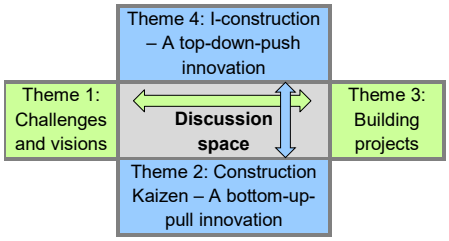
- Triple bottom line focus.
- Ask the question: ‘What is the value in this project (for the user)?’
- Innovation as an enabler.
- Show how construction has changed with better conditions.
- Who are the role models?

4

# THEME 2: CONSTRUCTION KAIZEN AND CONTINUOUS IMPROVEMENTS

# 4 THEME 2: CONSTRUCTION KAIZEN AND CONTINUOUS IMPROVEMENTS

Theme 2 was a closed session held on September 13, 2019, from 9:50 to 12:30 at BLOXHUB, Bryghuspladsen 8, Entrance C, third floor, 1473 Copenhagen K. In Theme 2, the focus is on construction Kaizen, motivation, and continuous improvements as a bottom-up-pull innovation strategy to improve construction workers' activities and results.




## Theme 2.1: Programme and introduction to Theme 2

Senior researcher Niels Haldor Bertelsen from Aalborg University Copenhagen.

**References**

Theme 1-1 Introduction Bertelsen 2019-09-13Bertelsen, N. H. (2019). *Japan-DK Seminar Sep. 13, 2019. Construction Kaizen and i-Construction.* Danish Building Research Institute, Aalborg University Cph. 8-9 pages.


Figure 19. Location for theme 2.

**Programme of Theme 2 at BLOXHUB (* changes in the timetable)**

09:50 Programme and introduction to Theme 2 by N. H. Bertelsen, AAU Cph.
09:55 Kaizen in Toyota as a joint practical exercise with examples from a construction company in DK by J. B. Frederiksen and S. Christensen, EogP a/s.
10:30 Video data at the construction sites in Japan by K. Tateyama and T. Yokoyama, Ritsumeikan University, Japan.*
10:50 Reflections in four roundtable discussions and break**
11:05 Continuous improvement training by organisations by M. Okking, Danish Craft Association, and M. Dalsgaard, United Federation of Danish Workers.***
11:25 Education in motivation and inter-professionalism, J. L. F. Djælund, Association for Architectural Technology and Construction Management.***
11:45 Reflections from four roundtable discussions and conclusion.**
12:00 Networking and 'walk and talk' to the construction site 'Postgrunden'.

**Changes in the timetable**

* 'Utilization of video data' and the presentations that were longer than expected.

** The two reflections in roundtable discussions were reduced to a summary, and the reflections from the four moderators are gathered at the end of the chapter.

*** The two presentations about improvement training and education were reduced to two 5-minute presentations.

**Introduction to Theme 2 Construction Kaizen**

In the supply of building materials after JIT and in the planning concept, the LPS pull from workers is a central principle; nevertheless, practice shows that the focus is still on a top-down push. A Danish study on the construction supply chain demonstrates that it is difficult to implement the pull principle, and we must train this in practice to make it work. We also see the same challenges concerning information technology, improvement, documentation, and other parts of the construction model (Figure 12). In the seminar in Theme 2, we focused on this challenge by discussing construction Kaizen as a feasible solution to obtain a better pull-push balance. We can use the principle at all levels in the construction project; nevertheless, we chose to focus on how we can improve the pull competence of the construction worker ('worker' in Figure 11). Theme 2 highlights essential activities in construction Kaizen for workers in Japan and Denmark and how managers and others can support implementation in relation to Table 6.

Table 6. Kaizen activities and support.

| **Worker activities** |
|---|
| a. Know customers and value requirements |
| b. See and experience the activity |
| c. Reduce waste and increase throughput |
| d. Lean flow and use the 5 why's |
| e. Communicate visibly with data |
| f. ? |
| **Manager support** |
| g. Motivate and allow space for innovation |
| h. Support collaboration and team activity |
| i. ? |

# Theme 2.2: Kaizen exercise and DK Kaizen example

Production Support Manager Jan Buur Frederiksen and Production Manager East Søren Christensen from the construction company Enemærke & Petersen (EogP) a/s (https://eogp.dk/).

**References**


Theme 2-2 Lean Construction DK Japan Study 2017

Lean Construction DK (2017). Studietur til Japan, Maj 2017 (in Danish). Bygherreforeningen, Lean Construction DK, Copenhagen. 45 pages.

Theme 2-2 Kaizen in EogP DK Frederiksen 2019-09-13

Christensen, S. & Frederiksen, J. B. (2019). *Enemærke & Petersen a/s; Kaizen exercise; Potential Check & Productivity Screening; 'The helping hand'; The future state*. Enemærke & Petersen a/s, Ringsted, Denmark. 27 pages.

**Abstract**

Enemærke & Petersen a/s (EogP) is an innovative construction company with around 700 employees working with decentralised management, where construction teams can take greater responsibility for the execution and development of individual construction projects. For many years, they have been a driving force in lean construction in Denmark, and their workers and construction managers are leaders in the application of location-based scheduling (LBS) and other digitally supported concepts in site management. Moreover, Frederiksen and Christensen discuss how EogP is carrying out step-by-step in the renovation of residential buildings like an assembly line production, where workstations move in steps from building entrance to building entrance with a fixed beat. They also review how they continuously train their project managers and workers in the various concepts, including construction Kaizen, as small incremental improvements with learning from one project to the next. They also discuss the challenges and difficulties of extending construction Kaizen to all corners of the company. Frederiksen and Christensen propose concepts for to future development of Kaizen activities and support.

**Practical exercise**

A Danish lean construction delegation visited Toyota and different construction sites in Japan in 2017 [Theme 2-2 Lean Construction DK Japan Study 2017]. Here an old Toyota worker demonstrated a practical exercise in which the Danish delegation tried the principles of Kaizen in practice. In Theme 2.2, Frederiksen and Christensen conducted the same exercise with Theme 2 participants so that the participants could see and feel the spirit of Kaizen. The exercise is a practical introduction to Kaizen that can be used in the following discussions on construction Kaizen in Japan and Denmark.


Figure 20. The Kaizen exercise ‘Write LEAN faster’ at the seminar by Christensen (left) and Frederiksen (right), EogP.

**Presentation**

Christensen and Fredriksen presented their and EogP’s journey of lean since 2004, including introducing Kaizen, workshops on site with craftspeople, the LPS, location-based planning, learning Gemba, and EogP productivity screening [Theme 2-2 Kaizen in EogP DK Frederiksen 2019-09-13]. See the results of EogP Kaizen in Figure 21 and the EogP results of productivity screening in Figure 22.


Figure 21. The E&P Kaizen results from Presentation 8 in Theme 2-2 Kaizen in EogP DK Frederiksen 2019-09-13

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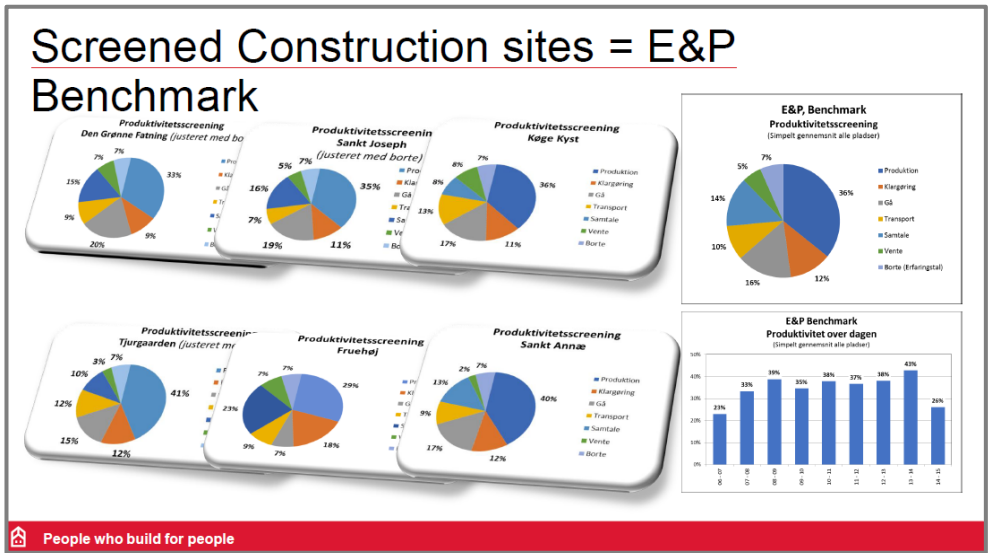



Figure 22. The results from EogP benchmarking and productivity screening of construction sites from Presentation 14 in Theme 2-2 Kaizen in EogP DK Frederiksen 2019-09-13.

The presenters also provided a short conclusion regarding how management handles the productivity of craftspeople, which is summarised in the following bullet points:

- Support and experience highly correlated good planning and the resulting productivity.
- Visible management promotes higher productivity.
- Planning at the beginning of the construction case smoothed flow.
- The right skills should be incorporated, and the workers should be involved.
- Honesty, visibility, and communication are the main paths to success for all.
- Workshops create good collaboration with everyone (customer values).
- Keep it simple – choose from the lean/LPS toolbox and develop new ones;
- Better and realistic schedules and LPS are needed.
- More ownership should be taken when involving craftspeople in planning.

**Reflections**

- Ownership from the main leader of the project and the company is needed;

- The chain is not stronger than the weakest link, and everyone on the team should be trained to gain synergy and understanding;
- 'Go Gemba' to obtain production data; then, one can find a new and better way;
- Process before finance and be ready to invest in the production line/process;
- Follow-ups and previous involvement are needed all the way to the deadline;
- Learn from the process and make it visible for the team;
- Knowledge sharing is power – use knowledge as a brand;
- The plans change with experience, so make a new plan if it makes sense.

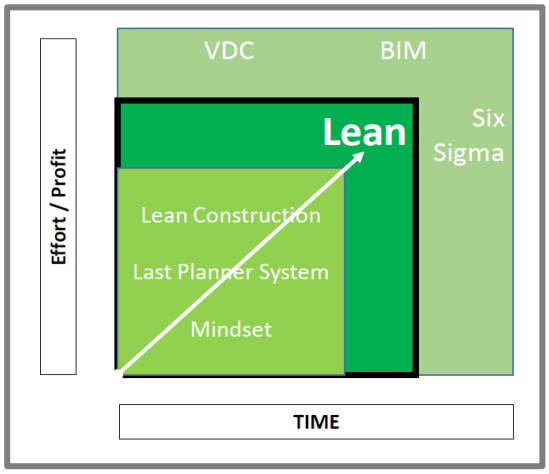



Figure 23. The next step in EogP from Presentation 24 in Theme 2-2 Kaizen in EogP DK Frederiksen 2019-09-13.

## Theme 2.3: Video data at the construction site in Japan

Professor, D.Eng. Kazuyoshi Tateyama and Ph.D. Takaaki Yokoyama from Ritsumeikan University, Japan.

**References**

Theme 2-3 Video data i-Construction Tateyama 2019-09-13
Tateyama, K. (2019). *A Notable Technology in Construction: 1. Visual Construction; 2. Work-style reformation.* Ritsumeikan University, Japan, 29 pages.

Theme 2-3 i-Construction in SME Yokoyama 2019-09-13
Tokoyama, T. (2019). i-Construction for small and middle size constriction company – Visualconstruction. Ritsumeikan University, Department of Environmental Systems Engineering, Japan, 36 pages.

**Abstract**

Both Tateyama and Yokoyama discuss how to use video data in planning, inspection and detection of damages and accidents at construction sites. They presented several cases from the PRISM programme (Public/Private R&D Investment Strategic Expansion Program) by Ministry of Land, Infrastructure and Transport. For example, Matsuzawa Pantile Co. Ltd uses drones to measure roof construction in 3D as a basis for industrialising dangerous roof work. This relocates the cutting of roof tiles to a factory so that the company can streamline roof work with fewer workers. Horiguchi Gumit Company use video image data in visual con-

struction and connect the head office to the construction site by internet. The visual construction includes safety inspection, in-house inspection, inspection by government, and weekly meeting, and they document reduction of traveling costs. Kani Construction Company employs foreign engineers to maintain ICT jobs, which Japanese engineers are not qualified to. IKee Group testing advanced quality and productivity control by use of video image data in visual construction. They analyse the maintenance of pavement work for example how to detect cracks in the surface and how to measure the surface temperature during the paving work. Tateyama and Yokoyama also outlines how the development disseminates from research to and between companies and how the Japanese construction sector evaluates productivity in infrastructure projects. They also provides their proposal for the future development of CGK activities and support.

**Presentation by Tateyama**

Tateyama is a professor at the College of Science and Engineering and is an executive trustee of Ritsumeikan University, Japan. He presented video technology under two items: 1) methods for visual construction control and 2) requirements for work-style reformation. He started his presentation by concluding that the construction sector in Japan never uses Kaizen. The government developed a top-down approach in the construction and civil engineering field, and companies supplement it with bottom-up-pull development.

**Methods for visual construction control**

Tateyama described the principles of the video recording system, including how the system files recorded information from the site in a database, and how the system analyses data intelligently and visualises the data. The companies used video in the inspection of construction over a long period. This method generates a heavy volume of data to be treated and filed. With a time-lapse of 30 s, the volume can be reduced, and it is easier to see changes, analyse accidents, and find causes. It could also be used in educating young engineers, in discussing improvements through Kaizen, and in informing clients and customers. The system could become a vital standard for inspection construction over time. See the summary of the principles of utilisation of video data in Figure 24.

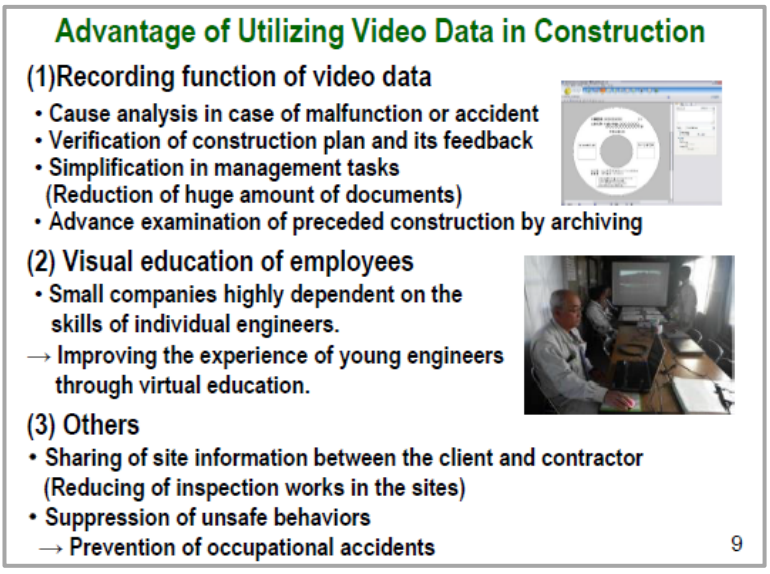



Figure 24. An overview of the principles of video utilisation in inspecting infrastructure projects on site. Presentation 9 by Tateyama.

Then, Tateyama offered practical examples from video recording in inspecting infrastructure projects. For example, highway bridge repair work shown in Presentation 10-11 illustrates how a concrete wall gradually collapses when large vehicles pass it. In Presentation 12, he illustrated the cause of a machinery accident, where the results have been used to educate people to prevent future accidents. He concluded with expectations for i-Construction. Video data contain much information that anyone can easily understand. In addition, many useful applications are accessible for advancing construction, and the accumulating on-site trials and sharing results will lead to improvements in video construction technology.

**Requirements for a work-style reformation**

I-Construction triggers the process in construction and requires new standards, guidelines, and surveying manuals. Tateyama pointed out that it is easy to introduce ICT, but the effect increases if the purpose is determined in considering using ICT. In addition, ICT is important to reduce document work, and it helps engineers reduce the time they spent on site. It requires a change in work style and a reformation, where more females are educated on using ICT on site. It is critical to introduce new standards and guidelines in addition to support for the changes. It also requires a work-style reformation by building a new organisation. It includes more women employed in companies, flexible work time, computer-aided design (CAD) education, and new skills for each employee, introducing new informatics facilities.

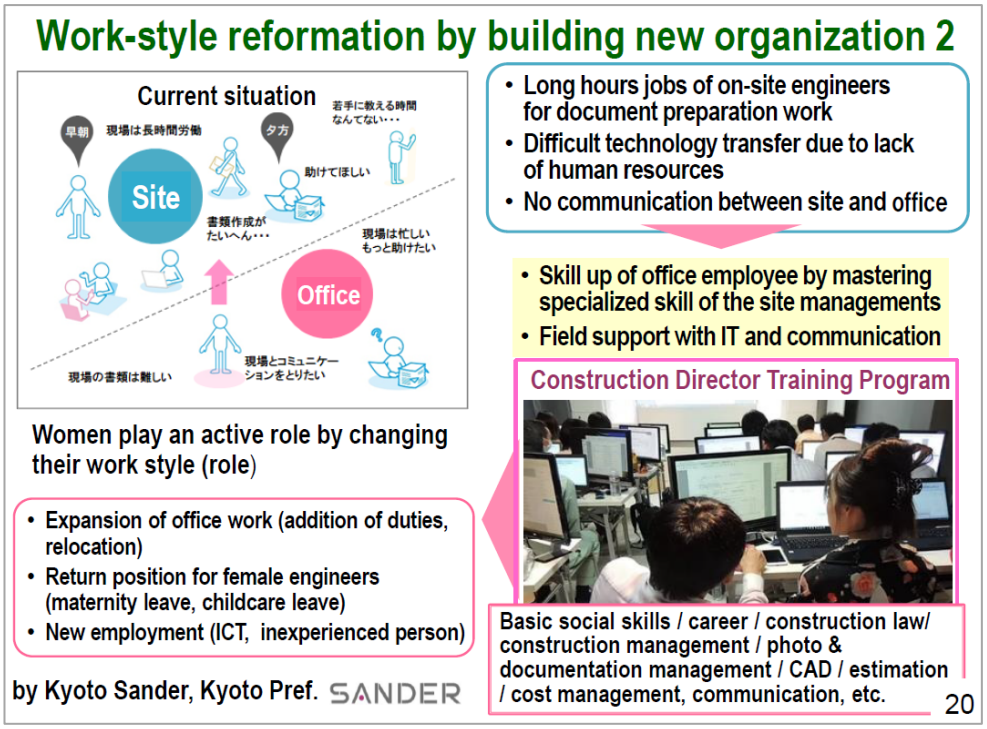



Figure 25. An overview of the principles of a work-style reformation in a new construction organisation. Presentation 20 by Tateyama.

Tateyama finalised his presentation by describing i-Construction in terms of renewing roof construction by Matsuzawa Pantile Co. Ltd., where the company used drones, reduced the work on site by skilled workers, and moved the work to a factory with women workers. See an overview of the new processes in Figure 26.

Tateyama summarised the experiences of implementing i-Construction as follows. Some unique efforts have emerged to improve productivity in construction as an alternative to standard methods. Some local small and medium-sized enterprises SMEs have introduced

noteworthy efforts on their issues. The construction industry is moving forwards now, which could transform construction into a vibrant industry.

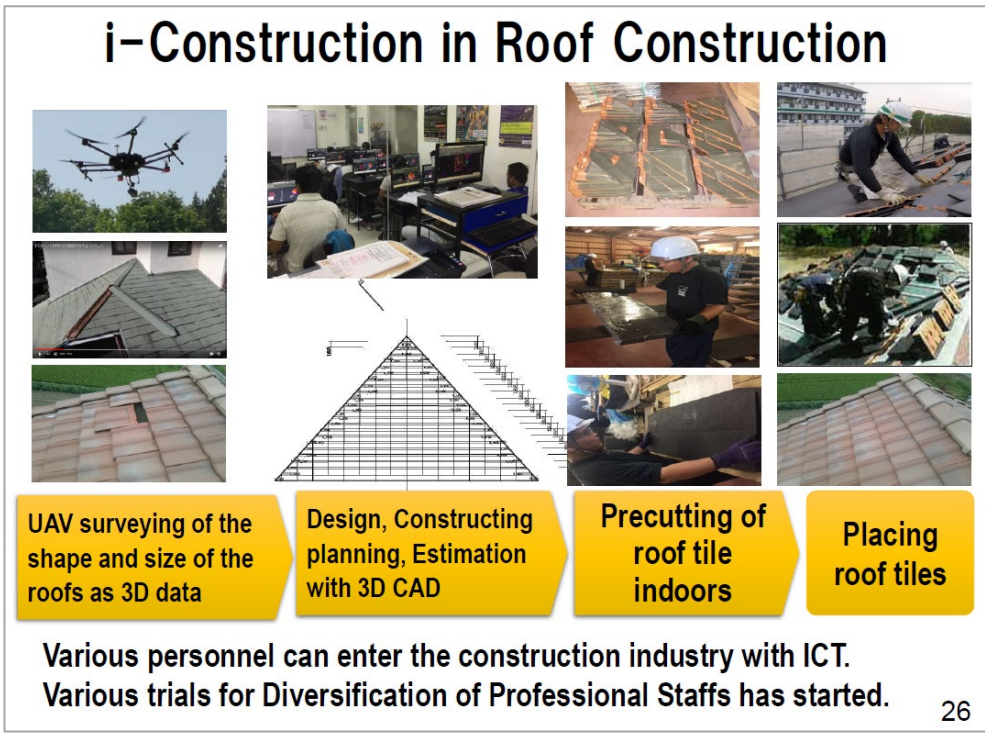



Figure 26. An overview of the new processes of using i-Construction in renewing roof constructions. Presentation 26 by Tateyama.

**Presentation by Yokoyama**

Yokoyama is a lecturer at the College of Science and Engineering, Department of Environmental Systems Engineering, at Ritsumeikan University. He presents three company examples from the PRISM programme (Public/Private R&D Investment Strategic Expansion Program) by Ministry of Land, Infrastructure and Transport. It is Horiguchi Gumit Company, Kani Construction Company, and IKee Group located in north, central and southern Japan respectively.

**Model optimization study**

| Case | Pictures processed | Calculation Time | 3D model | Output Quality |
|---|---|---|---|---|
| 1 | 500 Picture processed (481 after alignment). | 19hours and 51 minutes |  | Good quality and level of details |
| 2 | 300 (264 after alignment and merging) | 2 hours and 35 minutes |  | Medium quality and medium level of details |
| 3 | 200 (199 after alignment) | 13 hours and 44 minutes |  | Medium quality and low level of details |
| 4 | 150 | 2 hours 8 minutes |  | Low quality and very low level of details |

Figure 27. Optimisation study of four visual construction sites in Hoiguchi Gumit Company as part of the PRISM programme. Presentation 18 by Yokoyama.

Horiguchi is one of 14 companies in PRISM trying to improve productivity at construction sites, and Horiguche use video image data in visual construction. They connect the head office to the construction site by internet and they use video image in real-time communication. The visual construction includes safety inspection, in-house inspection, inspection by government, and weekly meeting. In the 30 inspections, they documented 90 hours of reduced travel time. They use video image data, created a video database, and including them in a 3D model by photogrammetry. Yokoyama presented examples of 3D models from construction sites, where they compare 3D CAD data with 3D photogrammetry model. See an illustration of the optimisation study in Figure 27.

I Kani, they has employed foreign engineers to maintain ICT jobs, which Japanese engineers are not qualified to (Figure 28).


Figure 28. Employment of foreign engineers in Kani Construction Co. Ltd. Presentation 19 by Yokoyama.

Ikee Group is one of the 19 companies in the PRISM programme testing advanced quality and productivity control by use of video image data in visual construction. They analyse the maintenance of pavement work for example how to detect cracks in the surface and how to measure the surface temperature during the paving work.

Yokoyama concluded his presentation. New information can be obtained through image analysis, and all information is recorded in video and can be retrieved when necessary. Use of ICT tools, 3D data and photogrammetric models are important, but related technical skills of engineers are still fundamental.

## Theme 2.4: Continuous improvement training by organisations

Development consultant Mads Okking from the Danish Craft Association (Danish: Dansk Håndværk; https://dhv.dk/) and consultant Michael Dalsgaard from the United Federation of Danish Workers, Construction Group (Danish: 3F; https://www.3f.dk/english).

**References**

Theme 2-4 SMART training DK Okking 2019-09-13

Okking, M, & Dalsgaard, M. (2019). *Once upon a time … Work SMART not hard*. 3F and Dansk Håndværk, København. 10 pages.

**Abstract**

The Danish Construction Association (Danish: Dansk Byggeri; https://www.danskbyggeri.-dk/english/) and the United Federation of Danish Workers (3F) from 2011 to 2018 offered development courses to contractor companies for employees and managers in what they call the *Better Bottom Line* (Danish: Bedre Bundlinje). Since 2018, the Danish Craft Association and the United Federation of Danish Workers have offered similar courses and training in what they call the *SMART training project*. Moreover, Okking discusses SMART and how employer and employee associations cooperate on the project. SMART is a lean-based offering including various full-day meetings with Kaizen, where the participants identify obstacles and suggestions for improvements, and where they receive training in board meetings concerning the LPS. Okking presents the challenges of 'selling' the Kaizen principals and the various other challenges companies and employees face. He also explains how the two organisations plan to develop additional concepts in project control and improvement, and how they plan to evaluate the effect of the process development. Both Okking and Dalsgaard make proposals for the future development of Kaizen activities and support.

**Presentation**

The presentation [Theme 2-4 SMART training DK Okking 2019-09-13] is in the following parts (Presentation no.):

- The Danish labour market model (P2),
- SMART, challenges, and cooperation (P3-6), and
- Okking and Dalsgaards approach to the company visit (P7-9).

The presentation was scheduled for 20 minutes, but due to time problems at the seminar, it was reduced to 5 minutes.

In Denmark, union density is among the highest in the world, and more than 70% of workers are members of a trade union. There is a long tradition of trade unions and employers' organisations to work together and develop the industry.

In SMART, the purpose is to work smarter not harder and to train employees regarding synergy, the working environment, better routines, and time efficiency. The focus is on SMEs in the construction industry and how they learn to think 'lean'. The two organisations work together during training in the company and discuss how to overcome challenges in practice, such as the conservative industry, bustle, no customary training, lack of management training, and lack of ability to adopt development.

The common approach of the organisations includes the following for companies:

- Company visit, newsletter, and personal contact to introduce and follow up on SMART.
- Planning the process and different management levels.
- A two-day SMART course with company employees, managers, and owners to train on lean and the critical path in the construction process.
- Visits at the construction site two months after the SMART course.
- Evaluation six months after the SMART course with management.

**Reflections**

It is difficult to 'sell' practical training in a company. Once the SMART course is up and running, positive results quickly emerge, and great interest is garnered through better collaboration to create practical results. If SMART training is to be more widespread among companies, the first meetings must be financially supported and the organisation must put more efforts in promoting the SMART course. The next steps could be practical training on site and determining how to establish company guidelines based on the improvements.

## Theme 2.5: Education in motivation and inter-professionalism

General manager of professional and international affairs Jette Leth Fejerskov Djaelund from Danish Association of Architectural Technologists and Construction Managers (Danish: Konstruktørforeningen; https://www.kf.dk/english/).

**References**

Theme 2-5 Education in motivation Djaelund 2019-09-13

Djaelund, J. L. F. (2019). *Education in motivation and inter-professionalism*. Konstruktørforeningen (Danish Association of Architectural Technologists and Construction Managers), Copenhagen. 12 pages.

**Abstract**

Briefly, Djaelund presents the Danish Association of Architectural Technologists and Construction Managers (Danish: Bygningskonstruktører) and their education (bachelor's degree in architectural technology and construction management (ATCM)) and the various backgrounds the students have from primary school (e.g. on projects and collaboration). She explains their education in ICT, BIM, and project management and the competencies they acquire concerning the needs in the entire construction industry. She then focuses on how they will be able to support construction Kaizen both in the design and construction phases as managers and co-workers. Moreover, Djaelund finally makes proposals for the future development of Kaizen activities and support.

**Presentation**

The presentation [Theme 2-5 Education in motivation Djaelund 2019-09-13] is in the following parts (Presentation no.):

- The organisation and the profession (P3-5).
- The education of architectural technologists and construction managers (with a bachelor's degree in ATCM; P6-7).
- The competences of architectural technologists and construction managers (P8-9).
- The perspective of future challenges and development (P10-11).

The presentation was scheduled for 20 minutes, but due to time problems at the seminar, it was reduced to 5 minutes.

The Danish Association of Architectural Technologists and Construction Managers (Konstruktørforeningen) is a professional organisation for and lead by around 9,000 architectural technologists and construction managers. The organisation was established in 1966, and it stands for quality in education, sustainability, professional development, and quality and safety in construction.

The education in ATCM is a 3.5-year bachelor study and is the largest higher education in construction in Denmark with eight university colleges in Denmark and one in both Iceland and Vietnam. The education aims to qualify the students to independently plan, manage, and perform technical and administrative work in the design and execution phases in construction. Architectural technologists and construction managers are generalists with many special skills, and the education is a mixture of theory and practice in combined problem-based learning, where they use BIM and ICT tools from the start to the end. The education is in seven semesters, as described in Figure 29.

The competences of the architectural technologists and construction managers include building regulations, architecture, engineering, and economics and with multidisciplinary responsibility and an integrated buildability process focus. They have jobs in all parts of the construction industry as contractors, engineers, architects, and production operators in facility companies and public administration.

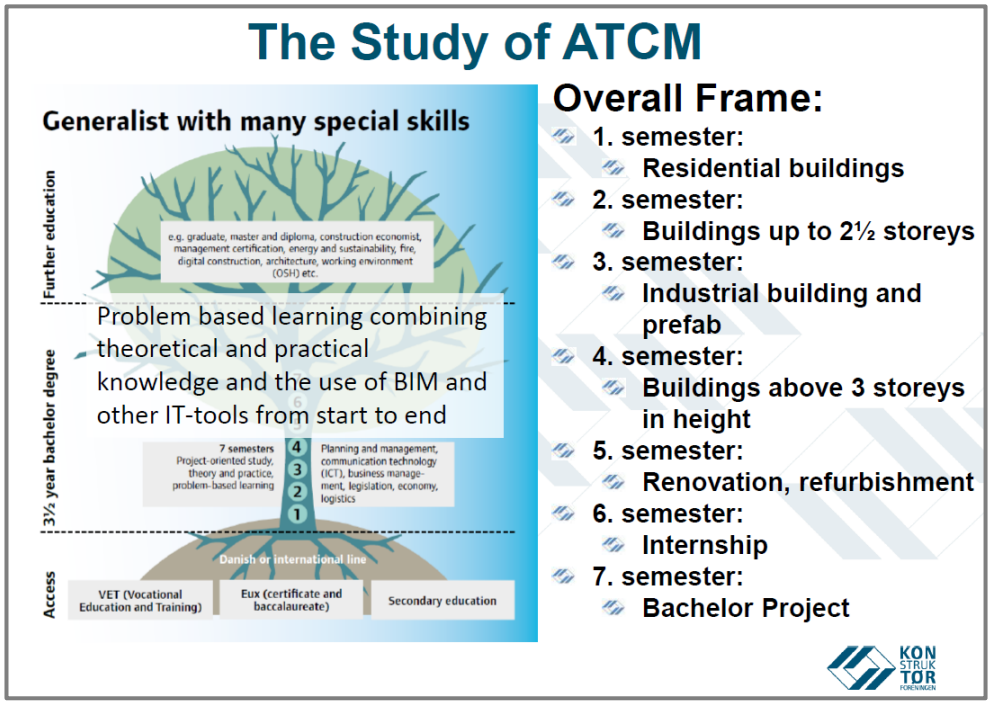



Figure 29. Semesters in Architectural Technology and Construction Management (ATCM) from Presentation 7 in [Theme 2-5 Education in motivation Djaelund 2019-09-13].

The lack of skilled craftspeople and workers and the increasing share of older people is a future challenge. Future employees must be more service- and client-minded and must increase their abilities to cooperate, communicate, and deliver process and construction quality to fulfil increasing demands from clients and society. The development focuses on digitalisation along the entire value chain. We shall develop better cooperation and processes by breaking down barriers between professions and implementing lean construction.

**Reflections**

The number of architectural technologists and construction managers with a 3.5-year generalist education has become larger than the total number of five-year academically educated architects and engineers. Is that a result of a change in the demands for shorter and more practical higher education of the workforce and managers or a shift in the proportion of complicated solutions and more digital work? The headlines in the presentation implies the need

for more motivation and inter-professionalism. Is that the answer? Compared to the seminar programme, a degree in ATCM can gather the bottom-up and top-down approaches in Themes 2 and 4 and implement the digital approach on the construction site in Theme 3. Can the ATCM degree maintain this balance between construction workers and academic management in the future?

## Theme 2.6: Reflections on construction Kaizen

Based on the Theme 2 introduction and the five presentations on construction Kaizen and small continuous improvements in Denmark and Japan, the plan was that the participants would briefly discuss the presentations and their reflections with the following actor focuses and moderators:

- At Table 1, the actor focus was on 'site crew' with moderator Erik Fog Larsen.
- At Table 2, the actor focus was on 'site management' with moderator Andreas Kragh.
- At Table 3, the actor focus was on 'client and consultants' with moderator Mikael Hygum Thyssen.
- At Table 4, the actor focus was on 'training and education' with moderator Carl Johan Fokdal Christensen.

The plan was changed, and instead of a group discussion, the four moderators provided a list of summary and reflections for each table as follows.

**Table 1. Site crew: Reflection on construction Kaizen**

- The Japanese system is perceived as a control system focused on security.

**Table 2. Site management: Reflection on construction Kaizen**

- Requirements, support, and articulation.
- Process, toolbox, and commitment.
- Construction leadership is the key.
- Follow-up and learning.
- Process is the driver with a focus on safety, quality, and 'sustainability'.
- Use video and drones to perform construction management tasks and optimisation and for training and documentation.
- Change job descriptions and functions and move them into practice (design).
- Reassess craftsmanship and subcontracting with technology.

Reflection on value:

- What creates lean and value for products and co-workers?
- Lean is a contractor effort (cost).
- Must also address value creation.
- It is difficult to see value creation on site.
- The construction process is being stalled.
- The technological transformation means 'change' on site.

Reflection on job satisfaction:

- A decrease in the labour force will probably occur.
- There is a lack of understanding by the site manager concerning job satisfaction on site.
- We must move out to the site, and we need to be invited to the site.
- What percentage of craftspeople are committed?
- EogP has craftspeople with great pride in the company.

**Table 3. Client and consultants: Reflection on construction Kaizen**

Construction Kaizen:

- Knowledge sharing is power.
- Visual construction: root cause analysis, verification of the plan, and education and information sharing.
- Decide on purpose and consider ICT (but not vice versa).
- Increase in administration office work and will give us lack of creativity.
- ICT gives more time on site.
- Off-site manufacturing.
- Lean thinking, training, and detailed evaluations.
- Use data to improve.
- Craftspeople are the experts.
- Visible management and adapt tools.
- Assess lean maturity.
- Stand-up meetings on Kaizen and safety.
- Competence specialisation requires we help each other.
- Management support (from the top).
- Keep it simple.
- Dynamic planning.

Learning Kaizen:

- Work SMART (work smarter not harder).
- Trade unions collaborate with employees will push for education.
- Higher education access for craftspeople will improve ICT from day one.
- Process focus.

**Table 4. Training and education: Reflection on construction Kaizen**

Construction Kaizen in DK:

- Spotting potential for improvement.
- Solutions include involving and analysing, implementing and learning, and starting over again.
- Management as support.
- Keep it simple and fun.
- Flow is important.
- Process before finance.

Construction Kaizen in Japan:

- Data-driven improvements.
- Video as an enabler as everyone can use.
- Use technology and find user.
- Enables a wider workforce for construction.

Learning Kaizen in DK:

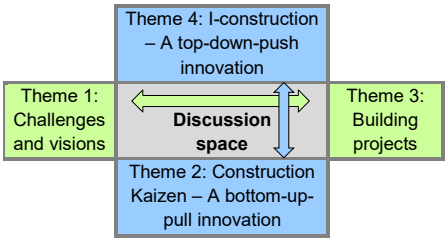
- SMART.
- Making it approachable: company visits, meeting days, etc..
- Combination of practices.
- Theory and practice joined.
- Process focus.

5

# THEME 3: BUILDING PROJECT ‘POSTGRUNDEN’ IN COPENHAGEN

# 5 THEME 3: BUILDING PROJECT ‘POSTGRUNDEN’ IN COPENHAGEN

Theme 3 was a closed session held on September 13, 2019, from 12:30 to 14:00 at the Per Aarsleff A/S construction site ‘Postgrunden’, Carsten Niebuhrs Gade 10, 1577 Copenhagen V.




**Programme for Theme 3**

- Presentation of the building site viewed from the terrace by project manager Jakob Groenlund, Per Aarsleff A/S.
- Presentation of the 3D model, VDC methods, and VR applied in the project by VDC by team leader Nikolaj Thomsen, Per Aarsleff A/S.

**References**

Aarsleff A/S has not shared the presentations as an open reference with the participants.


Figure 30. Location for Theme 3.

## Theme 3.1: The building site viewed from the terrace

Project manager Jakob Groenlund (M.Sc. in construction) from Per Aarsleff A/S.

**Summary of the project ‘Postgrunden’**

The city centre of Copenhagen will soon have a new district with city life, businesses, and residences. The area called Postgrunden is a close neighbour to Copenhagen Central Station. The development of the district connects the city centre and the waterfront with newly established green connections of bicycle paths, open squares, and footpaths for the public. The new district will be open to the railway tracks and connect the waterfront at Kalvebod Brygge. The architecture of this new city district will be a mixture of businesses, residences, and hotels. In the past, there was a mail distribution centre in the area.

Figure 31. Jacob Groenlund presenting the building site ‘Postgrunden’ from the terrace.

On the terrace at the end of the office building of Per Aarsleff A/S, where there is a fine view of the entire building site, Jakob Groenlund presented the project (https://www.aarsleff.com-/?ul=1). The municipal land plan was approved in 2018 (https://dokument.plandata.dk/20_-3107595_1515077154893.pdf). The city centre includes seven round buildings with two high towers of 93 and 115 m. The total built-up area will be 184,300 $m^2$, where 80 % is for commercial use and 20 % is for housing.

Figure 32. View of the building site ‘Postgrunden’.

Per Aarsleff A/S will carry out the first phase of the total contract from 2019 to 2023 for the new business district and with Lundgaard and Tranberg Arkitekter as architects. The headquarters consists of two connecting office buildings with 73,000 $m^2$ in total and a 40,000 $m^2$ parking basement. The total building price is around DKK 3 billion. Per Aarsleff A/S performed the demolition simultaneously and established a construction pit of 30,000 $m^2$. All this included dewatering the construction pit, removing the main sewer that was more than 100 years old, and restructuring a new main pipe for sewage from both Vesterbro and Frederiksberg. The work on the concrete structure is progressing as planned. All construction cranes are established, and the next construction stage will be initiated soon. In addition, KPC Copenhagen A/S will complete the next phase of 92,000 $m^2$ for Danica from 2020 to 2024 with Arkitema as the architect.

## Theme 3.2: 3D model, VDC methods, and VR applied in the project

The VDC team leader is Nikolaj Thomsen from Per Aarsleff A/S.

**Summary of the 3D model, VDC and VR**

In the office building on the construction site, Thomsen demonstrated how Per Aarsleff A/S had used VDC to design the construction and what software they used. With the Dalux software packages, it is possible to transfer all data on the project to an iPad in a few minutes (https://www.dalux.com/). He also presented the BIM process model with the operational areas for the tower cranes on the building site 'Postgrunden'. Finally, he offered the participants the opportunity to see the construction through a 3D visualisation using 3D glasses.

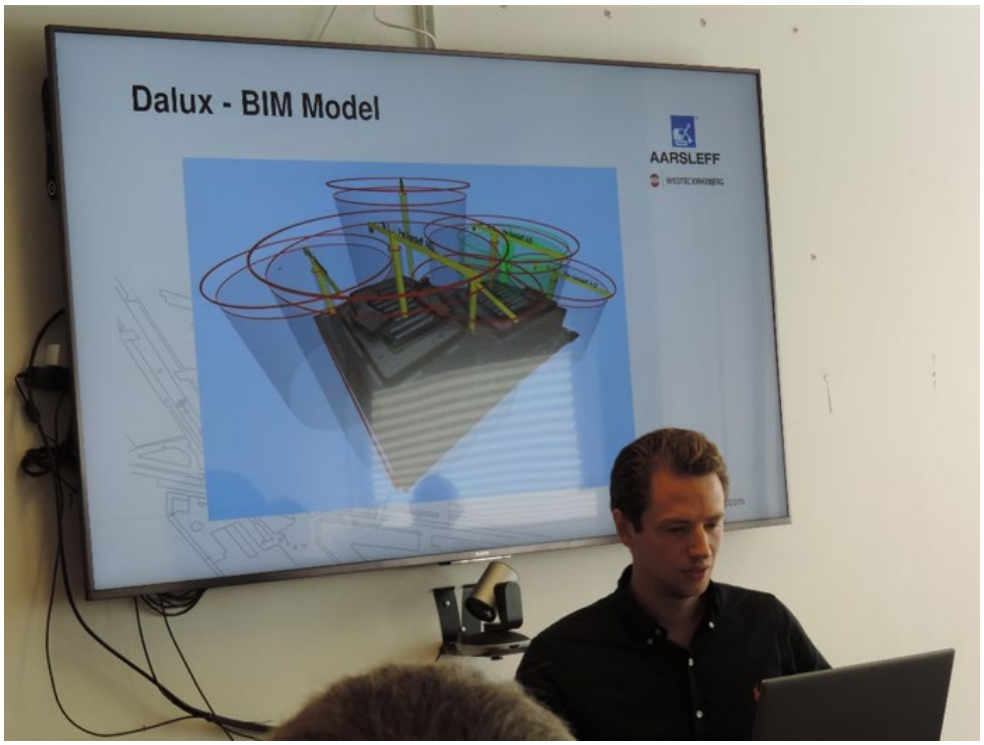



Figure 33. Nikolaj Thomsen presents the VDC model with tower cranes for the building site 'Postgrunden' based on Dalux software (https://www.dalux.com/).

Figure 34. In front, from left to right are three Japanese guests: Professor, D.Eng. Kazuyoshi Tateyama, Ritsumeikan University; Ph.D. Takaaki Yokoyama, Ritsumeikan University; and D.Eng. Hiroshi Furuya, Obayashi Corporation.

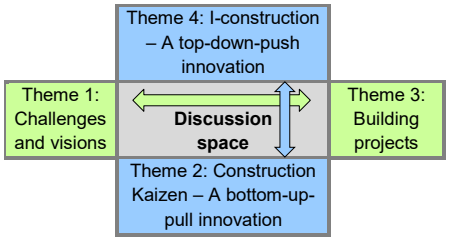
6

# THEME 4: I-CONSTRUCTION, ICT, VDC, ROBOTS, AND AUTOMATION

# 6 THEME 4: I-CONSTRUCTION, ICT, VDC, ROBOTS, AND AUTOMATION

Japan has a growing population of elderly people and a shrinking construction workforce. The construction sectors in Japan and Denmark/EU are fighting for better productivity and to fulfil the growing demands for cheaper, better, and sustainable buildings and infrastructures. However, we have only seen sporadic productivity improvements in practice. A small delegation from Japan led by Professor, D.Eng. Kazuyoshi Tateyama presented their initiatives about i-Construction, and the participants discussed the related Danish/EU initiatives.

In Theme 4, the focus is on i-Construction, new technology, VDC, autonomation (automation with a human face), drones, and robots as a top-down-push innovation strategy that pushes construction. Theme 4 was an open session held on September 13, 2019, from 14:00 to 17:00 in IDA house, the Danish Society of Engineers, Kalvebod Brygge 31-33, 1780-DK Copenhagen V.




## Theme 4.1: Programme and introduction to Theme 4

Senior researcher, architect, and system planner Nils Lykke Soerensen from Aalborg University Copenhagen was the moderator for Theme 4.

**References**

Theme 4-1 Introduction Soerensen 2019-09-13

Soerensen, N. L. (2019). Automation, ICT, VDC and construction robots in construction projects. SBi, Aalborg University Copenhagen. 4 pages.


Figure 35. Location for Theme 4.

**Programme**

14:00 Check-in, coffee, and networking.

14:30 Welcome to IDA house by the manager of IDA, Lene Christensen.
14:40 Introduction by senior researcher and meeting moderator Nils Lykke Soerensen, SBi
14:50 VDC, BIM, ICT, and i-Construction in Denmark by client advisor Andreas Kragh and consulting engineers Niras A/S.
15:10 From i-Construction to FM: Linking Commissioning, BIM and IoT by Nicki Blaadal, M.Sc. Eng., CEO of CXweb, and Marie Bryld Wolsing, M.SC. Eng., Cowi
15:30 Robots and Construction Site Automation in Denmark by co-founder and CTO Finn Christensen, Robot At Work ApS.
15:50 Break.
16:00 Utilisation and challenges in new technology by contractors in Japan by Professor Kazuyoshi Tateyama, Ritsumeikan University and Dr Hiroshi Furuya, Obayashi Co Ltd. (General contractor), Japan.
16:20 3D-printed construction and example from North Copenhagen by the project manager, Ole Ellinghausen, M.Sc., COBOD International A/S
16:40 Discussion: Development and implementation of i-Construction.
17:00 Closing, sandwich, and networking.

**Background**

ICT has found its way to design, construction, and logistics processes. BIM involves data input for physical objects concerning 3D, 4D, 5D, 6D, and 7D, which stand for dimensions, time, cost, performance, and FM. VDC is the process of creating digital information, where the building is virtually built before it is built in practice. Designers and contractors transform the requirements to product specifications and plan for the construction process.

In 2016, the Japanese government formulated a new policy on i-Construction to improve productivity through high wage levels, sufficient holidays, and safe work environments, which was to be implemented in three steps: 1) aggressive use of ICT in advanced construction technology, 2) standardisation of specifications and avoidance of single-item production, and 3) order-flow balance throughout the year. Construction technology, a labour focus, avoidance of single-item production, and marked regulations are included to improve productivity. More about i-Construction is available in the IPA Newsletter Vol. 2, June 2, 2017, called *'A New Stage of Construction in Japan – i-Construction'*, which is by Tateyama at Ritsumeikan University.

**Introduction**

Theme 4 addresses the top-down push from technology and research on the construction sector, which promises better houses and efficient processes. However, the reality is a limited practical application and an unbalanced bottom-up pull from construction concerning the heavy push. Moreover, the industry has not seen widespread productivity improvements. However, according to studies on Danish construction ICT use in 2018, 60 % of larger contractors never or rarely reuse BIM, and only 30 % often or always reuse data. The figures are even more skewed for SMEs. What is the cause of this, and can VDC enhance productivity in the current structure?

Theme 4 focuses on the development of information, ICT, BIM, VDC, and i-Construction in Japan and Denmark/EU. The presentations are on the principles and experiences of using VDC in design and construction planning. The presenters discuss how to introduce ICT in FM and in advanced construction technology to develop construction robots, construction machines not directly operated by people, and 3D-printed buildings. The presenters also discuss how construction can be autonomated (intelligent automation with a human touch), and

how VDC and i-Construction can be implemented more widely and quickly in practice to improve productivity.

**Presentation**

As an introduction, Nils Lykke Soerensen presented the programme for Theme 4 and the two presentations in Figure 36 and Figure 37 [Theme 4-1 Introduction Soerensen 2019-09-13].

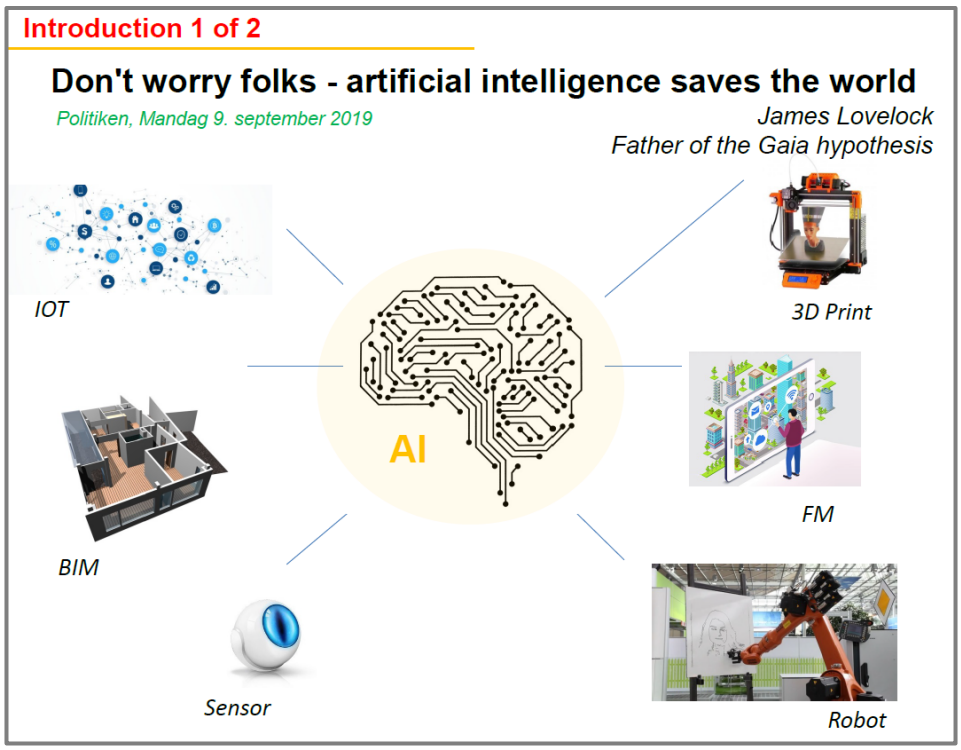



Figure 36. Presentation 3 of Soerensen: 'Don't worry folks – Artificial intelligence (AI) saves the world' (James Lovelock).

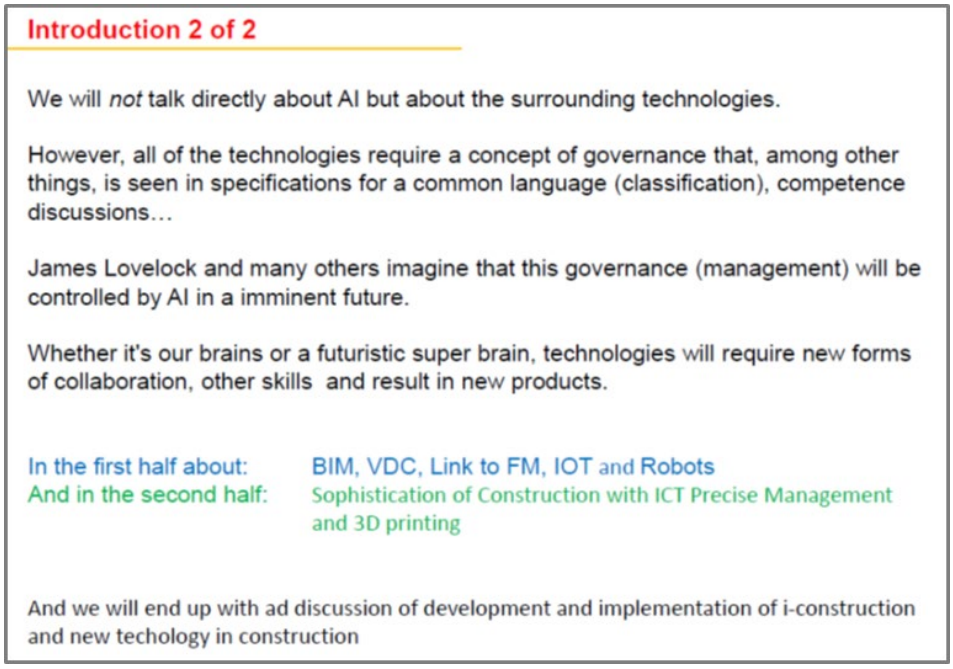



Figure 37. Presentation 4 by Soerensen: Artificial intelligence (AI) by James Lovelock and the three parts of Theme 4.

# Theme 4.2: VDC, BIM, ICT, and i-Construction in Denmark

Consulting engineer and client advisor Andreas Kragh from Niras A/S (https://www.niras.com/).

**References**

Theme 4-2 VDC BIM ICT in DK Kragh 2019-09-13

Kragh, A. (2019). *ICT, BIM, VDC and i-Construction in Denmark*. Niras A/S, Alleroed. 37 pages.

Some of the presentations are in Danish, and in the following, the Danish titles are translated to English in brackets:

- P6: Nye almindelige betingelser – Ny BR18 [New general conditions for construction contracts in Denmark – New Building Regulation 2018 (BR18)].
- P7: Tidlige digitale modeller med funktionskrav [Early digital models with functional requirements].
- P8: Koncept – Kravspecifikation. Forstå brugerne – omsætte ønsker til byggeri [Concept – Specification of requirements. Understanding the end users – translate desires into construction].
- P9: Opmåling og registrering [Surveying and registration].
- P10: Simulering [Simulation].
- P11: Koordineret forslag [Coordinated proposal].
- P13: Koordineret virtuel projekt. Check før vi bygger [Coordinated virtual project. Check before we build].
- P20: Region H – Børneriget. Planlægning [The Capital Region – The national hospital for children. Planning].
- P22: 4D_Simulering_Ned+Rå+Fac [4D_Simulation_Demolition + Basic construction + Facades].
- P30: Etagebolig Frederikskaj, 152 lejligheder [Block of flats at Frederikskaj in Copenhagen with 152 apartments].
- P33: Location-based Scheduling. Planlægning der viser hvem der arbejder hvor [Location-Based Scheduling. Planning showing who works where].
- P34: Tidsstyring: Last Planner (SKAL). Procesplanlægning [Time management: Last Planner (MUST). The planning process].
- P35: Tidsstyring: Leanværktøjer. BØR. SKAL. KAN. GJORT. FORBEDRE. VIL [Time management: Lean tools. OUGHT TO. SHALL. BE ABLE TO. DONE. IMPROVE. WILL].
- P37: Hvorfor granskning? Det er et krav …. Indlejret i vores rammesætning [Why review? It is a requirement …. Embedded in our framework].

**Abstract**

Kragh presents how VDC is applied in cooperation between front-running clients, consultants, and construction companies to specify the building and construction planning, and how VDC and i-Construction are generally applied among professionals in Denmark (e.g. concerning surveying, inspecting, and using drones). He shows how to specify requirements in a common 3D model for architects, engineers, and contractors, and how to divide building into repeatable building parts as ‘products’ in construction. He also shows examples of executing LBS in building projects, building parts, and activities along and across the supply chain and at different management levels. Finally, Kragh discusses the learning experiences

of educating project managers and construction workers and the effect on the productivity, quality, and work environment.

**Presentation**

The presentation [Theme 4-2 VDC BIM ICT in DK Kragh 2019-09-13] is in the following parts (Presentation no.):

- Highlights from the development of digitalisation in construction (P2-4),
- VDC, BIM, and ICT in the construction process (P6-13),
- Implementation of robots (P14-15), and
- Project management and LPS (P16-37).

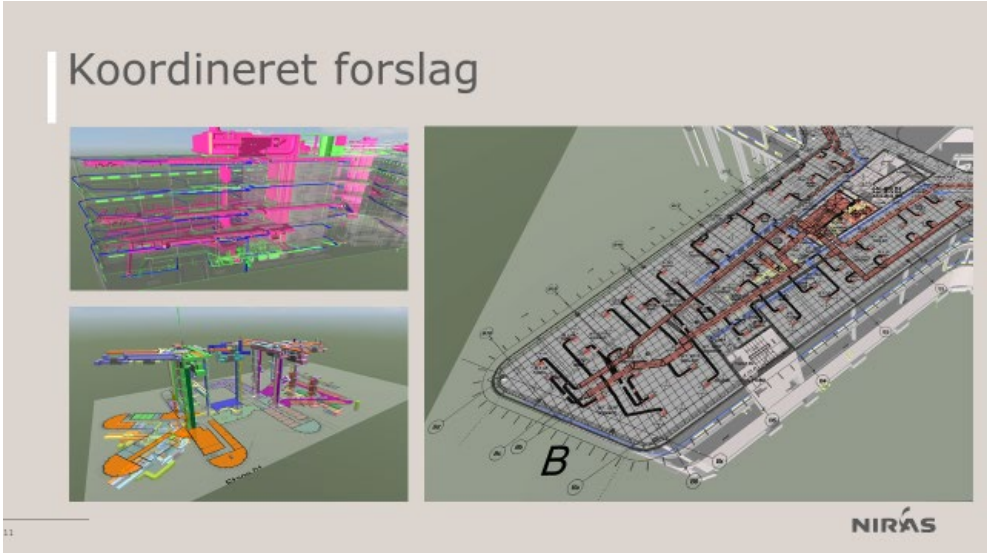



Figure 38. Presentation 11 by Kragh: The coordinated project proposal in the VDC model for 'The national hospital for children' in Copenhagen (also see Presentation 20).

In the construction process, VDC has gradually been included in the following levels of VDC models in construction projects (Presentations 6–13):

- The early digital model with functional requirements.
- In concepts with specifications of requirements to understand the end user and how to translate their desires into the construction.
- How to survey the site and register data and information.
- How to simulate the construction process and the final building.
- Based on how to formulate the coordinated project proposal.
- Finally, how to coordinate and check the virtual project before it is built.

The erecting of the Empire State Building in New York from 1929 to 1931 took only 410 days from start to finish because the constructors used LBS in the process. The inspiration came from the harmonogram or harmonograf by Karol Adamiecki (1866-1933). However, this was never proved [Kenley, 2010]. The harmonogram is a more sophisticated time planning system than the Gantt chart, where one can add the location to the time and activities. In the harmonogram, the three basic preconditions are defined for an optimal production: harmony in method, harmony in execution, and harmony in the mindset (the team).

Kragh described the content and values of LBS concerning different Danish building projects. The activity and output of planning are organised in terms of different process phases and planning levels and is supported by LBS in the design, planning, construction, delivery,

and follow-up. In addition, LBS is a visual planning system showing who works where, and LBS provides more cohesive planning, logistics, and construction phases. See the structure of the LBS diagram in Figure 39 and other examples in Presentations 25 and 26. Kragh also described how the LPS and lean construction work with LBS in different planning phases using the words *ought*, *should*, *can*, *did*, *learn*, and *will*. Finally, he concluded that it is important to review the individual phases before they are launched because it is required in the Danish Building Regulation (see Presentation 37).

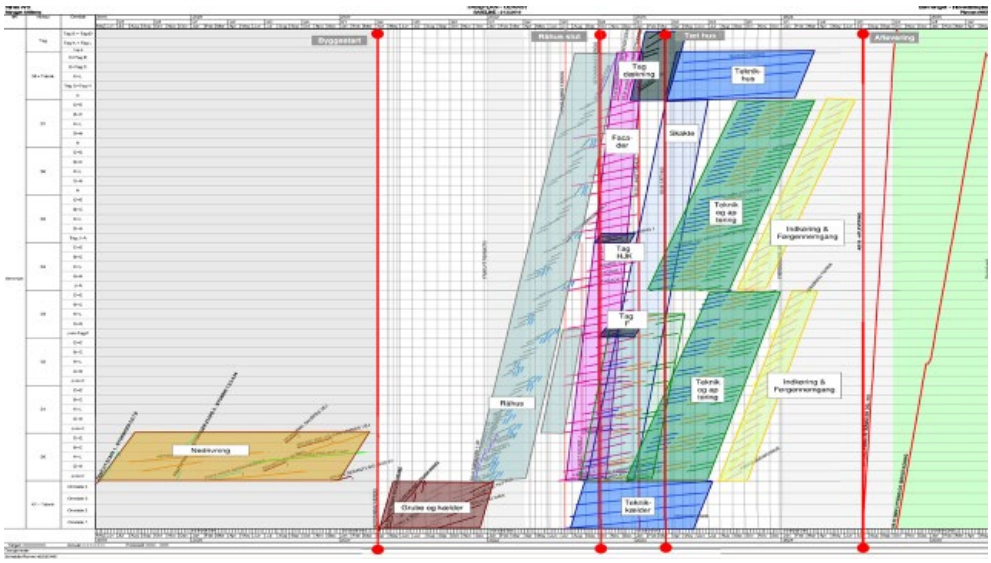


Figure 39. Presentation 23 by Kragh: Location-based scheduling (LBS) of 'The national hospital for children' in Copenhagen. The x-axis is the time, the y-axis is the location, and the main activities in the diagram are marked with different coloured rhombuses. Translation of the main activities from Danish to English: Nedrivning [demolition], Grube og kælder [pit and basement], Råhus [raw house], Facader [facades], Tag [roof], Tagdækning [roofing], Skakte [installation shafts], Teknik og aptering [Installations], Teknikhus [technical house], Indkøring & Førgennemgang [running-in technique and prereview], and Aflevering [delivery].

**Reflections**

VDC method is becoming a more commonly used tool in the main construction and design companies in Denmark, where it links design and planning in construction more firmly together. Moreover, LBS combines top-down and bottom-up planning and is a fine supplement to the LPS and lean construction. Gradually, construction companies in Denmark have implemented the principle in project management but often not in the working teams on site. Bothe VDC and LBS are illustrated in the presentation by many examples from construction projects in Denmark, and Kragh warmly recommended further dissemination and development in practice.

## Theme 4.3: Linking commissioning, BIM, and IoT technology

Nicki Blaadal, M.Sc. Eng., is the CEO from CXweb and Engineer Technical IT company (https://cxweb.dk/) and Marie Bryld Wolsing, M.Sc. Eng., from Cowi.

**References**

Theme 4-3 Commissioning ICT BlaadalogWollsing 2019-09-13

Blaadal, N. (2019). *Commissioning, ICT, IoT & Autonomation – Big Data*. CXweb, Copenhagen. 20 pages. www.cxweb.dk

**Abstract**

FM is the customer for construction and supports the end user in the daily application of the building. Blaadal presents the BIM linkages between design, construction, and FM and shows how IoT sensors are used in automating commissioning test performance monitoring in FM. Wolsing presents the results from an interdisciplinary FM research project between the Technical University of Denmark (DTU), School of Design and Technology (KEA) and CXweb. In the project, they installed IoT sensors in the DTU Library, and Wolsing shows how FM data can automatically control the indoor climate, ventilation, heating, and lighting systems. Finally, the presenters provide their assessment of the maturity of the IoT-sensor technique in FM and the linkages in BIM in design and construction.

**Presentation**

Blaadal presented the background and visions for CXweb (www.cxweb.dk) and how big data works with AI and the IoT. He discussed the degree of implementation of digital technology in the three main phases in construction (Figure 40). Wolsing presented the results from the interdisciplinary FM research project, where they installed and tested IoT sensors in the DTU library. The smart library systems include the mechanical ventilation system, temperature, and $CO_2$ measurements and the old one-string heating system. Different types and methods of mounting the IoT sensors were tested. The two systems were optimised based on the results of the detailed operation pattern. See the example of the ventilation system in Figure 41.

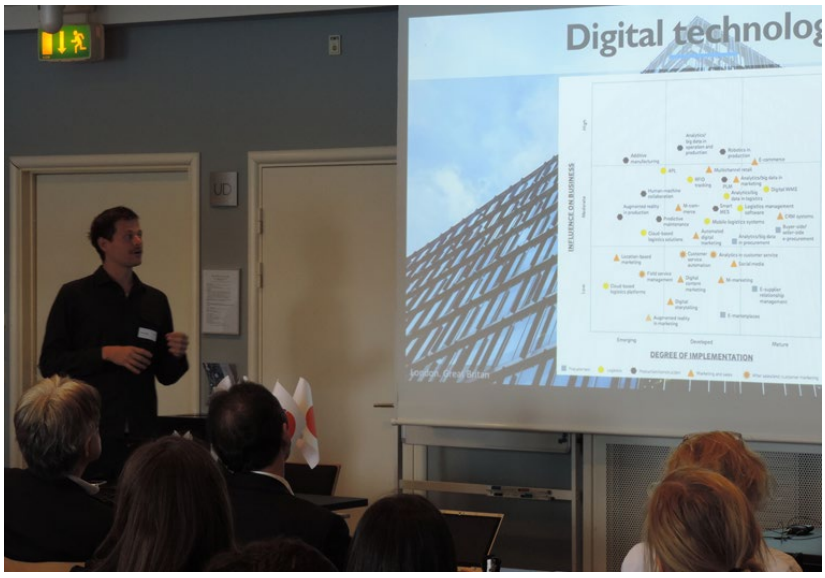



Figure 40. Blaadal (www.cxweb.dk) shows Presentation 4 about the degree of implementation of digital technology in the three main phases in construction.

**Reflections**

From the findings in the DTU library project, it is possible to obtain detailed time series data on building services from low-cost wireless sensors. The IoT sensors can obtain data concerning the room temperature, $CO_2$ concentration, air supply temperature, heating pipe temperature, damper operation, on/off status, and light levels. In addition, IoT sensors are cost-

effective and user friendly. The ventilation system is in operation for most of the day and night, which is inefficient. The supply and return temperatures in the heating pipes are close, which indicates efficient operation; however, this might be different in another period. It is possible to automate the demand control of building services and optimise the operation using IoT sensors. The prediction using a neural network provided no useful results; however, if further investigations are made, the use of neural networks could show potential.

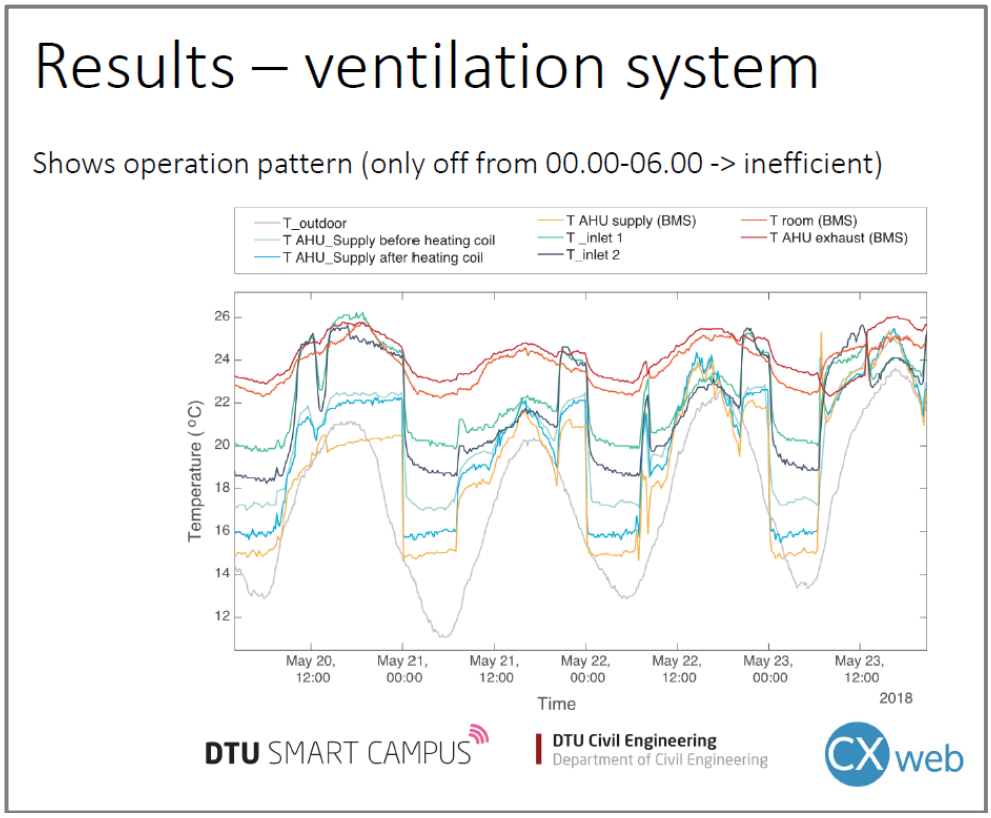



Figure 41. Presentation 18 by Wolsing. The results from the tests of IoT sensors are described by the operation pattern of the ventilation system from the DTU library.

## Theme 4.4: Robots and construction site automation in Denmark

Co-founder and Chief Technology Officer (CTO) Finn Christensen from Robot At Work ApS (https://robotatwork.com/).

**References**

Theme 4-4 Site robots & automation Christensen 2019-09-13

Christensen, F. (2019). *RAW robots and construction*. Robot At Work ApS, Odense. 9 pages.

**Abstract**

Robot At Work has moved the RAW robots to the construction site, where they collaborate with the construction workers to perform simple and complex tasks more efficiently with less effort for the workers. In addition, RAW is a user-friendly robot platform that can perform various tasks, which previously required human labour. Moreover, RAW has tools for painting,

milling, cutting, grinding, polishing, picking, placing, and 3D printing, which is easily programmed directly from 2D or 3D drawings. Christensen presents different applications and practical examples of how construction workers use the robots, and how they train to program and install the robots in different tasks on the construction site. He presents the effect on productivity, quality, and the work environment compared to manual processes and how it fits the philosophy of automation. Finally, Christensen assesses the maturity of robots in construction, the relation to VDC, and the competence of construction workers.

Figure 42. Presentation by Christensen.

**Presentation**

Robot At Work (RAW) is a low-weight, moveable robot based on a modular rail system in two dimensions. It can be quickly assembled on the construction site to use working tools, such as painting, milling, grinding, demolishing, and cutting tools, just like a computer numerical control (CNC) machine. Compared to the robots in the production industries, construction robots are bigger and must be able to work in dirty and changing environments. The program language normally changes from one robot to the other. In addition, RAW includes an easy-to-program tablet-based software, where data imports directly from 2D and 3D drawings without prior robotic education or training (Figure 43). Furthermore, RAW can carry out many of the same tasks as a craftsperson does, but more quickly and easily. Moreover, RAW is a new more-automated machine that craftspeople can work with and handle at the construction site. In addition, RAW focuses on the education of craftspeople and selling to companies with many repetitive work activities (Figure 44).

**Reflections**

Robot At Work is a new generation of machine that can work with craftspeople and execute repetitive work automatically. It is a fine link and first step towards a complicated robot. With simple training, it can be implemented in many construction companies if management and workers are interested. The proposed tools on the actual building parts could perform the first kinds of construction work, and as it is implemented widely in the sector, other kinds of construction work can follow.

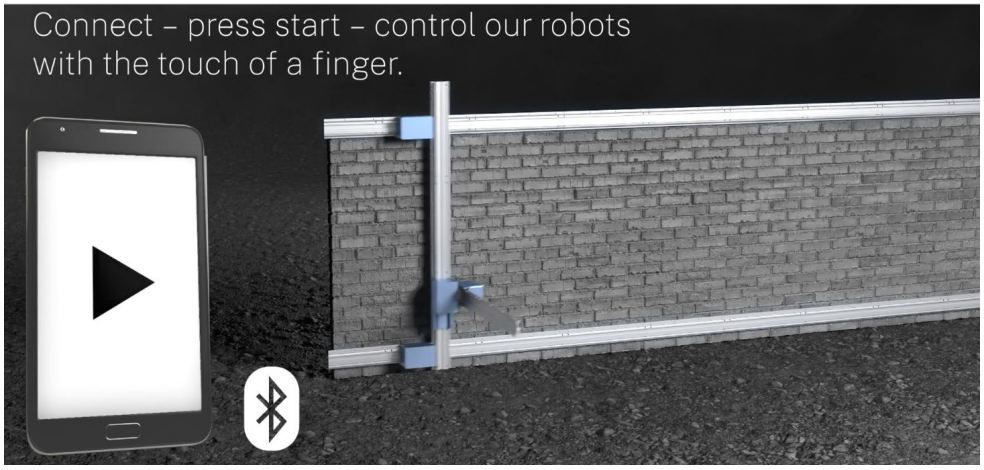



Figure 43. Presentation 4 by Christensen with a YouTube video on how to install a Robot At Work and control it using a tablet.


Figure 44. Presentation 7 by Christensen with a YouTube video of testing Robot At Work in practice.

## Theme 4.5: Utilisation and challenge of new technology by Japanese contractors

Professor, D.Eng. Kazuyoshi Tateyama from Ritsumeikan University, and D.Eng. Hiroshi Furuya from Obayashi Co Ltd. (General contractor) in Japan.

**References**

Theme 4-5 i-Construction new ICT Tateyama 2019-09-13

Tateyama, K. (2019). *Sophistication of Construction with ICT. Precise Management in Construction. Introduction of Construction Robots.* Ritsumeika Universit, Japan. 12 pages.

Theme 4-5 i-Construction new ICT Furuya 2019-09-13

Furuya, H. (2019). *Utilisation and challenges of new technology by Japanese contractors*. Obayashi Corporation, Japan. 41 pages.

**Abstract**

Earlier in Theme 1, Tateyama presented the challenges and visions for Japan, and in Theme 2, he and Yokoyama presented the utilisation of video data on site to improve the construction. Here, Tatyama and Furuya present the following:

Tatyama presents the following:

- Introduction to construction robots.

Furuya presents the following additional concepts:

- Contractor approach to i-Construction,
- From 3D to data models: examples of 3D models and utilisation of industry foundation classes (IFC),
- Construction robot development: unmanned machines and disaster investigation robots,
- Integration with new technologies (use of 5G network in the construction field), and
- Further developments and implementation of i-Construction in Japan.

In i-Construction, ICT is aggressively used through precise management and autonomous construction robots. Precise management accepts some unexpected conditions and margins between planning and real conditions, and it introduces flexible changes to the original plan to match the real conditions to better save on labour and materials.

**Presentation**

From a white paper from the Japanese government, Tateyama presented figures of the infrastructures in Japan, including railways, sewerage, levees, waterworks, expressways, and urban parks. The goal is to develop an efficient construction system to deliver infrastructure at a high level of quality within a short period, which is supported by a systematic design, specified rules or methods, precise management in construction sites, and reducing labour and materials. In addition, Tateyama provided examples of precise management in large size earthworks and offered figures concerning conventional methods on production volume per day and $CO_2$ emission volumes when the goal is to increase productivity and reduce the effects on the environment. Moreover, Tateyama introduced construction robots and automatic machines to handle drain-pipe inspection, bridge inspection, earthworks (soil and rocks) in infrastructure projects, and recovery from natural disasters. He showed diagrams on how construction robots gradually developed from machines to unmanned machines to autonomous robots (Figure 45).

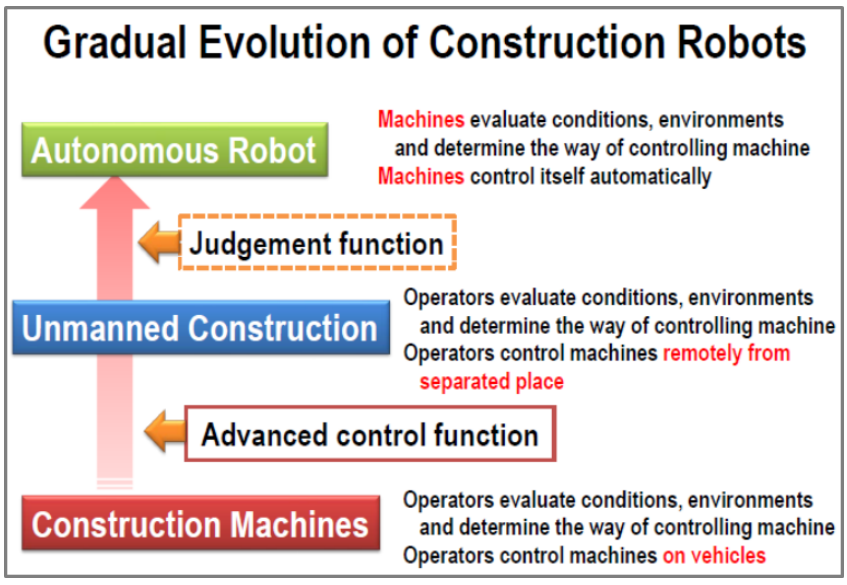



Figure 45. Presentation 9 by Tateyama on evolution levels of construction robots.

Furuya presented the viewpoint of Japanese contractors regarding the utilisation and challenge of new technology and i-Construction in planning and constructing infrastructure projects. It is not just a discussion on digging the soil and placing concrete, but now the work also requires knowledge and skills in other fields, and he discussed the trends of using ICT in the Japanese construction sector (Figure 46).

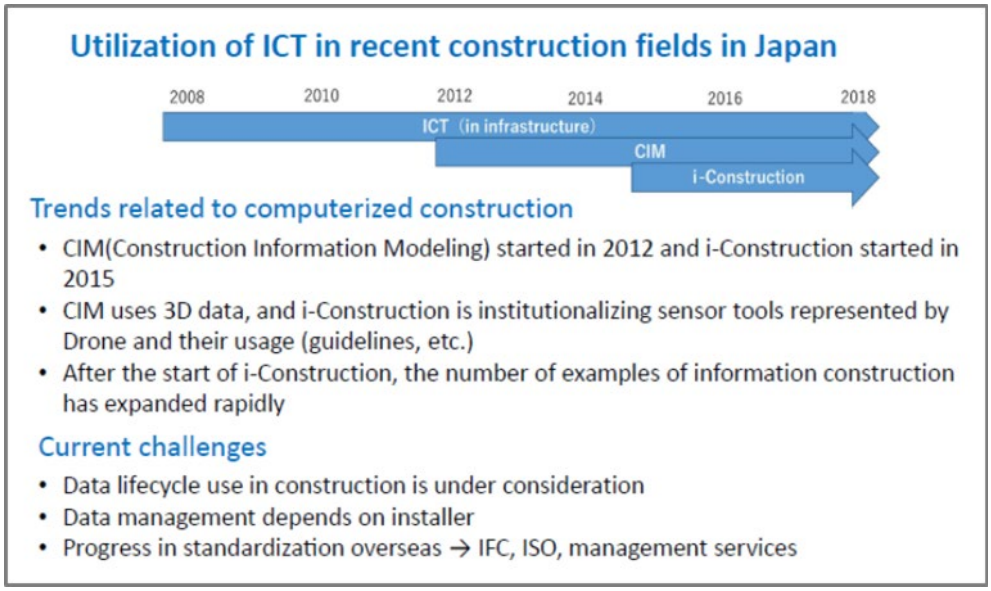



Figure 46. Presentation 5 by Furuya on the evolution of ICT in the construction field in Japan.

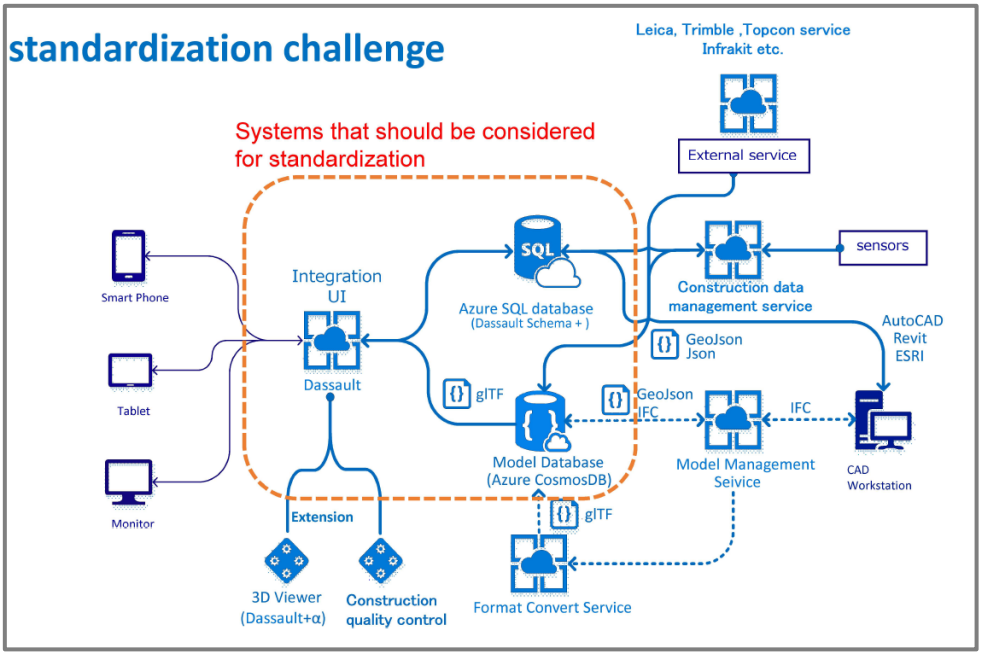



Figure 47. Presentation 15 by Furuya on challenges in standardisation in Japan.

Furuya then presented examples of on-site use of 3D models (e.g. how to use on-site laser scanners and combine them with 3D CAD data and how IFC is used in the civil engineering field). In 2020, a new IFC 5 standard was established in the civil engineering field in Japan, where the results from each field will be integrated. The challenges for standardisation in Ja-

pan are shown in Figure 47. Then, he presented examples of the development of the construction robots as unmanned machines, remote-control devices, disaster investigation robots, and an autonomous operation system for a backhoe. The autonomous operation system for the backhoe is under development, and practical testing and was driven by AI learning where the needs, purpose, and development goals include the following:

- Freedom from monotonous work and a shortage of experienced operators (needs).
- Loading earth and sand into a dump truck within a specified weight range.
- Discriminating piles of earth and sand and implementing optimal excavation.
- Recognising dump trucks and evenly loading within a specified weight range.
- Ensuring safety (automatic stop via detecting obstacles and people).

Then, Furuya presented visions for using 5G in the construction field with higher speed, larger capacity, lower delays, and multiple connections, and the results of a new test of remote-controlled heavy machinery, such as a backhoe based on 5D (Figure 48). Finally, he pointed out the following future work for i-Construction:

- Use of ICT tools and 3D data for data models.
- Moving from automation of single heavy machinery to the systematisation of construction.
- Reform of construction methods to autonomous methods.
- The technical skills of engineers are still fundamental.

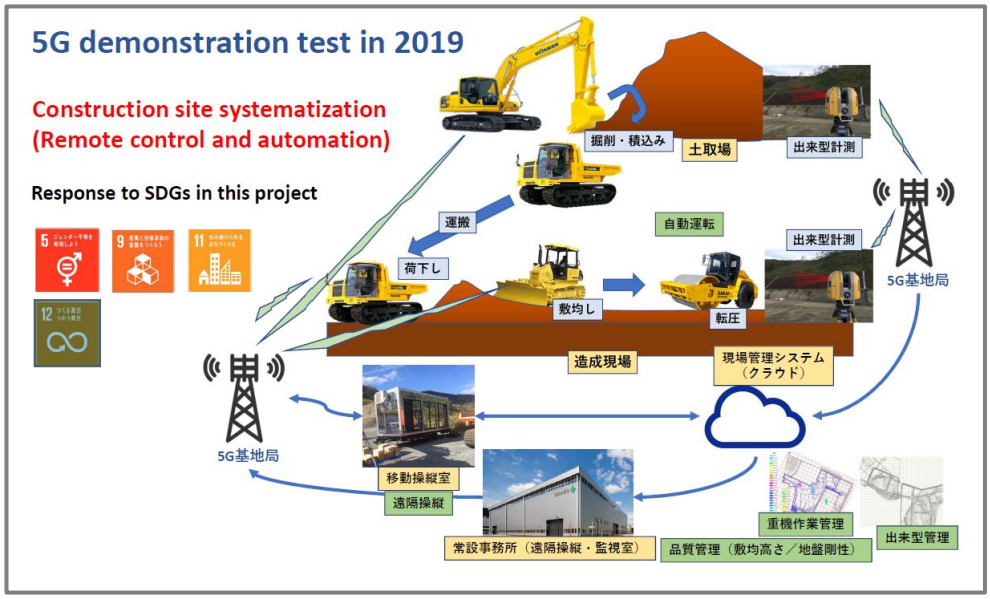



Figure 48. Presentation 37 by Furuya on the 5D demonstration test in 2019 of the remote control of heavy machinery, which is a response to SDG.

**Reflections**

From a Danish point of view, it is interesting to see how structured the Japanese government, research, and private construction companies are in the development of i-Construction. It is also interesting to see how quickly construction companies have adapted the plan through development projects and tests in the field, and how i-Construction has advanced from manual machinery to remoted-controlled machinery in developing construction robots in Japan. It is now important to discuss how we can transform these experiments into infrastructure projects in Japan to the Danish infrastructure and building projects. The first step could be exchanging experiences with the Danish examples of VDC, IoT technology, construction site automation, and printed construction in Themes 4.2, 4.3, 4.4, and 4.6.

# Theme 4.6: 3D-printed construction with examples

Project manager Ole Ellinghausen, M.Sc., from COBOD International A/S.

**References**

Theme 4-6 3D Construction Printing Ellinghausen 2019-09-13
Ellinghausen, O. (2019). *A future with 3D printed construction*. COBOD International A/S, Copenhagen, *https://cobod.com/*. 27 pages.

**Abstract**

COBOD International (before 3D Printhuset) printed the first fully permitted house in Europe in 2017. The project was intense, and COBOD learned a lot about the technology. All this experience was put into the second-generation construction printer BOD2, and the first unit was installed early in 2019 after winning the first-ever European tender for construction printers. COBOD writes: *"Printable construction must be the planner's ultimate dream".* Moreover, Ellinghausen presents 3D construction printing and how the BOD2 printer works. He presents the example of 3D construction printing from Copenhagen, a global overview of the status quo in 3D construction printing, and how the project costs are calculated. Finally, Ellinghausen provides his assessment on which construction methods and parts should be implemented first and how quickly this technology is likely to penetrate the construction market and become part of an automated construction site.

**Presentation**

Two years after having printed the first building in Europe, COBOD has improved its productivity on the construction site by more than 20 times with their second-generation printer, the BOD2. The potential disruption of the conventional construction industry through 3D construction printing is evident in prefabricated elements and large-scale projects where the most disruptive innovations are expected to happen directly on the construction site. However, COBOD was the first to explore the manifold possibilities of applying 3D-printing technology to construction. The direct translation of complex designs from BIM to printing, automation of operations, and reduction of material costs and manual labour are just a few of the disruptive potentials this technology offers.

After a general introduction, Ellinghausen presented examples of printed houses in Europe, Asia, and the US. In total, 26 buildings and nine structures have been produced, and there are 84 ongoing projects. The first 3D-printed building in Europe is a building on demand (BOD) produced by COBOD (Figure 50). Then, he shared some facts regarding the market of 3D printing, which he called 'the hype and the truth': No completed 3D construction printing projects have been competitive so far. We are now in the innovator part of the evolution, where the market, sales, and competition are low and awareness are on the business profile. He pointed out the following key points for future promises:

- Design freedom (complexity is free).
- Automation.
- Local production (vs prefabrication).
- Faster completion time.
- Reduction of waste.
- New materials (recycled).
- Direct BIM to construction.


Figure 49. Presentation by Ellinghausen.


Figure 50. Presentation 5 by Ellinghausen on the first European 3D printed building BOD produced by COBOD in 2017.

**Reflections**

The 3D printed buildings are still in the first phase of invention, and considerable hype exists around the first products. Moreover, the 'facts' are often 'fake news'. In addition, COBOD has delivered the first printed building in Europe, but much is still left to do in technical development, and the business plan must be specified. Focus is on different building parts, such as the foundation, finishing, and other systems, such as heating, water, and plumbing, but it covers only a small part of the construction both in terms of cost and time consumption. The main goal of the development is still to produce a digitally printed house that is faster and cheaper to produce and can fulfil the clients' demands better with a more sustainable footprint.

# LITERATURE AND PRESENTATIONS

**Literature**

The applied literature cited in the report.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**Presentations**

AAU-Build has filed all the following presentations on the site https://sbi.dk/japandk.

Theme 1-1 Introduction Bertelsen 2019-09-13

Bertelsen, N. H. (2019). *Japan-DK Seminar Sep. 13, 2019. Construction Kaizen and i-Construction.* Danish Building Research Institute, Aalborg University Cph. 9 pages.

Theme 1-2 Challenges DK Espersen 2019-09-13

Espersen, L. (2019). *Digitalization and value creation – Challenges to research and practice in the built environment*. Danish Association of Architectural Firms, Copenhagen. 23 pages.

Theme 1-3 Challenges Japan Tateyama 2019-09-13

Tateyama, K. (2019). *A New Stage of Construction in Japan i-Construction.* Japan-DK-Seminar, Copenhagen, September 13, 2019: Theme 1. Challenges and visions for construction. 13 pages.

Theme 2-2 Lean Construction DK Japan Study 2017

Lean Construction DK (2017). *Studietur til Japan, Maj 2017 (in Danish).* Bygherreforeningen, Lean Construction DK, Copenhagen. 45 pages.

Theme 2-2 Kaizen in EogP DK Frederiksen 2019-09-13

Christensen, S. & Frederiksen, J. B. (2019). *Enemærke & Petersen a/s; Kaizen exercise; Potential Check & Productivity Screening; 'The helping hand'; The future state*. Enemærke & Petersen a/s, Ringsted, Denmark. 27 pages.

Theme 2-3 Video data i-Construction Tateyama 2019-09-13

Tateyama, K. (2019). *A Notable Technology in Construction: 1. Visual Construction; 2. Work-style reformation.* Ritsumeikan University, Japan. 29 pages.

Theme 2-3 i-Construction in SME Yokoyama 2019-09-13

Tokoyama, T. (2019). i-Construction for small and middle size constriction company – Visualconstruction. Ritsumeikan University, Department of Environmental Systems Engineering, Japan, 36 pages.

Theme 2-4 SMART training DK Okking 2019-09-13

Okking, M. & Dalsgaard, M. (2019). *Once upon a time … Work SMART not hard*. 3F and Dansk Håndværk, København. 10 pages.

Theme 2-5 Education in motivation Djaelund 2019-09-13

Djaelund, J. L. F. (2019). *Education in motivation and inter-professionalism*. Konstruktørforeningen (Danish Association of Architectural Technologists and Construction Managers), Copenhagen. 12 pages.

Theme 4-1 Introduction Soerensen 2019-09-13

Soerensen, N. L. (2019). Automation, ICT, VDC and construction robots in construction projects. SBi, Aalborg University Copenhagen. 4 pages.

Theme 4-2 VDC BIM ICT in DK Kragh 2019-09-13

Kragh, A. (2019). *ICT, BIM, VDC and i-Construction in Denmark*. Niras A/S, Allerød. 37 pages.

Theme 4-3 Commissioning ICT BlaadalogWollsing 2019-09-13

Blaadal, N. (2019). *Commissioning, ICT, IoT & Autonomation – Big Data*. CXweb, Copenhagen. 20 pages.

Theme 4-4 Site robots & automation Christensen 2019-09-13

Christensen, F. (2019). *RAW robots and construction*. Robot At Work ApS, Odense. 9 pages.

Theme 4-5 i-Construction new ICT Tateyama 2019-09-13
Tateyama, K. (2019). *Sophistication of Construction with ICT. Precise Management in Construction. Introduction of Construction Robots.* Ritsumeika Universit, Japan. 12 pages.

Theme 4-5 i-Construction new ICT Furuya 2019-09-13
Furuya, H. (2019). *Utilisation and challenges of new technology by Japanese contractors*. Obayashi Corporation, Japan. 41 pages.

Theme 4-6 3D Construction Printing Ellinghausen 2019-09-13
Ellinghausen, O. (2019). *A future with 3D printed construction*. COBOD International A/S, Copenhagen, *https://cobod.com/*. 27 pages.

This Japan-DK Seminar on 'Construction Gemba Kaizen and i-Construction' was held on September 13, 2019, in Copenhagen and was arranged by Build, AAU Cph. The findings from a Build project on 'Construction Supply Chain Management' and a seminar on February 26, 2019, in the Consulate-General of Japan in New York on 'i-Construction as a new stage of construction in Japan' were the inspirations for this seminar.

A discussion between four themes forms the framework for the seminar:
1) Challenges and visions for construction.
2) Construction Kaizen and improvements.
3) Building project 'Postgrunden' in Cph.
4) i-Construction, ICT, VDC, and robots.

The four themes are presented in a flow matrix of 'Top - The paper world' to 'Bottom - The real world' and from 'Visions' to 'Construction projects'. The method of forwards and backwards analysis provides the conclusion.

The report summarises the 13 presentations and refers to presentations that are open on the AAU web.

In conclusion, today, it is difficult for the bottom-up approach to compete with the top-down approach. However, we miss the supplement from quick development and documented results with a direct influence on practice from the bottom-up approach, but today it has a low priority. It is important to focus more on the implementation of construction.

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