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ScienceDirect

Procedia Computer Science 121 (2017) 990–997

Procedia Computer Science

www.elsevier.com/locate/procedia

CENTERIS - International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies, CENTERIS / ProjMAN / HCist 2017, 8-10 November 2017, Barcelona, Spain

Standardization and Modularization of Prisons

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Abstract

An urgent need for additional prison capacity in Norway has resulted in the Directorate of Public Construction and Property Management (Statsbygg) and the Directorate of Norwegian Correctional Service (Kriminalomsorgen) developing a functional standard for prisons, along with an accompanying module-based prison concept called the M2015. By standardizing and designing for modularization, the expectation is that prisons can be planned and delivered faster, with high quality and at lower cost than with traditional building. We have performed 6 case studies, of which 4 are of prisons, in order to evaluate the extent of which the expected beneficial effects have materialized. Our findings are in line with the optimistic expectations; the concept has delivered on time, cost and quality compared with earlier prison projects. Still, some challenges with the concept have been identified during the process, most notably a shallow pool of capable suppliers.

Peer-review under responsibility of the scientific committee of the CENTERIS - International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies.

Keywords: modularization; industrialized building; sustainability

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1877-0509
Peer-review under responsibility of the scientific committee of the CENTERIS - International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies.
10.1016/j.procs.2017.11.128

1. Introduction

The construction of prisons can be a long process; deciding on location and finding suitable plots, going through the regulation process (including potential objections of neighbors and local businesses), designing and finally erecting the buildings and putting them to use regularly take more than 10 years. A growing need for prison capacity over the last decade coupled with growing need for maintenance and rehabilitation of current prisons and a shift in political priorities have resulted in an acute need for new prisons capacity in Norway. A temporary solution has been for the Directorate of Norwegian Correctional Service to be renting prison space in the Netherlands, flying prisoners out of the country to serve their sentence. In order to provide sufficient local long-term capacity, construction of new prisons is imminent, and fast project delivery is of the essence.

To facilitate fast planning and construction of prisons, a standardized set of functional requirements have been developed by the Directorate of Public Construction and Property Management (Statsbygg) and the Directorate of Norwegian Correctional Service (Kriminalomsorgen) in the years 2014-2015 [1]. The functional requirements subsequently served as starting point for the development of the M2015 prison concept. The M2015 is based on a combination (hybrid) of traditional place building for the first floor of the prison (which is multi-purpose) and modular building for the two upper floors that houses the prison cells. The M2015 concept does not represent the single solution to fulfilling the standardized functional requirements. However, by proposing a standardized concept for the design and construction methods of prisons, hopes are that learning effects and economies of scale can provide the grounds for fast and efficient delivery of national prison capacity in the upcoming years.

Modular construction, the use of pre-assembled volumetric units that constitute the majority of the actual building (including the load bearing structure) [2] can provide for shortened construction time and increased reliability and quality. Modularization allows for parallelization of tasks in construction projects, as groundwork and module construction can be executed at the same time. Modularization also provides for potential cost savings due to specialization in tasks, application of manufacturing approaches in production and increased ability for learning. Blismas, Pasquire [3] point out that evaluations of off-site construction versus on-site tend to have a narrow focus on cost, ignoring both “hidden costs” and benefits. Modularization provides potential for reducing common sources of construction waste such as waste due to design changes, leftover material scraps, wastes from packaging and non-reclaimable consumables, design/detailing errors, and waste due to poor weather [4-6]. Modularization can also facilitate planning and design, saving both time and resources, especially when coupled with standardization of projects where whole or parts of the building design is transferred from previous projects. Modularization generally provides reduced internal project uncertainty (such as lower risk of defects or damages) [7]. Modularization can also reduce external uncertainty as shortened lead times means decisions in planning and design can be made closer to the point in time when the building will be in use[8]. Prisons regularly consist of high repetitive units (many identical cells). It has also been a political view that prisons of equal security class should be equal in most aspects. These two traits combined indicate that standardization and modularization is a sensible strategy for prison construction. In this article, we investigate this further as we propose the following research question:

- *Is standardization of requirements and modular construction a good strategy for quick delivery of (high security) prisons?*

By project delivery, we include planning and construction time. In our attempt to answer the research question, we have identified the following sub-questions:

  - What are the effects on time and costs of the M2015 concept compared to traditional prison construction?
  - What are the effects of standardization and modularization on project uncertainty?

6 case studies provide the data; four of which are prisons either planned or constructed, and two of which are transit/holding facilities for the immigration authorities. Only the prisons employ the M2015 concept, but the transit/holding facilities provide a benchmark for comparison as these also consist of modules and employ comparable security measures in the building construction. In the following chapters we will discuss how standardized design and

functionality, and design for modularization have had an impact on the delivery time, cost and project uncertainty on highly complex building delivery – prison fatalities.

The M2015 prison concept consists of a single building where the first floor is place-built to allow for some adaptability to the specific needs of each prison and two floors of prison cells. It is the two floors of prison cells that is developed with modular building in mind. The floor plan is in the shape of a four-armed star, with one prison unit in each "arm". One such unit houses 12 prison cells, making the total number of cells in each building 96. The size of the M2015 building is set at this level to strike a balance between what is deemed efficient for rehabilitation purposes (where smaller units is preferable) and operation costs. It might be possible to add a third floor of prison cells to provide additional capacity, making the total number of cells 144. It is not, however, a part of the M2015 concept, as adding cells may incur additional alterations to the building (such as a need for wider or additional stairs) to accommodate a higher number of inmates.

2. Method

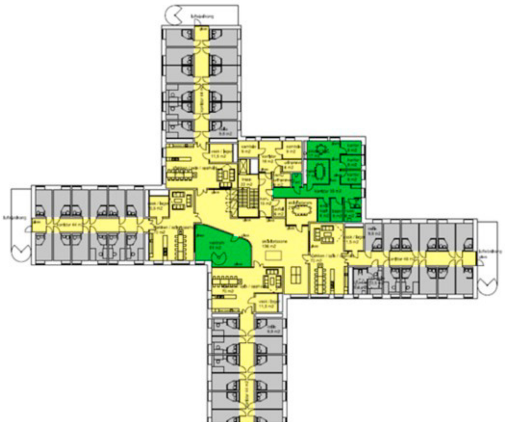

Fig. 1: View of M2015 floor plan.

We have approached the research questions with a mix of methodologies that have included both qualitative quantitative methods. Six case studies provide the data; four of which have been constructed and handed over by the time of publication and an additional two that will be constructed in 2018-2020. The case studies can thus be classified as both ex-ante (case 3 & 4) and ex-post analyses (case 1 & 2 and case 5 & 6). The four prison case studies consist of near identical principal buildings, however some differences are introduced to the projects by the amount and type of existing buildings on site. In one of the case studies, the existing prison has been in operation during the construction phase (case 1). To ensure sufficient validity and reliability of the findings we have applied triangulation as described by Yin [9]. The qualitative data have consisted of an initial literature review on the areas of standardization and modularization (summarized in chapter 3) that subsequently provided the theoretical background for the interview guide. Seven semi-structured interviews have been performed with actors belonging to different sections of the project owner organization. The interviewers are themselves employed by the organization, but have not been working on the development of the standardized functional requirements or the M2015 concept. As an additional source of information with regards to the effects of standardization and modularization on uncertainty, we have used the documentation of the project cost uncertainty analyses. The analyses have been executed by two external consultancies, in the planning phase for the 4 prison facilities. The uncertainty analyses are carried out to identify internal and external opportunities and threats to the project, as well as provide quality assurance of the estimates one time and costs in the project [10]. We have also had access to qualitative and quantitative data on the progress of the construction of the two prisons that have been constructed and the transit/holding facilities from the project owner's progress database, including cost data and lists of alterations and additions. Estimated progress and delivery time for case 3 & 4 are based on the progress plans developed in the pre-projects.

Table 1: Presentation of the four cases

	Project status	Size principal building	Additional buildings	Contract and partner
Case 1	Delivered - June 2017	6 800 sq.m	2 200	EPC – partner 1
Case 2	Delivered - June 2017	6 100 sq.m	2 350	EPC – partner 1
Case 3[†]	In planning	12 200 sq.m	7 000	EPC
Case 4	In planning	6 100 sq.m	5 500	EPC
Case 5	Delivered - 2013	1 820 sq.m.	-	EPC – partner 2
Case 6	Delivered - 2016	3257 sq.m	-	EPC – partner 3

3. Theoretical background

Modularization and modular construction is an example of industrialized construction or building. Modular building is defined by Gibb [11] as a building consisting of prefabricated volumetric units enclosing usable space where the units also constitute the actual building (as opposed to "volumetric pre-assembly" that describe sections of the buildings such as bathrooms). The size of a module is usually delimited by regulations for road transportation (unless other modes of transport are suitable). The degree of completion for the prefabricated modules for typical modular building projects is debatable, as some work must be carried out at the construction site before the modules can be installed, and some work must be executed to fit the modules together and couple piping, electricity and ventilation. Prisons is an example of a type of building with large degree of repetition of units, and is therefore often used as an example of a building suitable for modularization [12-14], alongside hotels, student housing and hospitals.

Shortened construction time is the most cited effect of modular construction [8, 15-18]. The shortened construction time is primarily due to parallelization of module construction at a designated production facility and the execution of groundwork at the construction site. The repetition of tasks, specialization of equipment and optimization of the production line at the production facility can also contribute to faster production of each module compared to place building.

Standardization and modularization include some extra requirements with regards to planning and design of the building in order to achieve efficient project delivery [15]. Subsequent projects that employ the same designs and functionality can then re-use some or all of the designs and plans from previous projects. Re-use of designs and plans can thus lead to *shortened planning time* and changes to the project delivery model. Performing internal or external quality assurance of the modular building concept in question rather than a full quality assurance process for each individual project can result in significant reductions in lead time from project initiation to construction begins [8].

Several authors also point to economic gains from potentially *lower cost* for modular building [8, 16, 17, 19]. Time-dependent costs, such as rig and operating expenses at the construction site will be lower as construction time at the site is reduced. Large projects that allow for mass-production of identical modules may further contribute to lower cost per square meter; however, modularization will also include some additional costs compared to building on site; duplication of walls, transportation cost and potential adaptation before installation on site contribute to higher cost for modular building.

Consistent and higher build quality is another frequently cited effect of modular construction [7, 15]. The modules are normally produced in a controlled environment shielded from fluctuations in humidity and temperature. Although the project owner's ability to inspect the production may be lower than on traditional building, factory building facilitates the quality assurance for the supplier[7].

Standardization and modularization can also affect project *uncertainty* or *project risk*. PMI's PMBOK guide [20] define risk as "*an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives*". We will reserve risk for the events or conditions that have a negative effect on project objectives,

[†] The project consists of two M2015 buildings

such as damages and delays to modules in transit. We reserve “opportunities” to denote the events or conditions that can positively affect the project outcomes, in line with Ward and Chapman [10]. Learning from experience is an example of opportunities introduced by the standardization of projects. Learning can contribute to reduced risk related to the contractors' ability to precisely predict time need for producing, transporting and installing the modules and the associated costs. The project owner can use the log of change orders and change requests for developing better tendering documentation for subsequent projects.

Finally, modular construction can positively impact on the *environmental effects* of the building [5, 6, 15]. There can be higher degrees of re-use and recycling of construction materials compared to traditional building. On the other hand, duplication of walls and transport of voluminous modules incur extra material use and emissions due to transport, especially if the distance between the construction site and the module factory is large.

4. Findings and discussion

Case 1 and 2 have been developed and constructed in parallel with the development of the M2015 prison concept and thus serve as “pilots” for future prison construction projects. We have included the prisons currently at the planning stage (case 3 & 4) where it provides insight into the research question, and used estimations for the overall planning and construction times where appropriate. The two transit/holding facilities provide a benchmark as we evaluate the M2015 prison concept along the dimensions of *time, cost, quality, project uncertainty and sustainability.*

4.1. Shortened construction time/quick project delivery (planning and execution)

The most recently completed permanent prison constructed in Norway took more than seven years to plan and four years to build. The two delivered M2015 prison buildings took significantly less: Close to one year of planning (in parallel with the development of the standard) and an additional year of construction. Even though the reduction is significant, it is by no means impossible to achieve similar planning and construction time with conventional building, especially with the ability of the standard to facilitate the client participation phase of the planning, as stated in the interviews. Case 3 and 4 will prioritize cost over quick delivery and represent new prisons where there will be other construction activities on site in parallel with the construction of the M2015 building. The M2015 building will not be in operation until the other buildings are finished, thereby removing one incentive of quick delivery. The tendering document does not specify the use of modules for the construction of M2015 in case 3 & 4 in order to increase the number of potential bidders. The planning time for case 3 and 4 consist of 16 months from the project owner initiated the projects until the EPC-partner is estimated to begin their planning phase. There are 4 months dedicated for planning activities until construction is estimated to begin. It is however, estimated that the EPC partner will continue with detailed planning in parallel with construction and building activities for an additional 5 months.

Table 2: Duration of planning and construction of the case projects

	Duration from initiation to construction	**Duration of construction phase**	**Project duration**
Case 1: M2015 prison	12	13 (11 months on site)	25
Case 2: M2015 prison	12	13 (11 months on site)	25
Case 3: 2xM2015 prison	(16 + 4 months for EPC partner)	18,5 (M2015) - 21,5 (all buildings)	41,5
Case 4: M2015 prison	(16 + 4 months)	18 (M2015) - 20 (all buildings)	40
Case 5: Holding/transit 2	5	10	15
Case 6: Holding/transit 3	17	6	23

4.2. Effects on cost

The cost per square meter (when adjusted for inflation) is almost identical for the four completed projects. The cost is higher than the average of buildings in the directorate's portfolio, but this is expected for prisons. The M2015 concept is not developed to minimize construction cost, but rather life-cycle cost and quick delivery. The interviewees were split on the question of whether the standardization and modularization provided cost savings. Some pointed out that there were savings for rig and operation cost during construction, while poor material usage was identified as a reason for increased cost. The pool of suppliers of modules and EPC-contractors with experience with modular construction is shallow and competition is weak, so the construction cost may deviate significantly from the suppliers' production cost. Case 3 and 4, where cost has priority over time and quality addresses this by opening up for conventional building as an alternative to modular construction.

4.3. Effects on quality

It is not possible to evaluate the durability and the effects of potentially higher build quality until the prison has been operating for some time. Initial skepticism towards the capabilities of timber modules and plasterboard walls for prison cells has been overcome after testing. The choice of construction materials is limited for modular construction, as is room (or cell) sizes as module sizes are limited by size limitations for road transport. Use of modules also resulted in doubling of walls, which translates to poor material usage and reductions of the usable space. An external evaluation of the fulfillment of inclusive design-requirements in M2015 identified only minor (and fewer) deviations from requirements. The project manager of case 1 state in the interview that build quality has been good and that there have been fewer errors. There have not been incidents of damages or mix-ups due to transport. At case 2 the project manager state that the quality and the amount of errors is comparable to other EPC-projects. Some of the modules however, were delayed due to weather conditions and there were also incidents of mix-ups with delivery order. There were also incidents of water having penetrated the modules while they were stored on site, so some interior walls had to be pulled down on several occasions.

4.4. Effects on project uncertainty

The principal element of risk identified in the uncertainty analyses for all the case studies is market risk; there are a limited number of local contractors that have experience with employing modules in their projects and an even lower number of actors with experience from prison construction. Only two contractors entered bids for the construction of case 1 and 2, resulting in case 3 and 4 opening up for other building methods in the tendering documents. The interviewees further elaborated on the marked situation and emphasized the fact that little experience with prison construction led the contractors in case 5 and 6 to underestimate the complexity of the projects and thus price their bids too low. Future projects may therefore be priced higher as the contractors adjust their bids to accommodate the complexity of the projects. Having the standard and the opportunity to learn from the first two cases and the experience of the project owner, on the other hand, can translate into better ability to handle the complexity for the project organization and alleviate the need for price increase. The project owner organization has also used the experience gained from the two first cases, including the log of change orders, in altering the tendering document for case 3 and 4. A principal example is in not specifying modular building to provide a deeper market of available contractors.

4.5. Effects on sustainability and environmental effects

The Directorate of Public Construction and Property Management emphasize the responsibility that accompanies an ambition of being a role model for the other actors in the property business. Sustainability is an important facet of this responsibility. The M2015 is developed to optimize life cycle cost over investment cost. Prisons, however, serve an especially important role with regards to social sustainability; a successful prison facilitates and supports the rehabilitation process of the prisoners. The functional standard does not incorporate additional requirements to sustainability, and the building adhere to national regulation concerning construction and operation.

4.6. Other effects and summary of findings

The interviewees pointed out that the M2015 had to be adapted to existing building and functions already present in the prisons. This point was primarily concerning the place-built first floor, however. Case 1 included for example underground access to other existing buildings in the prison. The shift in mindset of having to completely plan the whole building before construction was another identified challenge for applying modular construction. This is expected normalize as the organization gets more experience with modular construction.

Table 3: summary of findings

Effect of standardization and modularization	*Interview data*	*Other data*
Planning time	Reduced planning time from case compared with previous experience. Especially evident in case 3 where designs and plans were re-used. Client/user participation facilitated by having a standard.	Significantly reduced duration of planning phase. Case 3 and 4 have been allotted longer planning phases.
Construction time	Evident reduction with previous experience, mainly due to parallelization of groundwork/place building and production of modules.	5 months extra time in construction added to case 3 and 4 in order to attract contractors building with conventional methods
Project cost	Unclear effect as the pool of contractors with experience with modularization is shallow	-
Project uncertainty	The standard may facilitate learning from project to project, reducing uncertainty. Shallow pool of suppliers contribute to cost uncertainty	-
Quality	Perceived as higher or equal to conventional building	-

5. Conclusion

The interviewees experience the M2015 projects to have been successful with regards to delivery time, cost and quality, although there is a general impression of progress having been rushed both in planning and in construction. The interviewees are unanimous in the suitability of standardization and modularization for prison construction and they are to a large extent supported by the other data we have investigated. The M2015 prisons that have been delivered have been planned and constructed significantly faster than past prisons and at lower cost than what was initially expected. However, neither delivery time nor costs are lower than what is possible with conventional building methods.

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