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Shortening lead-time from project initiation to delivery; a study of quick school and prison capacity provision

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Abstract

Purpose:

Standardizing the development, planning and construction of public building projects can contribute to timely and efficient project delivery. This is especially relevant when there are urgent needs for capacity. This article shares the experiences from the development of standardized concepts for school extensions and prison building in Norway.

Design/methodology:

The research questions posed in this article is on the interaction between public entities project delivery or procurement models and standardizing building types and the construction method. To investigate the research questions, the article presents the findings from two case studies; school and prison development and construction projects. It is based on a literature review, semi-structured interviews, document studies and quantitative data on time and cost for the planning and construction phases.

Findings:

Standardization and use of modularized building systems can contribute to shortened delivery time by reducing the duration of both the planning and construction phase. The costs increased in the school case, but were reduced in the prison case. An important challenge faced in both cases is a shallow pool of capable suppliers; the actors have approached the challenge with different strategies, yet neither actor been successful in their attempts.

Originality

The article provides empirical data to add to the collective knowledge on the project management aspects of using standardized and modular building. However, by emphasizing the interaction between project delivery or procurement models and standardization of the planning and execution of the projects, additional insight into the benefits and challenges are highlighted.

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Introduction

Schools and prisons are examples of buildings that shape the areas of which they are located, and on whose functions society is vitally dependent. Through combinations of incentives for the private sector and direct public involvement, the various levels of government often dictate the public provision of these functions. In Norway, this generally translates into public ownership and responsibility for the buildings and the provision of the education and rehabilitation services housed within them.

Capacity needs evolve and change over time; populations change, as do local and national age mix and the requirements to the buildings that house in-demand services. In the course of buildings life-spans, which can be almost indefinite when carefully designed, constructed and maintained (Ashworth 1997), buildings must be modified accordingly or they are rendered obsolete. Meanwhile, public spending for maintenance activities and investments in buildings and infrastructure has been stagnant or reduced as countries strive with low growth or outright recession (OECD 2015). On-going urbanization and population increases put further strain on existing capacity, emphasizing the urgency when it comes to deliver capacity-increasing assets (UN 2016). Simultaneously, changing regulations and expectations from stakeholders with regards to things like environmental impacts and sustainability introduce new technological challenges in the delivery of the buildings (Pries and Janszen 1995, Testa, Iraldo et al. 2011). The public, control-oriented, "one-of-a-kind" project delivery models for public projects are under strain faced with these challenges.

This article presents how Norwegian authorities (Oslo municipalities in the case of school building and the Directorate of Public Construction and Property Management for prison construction) have experimented with changes to their project procurement and delivery models in order to profit from technological development and develop their capabilities to meet evolving needs and demands in a timely and efficient manner. In an environment of technological development and changing requirements we then raise the questions:

- *What are the effects on public entities project delivery models of standardizing both specific building types (such as schools and prisons) and the building method*

And subsequently:

- *Can standardizing buildings and building method contribute to timely and efficient delivery of capacity that serves the populations' needs?*

Ongoing development of the construction and building sector incorporates innovation within both processes and products, from the initiation or idea phase via planning, execution, and handover to operation. Technological tools, such as building information modeling (BIM) can facilitate both planning and execution of projects (Aranda-Mena, Crawford et al. 2009, Succar 2009, Chiocchio, Forgues et al. 2011) and development in materials and construction methods changes the projects and with it, the role of project management (Dvir, Shenhar et al. 2003). We use the terms *Industrialized building (IB) and industrialization of construction* to denote the ongoing development. Industrialization of the building and construction process is a generic term covering a range of methods and approaches with the joint goal of increasing the efficiency and productivity of the building and construction sector (Richard 2005, CIB 2010, Ågren and Wing 2014, Atkin 2014).

Simultaneously, other factors contribute to changing the requirements to public project delivery and outputs. The most important among them is probably those introduced by climate change (Morris 2016) and sustainability (Gemünden 2016). Sustainability and environmental concerns are a mega trend that shape current transformations and developments in many industries (Nidumolu, Prahalad et al. 2009) including management of projects in general (Gareis, Huemann et al. 2013) and construction or building projects in particular (Ortiz, Castells et al. 2009, Haberl, Fischer-Kowalski et al. 2011). It is a contextual factor for most current projects. The concept, understanding and role of sustainability are in transition within project management. From initially being associated with a specific type of project were the objective was sustainable development ("*sustainable development projects*"), to be considered in association with project execution in general (no injuries to work site personnel, focus on environmentally friendly materials and processes) to a new project management paradigm emphasizing long-term consideration of effects and consequences for an extended range of stakeholders (Maltzman and Shirley 2011, Hwang and Tan 2012). The dominant standards of project management are changing to accommodate the transition. Since Eskerod and Huemann (2013) documented a lack of integration of sustainability in project management standards (Individual Competence Baseline (IPMA 2006), PMbok (PMI 2013) and Prince 2 (OGC 2009)), IPMA has integrated sustainability as a central theme in the ICB4 (IPMA 2015).

The changing role of sustainability in project management and the ongoing industrialization of the building and construction process challenge the "*what"* (the projects' outputs) and the "*how"*(the procurement or delivery process) of construction and building projects. In order to benefit from development and to be capable of providing assets for the public, organizational learning becomes a key quality for the organizations involved. Standardization of requirements, functions and products can be one way of institutionalizing learning and experience. Over the course of the last ten years, Oslo municipality, the Directorate of Public Construction and Property Management (Statsbygg) and the Directorate of Norwegian Correctional Service (Kriminalomsorgen) has experimented with standardization and development in project delivery models for the provision of public schools and prisons. In the following sections we evaluate the projects performance with regards to time, cost and quality (including sustainability aspects) and discuss the relationship between the project delivery or procurement model and the standardization of functional requirements and building methods.

Public stage-gate process and project delivery models

According to Kerzner (2013), a stage-gate process is normally the starting point when companies first recognize the need for developing standardized processes for project management. The stage-gate process allows for the horizontal work-flow of projects in organizations designed for top-down, centralized management. Both governmental or municipal entities and private companies regularly implement stage gate models with tollgates or decision points between each project phase (Morris 2013). At each gate or decision point, proper documentation or argumentation must be provided to determine if a project will go ahead to the subsequent phase. Each phase as the project develops is likely more expensive than the preceding phase, so sound evaluation of projects at the stage gate is critical for proper allocation of resources (Cooper 1990). Successful use of a stage-gate process can provide structure, standardization (in planning, scheduling, and control) and allow for structured decision-making (Kerzner 2013). The success of a stage-gate process depends on properly designated gatekeepers, with sufficient power to make decisions and the ability to terminate failing projects. The pitfalls associated with a stage-gate process include the risk of turning project teams' attention more towards the gates than to the overall objectives (Kerzner 2013).

----location for figure1----

The project delivery models or alternatively, project delivery method (PDM), goes beyond the introduction and use of stage gates and can be defined as "*a system for organizing and financing design, construction, operations and maintenance activities that facilitates the delivery of a goods or service*" (Miller, Garvin et al. 2000). It consists of several elements, including the decision-making structure, tendering process and contract formats. The Norwegian Center for Project Management (Project Norway) defines PDM as: *"a principal description of how the project work is to be executed. The strategy for project execution should include the degree of user involvement (when and how much), use of technology (new or mature), ambitions on handling change et cetera" (Prosjektwiki 2017,* translated by the author*).* The Associated General Contractors of America (AGC) define project delivery method with a stronger focus on the stakeholders. According to AGC (2004), project delivery method is *"the comprehensive process of assigning the contractual responsibilities for designing and constructing a project. A delivery method identifies the primary parties taking contractual responsibility for the performance of the work" (AGC 2004*). The generic project delivery models are typically pure descriptions, e.g. RIBA Plan of Work (RIBA 2013) and Next step (Knotten et al. 2016).

Public investment projects, such as architecture, engineering and construction (AEC) projects, are rarely executed by the public entities themselves, and are thus not fully described in generic stage-gate models. In order to execute AEC-projects, the public actors engage with designers, engineers, architects and contractors. Walker and Lloyd-Walker (2015) introduced a project procurement taxonomy based on three main procurement types differentiated by the level of integration. (1) "Traditional", in which design and delivery is segregated, (2) integrated design and delivery procurement arrangement, emphasizing planning and control, and (3) integrated project teams, emphasizing collaboration and coordination. Design-Bid-

Build (DBB) is the prime example of the first group, which separates the design and construction processes. Design and Build (DB) or design and construct (DC) is an example of the second group in which design and delivery is integrated. Different Public Private Partnership (PPP) also belongs in this category, including Design/build/operate (DBO) and Design/build/finance/operate (DBFO). Finally, there is integrated design and delivery team focusing on collaboration. This include different types of partnering, alliances and integrated project delivery (IPD).

-----suggested location for figure 2 -----

Several authors discuss the selection criteria for project procurement or delivery model (Chan, Yung et al. 2001, Al Khalil 2002, Hosseini, Lædre et al. 2016). Different factors influence the make-up of the resulting project organization, including the capabilities and availability of resources in the project's parent (owner) organization, the complexity and uncertainties associated with the process and the product of the project (Turner and Simister 2001). The resulting project delivery model is a combination of adaptions of the project owner's model and those of the other partners.

Public sector projects can be even more difficult to execute than private projects due to factors such as conflicting goals, many layers of stakeholders, constraints imposed by administrative rules and often cumbersome policies that delay projects and consume project resources (Kerzner 2013). It can even be hard to identify the project owner for public projects (Olsson, Johansen et al. 2007). A project owner bears the owner rights and responsibilities of the project (Olsson, Johansen et al. 2008) and it should be the project owner that takes the risk related to the cost and future value of the project (Olsson and Berg-Johansen 2016). The issues of unclear project ownership in public projects are related to New Public Management (NPM) and the internal buyer-supplier model, still present in many areas of the public sector. NPM ideas are based on several topics, including agency theory and transaction cost economics (Boston, 2013; Christensen and Lægreid, 2013), both of which are central to the separation of ownership and control through the use of contracts (Boge, 2012).

A history of cost and time overruns on high profile public projects has resulted in adaptions and introduction of the stage-gate model with special emphasis on control activities at the national and later municipal levels in Norway (Torp, Austeng et al. 2004). The deliverables from selected phases are standardized for external quality assurance before the points of political decision-making (choice of project concept and decision on financing) and to facilitate the transfer and handover of project ownership between the public entities.

Contracts regulate the relationship between the project owner and other parties. Risk and compensation is at the heart of contracts, yet the purpose of the contract is to create rules for collaboration in the project organization based on shared objectives (Turner and Simister 2001). Matching contract type to the characteristics of the project is thus important as the project moves through its life-cycle. Turner and Simister (2001) present a framework for selecting compensation form and organization based on uncertainty (of product and process), the complexity of the project and the owner/client's ability to contribute.

---------suggested location for figure 3 --------

Low uncertainty and complexity: Design bid build (DBB), alternatively "Build Only", is probably the most common form of organizing construction and building projects. It is the traditional model for project procurement in the terminology of Walker and Lloyd-Walker

(2015). An engineering/design group develops complete design and construction documents for the project owner. These documents serve as the foundation for the contractors' bids. The owner then chooses amongst the available tenders. The contractor is then responsible for delivering the project according to specification. Compensation is defined by an agreed schedule of rates or bill of quantities, at a level that gives the contractor a reasonable profit. The engineering/design group and the contractor are independent of each other and may provide checks on each other's work. There is no incentive however, for the contractor to suggest improvements unless they share the benefits from the improvements. After completion, the owner assumes the responsibility of operation and maintenance of the delivered asset (or these activities are the subject of subsequent tenders). The project owner provides financing of the project.

Design build (DB) and **alliancing** allows the contractor more freedom in designing the outputs of the construction or building project. Depending on the project owner, the available solution space may be large or small. A large solution space will allow for large variance in proposed solutions, potentially providing new ways to meet the project owner's needs. DB is an example of the second group of project procurement categories in the terminology of Walker and Lloyd-Walker (2015). Compensation can be set at a fixed price, ensuring that the contractor gains from any innovative solutions found. Alternatively, alliance contracts can be useful where there is uncertainty in the product and process and the client has some knowledge of the situation to help the contractor directly to reduce the contract cost (Turner and Simister 2001). Walker and Lloyd-Walker (2015) place alliancing with the third group of project procurement categories, where emphasis is on collaboration and coordination. Upon completion of construction, the owner assumes responsibility for its operation and maintenance. The owner provides all financing.

Design/build/operate (DBO): The DBO-model extends the role of the contractor to include operations for a set number of years, incentivizing designs that consider the operating costs during the period in which the contractor provides the operation. In the terminology of Walker and Lloyd-Walker (2015), DBO is in the second category of integrated design and construction with emphasis on cost and control. At completion of the contract, the owner assumes operation and maintenance responsibilities itself (or re-competes this task through another procurement process). The owner provides the financing either directly or by collecting user fees in during the operative phase.

Method and research design

The paper is built on two longitudinal case studies investigating planning and execution time on building and construction projects from two different public entities, conducted in between 2014 and 2017. Both entities apply stage-gate project management frameworks, are subject to external quality assurance at selected decision gates and operate in similar conditions with a mix of political and private stakeholders. Several project management theory aspects are relevant to the investigation: A literature review into the areas of PM aspects of industrialization of building, sustainability and project procurement and delivery form the theoretical base. Project management is a trans-disciplinary field with relevant publications in journals not primarily focused on project management alongside the dedicated project management journals. To ensure thorough coverage of the field three dedicated project management journals were targeted during the search; PMI's "Project Management Journal"(PMJ), "International Journal of Project Management" (IJPM), "International Journal of Managing Projects in Business"(IJMPB). Additional articles were collected from "Construction Management and Economics"(CME), "Automation in Construction" and

“Innovation in Construction” under the prerequisite of some attention allocated to PM aspects of industrialization or sustainability of construction or building projects.

Empirical data has been collected from two case studies; school and prison construction. Both case studies contain several embedded projects (see **Error! Reference source not found.**). The primary focus has been on standardized, modular school extensions and modular prisons, but data from site-built and non-standardized modular school and prison projects have been collected and serve as reference and basis for comparison.

A larger dataset consisting of time and cost data for 64 school projects and 81 other public building projects provide additional basis for comparison of project pace and cost. The data has been collected in a combination of guided self-reporting and interviews with project managers of the individual projects. The information collected included factors such as the domain (private/public), project team composition, five pre-defined project milestones, economical data, construction metrics (sq. meters, number of buildings) and subjective assessments of logistical complexity and constructability.

Qualitative data has been collected by document studies and semi-structured interviews (with interview guide). The document study included public standards for the building type in question and in general, progress plans, tendering documents, quality assurance reports and contract documents.

We have applied triangulation and the combination of the qualitative and quantitative methods as described by Yin (2013) to answer the research questions. The iron triangle of time, cost and quality, joined by sustainability is used to structure the analyses and present the findings of the investigation.

------suggested location for table 1 -----

Case study 1: The delivery of schools in Oslo municipality

There are 152 primary and lower secondary schools and 26 upper secondary schools (high schools) in Oslo municipality (excluding private schools). The total number of pupils is 60 000 in primary and lower secondary schools and an additional 16 000 in upper secondary. Due to large population growth over the last 10 years, the number of pupils is expected to grow by around 9000 in the primary schools and around 4000 in the upper secondary schools over the course of the next ten years. The majority of the increase however, is expected in the first five years. The case study is based on a sub-set of the 64 school projects of which time and cost data are available.

------suggested location for table 2 -----

Along with a growing number of pupils, measures must be taken to ensure that current capacity levels are maintained. Many existing school buildings need rehabilitation or additions in order to comply with the municipality's standards. The condition of many temporary school barracks further underline that a significant investment in school buildings over the next ten years. In the period 2016-2019, 8.2 billion NOK (close to 1 billion €) has been earmarked for investment in new schools and rehabilitation to meet future capacity needs.

Investment projects in the municipality, such as new schools and school extensions, are executed in an internal buyer/supplier –model consisting of the principal buyer (the office of the Vice Mayor for Education) and supplier (the office of the Vice Mayor for Business Development and Public Ownership), both of which are under direct political leadership. At the operational level the buyer is the agency for education and the supplier is the Municipal Undertaking for Educational Buildings and Property.

------suggested location for figure 4 -----

The superior buyer and superior supplier perform control activities with regards to project cost and progress. The actors at the superior level are also responsible for enacting measures if there are conflicts (of interests or other) at the operational level. The actors at the superior level are also responsible for financing the investment projects. The role of project owner however, rests with the actors at the operational level. The project owner role changes hands between the buyer and executive party during the project and denotes the party that sets the project goals and objectives for each phase.

The City Council (the political leadership of the municipality) had signaled that *cost efficiency* on the municipal level were to be the decisive factor in constructing the school portfolio. Standardization was to be key in the construction and rehabilitation of schools. Guidelines were developed for all types of buildings in the municipality's portfolio from kindergartens, via schools to retirement homes. The rationale behind the drive for standardization was cost-savings (due to economies of scale), predictability in operations and maintenance, uniform and plain demands to suppliers and contractors, increased ability to transfer experience and learning within the municipality, and a drive for sustainable, environmentally friendly buildings.

The school projects are initiated by the office of the Vice Mayor for Education by way of an instruction to the agency for education. The instruction informs the agency of which schools or set of schools for which there will be developed concept reviews. The concept reviews provide an overview of potential projects or sets of projects in a geographic area of the municipality that is needed in order to provide sufficient capacity. The reviews lead to recommendations of projects and outlines the alternative deliveries of the projects (such as adding capacity for an additional parallel). The concept reviews are the subject of external quality assurance before political treatment. The portfolio of school investment projects is collected in a comprehensive 10-year plan that collectively have the political "go" for moving to the next project phase. The plan revolves every two years. Three alternative execution models have been identified for projects that are included in the plan: (1) Design bid build (2) design/build/operate/transfer or (3) design build (DB)/Partnering approach

"Traditional" design bid build for school projects (projects S9-S22)

The traditional way forward through the project life cycle is depicted in **Error! Reference source not found.**. The agency for education orders a pre-project from the Municipal Undertaking for Educational Building and Property in which project costs are estimated for the recommended concept (along with at lest two alternative projects that provide sufficient capacity according to the plan's needs). The estimated costs along with comments from the Agency for Education forms the basis for a second external quality assurance, this time to provide ensure the quality of the cost estimates. After the quality assurance, political treatment takes place in order to secure financing of the project in the bi-yearly budget process of the municipality. When financing is secured, the process moves to detailed planning and signing of the tenancy agreement between the agency for education and the Municipal Undertaking for Educational Building and Property. The role of project owner is transferred as the project moves to the detailed planning phase. The new project owner then conducts the project in the design/bid/build fashion.

------suggested location for figure 5 -----

Integrated design and construction; Design Build Operate Transfer (projects S7-S8)

Two new schools were completed under a design/build/operate organization during the autumn of 2015. Instead of ordering a regular pre-project for planning the schools, the agency for education were sent an instruction in 2010 to further develop the preferred concept and to develop the documentation needed for a design/bid/operate tendering process. The tender documentation was then subject to external quality assurance.

The pre-qualification resulted in four tendering consortiums. The agency for education worked with the participants to further develop the alternative projects before the final decision and the approval of the tenancy agreement were taken by the city council.

The design/build/operate projects effectively leapfrogged the Municipal undertaking for Education Building and property, and the office of vice mayor for business and public ownership as municipal suppliers of school buildings. A few years before, two other school projects in the municipality were executed under a design/build/operate contract in which the Municipal Undertaking for Education Building and Property took on the role of project owner, subletting the school building to the Agency for education.

-----suggested location for figure 6-----

The requirements set in the tendering documentation for the two schools went beyond the municipality's standard program for school building. The requirements set in the tendering documentation emphasized social and environmental sustainability, and included 50 % reduction in climate emissions from transport, building and operation. A 30-year tenancy agreement provided incentives for thorough life-cycle evaluations during the detailing phase for the project team and resulted in several alterations to the design and construction.

Design Build/partnering: Standardized building and building method (projects S1-S6)

Long lead times from project initiation to school handover inspired the Municipal Undertaking for Educational Building and Property to develop a module-based concept for school buildings in 2010-2011. The concept fulfills the municipality's requirements for permanent schools, but is delivered at speeds comparable to temporary barracks. By performing a quality assurance of costs for the *concept* rather than individual projects, using standardized units to simplify planning and performing groundwork and production of the modules in parallel, lead times from financing was secured to hand-over could be as little as a year.

Although it was not conceived as a partnering project initially, the concept named the "Super Cube" was developed in partnership with a supplier of steel-modules, who subsequently also won the contract for delivering the modules.

The concept consists of factory-built units of 3x3m, 3x6m or 3x9m that are between 85 % and 90 % finished when leaving the factory. Customization of the facades and floor plans counterweights any "temporary" feel. The projects are initially executed in the same manner as the D/B/B projects, however, the process is different from the stages of concept definition and quality assurance. The detailing and planning phase is simplified and split between the Municipal Undertaking and module supplier. Groundworks and foundations work are handled by a separate contractor following normal procurement procedures. The Municipal undertaking handles coordination between the two.

---suggested location for figure 7 ----

Six Super Cubes have been constructed so far and have proved to be popular both with the Agency for education and the teachers. For the construction of the two first cubes, groundwork and foundations were organized by the module-supplier. For the subsequent four cubes, organization of the construction have been coordinated by the Municipal Undertaking for Education Building and Property with separate contracts for delivery of the modules and foundations.

Case study 2: Prison planning and building

An urgent need for additional prison capacity in Norway 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. Worn-down facilities combined with increasing need for capacity result in a similar situation as for the schools; new capacity must be added to the prison system as fast as possible, either by extending existing prisons or by building new ones. Seven prison projects make up the case study.

----suggested location for table 3 ---

The most recently completed permanent prison constructed in Norway (P7) took more than seven years to plan and an additional four years to build. Repeating the model employed then was not suitable faced with the current situation.

Traditional design bid build for prison construction (project P7)

As a point of reference, we briefly present the model employed in the P7 prison project. The project was politically initiated in 1999, and the Directorate for Public Building and

Management formally started the feasibility study in 2000. The Directorate of Norwegian Correctional Service participated in developing the decision criteria for the prison's location; close proximity to police, fire department and hospital facilities. The decision on location was made in March 2003 as the feasibility study ended. A revised feasibility study was then executed from November 2004 to March 2005 that was the made the subject of external quality assurance before funding was approved for detailed planning from March 2006. The cost estimates increased significantly from 2006 to 2007 due to the market conditions, and market inquiries led to the decision of splitting up the project into several contracts: design, peripheral wall, building for cell quarters, activity building and administrative building. The prison has a capacity of 251 prisoners of both sexes, split on three security levels, and the combined are of the prison buildings is 27 617 square meters.

-----suggested location for figure 8 ----

The P7 prison was developed and designed with extra emphasis on rehabilitation of the prisoners and ensuring good quality of life while serving their sentence. It was therefore accepted that both building and operating costs were higher than previous experience. The project has received a lot of attention in the years following its construction, including prizes for good architecture. The benefit of higher rehabilitation rates for the prisoners has yet to materialize, however, paving the way for the more efficiency-oriented M2015 concept for future prison projects.

Design – bid – build for modular prison construction (project P5 and P6)

The Directorate for Public Building and Management acquired some experience with modular prison construction while building the Police immigration detention center at Trandum, in close proximity to Gardermoen airport. The detention center is not a prison per definition, but the facilities are characterized as “prison-like”, and the client was the National Police Immigration Service, not the Directorate of Norwegian Correctional Service. The facilities have been constructed in three stages and have been in operation from 2012, 2013 and 2016 respectively. The most recent addition, Module 3, consist of 90 regular cells, 8 reinforced cells, 3 isolation cells, and common rooms. The total area of Module 3 is 3267 square meters. Rapid delivery was a priority in the tendering process, and the use of modular construction was specified as a prerequisite.

Module 1, 2 and 3 at the detention center does not provide identical functionality; Module 3 receives newly arrived and short-term detainees (<two weeks), Module 2 houses intermediary detainees (intended for between two weeks and three months duration) and module 1 houses long term detainees (in excess of three months). Three different contractors have delivered the buildings, so there are no expectations with regards to effects of serial building on the contractors’ side. However, the three projects was among the first with modular building for the Directorate for Public Building and Management, so some effects due to experience in planning and organizing the tendering and building process could potentially materialize. The projects followed the same steps as in the model depicted in **Error! Reference source not found.** 8, albeit without external QA of cost estimates.

Design bid build for standardized modular prison construction (projects P1-P4)

The functional requirements developed in 2014-2015 served as starting point for the development of the M2015 prison concept. The M2015 is based on a combination (hybrid) of traditional on-site construction 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.

The M2015 prison concept consists of a single building where the first floor is built on site 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.

The standardization and development of the M2015 concept are expected to provide significant benefits within the cost and time dimensions. The tendering documentation and plans can be transferred between projects, reducing time and resource use. Experience and knowledge acquired in projects can be coded into future requirements, facilitating knowledge transfer. The contractors involved similarly gain experience that may be transferred to subsequent projects and result in serial-effects.

---suggested location for figure 9 ---

Findings and Results

The following chapter present the findings form the two case studies under the headings of time, cost and quality. Sustainability will be included under the heading of quality, even though it also influences time- and cost-aspects of the projects. A goal hierarchy is integrated in the stage-gate processes on both the national and municipal level. The national and municipal steering document template has the project owner make a principal ranking of the relative importance of the three dimensions cost, time and quality. Time and cost alternate at the top at every project; some projects are urgent and must be finished to the start of a certain school year for example (especially those that include the demolition of parts of or the whole of existing school buildings). Cost has consistently the highest priority in the projects that are not deemed urgent.

Findings regarding time

The duration of school construction projects vary considerably. Variations in time spent in the planning phases leading up to construction have several potential explanations. The most important of these is due to how the overall plan for school capacity has a planning horizon of ten years, yet it is revolving every two years. There are therefore a lot of projects that pass though the concept definition phase, is included in the plan, yet remain unfinanced. Another explanation for variation in planning and construction time lies with the Agency for Education preference to be handed new school buildings during the summer holidays, alternatively during holidays in the fall or Easter. The projects are therefore typically executed in order to meet these deadlines, translating into some projects having significant slack. The sizes of the projects also vary a great deal, from extensions of about 2000 square meters, to the construction of new schools. Another factor that contribute to slower project delivery include on-site execution of the construction while the school is in operation. This is the case for most extension projects.

There was little difference in the projects executed in the traditional DBB fashion and the DBFO with regards to time. The standardized, modular concept intended for rapid planning and construction ran into some cases of delays due to local stakeholders advocating for traditional site-built alternatives in the first two instances. Subsequent projects were delivered significantly faster than comparable DBB-projects. The duration of the construction phase ranged from seven to 16 months, significantly shorter than other school projects. The modular Super Cube-concept has only been used for school extension projects of between 2000 and 3000 square meters, however. The size of the project influences both the time and cost (per square meter) aspects of projects. This must be taken into consideration when it comes to comparing school extensions and the construction of complete schools.

----suggested location for table 4 ----

The most recently completed site-built permanent prison constructed in Norway took more than 7 years to plan and four years to build. It included a design contract, four main contracts and several technical transverse contracts. The urgent need for additional prison capacity has been the main argument for development of the new prion concept known as M2015.

-----suggested location for table 5----

The two delivered M2015 prison buildings took significantly less time: 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, interviewees state that it is by no means impossible to achieve similar planning and construction time with conventional building. User (or client) participation was very efficient in the planning phase of the M2015 prisons, and was identified as an important reason for shortening the planning phase. It is difficult however, to pin this to M2015 concept, or the standard.

Prison projects P3 and P4 will prioritize cost over quick delivery. These projects include significant construction activities on site in parallel with the construction of the M2015 building. The M2015 building will not be in operation until the other (site-built) buildings are finished, thereby removing the incentive for quick delivery of the M2015 buildings. The tendering document for these projects does not specify the use of modules for the construction of M2015. This has been done 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 four 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, resulting in a total of 21 months of planning.

Findings regarding cost

Cost is a primary concern for the municipality in order to provide sufficient school capacity and to be able to keep up with maintenance activities. Small school construction projects (such as school extensions) are more expensive per square meter than large ones. The cost per square meter of site-built school extensions and site-built new schools are quite similar (site built extensions are 6 % more expensive per square meter). The construction cost is almost identical (site built extensions are on average 1 % more expensive), the generalized management cost on the other hand is 29 % higher for the site-built extensions per square meter. The standardized concept is significantly more expensive; the construction cost is 37 % higher per square meter than site built extensions. Even though the generalized management cost are 42 % and 25 % lower than site built extensions and new schools respectively and as such show significant reductions in planning costs, these savings are more than offset by the increased construction cost. The total cost per square meter of the standardized concept has been 21 % higher than for the site built extensions on average. The size of the school extensions with the standardized concept ranges from 1 721 square meters to 2 484 square meters, whereas the site built extensions has a much wider range (from 1 407 square meters up to 9 170 square meters). Limiting the sample of site built school extensions to only include projects of less than 3 600 square meter (3 projects), could be expected to produce more equal results; the difference in total cost, however, remained at 23 %. Neither has repeating the concept in several extension projects lead to any form for reduction in cost. Over the course of the six projects, both construction and generalized cost have increased, rather than declined. A simplified LCC-analyses of four schools extension projects has been carried out by the Municipal Undertaking for Education and School Building, indicating that the site-build alternatives and the Super Cubes are close to identical with regards to energy use and operations cost. Maintenance costs, however, are assumed to be 20-30 % lower for the standardized concept.

----suggested location for figure 10 ----

The construction cost of the new schools varied significantly under both DBB and DBFO-models. The cost per square meter for school projects delivered by the Municipal Undertaking for Education and School Building vary between 25 % lower and 17 % higher than their average square meter cost. The square meter cost of the two D/B/O/T-schools were

13 % lower and 12 % higher, respectively, than the average square meter cost. It is not yet possible to determine the maintenance and operations costs associated with these schools. However, the two previous projects executed in the D/B/O/T in the municipality have maintenance costs at levels 25-35 % higher than average.

The Directorate for Public Building and Management claims that there will be considerable savings by the application of the M2015 and that use of modules will reduced the cost of construction by 20% compared to site-built construction. In prison projects P1 and P2 the savings translate into 60 – 80 million NOK (6,6 - 8,8 million €) per project.

Despite good experience from the two first M2015-prisons, the strategy with modularized design is partly abandoned in P3 and P4 The pool of suppliers of modules and EPC-contractors with experience with modular construction is to shallow and competition is considered to be too weak in Norway. Lack of completion among the suppliers can result in few bids and the construction cost may deviate significantly from different suppliers' production cost. In 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. The result of this strategy is a almost doubled expected project duration for case 3 and 4.

The cost per square meter (when adjusted for inflation) is almost identical for the four completed modularized prison projects. The cost is higher than the average of buildings in the directorate's portfolio, but this is expected for prisons, as they are regarded as complex and include some special requirements. The site built P7 project, on the other hand, was 20 % higher than the other prison projects. The M2015 concept was not developed to minimize construction cost, but rather to optimize life-cycle cost and achieve 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.

Findings regarding quality and sustainability

Build quality is hard to evaluate for new schools, and previous evaluations have concluded that both DBB and DBOT provide high-quality school buildings. The standardized concept for school extension include some superior quality materials on classroom wall surfaces, however on the whole, it is the absence of mistakes in construction and the ability to operate correctly from handover that are emphasized as the concepts strong point. Other positive traits generally recognized in association with modular construction such as reduced waste generation have not materialized; the Municipal Undertaking for Education and School Building state that the amount of construction waste generated at the construction sites of Super Cubes is almost equal to that of site-built schools.

Environmental factors and sustainability concerns have been emphasized in the competition leading up to the construction of the two DBOT-schools. Both schools are designated as "passive house" and achieve BREEAM classification "very good". In the years following the competition, a bill has been passed by the city council ensuring that all new municipal buildings are to be passive houses. The Super Cube was easily adapted into fulfilling the requirements.

The initial arguments for developing the concept included movability (the modules could be demounted and moved if capacity needs changed) and ease of extension (an additional floor could be put on top of existing Super Cubes) and potential cost savings have proved less relevant than expected. Instead, (near) zero fault in construction and the simplicity in upgrading the concept to achieve passive house-standard have been welcomed.

Environmental concerns play a large part in the municipality's tendering documents and contracts. The municipality is certified according to ISO14001 and both the Agency for Education and the Municipal Undertaking of Education and School Building are obliged to take environmental concerns and life cycle costs into account in the tendering process. Still, price remains the most important criteria for choosing contractors. Normally 70-80 percent of the decision is based on price; total costs, unit costs, labour costs and the cost of potential options. The remaining 20-30 % consists of capacity, ability to deliver and competence of involved parties.

As with school buildings, it is difficult to evaluate the durability and the effects of potentially higher build quality of the M2015 prison concept until the prison has been operating for some time. There was significant initial skepticism towards the capabilities of timber modules and plasterboard walls for prison cells in the project organization, but this 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 prison case 1 state in the interview that build quality has been good and that there have been fewer errors than usual. There have not been incidents of damages or mix-ups due to transport. At prison 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.

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.

Discussion and concluding remarks

This article raised the question of *what the effects are on public entities project delivery models of standardizing both specific building types (such as schools and prisons) and the building method, and the extent this contributes to timely and efficient delivery of capacity that serves the populations' needs.* This chapter will provide a discussion of the findings from the two case studies, and the general validity of the insights gained from them.

Effects of standardization of public buildings and building methods

The expected effects of standardization buildings such as schools and prisons include time-savings in the planning and construction phase due to re-use of documents and plans, learning effects (due to repetition) and increased efficiency in user and stakeholder participation. The two cases represent two different stages of integration between project owner and the contractor. The M2015 prison project construction contracts are awarded on a project-basis following a tendering process. In the case of the standardized school projects, a tendering process lead to a framework agreement between the municipality and a single contractor (module-supplier).

Time-savings in the planning phase was not the primary motivation for standardization in either of the case studies. There are several explanations for this; planning does not incur large costs compared to construction, and the potential time-savings in these phases generally receives little attention. Yet it is in the planning phases that the effects of standardization is manifested most clearly. The external quality assurance scheme at both municipal and national level generally make up three to six months of projects' planning phase. By having the QA-process evaluate the standardized concept, subsequent projects can proceed through the stage gates with a simplified (and much shorter) QA-process. The standardized projects are then more likely to proceed on time to the public budget sessions (twice per year). Serial effects in the planning was also manifested in time savings where tendering documentation was re-used (in the case of prisons). Figure 11 illustrates the potential time saving. As the need for both prison and school capacity remains urgent, it is surprising that the reduction in planning time has received such little attention.

----suggested location for figure 11 ----

Both organizations have promoted the short construction time of their standardized building concepts. Although the construction time is significantly shorter than other site-built projects in their portfolio, constructing buildings of 3000 and 7000 square meters in the course of 10-12 months time is in general not exceptionally fast, and could be achieved with site-built structures rather than off-site modules. There are options available to achieve faster construction (such as three shifts working around the clock), yet both organizations appear satisfied with current pace of project delivery.

----suggested location for figure 12 -----

Economic benefit of standardization has materialized to a low degree in both cases. The cost of the standardized schools did not fall over the course of the six projects. It was deemed high by the municipality, yet it was too low for the module supplier to make a profit. A contributing factor was the degree of adaptions necessary for the supplier to produce the school modules compared with their "standard" products. Economies of scale were thus not obtained. The less integrated approach applied in the prison projects allow more of the decision space for the suppliers in an attempt to limit the adaptions necessary and increase the number of potential bids. Experience from the first two M2015 projects has shown that the pool of potential suppliers remains very shallow. To address this, the next M2015 projects will not require the use of modules, and allow potential contractors to build all the buildings at the site.

The Agency for Education and the Municipal Undertaking for Education and School Building and Directorate of Public Construction and Property Management can be regarded as experts in the traditional Design/Bid/Build process, which is tightly integrated in the municipal organization. The two organizations have used differing approaches to establish a sufficiently deep pool of suppliers: Whereas the school projects were awarded by a two-step competition and a ten-year contract for all projects with a single contractor (even though the number of projects were undecided), the prison construction contracts are awarded on a project-basis. The partnering agreement with the module supplier for the school projects resulted in turning the municipality quickly into the largest client of the supplier, commandeering large proportions of its production capacity. Three years into the agreement, the two parties had developed a strong dependency on each other; the supplier was in financial difficulties and needed the guarantees from the municipality in order to fulfill its obligations to its subcontractors. The municipality on the other hand, had no alternative suppliers available who was able to deliver the specialized modules developed for the concept, yet did not want to stop ongoing extension projects.

Ability to deliver timely capacity

The case studies show that standardization has the potential for reduction of project time, while maintaining quality at similar cost compared to building on site. There is no clear indication that schools or school extension projects delivered by a particular method is superior to the others. The school buildings are functional, perform according to expectations and the users are satisfied with the usability aspects. The newly constructed prisons are not yet in operation, but according to the interviews, nothing has been detected during the construction period that indicates deviations from expectations. Planning and construction time are significantly reduced, as are costs that are time-dependent.

Learning effects within the organization and evolving capabilities are central for both the standardized school and prison concepts. It has not, however, translated into significant reductions in cost. The learning effects have mainly been in the planning phase, in which costs are low compared to construction cost. The use of modules for school building allows the municipality to be more responsive to changing capacity needs; it became capable of providing school extensions in the magnitude of 2500 square meters from one year to the next without resorting to temporary barracks. What has been identified as a key benefit in the prison projects, simplified interaction with stakeholders, has had some unfortunate effects with the school projects. Both school-parents and neighbors are key stakeholders in school construction or extension projects. The reductions in lead-time create a sense of urgency and a risk of stakeholders feeling "not heard or listened to". In custom-built school-projects, there might be sufficient room to adapt plans and designs to stakeholders' input even after the early phases of groundwork and construction has started (even though this is rarely ideal for progress). Stakeholders' concerns resulted in delays in the construction of the two first standardized school extensions. Stakeholders making sure they were heard through the media delayed the delivery of one project.

Several lessons have been learned from the development and use of the Super Cube concept that is in the process of being integrated in coming school extension projects as well as school construction projects. A second generation of Super Cubes will most likely be based on timber-frames to increase the number of potential suppliers of the modules. The movability of the modules, which was incorporated due to sustainability arguments as a response to uncertainty in demand for capacity for the medium-long term, will likely be abandoned. Another option currently being investigated to achieve economies of scale for potential suppliers is extending the concept to also incorporate kindergarten and nursing homes.

Transferability of findings and further research

Standardization of buildings and building methods are a recurring theme in project and construction management. Both public and private construction projects strive with consistently obtaining the upside of standardization; savings in construction time comes at a cost. The savings in planning time, on the other hand, has received less attention even though the time savings, as we have seen, can be significantly larger in the planning stages than the construction phase. These findings are especially relevant in countries with conditions similar to those present in the case studies; when facilities and services such as education and the criminal justice system are publicly provided and managed, and in which stage-gate processes have been put in place to handle project delivery and procurement.

Additional research can provide further insight into the limits to shortening delivery times, especially from additional countries or other building types, into the effects of stage-gate models and the trade-offs between control activities, cooperation and integration between external contractors and internal stakeholders

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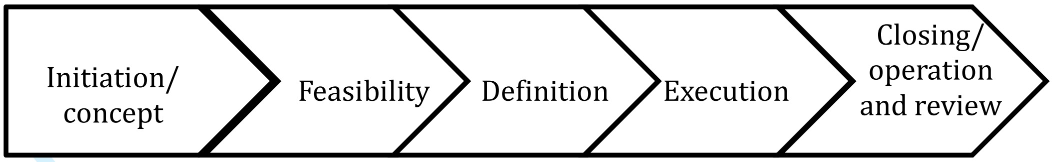

Figure 1: Generic project life cycle model (Morris 2013)

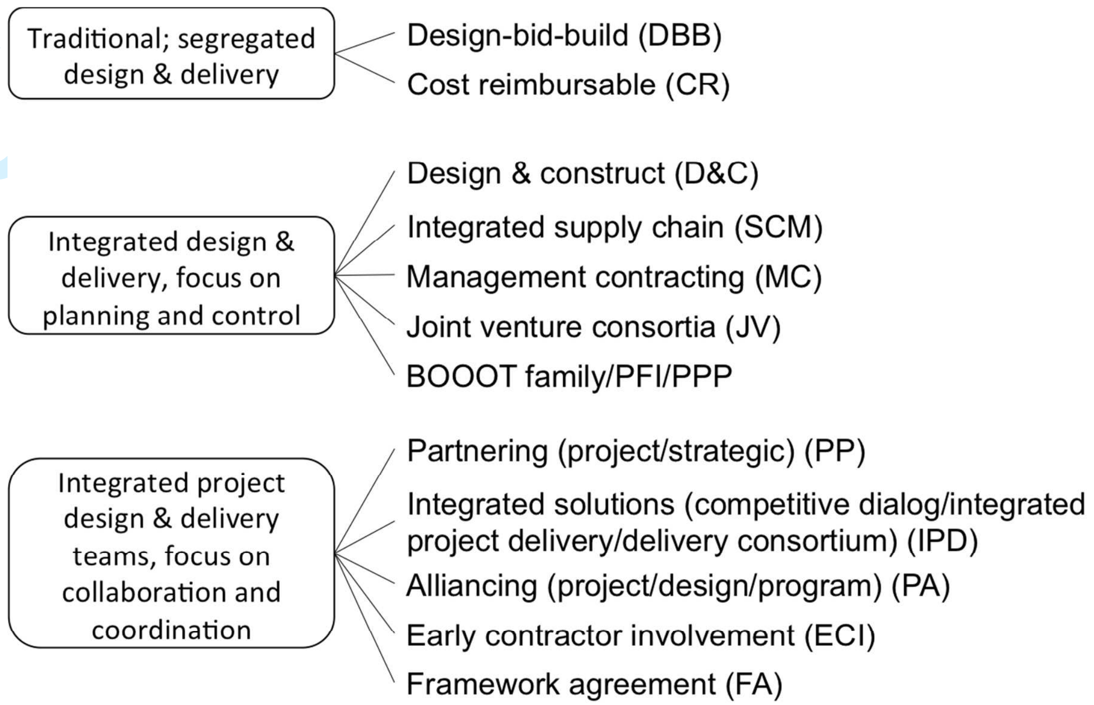

Figure 2: Overview of project procurement (Walker and Lloyd-Walker 2015)

		Uncertainty of the product			
		Lo	Hi		
Uncertainty of the process	Hi	Fixed Price Design and Build	Cost Plus Design and Build Alliance	Hi	**Complexity**
	Lo	Remeasurement Build Only	-	Lo	
		Lo	Hi		
		Ability of client to contribute			

Figure 3: Selection of contract types (Turner and Simister 2001)

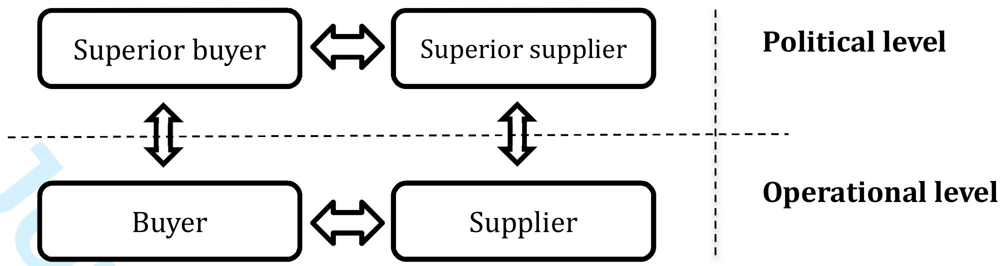

Figure 4: The Oslo municipal buyer/supplier arrangement. Superior buyer and superior supplier are under political leadership.

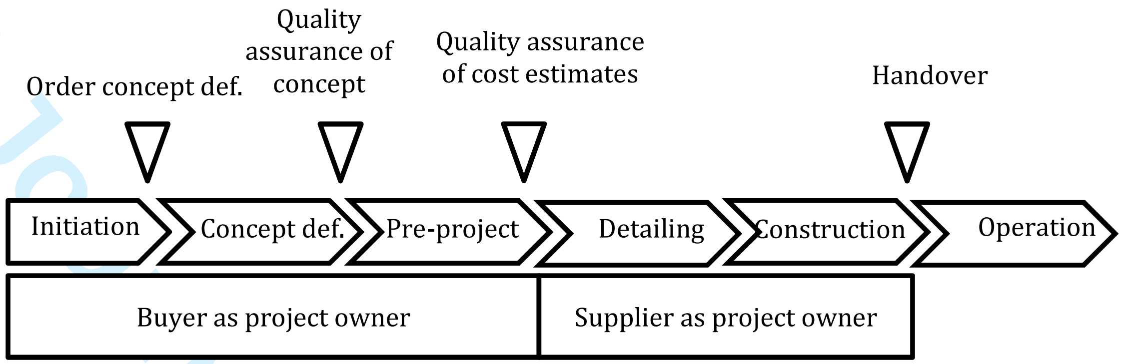

Figure 5: Primary Design/Bid/Build project model for school investment projects in Oslo municipality

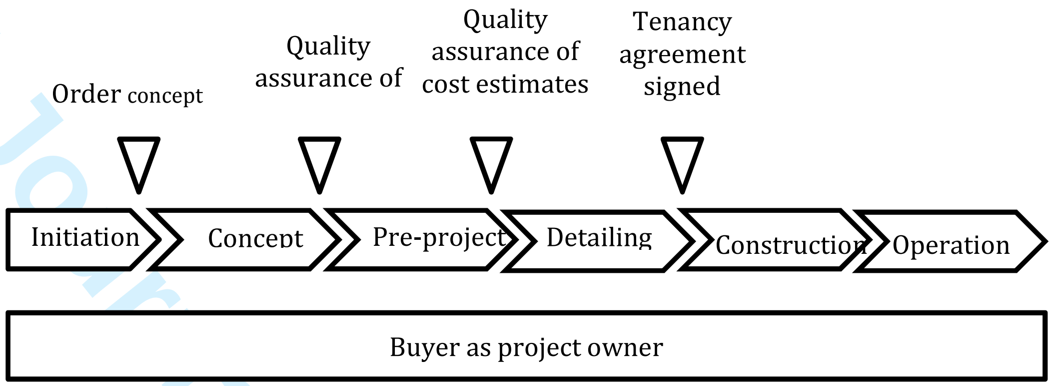

Figure 6 Design/Build/Operate/Transfer model

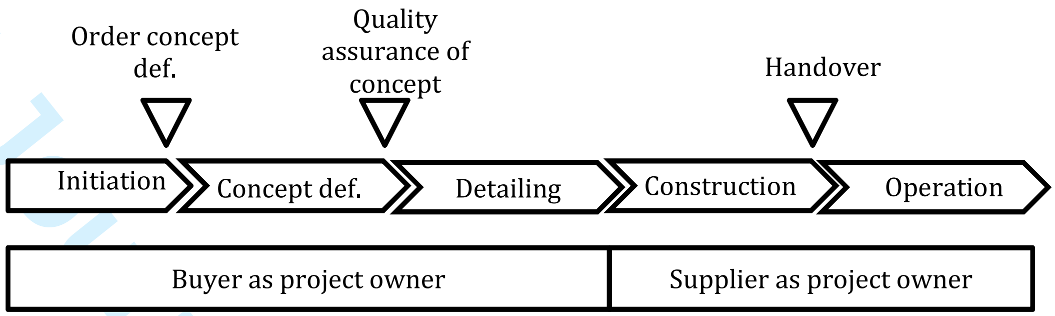

Figure 7: Model for the execution of Super Cube projects; hybrid Design/Build partnering model

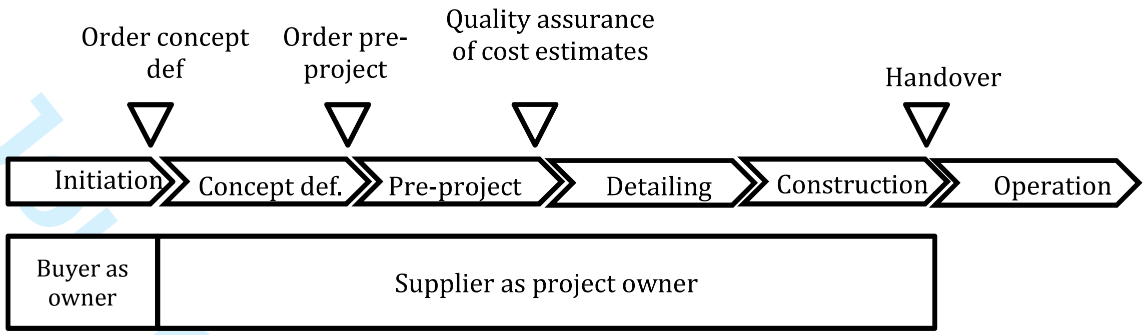

Figure 8: Project life cycle and decision gates as applied by the Directorate for Public Building and Management for the P7 prison

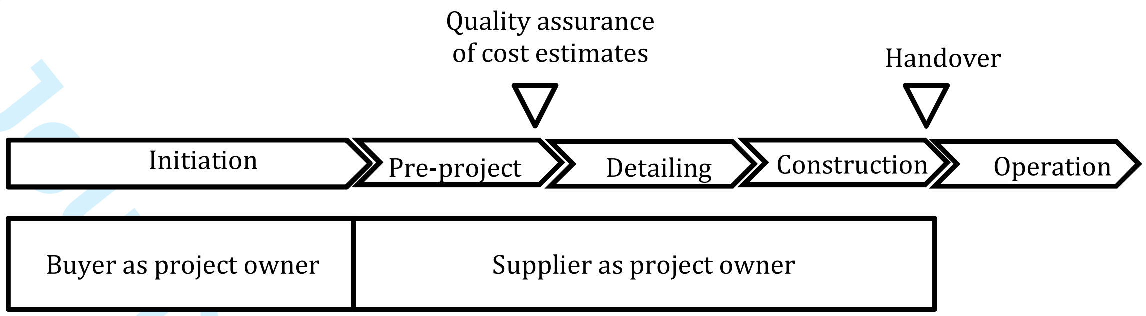

Figure 9: Project life cycle and decision gates as applied by the Directorate for Public Building and Management for M2015-concept prisons

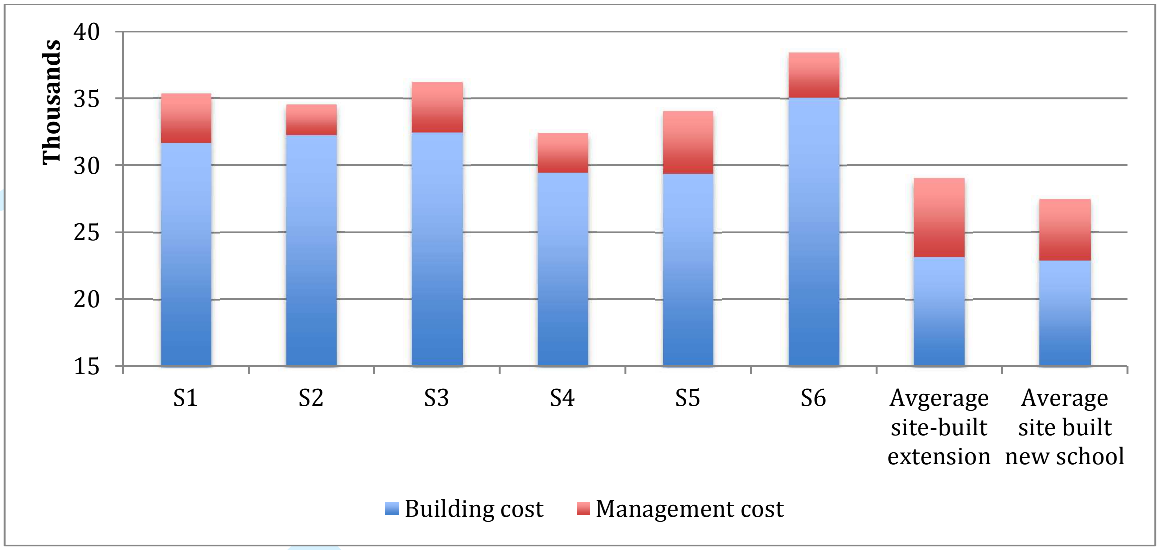

Figure 10: Cost per square meter of the modular school extension projects and the average cost of site-built school extension projects and average cost of site-built new schools

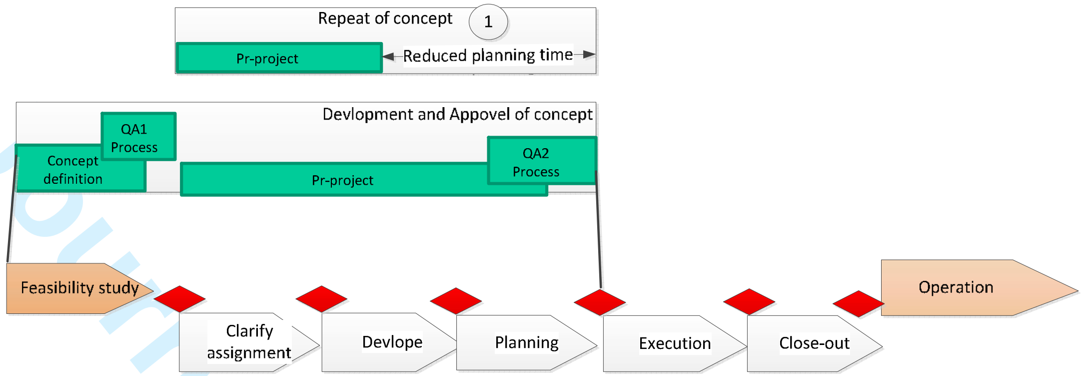

Figure 11: Illustration of potential time-savings in the planning phases by repeating a standardized building concept

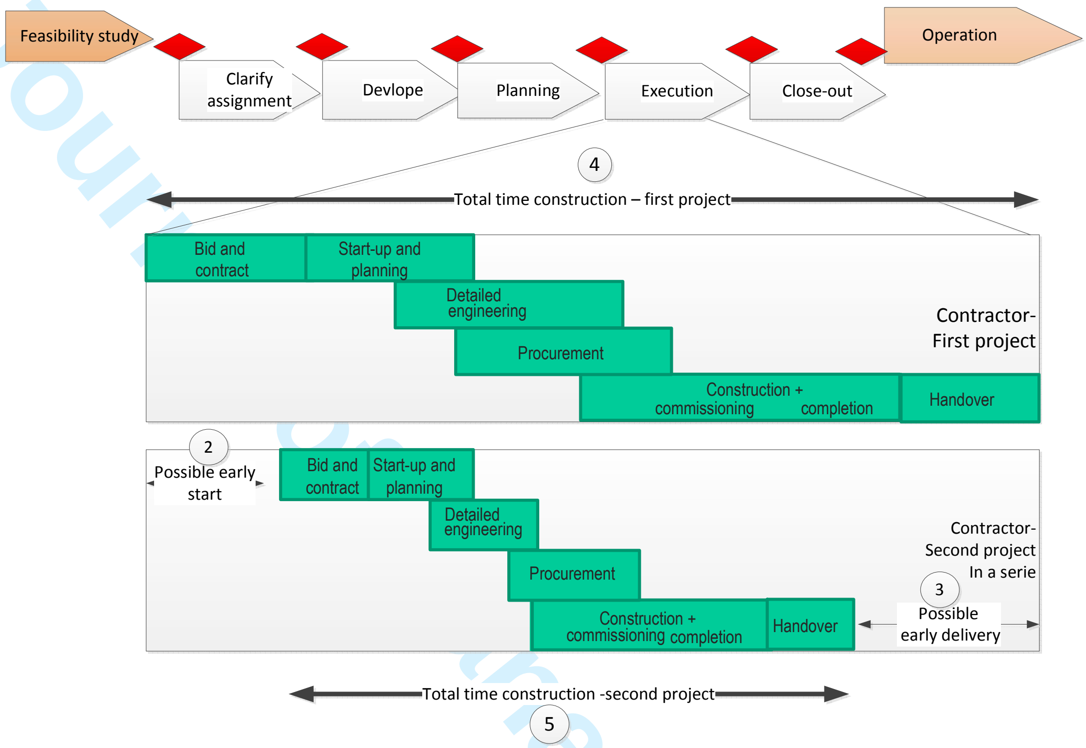

Figure 12: Illustration of potential time-savings in the execution phase of repeating a standardized building concept

Table 1: Empirical data collection methods

	Type of project	**Interviews**	**Additional data sources**
Case 1: School building	6 modular school extensions 6 site-built extensions 7 site-built new schools	15	- Progress plans - Uncertainty analyses - Contracts - Tendering documents - QA-documentation
Case 2: Prison building	4 modular standardized prisons 2 modular detention centers 1 site-built prison	7	

Table 2: Overview of school projects in the Case study 1:

		Type of project	Size (sq.m.)	Contract type	Project status
S1-S6:	Cube 1-6	Standardized, modular extension	1 566 - 2 422	DB/partnering	Delivered 2012 - 2016
S7-S8:	Site built new schools	New	8 633 – 12 700	DBOT	Delivered 2015
S9-S16:	Site built new schools	New	6 014 – 12 522	DBB/EPC	Delivered 2014 - 2016
S16-S22	Site built extension	Extension	1 407 - 9170	DBB/EPC	Delivered 2013 - 2016

Table 3: Overview of prison projects

	Size principal building(s)	Additional buildings	Contract and partner	Project status
P1: M2015 prison	6 800 sq.m	2 200	EPC – partner 1	Delivered - June 2017
P2: M2015 prison	6 100 sq.m	2 350	EPC – partner 1	Delivered - June 2017
P3: 2xM2015 prison	12 200 sq.m	7 000	EPC	In planning
P4: M2015 prison	6 100 sq.m	5 500	EPC	In planning
P5: Holding/transit 2	1 820 sq.m.	-	EPC – partner 2	Delivered - 2013
P6: Holding/transit 3	3257 sq.m	-	EPC – partner 3	Delivered - 2016
P7: Site-built prison	36 151 sq.m	-	4 EPC contracts	Delivered - 2009

Table 4: The duration of project phases (in months) for the selected school case study projects

	Duration from initiation to construction	Duration of Construction phase	Project duration
S1: Cube 1	4	9	13
S2: Cube 2	9	8	17
S3: Cube 3	12	8	20
S4: Cube 4	10	7	17
S5: Cube 5	18	12	30
S6: Cube 6	15	16	31
S7: DBOT School 1	28	24	52
S8: DBOT School 2	35	22	57
S9: Site built extension	30	21	51
S10: Site built extension	37	24	61
S11: Site built extension	39	21	60
S12: Site built extension	17	18	35

Table 5: The duration of project phases (in months) for the prison case study projects

	Duration from initiation to construction	Duration of construction phase	Project duration
P1: M2015 prison	12	13 (11 months on site)	25
P2: M2015 prison	12	13 (11 months on site)	25
P3: 2xM2015 prison	(16 + 4 months for EPC partner)	18,5 (M2015) - 21,5 (all buildings)	41,5
P4: M2015 prison	(16 + 4 months)	18 (M2015) - 20 (all buildings)	40
P5: Holding/transit 2	5	10	15
P6: Holding/transit 3	17	6	23
P7: Site-built prison	90	39	129