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CRAFTSMANSHIP IN THE MACHINE

Sustainability through new roles in building craft at the technologized building site

by Håkon Fyhn & Roger Andre Søraa

The building industry is becoming increasingly characterized by automated production, and in line with this, the nature of craftsmanship is transforming. In this article, we look for a sustainable path for this transformation through a case study that follows a team of carpenters building a set of tower blocks at a high-tech building site using "lean" construction techniques and robotic production technology. The builders are organized according to complex schedules of lean construction, making work at the building site resemble that of a large machine. The builders hold multiple roles within this machine: more than simply "living mechanisms" inside the machine, they also take on more parental roles as "machinists," employing their crafting skills in planning, problem solving, improvising, coordinating and fettling in order to make the building machine run smoothly and to minimize environmental uncertainty. The craftsmanship in action is characterized by what we call workmanship of uncertainty – the ability to produce certain results in uncertain conditions. We identify this as the collective skill of a community of practice. The sustainability of craftsmanship in the machine is analyzed according to three kinds of sustainability: cultural, social and ecological. We suggest that all three forms depend on the building company's ability to provide working conditions that allow the builders to form stable communities of practice in order to perform, share and develop craftmanship. Finally, we show that working in and with technological production systems does not require fewer skills (of craftsmanship) than traditional building, but a nuanced application of these skills.

Keywords: *craft; work automation; community of practice; lean construction; workmanship of risk*

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Introduction

What will be the nature of craftsmanship in the building industry of the future? In this article, we explore this question by observing the building crafts in action at a modern, high-tech building site. At the site, builders and machines work together in a complex production system designed to raise five tower blocks. The towers are made from wooden elements that are produced by robots at a factory and built through a "lean construction" system on site in Trondheim, Norway. Lean construction implies a tightly coordinated building process wherein the builders contribute to planning and improving the process (Koskela et al. 2002[r]). In this study, we follow a community of carpenters through the entire building process, focusing on the transformation in their craftsmanship as the building process becomes increasingly technological, and exploring their work as a community of practitioners. We investigate the particular skills that enable this community of workers to transform plans and designs into reality in the form of five tower blocks.

In any investigation of the future of craftsmanship, sustainability is an issue. Analyzing the direction of a certain development leads one to question whether this development forms a trajectory that is able to sustain itself, including the society and environment it is part of, both now and in the future. For building crafts, three kinds of sustainability seem particularly relevant: cultural, social and environmental sustainability. (A fourth kind of sustainability, *economical sustainability*, is not addressed in this paper). *Cultural sustainability* is addressed through an analysis of the preservation and development of traditional building crafts and craft cultures in the technologized building industry. *Social sustainability* is investigated through an analysis of the transformations in the building industry that have made it increasingly difficult for builders to sustain a decent life. Finally, environmental sustainability is addressed through an analysis of the building industry's increasingly important role in the transition to a sustainable low-carbon society (European Commission 2011[r]). While environmental sustainability is not the main focus of the present study, the case indicates that the building industry's ability to contribute to environmental sustainability depends, in large part, on the former two kinds of sustainability.

In the following, we give a brief account of the technological and social transformations occurring in the building industry, before presenting our methods and the case study analyzed in this paper. We then introduce a theoretical framework for craftsmanship and technologization, before describing the role of crafts in the "machinery of building" and discussing this role as it relates to sustainability.

Technological Unemployment, Deskilling and Reskilling

For a long time, the Norwegian building industry has been seen as rather conservative (Ryghaug and Sørensen 2009[r]); but during the last couple of decades, many changes have occurred in the industry, taking it in the direction of automatized production. We identify this tendency through the adoption of two kinds of technologies: First, automation technology, such as robots that perform tasks such as drilling, painting and laying bricks (tasks previously done only by humans). Such technology also includes the more radical development of large 3D printers that are able to print complete houses[1]. The increased use of prefabrication is also part of this development, wherein elements are produced in a factory for later assembly on the building site. Prefabricated houses have been produced in Norway for more than a hundred years, but the scale of such production has escalated during the past decade, with the added element of customisation. As a result, prefabrication now plays a role at almost every building site. The second new technology comprises advanced production techniques, such as lean construction (Koskela et al. 2002[r]), which make the on-site building process subject to the same kind of technological management as factory production. Such technologization gives the entire building process a machine-like quality. While technologization of the building site is the main focus of the present paper, we see it in close relation to automated production.

A narrative that is often used to frame automation in relation to craftsmanship is that of machines taking jobs from humans: rather than serving as a tool for a bricklayer, the bricklaying robot may replace the human worker altogether. Although, historically speaking, automation has produced a variety of new jobs for humans (who must subsequently construct and operate the machines), the fear of "technological unemployment," as Keynes described it in the 1930s (Susskind and Susskind 2015:284[r]), has gained renewed interest in recent years. This is particularly true in relation to the so-called "Industry 4.0," wherein industrial robots are able to perform rather customized forms of production that were previously restricted to humans (Schwab 2016[r]). The situation has inspired many public reports estimating the number of jobs that will be lost to machines within the next couple of decades. The reports indicate that a significant proportion of contemporary jobs will disappear in countries such as the USA (Frey and Osborne 2013[r]), Sweden (Hultman 2014[r]) and Norway (Pajarinen et al. 2015[r]). These reports tend to be particularly pessimistic with respect to the fate of skilled workers in the building industry. For instance, a Norwegian report estimates that eighty-two percent of bricklayers will be redundant within twenty years, along with eighty-one percent of painters, eighty percent of building construction workers and seventy-two percent of carpenters.

However, when discussing the issue with builders, we found that they did not seem very concerned about being replaced by machines. "No, the building process is too unpredictable, you will always need human workers," a crew leader said, rather confidently. It was another aspect of this development that seemed to concern the builders – not the loss of work, but the loss of craftsmanship. This was particularly voiced in relation to prefabrication technology.

1 https://www.sciencealert.com/the-world-s-largest-3d-printer-can-now-make-entire-houses-out-of-clay

Although the production of prefabricated elements required much of the same work as on-site building, it was not always seen as proper craftsmanship: "You are not a craftsman, you are a factory worker," an old master mason told us. "Being able to work outside, in rain, snow, and sunshine is part of real craftsmanship," he argued. A more precarious threat to building craft seemed to face the builders who worked out in the snow and rain, assembling the prefabricated elements: the risk of deskilling, or losing the ability to build houses from scratch. A young carpenter who worked with prefabrication commented: "With this, you are not a craftsman; you are an assembly worker." *Deskilling* implies a loss of status and identity (Fyhn forthcoming[r]), but as our study indicates, there might also be an element of reskilling (acquiring new skills) that deserves inclusion in the narrative of technologization and craftsmanship.

The Nordic Model of Work

The craft skills in question exist in a cultural context: Norwegian builders tend to regard themselves as craftspersons and they distance themselves from unskilled workers, industry workers and assembly workers (Fyhn forthcoming[r]). This status reflects the training system in Norway, which is a standardized version of the traditional training system for the crafts: one to two years of vocational school followed by two years of apprenticeship before the journeyman test, which initiates builders into the ranks of journeymen. This educational structure is the same for carpenters, bricklayers, plumbers and electricians, as well as goldsmiths, potters and other manual craftspersons.

The status of craftsperson in the Norwegian building industry is also affected by what is commonly called "the Nordic model of work" (Gustavsen 2011[r]). See our figure below:

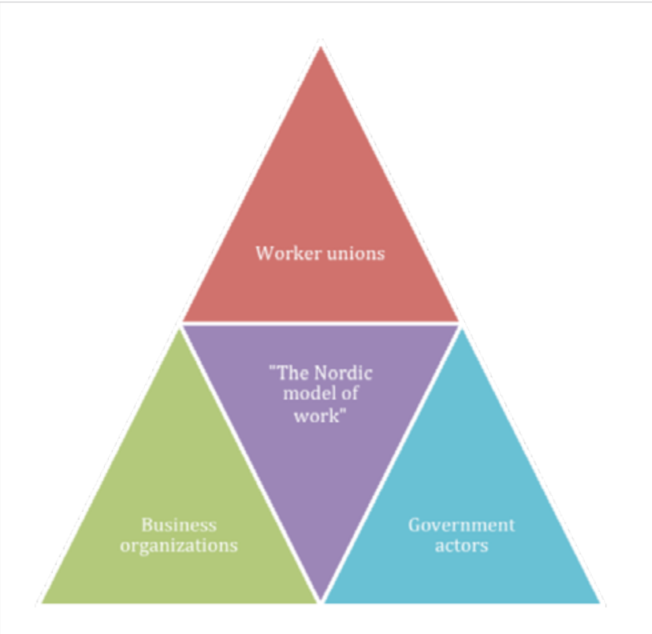

Figure 1: The Nordic model of work

The hallmark of the Nordic model is an organized relationship between worker unions, organizations (representing business leaders) and government. This three-part collaboration is responsible for ordered and relatively fair negotiations about workers' conditions and serves to give workers a voice. As a result, builders expect to have a say in how things should be run at the building site, and they are prepared to take responsibility for solving any problems that occur. Taken together, the Nordic model and the Norwegian emphasis on formal skills seem to empower builders in Norway (see Tesfaye 2013[r]).

Over the past ten to fifteen years, working conditions in the building industry have changed, due to new business models and the internationalization of the labour market. Building companies are shifting from their previous reliance on permanently employed builders to relying on casual workers, who they employ from job to job – a business model associated with "social dumping" (Alber and Standing 2000[r]; Bals 2017[r]). Today, the number of casual workers employed through vacancy agencies is far greater than the number of permanently employed builders at major building companies (Marsdal 2015[r]). The typical building company is no longer a community of builders and office workers, but only office staff – those who plan projects and produce tenders; the focus of such companies seems more oriented towards economic speculation, while the actual building work is outsourced (Røyrvik 2011[r]). Builders on temporary contracts provide the office flexibility in the event that the company does not win a contract. But it is the builders who pay for this flexibility, as they are forced to live in uncertainty and form what Standing (2011[r]) calls a "precariat." This development is dreaded by builders in Norway, who wait for the day on which *their* company will sack its permanent builders and rely on vacancy agencies for staffing. Having to work for vacancy agencies and line up for jobs with the "casuals" is described by the builders as a "worst nightmare" (Fyhn forthcoming). In many cases, working conditions on job sites are illegal, but this is difficult to prove, as workers hired by a subcontractor may have been hired by another subcontractor, which again may have used a third subcontractor (etc.), comprising a network that is designed to be difficult for authorities and unions to track (Bals 2017[r]). As a result, the Nordic model is irrelevant at many building sites, and achieving the necessary conditions for social sustainability proves difficult.

Cultural sustainability is also threatened when building sites and companies no longer exhibit stable communities of practice. We were told that it takes several years of training following the apprentice period to become a skilled carpenter. This learning becomes difficult when there is no community to learn from. The quality of the work is said to drop without a stable community of practice. "The casuals come in for a few days to do a job, they make lots of building errors and then they leave without even knowing they made them," a frustrated builder told us. He continued, "at the next building site they make the same mistakes over again, happily unaware." According to some builders, such errors have consequences for environmental sustainability, as houses may not perform as well as they should in terms of energy efficiency.

From the builders' perspective, it seems that the tendency to rely on casual workers does not enhance sustainability. Despite this, it has proven difficult for companies relying on permanently employed builders to compete with companies using outsourced workers, due to higher personnel costs. However, some companies still seem able to compete. The company responsible for the building at Moholt (the site examined in this case) is an example: rather than sacking its skilled builders, it employed more. Relying on relatively expensive yet permanently employed builders, the company engaged in a stable community of practice. Its argument was that this community would be able to build more effectively and with fewer errors than would temporary workers at other companies. An essential aspect of this approach was involving builders in the planning process and applying lean construction principles. But this system also implied challenges in terms of redefining the traditional role of craftspersons. What is the new role of craftsmanship in the building industry? Does it point to a way forward for craftsmanship that is sustainable in any of the three ways we have suggested? We approach this question through a case study of the Moholt site.

Studying Craft at the Building Site Moholt 50-50

This study is based on fieldwork at a building site at which the company Veidekke built five tower blocks for student housing for the local university. The tower blocks stood nine storeys high. They were energy efficient, fulfilling the passive house level, and were made entirely of massive wood – except for the basement and ground floors, which were made of concrete in order to "anchor" the light towers. While concrete production produces substantial CO_2 emissions, massive wood binds with CO_2 in the air, reducing carbon emissions by fifty-five to sixty percent.

The tower blocks' wood construction made the building site special. While concrete-based building sites tend to be wet, drafty and noisy from constant drilling, this site was dry and quiet. There was no need to drill holes as screws could be inserted directly into the wood. Also, the site had a distinct smell of pine, rather than wet concrete. "This warms the heart of a carpenter," one of the crew leaders said on one of the first days of the fieldwork, reminding us that the craftsperson identity also has an aesthetic side.

The fieldwork was conducted by the first author in concentrated periods throughout the entire building process, during which the same community of carpenters was followed. These carpenters called themselves *snekker*, in Norwegian. In English, we would use the term "carpenter," but in other contexts the term may also be translated as "builder" or "construction worker" (even though a *snekker* is always considered a craftsperson). The fieldwork started in February 2016, when the building site was covered in snow. At that time, the first storeys had been built atop the concrete basements. The next period of fieldwork was in March and April, during which most towers were erected to their full height. The fieldwork continued in June, which saw much work done on both the inside and the outside of the fully erected towers. In June, the weather was nice and the builders wore short working trousers in signal colours, in addition to their obligatory safety shoes, helmets and protection glasses. At this time, the builders clearly longed for the summer holiday, but they had to work hard as the first three towers were scheduled to be finished at the end of the summer. The final period of fieldwork was in November 2016, after students had moved into the first three towers and as the final two were being prepared for the final inspection before being handed over to the client.

The fieldwork involved participation in many planning meetings, daily conversations with people and observations at the site. Much of the fieldwork focused on understanding what the builders did and said, attempting to learn their vocabulary and the principles by which they worked. In particular, the fieldwork involved significant contact with the crew leaders on site (called *bas* in Norwegian) and the foremen at the office (*formann* in Norwegian), who were all extremely helpful in making the process of building a tower block understandable for us anthropologists. In addition to participating and observing, we also conducted eight formal interviews with people involved in the building process: one with the client, two with engineers and five with carpenters.

The fieldwork was framed by a larger study of craftspersons and apprentices in the Norwegian building industry: "Crafting Climate Transitions from Below." This research project seeks to understand the role of craftspersons in the transition to more climate friendly building practices. The project includes studies of discourses of craftsmanship tools and policy, in addition to analyses of interviews with craftspersons, conducted by all authors between 2013 and 2017.

Understanding Craftsmanship in a Technologized Context

Craftsmanship at a high-tech building site such as Moholt must be seen in relation to the technology it works with. This implies automation and technological production systems such as *lean* construction. While craftsmanship, in its simplest definition, refers to "skills in a particular craft" (*Oxford English Dictionary*), craftsmanship in a technological context requires more specificity. The craftsman and philosopher David Pye offers some direction in his work *The Nature and Art of Workmanship* (1968[r]). Pye prefers the slightly more modest term "workmanship" over "craftsmanship," commenting that it is not possible to say where one ends and the other begins (ibid.: 20). In his work, Pye concludes that it is futile to separate between work done by hand and work done with machinery (ibid: 25). For example, a dentist drilling a tooth with an electric drill is more reliant upon his steady hand than a carpenter using a hand-driven wheelbase to drill a straight hole in a piece of wood. Rather, Pye suggests that the degree of *risk* at play serves as a better way to distinguish workmanship from machine production. While the dentist drills with great risk of failure, the carpenter operating the wheelbase hardly exercises any risk at all, unless he/she is fool enough to break the drill. Pye thus introduces the term *workmanship of risk*, in contrast to *workmanship of certainty*. An example of workmanship of risk is sawing and scarfing boards to build a cabinet by hand. When using a planer and other tools, a workman still relies on his judgment, dexterity and skill to achieve the desired result. The workman needs to be alert and present in the work as the result is *continually at risk* through the whole process of making. This presence implies being more or less "immersed with his whole being in a sensuous engagement with the material," as Ingold (2000:295[r]) puts it (even though the degree to which his "whole being" is immersed, in practice, seems to vary).

If, on the other hand, the pieces of cabinet are routed by machines at a factory, the result follows from the set-up of the machines and does not depend on the judgement, dexterity and skill of the workman. As such, workmanship of certainty is in effect when the workman is operating the machine. Let us not forget that workmanship of certainty is also workmanship, and implies the worker's skill and presence. Such workmanship is different from a traditional understanding of workmanship, but may become more important as machines and machine systems become more complex. In practice, building work at a contemporary building site implies both forms of workmanship and, as we suggest, also a third form.

While workmanship of risk has traditionally played an essential role in house building, the introduction of prefabrication and automation has moved more of the work into the sphere of workmanship of certainty. Still, workmanship of risk plays a role. At a modern building site it can apply to more than scarfing boards, fittings and joinings. As the following case study indicates, unforeseen things tend to happen at building sites, introducing an element of uncertainty to even the simplest tasks. This calls for a form of workmanship we might call *workmanship of uncertainty*, rather than of *workmanship of risk*. The word "risk" points to the risk of loss, as the desired result is at stake at every moment of the work. The word "uncertainty," on the other hand, points to a condition of not knowing what lies ahead (Whyte 2009[r]). While Pye's workmanship of risk implies a reliance on judgement, dexterity and skill to produce a certain result under the constant risk of error, workmanship of uncertainty implies the production of certain results under uncertain conditions. Risk is always present, as the result is at stake throughout the entire process, but the risk of messing it up is also connected to not knowing exactly what is ahead, and this risk seems to increase as the building process becomes more complex. In this respect, even the task of assembling prefabricated elements implies a risk that calls for skill and judgement.

The ability of craftsmanship to produce a certain result under uncertain conditions also implies an element of *improvisation*. While improvisation in this setting means dealing spontaneously with situations that arise, it does not mean being unprepared. On the contrary, improvisation in the building process is something builders should be well prepared for. When a carpenter sets out to build a house, he/she cannot know all the challenges that will occur further down the track, but he/she will have already built so many houses that he/she will have a certain idea of what to expect, and will trust that he/she will make the right decisions along the way, even if he/she cannot foresee all these decisions. The carpenter's skills, experience and preparation become *improvisation potential* (Jørgensen 2004[r]) – the potential to make the right decisions and perform the right actions at the right times during an unpredictable process. Improvisation along the way, involving finding solutions to problems as/when they occur, makes it possible to produce even and predictable results from uneven and unpredictable situationa. This is workmanship of uncertainty.

Workmanship of uncertainty also implies planning – not necessarily planning in terms of articulating the finished state of the building (as in an architect's drawing), but planning in terms of looking ahead, beyond the next step, to find a sustainable way forward – planning in terms of discerning the way, rather than articulating the result, as distinguished by Ingold (2013:109–11[r]). The ability to plan is part of improvisation, as it is part of any craft. At a large building site, the ability to plan stands out as even more essential than it might otherwise be for a craftsperson working alone.

Building a house is rarely a solitary activity; rather, it typically involves teamwork. In the present case, more than 50 builders were engaged in work at the building site. The community of builders solved problems, improvised and produced steady results, because they worked in uncertainty. Their ability to succeed depended on their ability to collaborate, learn, plan and improvise as a community of practice (cf. Wenger 1998[r]). This required a certain level of organization.

The community of practice was also essential for managing the different skill levels between builders. Builders' concerns with respect to their skills often relate to fears about becoming assembly workers, but losing a community of practice may be equally detrimental for their skill development. Building skills are learned and practiced (trained) through work at the building site. The apprentice learns through active participation: doing the practical work and making mistakes while being guided and corrected by senior builders on site. Also, after the apprentice period, training continues through engagement with actual work. It is the collective of builders that develops new builders – enabling them to observe and learn from more experienced members of the community – through the combined efforts of colleagues in the community of peer practitioners (Søraa et al. 2017[r]).

Craftsmanship in the Era of Technologization

Understanding craftsmanship in technologized building projects calls us to inquire into the nature of the technological more closely. In particular, the aspect we might conceive as machine technology might be useful for the craft perspective. A machine is defined as "an assemblage of parts that transmit forces, motion, and energy one to another in a predetermined manner" (*Webster's English Dictionary*). While a machine is often understood as one particular solid entity, such as the engine of a car or a robot at a factory, it can also be understood more abstractly, as a principle. However, there is always design behind it: the dictionary points out that a machine is "a constructed thing whether material or immaterial." The term can also be used more metaphorically to describe "a group of people who control and organize something," as exemplified by "Churchill's war machine" (*Oxford English Dictionary*). The technologization of the building site implies the introduction of machines as entities; but more importantly, it makes the more abstract principle relevant, as the building process is organized as an assemblage of parts and people that work together in a (more or less) predetermined manner.

One characteristic of the machine – be this an entity or a principle – is the *predetermined manner* in which it works and is expected to produce results. From the point of view of craftsmanship, this is what links the machine to workmanship of certainty. Ingold's (2000:304–8[r]) deconstruction of the industrial production machine throws light on this: in the old manufacturing workshop, the craftsperson would guide the tool with his dexterous hands, in interaction with the material. With "machinofacture," the tool is guided by the machine, as the edge of a carving knife or the spindle of a loom (the "working-point") is mounted on a moving mechanism. As the movement of the working-point follows a set course – one that is fixed in advance by the machine's design (cf. Ingold 2000:296–306[r]) – a particular kind of certainty is introduced to the work, even if errors might still occur. Further, the machine implies a particular instrumentality, which is separate from the experiencing human hand and sensibility (cf. Bruzina 1982:167[r]).

Ingold's argument suggests an opposition between the craftsperson, who is "immersed" in sensuous engagement with the material, and the machine operator, "whose job is to set in motion an exterior system of productive forces, according to principles of mechanical functioning that are entirely different to particular human aptitudes and sensibilities" (Ingold 2000:295[r]). Still, he does not suggest a fundamental duality between the human operator and the machine, as the operator should be seen as part of the machine (transmitting force, motion and energy), in addition to the workpiece (following the argumentation put forward by Relaux in 1871[r]). As part of the machine system, the human operator can be said to be in a different relation with the machine; it is not the machine that is serving the human, but the human operator serving the machine system (as pointed out by Marx 1930:451[r]).

Marx describes a similar role for human workers in the pre-industrial manufacturing workshops, as "the living mechanisms of manufacture" (1930:356, 451[r]; Ingold 2000:309[r]). The idea of humans serving machines becomes more obvious as the manufacturing workshop is turned into a factory hall in which lines of machines form a single production system. The archetypical example is Ford's plant at Highland Park, where a great number of machines were coordinated into a production line transforming raw steel bars into finished Model T cars. The production and transportation of steel into the plant were coordinated as parts of the same machine system, along with the workers on the production line. This plant represented the start of what was a few years later called *mass production*.

Mass production is characterized by a great number of similar products being pushed forward along the production line. The focus is on large quantities, minimal costs and continuous operation of the production line. Work at each work station should be so simple that a worker can be trained for the task within minutes. Thus, workers are not only parts of the machine system, but *replaceable parts*, in stark contrast to the craftspersons of manufacturing workshops. The activities of mass production workers are limited to the monotonous and predetermined tasks of the workstation; they are not included in planning, nor do they make any other contribution to improving production. The slightly inhuman aspect of mass production work has been caricatured in movies such as *Modern Times* by Charlie Chaplin, forming a clear opposition to the rather romantic view of craftsmanship presented by Ingold.

Lean production replaced much mass production in the car industry during the 1990s, and is currently becoming integrated into other industries. Lean production systems tend to be coordinated in such a way that they align with understandings of a machine, as both an abstract principle and a metaphor. "The Toyota machine" is similar to "Churchill's war machine," as suggested in the title of the book that opened the world's eyes to lean production: *The Machine that Changed the* World (Womack et al. 1990[r]). This book presents the principles that developed Toyota from almost nothing after WW2 to the largest car producer in the world. The Toyota production system has some different properties than mass market production systems, also when seen from the perspective of the workers.

Lean production is more than a production system; it is also a different way of thinking that requires penetration throughout the entire organisation in order to work. For workers, lean production implies a different role for worker groups, giving them more responsibility and multiple functions in the production process than what is otherwise offered to them in mass production systems (Melles 1997[r]). It moves from a "push system," wherein products and components are pushed down an assembly line, to a "pull system," wherein only the products and components that are asked for are delivered to each station. "Just in time" (JiT) delivery is an essential aspect of lean production and implies the tight involvement of external suppliers. This calls for a different relationship between producers and subproducers, wherein a strict contract relationship allows for a trust-based relationship founded on a sense of shared destiny. This sense of shared destiny is also said to characterize the relation between workers and the company at Toyota, as the workers are often employed for life.

With JiT there are no reservoirs of components piling up at workstations, as buffers. This implies the constant risk of stops in production if a component does not arrive in time, but such risk is actually said to make workers and producers more alert (as we saw in workmanship of risk), contributing to fewer stops. The build-up of spare components that is so typical of mass production is, within lean, considered a form of waste (called *muda* in Japanese). Unnecessary use of space, time and movement are also forms of *muda*. Another essential term in lean is *kaizen*, referring to the philosophy of continuous improvement. In a lean production system, when a mistake is detected, the assembly line is stopped and the source of the problem is tracked down and removed. This process actively involves all workers and any worker is allowed to stop the production line; in mass production systems, only production leaders are entrusted with this task. *Kaizen* significantly reduced the time that Toyota's production lines stood still, as the causes of stopping were continuously removed. Another essential term in lean is *genchi genbutsu*, meaning something like "go to the right place and see." The idea here is that decisions should be made as close to the actual work as possible – normally in the production hall – and leaders should spend time there, rather than at the distant office. As variations of the lean production philosophy have been introduced at other car producers, the costs of production have significantly reduced. For example, Porsche was able to reduce its production costs per car by 53 percent by adopting lean production techniques (Khattak and Sharwar 2014[r]). However, while achieving high customer satisfaction, lean production has been criticised for not sufficiently considering worker satisfaction (Babson 1993[r]).

Lean production principles were first introduced to the building industry under the description of *lean construction* (Koskela 1997[r]). In contrast to cars, which are produced in great numbers, building projects are typically bespoke projects. They are also more stationary and take more time to complete. For these reasons, lean philosophy had to be modified to suit industry needs. But the fundamental principles of lean remained: *kaizen*, constant learning; *muda*, elimination of waste; *JiT*, just in time delivery; and genchi genbutsu, worker involvement. In lean construction, worker involvement implies significant involvement in project planning, as every project needs to be planned in a more unique way than in car production. The *Last Planner System* is a systematic approach to construction planning that is commonly associated with lean construction, involving regular meetings with workers. At Moholt, a planning system called *Involved Planning* was developed to take advantage of the Nordic model of work and to involve the workers to an even greater extent than was otherwise possible through the Last Planner System (Andersen 2012[r], 2017[r]). The practice at Moholt showed traces of Volvo's *Reflective Production* program, which was also developed within the Nordic model and emphasised workers' involvement in planning to ensure meaningful work situations (Ellegård 2007[r]). Similarly, over time, Toyota's production system became more worker-focused than the original customer-focused system that served as the model for lean (Pil and Fujimoto 2007[r]).

Lean building at Moholt

The Moholt project followed a specific principle within lean construction called *TAKT*. TAKT was developed by Porsche Consulting[2] and adjusted to fit Norwegian work life. When the building work started, there was much excitement as to how the TAKT model would work. This was the third building project in which the company had used this principle. In their first attempt, they had not managed to maintain the required pace of work, but many essential lessons were learned from the problems that occurred (Andersen 2012[r]; Khattak and Sarwar 2014[r]). The second attempt was executed more smoothly, but was still not perfect (Mordal 2014[r]). By the time they were preparing for the third attempt, the workers had gathered so much experience that they hoped to hit the mark properly.

With TAKT, the entire building process was structured as a factory hall – an assembly line through which objects being built moved from work station to work station, where the necessary operations were-conducted. At the building site, it was the workers who moved through the building, resembling a production line, while the building stood still. The moving teams of builders were called "wagons," as they moved through the building like wagons in a train. The wagons typically consisted of two to four builders performing specific operations. In total, twenty-three wagons moved through the tower blocks at Moholt, covering all operations, from putting up structuring walls to cleaning the finished rooms. Each wagon completed one storey of a single tower in one week, implying that the towers were built at the speed of one floor per week. When wagon one fished the first floor, it would move up to work on the second floor while wagon two would move onto the first floor. The week after, wagon one would move to the third floor, wagon two would move to the second floor and wagon three would start working on the first floor. In this way, the process progressed until all twenty-three wagons were engaged "in the train." Once the first wagon finished the top floor of the first tower, the "train" would move on to repeat the process in the next tower, until all five towers were complete. Every wagon used forty weeks to move through the entire building complex, with the last wagon starting and finishing twenty-three weeks after the first.

When the concrete foundation was in place, workers started to assemble the prefabricated elements that made up the outer and inner walls and served as a carrying structure for the towers. When the roof was tightened and the wood dried, work started inside the building. This preparation was conducted by the first wagon. The second wagon consisted of carpenters, who carried out the timber work on the floor. The third wagon installed plumbing, whilst the fourth installed the main ventilation. The fifth and sixth wagons installed electric gates and cables, respectively. The seventh installed insulation and plasterboard, and the eighth and ninth wagons put up the inner roofing. The tenth installed more ventilation and plumbing. The eleventh put up more roofing and

2 https://www.porsche-consulting.com/en/services/industry-expertise/construction/.

inner cladding. The twelfth laid the floors, and the thirteenth wagon painted. New wagons with new tasks continued to move through the towers until the twenty-third and final wagon, which consisted of cleaners, prepared the building for handover to the client.

During this period, the builders found ways to be more effective and to build faster, according to the *kaizen* principle. As the speed of the train was fixed to one floor per week, increased efficiency was "cashed out" by gradually reducing the number of builders in each wagon. During the building time, we saw fewer and fewer builders in each wagon. Reducing the number of builders in different wagons was a common topic at weekly meetings. Builders removed from a particular wagon would be given other tasks on site or added to other wagons later in the train. When this process worked smoothly, it could radically improve building efficiency; but it was also quite vulnerable, as it depended on tight coordination. Delay in a single wagon could halt the train and stop the building.

Looking at the building from a distance, over time, we formed an impression of the building site as a gigantic machine, with a production line that moved systematically through the tower blocks, one floor per week, like an old steam train with the sound of carpentry. It was constantly fed stacks of plasterboards, pipes and other material. At regular intervals, the machine stopped and builders came out for their nine o'clock coffee breaks and lunch breaks, before they – and thus the machine – moved on. In this way, the large machine moved rhythmically according to the predefined movement of the schedule, just as one would expect from a production machine.

Workmanship of Uncertainty in the Machinery of Building

What was the role of craftsmanship and builders in the machine building at Moholt? Looking at the steady movement of the wagons from a distance, we imagined that the builders were playing the role of cogs in the machinery, striving to work according to the predefined course as smoothly and predictably as possible, not unlike the machine operators of mass production. Being inside the building, observing a single wagon in action, we saw carpenters, painters and other craftspersons doing handiwork. The carpenters were happy to have the floor to themselves, without having to step over plumbers or wait for electricians to install cable gates – situations that were apparently quite common at other building sites, but which the TAKT machine had ordered. Observing their work, we saw that plasterboards and listings were cut by hand and put into the timber frames with screwdrivers; measures were made with rulers or by eye; paint was put on the walls by hand. No robots or production machinery were present inside the building. Seen in isolation, the work on each floor resembled old fashioned craftsmanship, characterized by workmanship of risk. The craftspersons seemed to resemble "the living mechanisms" of manufacture more than "cogs" in the machinery of mass production; they were organic, more than mechanic.

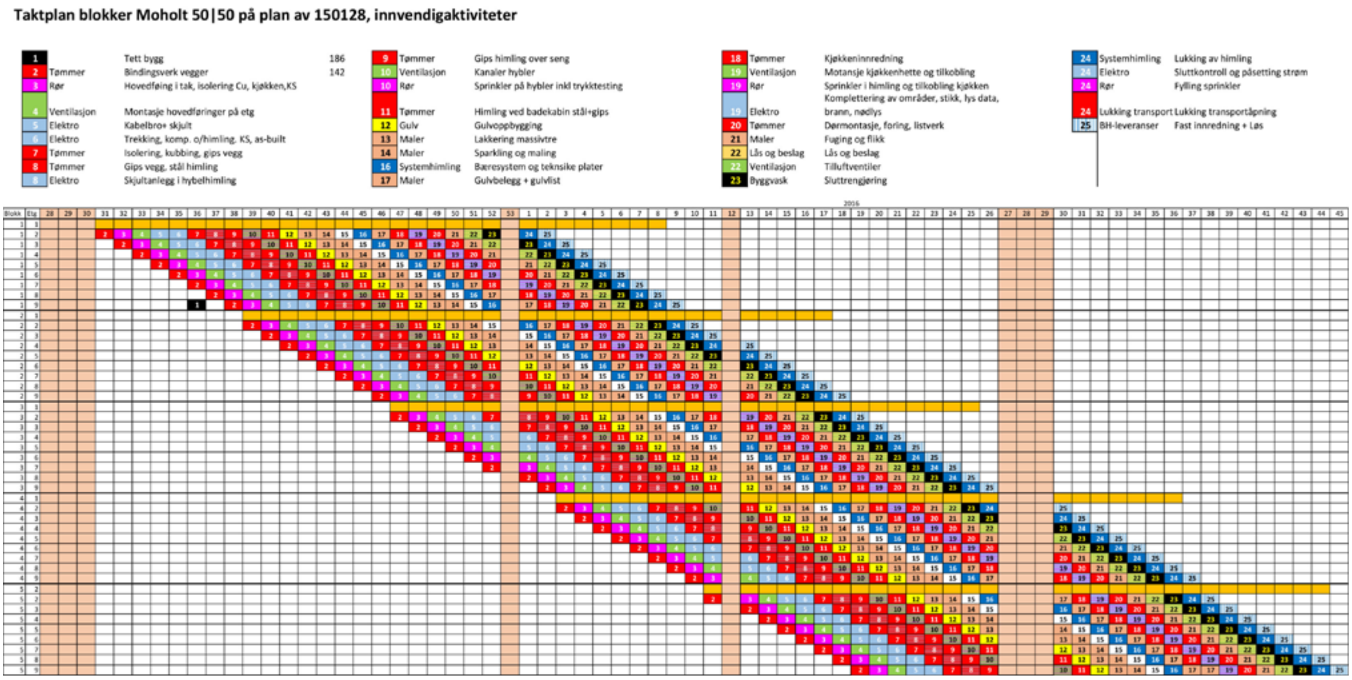

Figure 2: The Gantt diagram shows the plan for the building process. Horizontal lines show time, squares equal one week and vertical lines represent tower floors. Each wagon has an individual number and each craft an individual colour; one coloured field is the work of one wagon in one week. It might be difficult to see all the details in this image, but the idea is to show the complexity and general movement of the whole system, as a train working its way diagonally down the diagram. The light pink vertical lines that interrupt the general movement represent holidays; building halts for one week at Christmas, one week at Easter and three weeks over the summer holiday.

Another difference from machinery, which is routed permanently in steel, was that the character of the work changed over time. For example, the carpenters learned and found new ways of doing things (*kaizen*). After a few weeks, they stopped using rulers and cut plasterboard directly with their dexterous hands. They also had plasterboards delivered in increasingly efficient ways: rather than storing a large stack by the loading window, they spread them out in smaller stacks closer to the rooms in which they were actually being used. Even after thirty weeks, the carpenters managed to find new ways to improve their efficiency and reduce the number of workers in the wagons. As expected in lean construction, it was mainly the workers (e.g. the carpenters) who came up with these improvements and put them into effect; in this way, the workers' roles were more than simply parts in a machine.

But the builders were also less predictable than machine parts. They got sick and made errors, thus representing an element of risk for the goal of having the machine run at the exact pace of one floor per week. How was this handled? One approach was economic encouragement, requiring each wagon to compensate the subsequent wagon according to an agreed rate if they did not finish their floor in time (by Friday). Also, as their piecework rate required them to perform at pace, much of their income depended on them finishing on time. If a wagon was not finished by Friday, they had the option of working through the weekend to keep to schedule, but that option was rarely used; rather, the wagons almost always finished on time. When the builders were asked how they managed to keep the pace, several stressed that more important than the contractual arrangements was the shared understanding of how this building method worked and the *necessity* of keeping the pace. There was also a strong sense of shared destiny, as they all wanted to succeed. Thus, the different professions helped each other finish on time, and there were many informal agreements between wagons, providing flexibility by adjusting the strict schedule. For example, the electricians would allow the carpenters in the next wagon to deliver their stacks of plasterboards while they were still working on the floor on the Friday, and in return, they would be allowed to return to install the heaters after the painters had finished, later on. Such agreements were natural, given the holistic understanding of the building project and the mutual interdependence of the workers involved (Andersen 2017[r]).

The flexibility of the builders was absolutely necessary for the wagons to move at the right pace. Our impression from the building site was that much of the work – particularly for the crew leaders – consisted of solving the more or less unforeseen problems that occurred each day. There were many sources of unforeseen events; some were due to the human nature of the builders, while most had other causes. Such causes could include surprising discoveries made during groundwork or rough weather conditions. For example, strong winds could stop the building by preventing cranes from lifting large prefabricated elements in place, as the winds would blow these elements away, like kites.

The most important source of uncertainty was the JiT delivery of materials, components and services. The building plan was vulnerable, as it presupposed that everything would be delivered to the place in which it would be used at the time at which it would be needed. On a Monday morning, when the carpenters in wagon seven would be starting to put up the walls for fire protection on the fifth floor, the stack of plasterboards would be there, ready for use, as it would have been delivered through the window hatch on the Friday evening. The following week, the same delivery would come through the window hatch onto the sixth floor, and so forth. For this system to work, the plasterboard supplier needed to perform precise deliveries. If the boards came in too late, the entire train would halt. Thus, the producers and suppliers were enrolled in the pace of the building machine, just as the builders were – preferably by sharing the sense of a common destiny. This was managed sufficiently well by the suppliers who collaborated directly with the building project, but these suppliers also depended on third parties that were one step further away; further, some of these suppliers depended on even more distant suppliers. The more distant the supplier from the building site, the less likely they were to appreciate the importance of JiT delivery. Having suppliers and producers understand the principles of lean building and realize the importance of JiT delivery was said to be one of the most challenging tasks at the building site. Suppliers who were out of pace seemed to be the most common source of problems. This vulnerability called for the community of builders to improvise.

Small delays were handled by borrowing from other wagons, reorganizing the work order or finding useful things to do while waiting for a delivery. Major delays, however, needed major transformations in the plan. For example, a flood during the winter of 2016 destroyed the factory that was producing windows for the tower blocks. Suddenly, no more windows were coming and no new deliveries were expected for three months. This called for a series of sudden rearrangements to the work order.

Deliveries not only caused problems when late but also when too early. If the plasterboards for the carpenters in wagon seven arrived a week too early, the boards would fill the workspace and cause a mess for the electricians in wagon six. There was simply no place to store materials that arrived too soon. Such deliveries also required personnel to unload the truck as it arrived, and no one was happy about dropping out of their wagon to handle such tasks, risking a delay in their scheduled work. The message that deliveries should not arrive early did not reach all suppliers. One example pertains to the delivery of kitchens from an Italian producer. The exact date for the delivery was set according to the building plan and agreed with the kitchen supplier. The drive through Europe would take several days and a truck was sent from the factory at a precise time in order for it to reach the building site at the right moment. Once on site, the kitchens would be unloaded to a temporary storage. But miraculously, the truck transporting the kitchens arrived several days ahead of schedule. In order to manage this, the truck driver, who had been hired for the occasion, must have broken all possible speed limits and neglected all possible requirements for resting time. He probably expected honour for arriving ahead of schedule, but instead was made to wait until the next day, when the truck could be unloaded. The truck driver was very unhappy, but unloading the kitchens ahead of schedule was simply not possible.

Yet another source of uncertainty pertained to the periodic building errors. Although the number of errors at this building site was said to be exceptionally low, they did still occur, and they required improvisation. For example, in one instance the attachment points for the lift system in one of the towers proved sixty centimeters off, and this prevented them from being installed. The carpenters' and lift fitters' drawings had not been properly coordinated, and showed different heights. In a complex building project, it is difficult to avoid such mistakes, but it seems that they can be handled by builders who are able to work in uncertain conditions.

Observing the building over time, we saw an almost constant stream of unexpected problems and builders engaged in solving these. This lends yet another dimension to their workmanship of uncertainty, implying that they held more than skilled, flexible and learning roles inside a larger machine. The craftspersons also worked *outside* the machine, as "machinists." Viewed as a machine, the building process at Moholt was not a modern engine that ran smoothly independently; rather, it was an old steam engine with all kinds of whims. The constant fettling and adjusting needed to keep it running called for the craftsmanship of a skilled machinist. The lean construction system at Moholt was a machine that required constant attention of a quite sophisticated kind, calling for craftspersons to improvise, communicate and rearrange plans.

Planning

The plan for the building process at Moholt resembled the outlines of a machine: when set in motion, the causal relations between the rubrics of the Gantt diagram produced the desired results with a similar form of causality as when the parts of a production machine work together. The "building machine" ran smoothly only when the builders were able to follow the plan with precision and fettle and improvise to keep it running. But this was not enough. The plan also needed to be "buildable." Thus, it was essential for the builders to be involved in the planning process.

As described above, the planning practice at Moholt was called Involved Planning, and it had been developed within the company in collaboration with the researcher Lars Andersen (Andersen 2012[r]; Veidekke 2011[r]). The system built on the principles of lean construction and the Last Planner System (Ballard 2000[r]), but was more oriented towards the Nordic model of involving employees in decision processes and implied more worker participation in planning. The Involved Planning system included the builders throughout the entire building process, forming a systematic approach to all levels of planning, from the general project design to the day to day planning. Builder representatives were involved in much of the planning that had traditionally been left to architects and engineers. At the other end of the spectrum, much of the planning that had traditionally been done by builders on site was moved into the barracks meeting room and formalized.

The lean construction system required a lot of detailed planning. As with most building sites, Moholt was initially planned by architects, and this initial plan was later developed into more detailed technical plans that were eventually made into specifications for each craft involved (e.g. plans for the electric system, the plumbing and ventilation systems, the firewalls, etc.). These more detailed plans were developed alongside plans describing the building process. Both kinds of plans needed to interact perfectly.

The structure of the tower blocks consisted of prefabricated wooden elements that were routed by robots at a factory and joined together on site. Within these elements, the holes for cables and pipes were also routed by the robots. The order in which the carpenters, plumbers, electricians and painters worked had to be reflected in the position of these holes. For example, because the wagon with the plumber came before the electricians, it was essential that the holes for plumbing were located inside the holes for the electric cables, so the sewer pipes would not block the electricians when it came time for them to pull their cables. Not only the holes, but a myriad of building logistics needed to be incorporated into the elements, together with detailed specifications for each of the professions involved. All this was sorted out and fed to the robots before any of the actual building work started. Thus, the participation of builders in the early stages of planning was essential, as only they knew their work in sufficient detail to feed into completely buildable plans. In these early meetings, the rough order of the building process – as shown in the Gantt diagram – was planned. However, much still depended on factors that could not be easily foreseen, and thus more had to be planned at a later stage.

Planning meetings were arranged throughout the building process. In these meetings, builders, leaders and engineers would meet to plan work for different periods of time, such as two months, two weeks or one week. For example, the foremen and crew leaders would meet every Thursday to plan for the next week. Every Monday, the carpenters would meet to plan for the current week. During these meetings, plans would be made according to the information at hand; the closer the meeting was to the time planned for, the more up-to-date the information would be. Therefore, it was important that planning was conducted at the right times, often as late as possible, to ensure the best information was available. For example, on Thursdays, it would be possible to predict rather accurately which builders would be present the following week and to plan the task for each builder in detail; on Mondays, it would be possible to know (for example) who had an appointment with the physiotherapist on Wednesday at twelve o'clock. Such details could not have been planned two months in advance.

Planning has always been part of craftsmanship and improvisation, in terms of "looking ahead," and it stands in contrast to the articulation of the finished state that characterizes architectural drawings. While architects and engineers traditionally generate articulate plans, builders – as craftspersons – tend to plan along the way, whilst embedded in the actual building work (Ingold 2013[r]). At Moholt much of this planning was formalized in regular meetings, in which the builders took part in terms of both looking ahead and articulating the finished state. All in all, the builders spent more time making plans in the meeting room than they would have in a traditional building process. Still, the builders seemed to agree that they actually saved time by doing this, as the building went more smoothly, with fewer errors. Also, participation in planning was said to contribute to a feeling of having a say in their working situation and being included more fully in the project.

To plan in such detail and with such accuracy as the lean construction system required, it was essential that the crew leaders who were coordinating the plans knew the builders well. A crew leader stressed that they could never have built in this way without permanently employed builders: "It would be impossible to have this matrix work if I did not know the lads," he commented one Thursday whilst organizing tasks and people for the following week. "One working hour is never similar to another working hour," he said. "The difference can be as much as a hundred percent." Also, when unforeseen tasks arose, he needed to know exactly who could handle that particular job and who could not. For example, he knew that "Jon" would go mad if he had to screw roofing for four weeks in a row, while "Paul" would actually prefer to have the same task for months. He also knew that "Simon" needed a proper task with good piecework pay, following his efforts in the basement. And when "Peter" came to him with an aching back, the crew leader was able to find him alternative tasks that would not cause him greater injury. Because the crew leader knew "Peter" well and could constantly adjust the plans, it was possible for him to negotiate the situation and avoid losing a good carpenter to sick leave. Had he not known the builders, he could not have managed this. This day to day negotiation of solutions suited the builders and was necessary for the successful implementation of the project. Solutions could not be standardized as in mass production, as the matrix of builders and tasks had more in common with a living polyphony than a Gantt diagram. They were more like crafted items – tailor made for each situation and flexible to accommodate moment to moment adjustments in line with unpredictable occurrences. Managing the building project required constant attention, as the result was constantly at risk. In this way, even the day to day planning on site was an aspect of workmanship of uncertainty.

Day to day planning of work tasks was not the responsibility of the crew leader, alone. It also required active contributions from the entire community of builders. When asked directly if he could have managed this process with casual workers, the crew leader asked how we thought Rosenborg, the local football team, would have performed if they had relied on hiring players from match to match. "Impossible!" he said. This analogy reminded us that the day to day fettling of the work matrix required more than knowledge of the players; the players took active roles in the polyphonic dialogue we call a community of practice, learning and developing together, and handling uncertainty together.

Towards Sustainable Building Crafts

Above, we described the Moholt building project as one in which skilled builders interacted with each other, suppliers, the materiality of the building site and the robots that prefabricated the elements. The builders formed a community, applying their skills both within and outside the complex building system and constantly reformulating plans. In our eyes, this building project had some properties that pointed to a possible path for future building projects. Could Moholt represent a sustainable path for building crafts? We approach this question in terms of the three forms of sustainability defined above: cultural, social and environmental sustainability.

Cultural sustainability concerns the continuation or preservation of craftsmanship in terms of skill, culture and tradition. The increased use of prefabrication and robot technology is connected to a concern among builders about losing their craftsmanship and status as craftspersons and becoming "assembly workers." The negative connotations that are attached to this term can be linked to its association with mass production and assembly workers spending their days doing monotonous tasks it takes them fifteen minutes to learn. The preservation of craftsmanship does not seem complementary to the idea that builders are replaceable parts in the machinery of building. In this sense, lean production models may be relevant, as they are generally more focused on the skills of builders and other workers. But lean has also been criticised for placing too much focus on organizational performance at the expense of worker status (Pil and Fujimoto 2007[r]). In this respect, Volvo's *reflexive production*, developed within the Nordic model, may serve as an alternative source of inspiration. At Volvo's experimental Uddevalla plant, the same team of skilled workers assembled the entire car, in sharp contrast to the task breakdown in mass production and lean systems. The car stood still while the workers moved around it, using mostly handheld tools (Ellegård 2007[r]). In this production system, the development and use of skills was more aligned with traditional craftsmanship, and this led to increased worker satisfaction (ibid.). We see some clear parallels between the system at Uddevalla and the Involved Planning principle at Moholt, even though the latter explicitly adhered to lean, with the TAKT principle producing an "assembly line effect" throughout the buildings. The TAKT system was welcomed by the builders, as it gave the different wagons good working space by allowing them to have entire floors to themselves. But it also involved monotonous tasks for the builders. For example, even though most carpentry jobs began as craftsmanship of risk, these same work operations were repeated over forty floors, resembling the production lines of mass production. The crew leaders told us that they strove to rotate the builders in order to prevent them from performing the same task for too long. But not all of the builders wanted variation; some actually preferred the monotony of nailing identical plates of plasterboard for forty weeks in a row. Seen in this perspective, the idea that there is one narrow understanding of craftsmanship seems futile. At the building site, we saw a polyphony of skills in action, but as the builders worked in a community of practice, they complemented each other. The "polyphonically skilled" community may be a more fertile unit for analyzing the cultural sustainability of craftsmanship than the skilled individual.

Is craftsmanship threatened by automation? Although the builders at Moholt had concerns about becoming assembly workers, the constant uncertainty inherent in building projects made them rather certain that they would *not* be replaced by machines. Their skills as builders enabled them to handle unforeseen situations that, to date, no machine has been able to. For this reason, they seemed to believe that human craftsmanship had a future even in a world of machines, emphasizing elements we associate with workmanship of uncertainty. To the builders, the traditional skills of workmanship of risk were still needed, but their nature seemed to be transforming in line with developments in building technologies. In addition, they felt that automated production technology and lean construction systems put more emphasis than traditional building on the ability to *work with machines* in complex, machine-like construction systems. We describe this as working simultaneously *in* the machine as craftspersons and *outside* as "machinists" and planners, navigating uncertainty; these builders *were* the machine as much as they were running the machine. Such systems required the builders to work with not only machines, but also other humans in functioning communities of practice. This last issue was said to be essential for handling uncertainty, and an essential aspect of workmanship of uncertainty. If the practice at Moholt pointed to a culturally sustainable path, this path was not a museum-like preservation of old school crafting and building techniques; rather, it depended on sustainable communities of practice involving learning, using and developing high-level crafting skills in a transforming world.

As for social sustainability, which path did Moholt point to? When the first attempts at lean construction were introduced in Norway, there was some critique from labour unions – for example in a document published by NTL in 2011: "Yes to participation and trust. No to lean." Some argued that the Nordic model of collaboration could be threatened by lean if the autonomy of workers was lost when standardized, short-term decision processes replaced the Nordic model's participatory decision processes (Ingvaldsen et al. 2012[r]). However, they also pointed to the possibility that lean principles could be adapted to accommodate the tradition of participation in Nordic work life. The system of Involved Planning can be seen as seeking exactly that, as it involves builders in the planning in a more fundamental way than in some versions of lean. For example, the lean principle TAKT, which was applied at Moholt, was said to be very different from the German version, which had a more top-down command structure. Lean and similar principles should be discussed in relation to the cultural circumstances they are adapted within. In this case, the Nordic model of work played a key role.

Seen from the perspective of builders and craftsmanship, another major issue regarding lean and lean-like practices is the business model of outsourcing that has come to dominate the building industry during the past decade. This model relies on casual workers on short-term contracts to achieve flexibility for the company office. The burden of uncertainty connected to winning or losing contracts is thus carried by the builders, who go from being permanent employees to not knowing whether they will have work the next day. This business model creates conditions for the builders – both Norwegian and immigrant – that do not appear sustainable in a social sense. The use of casual workers invokes the logic of mass production, wherein workers are seen as replaceable parts, rather than able members of a skilled community. The practice also seems to put the quality of the building at risk. If part of a company's workforce is temporal labour, then the quality of production can be secured by various control systems (as exemplified by Pil and Fujimoto 2007[r]). However, if almost one hundred percent of a workforce consists of temporal labour, the community of practice is destroyed and, with it, the level and development of the workers' crafting skills. The role of the community is particularly obvious in complex building projects. Builders at Moholt stressed that they could not have built in that way if they had not been permanently employed builders who knew and trusted each other. This was also key to the company's competitive advantage: by relying on a steady community of skilled workers that had been trained by the company, the company was able to achieve a high level of skill and handle complex constructions, enabling them to build quickly and with few errors, and thus to compete with companies relying on cheaper, temporal labour. In contrast to temporary workers, who provide certainty in an uncertain situation by living uncertain and precarious lives, a community of permanently employed builders provides certainty through workmanship of uncertainty. Although some critiques of lean construction might hold weight in this scenario, lean seems far better suited to accommodate sustainable social conditions than outsourcing, as it requires skilled communities and thus permanent employment. In combination with Involved Planning, it also seems to take a step towards the Nordic model of worker involvement.

Finally, lean building practice is also relevant for environmental sustainability, as the constant focus on eliminating waste (*muda*) contributes to a building process that minimises material use. Further, the ability to build with accuracy and few errors is important for achieving low-emission buildings (such as the Moholt tower blocks), which are characterized by technological complexity, a need for high accuracy and tightness and great negative consequences for building errors (for example, in terms of moisture damage). The engineer responsible for the environmental aspects of Moholt stated that they would not have been able to achieve these results without the active involvement of the builders. Other companies might have been able to achieve the same results in other ways, but when the builders left Moholt, they had managed to finish on time, below budget and apparently without serious errors. Also, they had avoided major injuries and had almost no short-term sick leaves. The leaders told us they were certain that they would continue to develop down this path.

A general conclusion regarding craftsmanship is that high-tech building projects that are increasingly characterized by prefabrication and complex building systems do not diminish the importance of high-quality craftsmanship. Rather, the quality of craftsmanship may be even more important, though it is transformed into a craftsmanship of uncertainty, with greater emphasis on improvisation, planning and collaboration. These skills should be approached as collective skills, and the results they produce should be subject to the same kind of professional pride as more classical skills. Thus, technologization does not necessarily imply a loss of craft

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