More Than Meets the Eye? Robotisation and Normativity in the Dutch Construction Industry

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Abstract. Construction robots are becoming more common in the Netherlands, but remain rarities in contexts aside from state-of-the-art factories owned by wealthy or technologically-orientated companies. In its current state, the construction industry would have to change significantly to make room for robots. To understand whether these changes are welcome or not, this paper presents qualitative, exploratory research concerning 10 stakeholders' perspectives of robotisation and construction robots in the Dutch construction industry.

Keywords: robotisation, stakeholders, industry 4.0, construction industry, ethics, health and safety, trade unions

1. Introduction

During one of the first interviews we conducted for this study, we asked a participant, who works at 3D-printing company, to define robotisation. Without hesitation, they stated 'that robot' then pointed towards a mechanical arm, standing in the corner of their lab. At the risk of over-interpreting their statement, their readiness to define 'robotisation' qua a physically present and operational robot highlights something worth discussing. Thanks to innovations in additive manufacturing, computer programming and industrial engineering, their company has created a mechanical replacement for human concrete workers, that never needs vacation time or suffers from backaches (Contant, 2014). The robot manoeuvres on a linear track and funnels concrete from its arm to build 3D objects for construction purposes. Although it may outperform human workers, it must remain within a controlled, sheltered setting while it works.

If everything stays the same within the Dutch construction industry, this robot and others like it will likely remain rarities. To make room for them, many aspects of construction work need modification. Whether stakeholders see these changes as welcome remains largely unknown. Although substantial research has been conducted on robots' negative and positive impact on working conditions in other industries, accounts that focus on construction are scarce. This holds true in countries aside from the Netherlands, but for this research paper we exclusively focus on the Dutch context. After

providing a state-of-the-art literature review on construction robots in the Netherlands, this paper will present exploratory, qualitative work concerning stakeholders' perceptions of these technologies and robotisation. It will put forward the following claims:

1. The term 'robotisation' carries significant normative weight within the Dutch construction industry and represents a desirable or undesirable progression away from the status quo.
2. Many aspects of the Dutch construction industry require modification to accommodate robots
3. According to our participants, increased robot uptake will have multifarious positive and negative affects on the construction industry.

2. Literature review

Construction robots are becoming more common in the Netherlands. In the past three years alone, two of the largest Dutch construction contractors, BAM and Bruil, opened their first robot-centred factories[1,2]. Nowadays, many off-site manufacturing plants in the Netherlands also (partially) rely on robots, to produce components for construction purposes such as timber and welded steel. Several, small-scale but noteworthy start-ups have increased their robot uptake too[3]. Including MX3D who received significant media attention over the past two years, after they employed custom-built robots to complete a steel, pedestrian bridge ready for installation on Amsterdam's Oudezijds Achterburgwal canal (Buchanan and Gardner, 2019). These robots almost exclusively operate behind closed doors, in contexts more akin to factories than construction sites. Like most other industrial robots, they were created to perform structured activities in enclosed spaces, built to accommodate them.

When compared to factory-floors, construction sites are hostile environments for robots. Every construction site changes from day to day, and has its own, unique environmental hazards, including heavy moving objects and varied geographical elevations. Also, human workers are unpredictable. Whereas one may prefer to carry loads under their left arm, another might move the same object by perching it on their right shoulder. It is (currently) impossible to account for every action workers might perform on construction sites, as human behaviour varies massively between individuals. Designing robots to safely operate in dynamic environments of this kind is challenging, as it is necessary to equip them with state-of-the-art software and hardware that allows them to process sensory data (Helm et al, 2014). For these reasons, it is unlikely that robots will appear en-masse on construction sites on short notice.

Aside from the exceptions mentioned earlier, Dutch construction companies tend to avoid robots. It is difficult to find reliable numbers, but current figures suggest that only 3% of construction companies employ robots in some capacity. A percentage that stands well below the production sector's national average (29%) (de Leeuw, 2019).

[1] https://www.baminfra.nl/nieuws/primeur-weber-beamix-en-bam-infra-openen-3d-betonprintfaciliteit

[2] https://www.bruil.nl/prefab-printing

[3] For instance, RAMLAB, MX3D, Cybe, and Vertico

Of course, companies cannot purchase new technologies unless they are available on the market. This issue has undoubtedly stalled uptake rates in the industry, as construction robots weren't available for purchase until recently. Even though vendors such as ABB, Kuka and Universal Robots are currently working to increase construction robots' availability, other factors would almost certainly dissuade construction firms from investing in robots. Among the 194000 currently active Dutch construction companies, 193000 (99%) employ less than 50 workers. And the majority of these companies are one-person operations (CBS Statline, 2020). Generally-speaking companies of this size lack the financial capital necessary to invest in robots, let alone the scientific know-how to adapt their production strategies around these technologies.

This isn't to say there's no demand for construction robots. On the contrary, the Dutch construction industry currently suffers from a severe lack of workers. While the demand for new homes, roads and civic buildings has risen over the past decade (Doodeman 2019), the number of available construction workers has decreased from 543000 in 2008 to 475000 in 2018 (CBS Statline, 2020). These decreasing numbers reflect that construction has become an unattractive profession for new workers.

When occupational hazards and health risks are taken into account, it is unsuprising that people prefer to look elsewhere for work. According to a report by Nederlands Centrum voor Beroepsziekten (NCvB) published in 2018, construction workers risk developing many occupational diseases over their careers. Indeed, construction is the 13th (out of 44) worst profession in this regard and ranks number 2 when it comes to conditions 'of posture and body movement' (NCvB, 2019). Considering that other industries facing similar problems have started to turn to robots in recent years, it seems logical for construction to follow suit.

At this point, it worth returning to our participant's remark - which we cited at the beginning of this paper. In light of the information outlined above, does their robot and others like it represent robotisation? To answer this question it is necessary to define robotisation. Or more precisely, what this term means for the Dutch construction industry. By presenting research concerning relevant stakeholders' perspectives on construction robots and robotisation, this paper addresses this task.

3. Methods

The Collins English Dictionary defines robotisation as 'the introduction of robots to carry out industrial tasks'. Before setting out to gather insights on stakeholders' attitudes towards robotisation, we were aware that this term would likely carry significance beyond its dictionary definition. As robots remain largely absent from the Dutch construction industry but have the potential to meet demands that are currently unsatisfied, we expected that robotisation would signify change to some degree for our participants. Like other words with -ation suffixes, it implies an ongoing process. With this in mind, we chose to (preliminary) interpret robotisation as the movement towards a state-of-affairs where robots are more present and operational in the Dutch construction industry. We anticipated that our participants would express their support or opposition to-

wards this process. Or in ethical terms: employ normative language to talk about robotisation and construct robots in general. Overall, we aimed to answer the following research questions:

1. How do participants working in the Dutch construction industry define 'robotisation'?
2. What normative connotations do they attach to this term?
3. What do stakeholders consider to be the advantages and disadvantages of robotisation?

We relied on convenience sampling to recruit participants, by approaching ten stakeholders we knew were active in the Dutch construction industry and knowledgeable of robotics. To ensure that our participants' interests and perspectives were heterogeneous, we contacted stakeholders representing the following, distinct groups.

Academics

Number: four

Summary: All four, leading technological universities in the Netherlands have established research projects dedicated to construction robots over the past few years. Because they have expert knowledge of robotics and the Dutch construction industry at large, we arranged interviews with academics working on two of these projects. Among them were two full professors, one associate and one assistant professor.

3D Printing Experts

Number: two

Summary: At least in the Netherlands, construction robotics and 3D-printing go hand in hand. Most construction robots found in the Dutch context are effectively programmable, semi-autonomous 3D-printing machines that can move around three or more axes. As such, we chose to speak with stakeholders from this field who work with robots.

Trade Union Representatives

Number: four

Summary: Within the literature on robotisation, authors often suggest that increased uptake in industrial robots may displace or de-skill workers (Frey and Osborne, 2017; Schwab, 2017). As such, it was important for our research to gather insights from workers on robotisation. Due to time constraints, we couldn't directly interview workers, so instead chose to speak with their trade union representatives, working for the two largest unions in The Netherlands. As these stakeholders are responsible for improving trade union members' employment conditions, their opinions at least partially reflect workers' concerns.

Due to the exploratory nature of the research, we employed a semi-structured format during the interviews. More specifically, we created a selection of open-ended questions beforehand to guide the interviews, but left time for participants to discuss other,

relevant topics. Before we began, we briefed each participant about the nature of our research and asked them to sign an informed consent slip to show that they agreed to take part in the study (which they did unanimously). After the interviews were completed, they were fully transcribed then manually coded to identify thematic similarity and differences (Braun and Clarke, 2006; Charmaz, 2014; Thomas, 2006). To preserve our participants' privacy, we have omitted their names from this research paper and only refer to them according to their occupation, coupled with a numerical value (e.g. Trade Union Representative 1). All interviews were conducted in Dutch, but quotes in this paper have been translated into English. Before presenting our results, it is necessary to state that these findings are exploratory and represent an interpretation of our participants' responses.

4. Results

4.1. What is Robotisation? (According to our Participants)

At the beginning of the sessions, we asked each participant to define robotisation. As it was our opening question, we expected largely descriptive responses from our participants. However, they almost unanimously provided accounts of robotisation that were value-laden. Before outlining these results though, we should make clear that our participants were aware of the nature of our research and knew that we were gathering insights on robotisation's normative significance. Hence, their responses were almost certainly influenced by this.

Most of our participants implied that robotisation substitutes human labor. They agreed that robots are programmable, autonomous machines that perform production tasks. Many suggested that robotisation would help ease labor shortages, by providing means to complete activities that were previously fulfilled by humans. However, their descriptions regularly veered into normative territory and served to justify or question the legitimacy of robotisation.

Around one third of our participants tailored their responses around robotisation's potential to invigorate the construction industry. Many highlighted that construction has historically trailed behind other industries in terms of productivity, because it suffers from some form of technological conservatism. Robotisation, they argued, would buck this trend and bring construction into the twenty-first century. As Academic 1 states:

> *"We do it [construction] in a very traditional way. We have been doing it the same for years. For example if you look studies on productivity and so on, you see that construction is lagging behind. There is hardly any increase in productivity compared to other industries that are fully automated or robotized".*

Aside from improving productivity, Academic 1 stated that robotisation would bolster sustainability - a relatively new concern within the production sector at large (van

de Poel, 2018). Academic 2 shared similar thoughts, but went a step further by suggesting that we, as a society, cannot afford to let construction stagnate, as productions demands are simply too high to ignore. The idea that construction needs to catch up with other industries, for its own and society's sake, was mentioned many times during this phase of the interviews. Academic 2 also mentioned the social obligation to work more efficiently, not to make more money, but to allow society to spend the saved money on more important things than construction, such as education, elderly care or climate. Indeed, participants seemed to tie robotisation to beneficial growth in general.

Of course, what's good for society - or in this case the construction industry- isn't always good for the individual. The majority of participants implied that robotisation will disrupt traditional working conditions. More specifically, they suggested that skills that were once valued in the construction industry, may become antiquated due to robotisation. Workers who rely on traditional methods to complete tasks will experience the brunt of this change. None of our participants unequivocally stated that robotisation would increase unemployment, but they did suggest that some workers will face deskilling. Trade Union Representative 1 was clear about this point:

> *"Robotisation also has consequences for the content of work. Sometimes it also has the effect that people feel that their function is being eroded, as it were, the traditional is being taken over by the robots".*

It is worth highlighting that both Trade Union Representative 1 and 2 explicitly mentioned that de-skilling may cause emotional or psychological distress for workers. They implied that robotisation may take something away from workers and create holes that were once filled by traditional labor. Traditional work, they suggest, has value beyond productivity for workers. Trade Union Representative 1 continued by giving an example involving bricklaying robots. They suggested that there's no need for experienced, human bricklayers to employ their expert skills when these machines are present. As they state, human bricklayers 'only have to clean up the mess that the robot leaves behind'. Rather than outright opposing robotisation for these reasons, they argue that these problems need to be addressed to ensure that workers can still access meaningful work in construction.

After looking over our participant's responses, we noticed that they tended to portray robotisation as something that creates new opportunities for the construction industry while limiting others. When viewed collectively, their responses implied that there's a tension between old and new means of production, as reflected by their regular references to 'traditional' manners of work. Whereas some saw this traditionalism as problematic, other recognised that it currently gives meaning to workers employed in the industry. Overall, their responses demonstrated that 'robotisation' represents a desirable or undesirable progression away from the status-quo.

4.2. Advantages and Disadvantages / Opportunities and Limitations

After the first stage of the interviews, we continued by asking our participant's more in-depth questions concerning robotisation's significance for the construction industry.

To ensure that their responses were relatively structured and prompt them to express their opinions on this subject matter, we framed these questions around the themes of "the advantages and disadvantages of robotisation". For instance, by asking them "Could you tell me about the benefits of robotisation, generally-speaking?" followed (or preceded) by questions such as "Do you also see any disadvantages?".

The majority of participants provided responses that followed these themes, for instance by highlighting that robots are expensive (disadvantages), but nonetheless lower production costs once deployed (advantages). After assessing our interview transcripts, we discovered that two other themes were identifiable, which we labeled as "the limitations and opportunities of robotisation". Our participants frequently expressed that the construction industry in the Netherlands has its limitations in regards to robots and cannot accommodate them in its current state. As Academic 1 stated:

> *"Yes, you see, construction is traditionally also a bit more conservative. [Profit] has to be achieved on projects, so you cannot innovate very easily if you always have to deliver a project. If you look at telephones or cars, they are completely engineered and optimised, and from there tens, millions are made of them, and with buildings and civil works that is of course more difficult".*

Unlike mass-produced objects such as telephones or cars, Academic 1 suggests, construction projects are unique. It is difficult to develop a one-size-fits-all approach to construction, as industry actors must deliver products (buildings, civic works, etc.) that are highly differentiated from one another. According to Academic 1, the unique nature of construction projects hinders innovation in the field. Because they are responsible for creating products that don't lend themselves to mass-production, industry actors would risk losing out financially (or otherwise) if they were to innovate their workflows. It is worth highlighting here, that Academic 1 refers to construction as 'traditionally a bit more conservative' and ties this quality to the industry's general approach towards production. For them, it seems, 'traditional' and 'conservative' mindsets are present in the industry, because contemporary material and economic conditions limit the availability of alternative means of production.

In contrast, several participants expressed that robotisation opens the door for new opportunities in construction, that could bypass or address the industry's limitations. For instance, Academic 4 highlights that contemporary construction processes are usually developed to create specific products, on a largely project by project basis. When industry actors are tasked with building a bridge, for instance, they design their production processes around this product. After the project is completed, its tailor-made production processes effectively become redundant, as they were specifically designed to fulfil one purpose, in this case, the creation of one particular bridge. Rather than continuing to follow this strategy, Academic 4 suggests that processes should take centre stage and be optimised via robotisation. As they state:

> *"We do not optimise the process, we are actually starting a new process again. [We] still place the viaduct [the product] at the centre of our industry*

and then start designing something to make that viaduct. We should start designing our processes".

For Academic 2, the construction industry should take into account available resources, for instance robots, then create production processes that harness these technologies' strengths. By recognising what robots can and cannot do, it becomes possible to design production processes around them. Rather than building twenty different bridges by implementing twenty different production processes, Academic 2 suggests that industry actors should standardise their approaches to some degree by creating repeatable strategies that utilise robots and other technologies (relevant) capabilities. For Academic 2 at least, robots provide the industry with an opportunity to move away from its focus on products over processes.

Our participants mentioned many other advantages, disadvantages, limitations and opportunities they associate with robotisation during our interviews. With this in mind, we clustered their remarks into 15 additional sub-themes listed below, which represent recurrent or significant topics that were discussed during the interviews.

4.3. Advantages

Number: four

Summary: All participants expressed their support for robots at some point during our interviews, by referencing ways these technologies could improve various socio-economic conditions associated with the Dutch construction industry. We have clustered together comments of this kind as "Advantages".

Health and Safety

Almost every participant mentioned that robots would improve health and safety to some degree in the industry, by performing dangerous tasks previously fulfilled by humans. Additionally, several participants highlighted that workers often develop chronic health condition from years of manual labor. If robots were employed to carry out strenuous tasks that contribute to these health problems, workers would benefit.

Productivity and Precision

According to many of our participants, robots stand to improve productivity in the construction industry, as they can produce resources faster, more effectively and on a larger scale than humans. Also, robots are considerably more precise than humans and the products they create are cut, welded or sawed with mathematical accuracy. As a side-note, several participants also mentioned that robots can create unique products, including seamless 3D-printed objects, thanks to their heightened precision and ability to operate uninterrupted over long time-periods, thus addressing the demand for 'mass-customised' objects.

Costs

Many of our participants claimed that employing robots to perform construction tasks could lower production costs. They mainly justified this claim by referencing how robots improve productivity, which in turn would lower the financial cost of producing construction resources. For instance, Academic 3 references how other industries have lowered costs this way:

> *"Generally in the manufacturing industry, the costs of the products have of course gone down enormously. The more you control automatically, the more you can produce for very little".*

4.4. Disadvantages

Number: five

Summary: All participants made clear that robots may create new or contribute to pre-existing problems associated with the Dutch construction industry once deployed. We have clustered comments of this kind together as "Disadvantages".

Productivity

Whereas most participants mentioned that productivity would increase due to robots, 3D Printing Expert 1 highlighted that this isn't necessarily the case. More specifically, they stated that employing 3D-printing technology to mass-produce products is more time-consuming than relying on traditional construction methods at the moment. Overly relying on these methods then, could lead to lower production rates for the industry.

Social Acceptability

Because they are novel, largely untested technologies, many participants highlighted that people may distrust robots. It is still unclear how (or whether) robots actually add value to working environments. Indeed, workers may treat them as objects that hinder their ability to work and have very little incentive to interact with them. Additionally, Trade Union Representative 3 stated that contractors have historically shown discontent whenever they were forced to implement new technologies they view as unnecessary.

Unemployment, Adaptability and Meaningfulness of Work

As stated earlier, none of our participants suggested that robots will displace workers from their jobs. However, several did suggest that workers may fear this outcome nonetheless and therefore oppose increased robot uptake. Even if workers aren't concerned about this, some may have trouble adapting to robots, especially older people who have spent their entire careers relying on traditional construction methods. Also the risk was mentioned that robots could make the work of human workers less valuable and less meaningful, possibly leading to reduced satisfaction and sense of contributing.

Collective Labour Agreements

Trade Union Representatives 3 highlighted that increased robot uptake could jeopardise their unions' ability to create collective labour agreements on construction workers behalf. Like other trade unions, they negotiate with employers to improve employment conditions for workers. Robots are machines, and do not need representation by a union, thus reducing the reason for the existence of unions. Furthermore, companies that produce, own or operate robots aren't usually considered construction firms or indeed employ construction workers - thus they are not represented or impacted by trade unions' decisions.

Disruptive Wealthy Actors

Several participants expressed their concern that wealthy, technologically-focussed companies, such as Google, may see an opportunity in the future to disrupt the construction industry by financing 'brands' that employ state-of-the-art robots for construction purposes. As smaller firms almost certainly wouldn't have the means to compete with multi-national companies like Google, they may face difficult times.

4.5. Opportunities

Number: four

Summary: Many participants discussed how robots could provide actors with opportunities to overcome or address contemporary issues associated with the Dutch construction industry. These comments were similar to those clustered as "advantages", but focused on how actors could bypass or navigate around problematic socio-economic conditions by employing robots - rather than how robots could outright improve conditions in the industry. We have clustered comments of this kind together as "Opportunities".

Public Image and Appeal

Several participants suggested that increased robot uptake would improve the construction industry's public image. For one, it would demonstrate to external actors that the industry was attempting to improve its production methods in accordance with modern technological developments. Additionally, it could make the industry more attractive to new workers, especially young people who may see robots as appealing.

Replicating Successes from other Industries

Throughout our interviews, many participants claimed that construction 'lags behind' other manufacturing industries in regards to innovation. Several suggested that construction should emulate other industries to increase innovation, for instance, by borrowing methods involving robots from other fields that have proven successful. Rather than starting from scratch, this would allow construction to learn from other industries' successes (and mistakes).

Adoption of Better Business and Production Strategies

Many participants spoke extensively about how they viewed the construction industry as 'traditional' or 'conservative'. They tended to use these words to describe business and production strategies they saw as outdated or ineffective. Several made clear that increased robot uptake could change this situation, by allowing industry actors to experiment with different, potentially more advantageous business or production strategies.

4.6. Limitations

Number: four

Summary: All participants highlighted that the Dutch construction industry is currently ill-suited to accommodate robots, in some way or another. Or conversely, that contemporary robots are ill-suited to operate within the industry. We have clustered remarks of this kind together as "Limitations".

Investment Costs

Many participants mentioned that robots are prohibitively expensive for most actors working in the Dutch construction industry. They explained that most companies don't have the financial capabilities to justify investing in robots. Additionally, some participants made clear that construction companies in the Netherlands often work with tight-budgets and must deliver unique, large-scale products under time constraints. Thus, it is unlikely they would invest in expensive robots, when they could instead simply rely on tried-and-tested traditional methods which have consistently proven successful in the past. It is worth noting here, that many participants expressed that it is difficult to innovate in the construction industry for these reasons.

Working Conditions

Several participants explained that robots work best in structured, standardised environments that bear little resembles to traditional construction sites. As each construction site is unique, robots would need to be highly flexible to operate within them. Several participants mentioned that construction 'lags behind' other industries for this reason, as actors must create products (building, bridges, etc.) in environments that don't lend themselves to automised processes.

Sequential Work Patterns

As construction work involves many different tasks, that eventually lead to the completion of one large product - namely a building or series of buildings - its workflows are highly sequential. Several participants expressed that robots are ill-suited for sequential work patterns, as they can only perform one set task, for instance welding steel or cutting timber. Whereas a single human worker can cut, carry and install timber elements ("from foundation to roof"), robots can only complete one of these tasks. Even when they do take part in sequential work, robots can only complete singular tasks,

leaving human workers to perform everything else. Especially in renovations of existing building stock, robots would have a hard time, since they would be confronted with many unforeseen surprises that require human improvisation and ingenuity.

5. Conclusion

Innovation in any industry rarely, if ever unfolds without a hitch. Whenever new technologies are introduced to pre-existing contexts, 'it is possible, and even likely that there will be unanticipated social consequences' (van de Poel, 2013). Our participants attitudes towards construction robots reflect this statement. Construction robots, for them, have the potential to ease many issues related to construction, while helping to improve productivity, sustainability, safety and working conditions (etc.) in the industry. Nonetheless, these improvements aren't cost-free and robots may contribute or create new problems once deployed according to our participants.

Furthermore, they were clear that the industry itself - or at least certain aspects of it - could or would benefit from higher robot deployment rates, but will also stall this process for various reasons. The main hurdles here include the industry's focus on creating unique, complex products in physically demanding work environments and reliance on small-scale companies. Many participants highlighted that these 'traditional' or 'conservative' approaches towards production has significant pitfalls that could be addressed by robots, but will also slow down uptake rates because they are the norm within the industry. With this in mind, it is worth asking: does the construction industry actually have sufficient space for robots? In its current state, probably not. Robots are still rarities and our participants frequently suggested that many things need to change to accommodate them.

It is perhaps more constructive then, to focus on how the industry would need to adapt around robots, rather than centring discussions around how robots will change the industry. Many of our participants remarks make more sense from this perspective, as they frequently discussed socio-economic factors that require attention before robots could be deployed in significant numbers. To be clear, if robots were to become present and operational in more construction contexts, it would be safe to assume that the industry had already undergone substantial changes. Our participants definitions of 'robotisation' aligns with this theme. According to our interpretation, many of them suggested that 'robotisation' signifies a movement away from 'traditional' or 'conservative' production methods - which, for better or for worse, requires change to gain momentum.

As our research was exploratory and only involved ten participants, its result are limited. Nonetheless, we have shown that 'robotisation' means substantially more than its dictionary definition implies and carries significant normative connotations for our participants. Additionally, this contribution has outlined several, distinct ways robots may positively or negatively impact the construction industry - according to our participants. Due to the limited nature of this research, we did not recruit construction work-

ers or contractors as participants. Considering that they will be affected by the (potential) changes outlined above, we highly recommend that further research in this area takes into account their perspectives.

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