Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Engineering
Department of Mechanical and Industrial Engineering

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The impact of carpenters' characteristics on performance of cabin construction in Norway

Master's thesis in Engineering and ICT
Supervisor: Marco Semini
June 2023

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Summary

Background: Low productivity is one of the construction industry's most critical challenges. Labor productivity significantly affects the profitability of construction companies, which makes it important to understand factors that affect worker productivity. The understanding can help develop strategies to reduce inefficiencies and manage the workforce in the construction industry, which in turn makes companies more competitive and increases the chance of survival in a highly competitive sector.

Purpose: This thesis aims to investigate how construction workers' characteristics, especially age, education/ experience, and language/ nationality, affect the performance of cabin construction.

Design: The purpose is achieved through a literature study that examines how age, education/ experience, and language/ nationality can affect the performance of a construction project. Hypotheses were then made based on the theoretical findings, and a case study with data analysis was carried out to test the hypotheses.

Findings: An analysis of 288 cabin projects found that the number of man-hours and construction days has a statistically significant relationship with the number of years in the company. Age and nationality were not found to be significant. In addition, there were interesting findings with a recently introduced assembly instruction, where the projects that used the instruction used an average of 11% fewer hours and 13% fewer days.

Sammendrag

Bakgrunn: Lav produktivitet er en av byggebransjens mest kritiske utfordringer. Arbeidsproduktiviteten påvirker lønnsomheten til byggefirmaer betydelig noe som gjør det viktig å forstå faktorer som påvirker arbeidernes produktivitet. Forståelsen kan bidra til å utvikle strategier for å redusere ineffektivitet og administrere arbeidsstyrken i byggebransjen, som igjen gjør bedriftene mer konkurransedyktige og øker sjansen for å overleve i en svært konkurranseutsatt sektor.

Formål: Denne oppgaven har som mål å undersøke hvordan snekkerenes egenskaper, spesielt alder, utdanning/erfaring og språk/nasjonalitet, påvirker ytelsen til hyttebygging.

Design: Formålet blir oppnådd gjennom et litteraturstudie som undersøker hvordan alder, utdanning/ erfaring og språk/ nasjonalietet kan påvirke ytelsen til et byggeprosjekt. Deretter ble det lagd hypoteser basert på de teoretiske funnene og gjennomført en case studie med dataanalyser for å teste hypotesene.

Funn: En analyse av 288 hytteprosjekter fant at antall man-hours og konstruksjonsdager har et statisktisk signifikant forhold med antall år i bedriften. Alder og nasjonalitet ble ikke funnet signifikant. I tillegg var det interessante funn ved en nylig innført monteringsanvisning, hvor prosjektene som brukte anvisningen i snitt brukte 11% færre timer og 13% færre dager.

Preface

This master's thesis concludes the 5-year master's program in Engineering and ICT with a specialization in production management at The Norwegian University of Science and Technology (NTNU) in Trondheim.

First, I would like to thank my supervisor Marco Semini for good follow-up, advice, guidance, and feedback. I also thank representatives from the case company for the provided data and feedback.

Lastly, I would like to thank my friends and family for the support and motivation they have given me in this process.

Silje Odland, June 2023

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Glossary

EF Education First. 35, 58

EPI English Proficiency Index. vii, 36

HSE health, safety and environment. 16, 25, 32, 36, 42, 43, 45, 46, 56, 58

LOESS locally weighted scatterplot smoothing. 51

MRA Multiple regression analysis. viii, 49, 76

OLS Ordinary Least Squares. 53

RR Relative Risk. 43, 44

SSE sum of squared error. 53

VIF Variance Inflation Factor. 67, 76

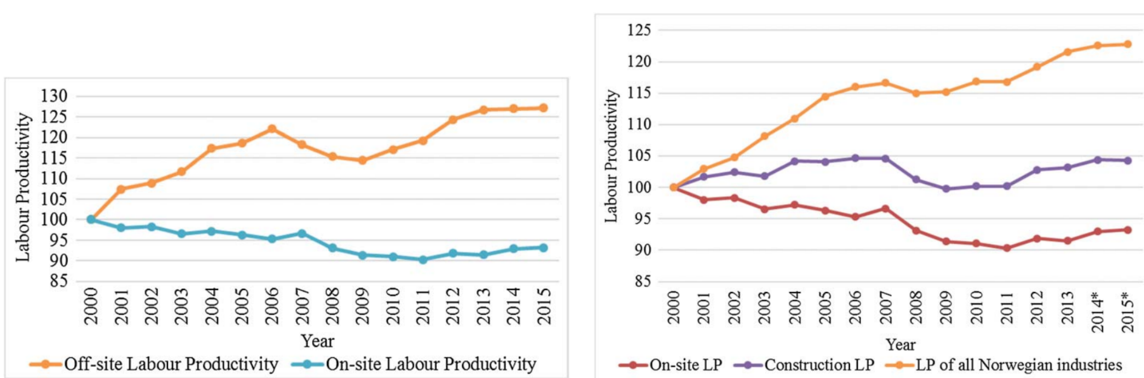
WAI Work ability index. iv, vii, 19–23

1 Introduction

This chapter will first introduce the project and present some background and motivation for the thesis. Next, the objective and the research questions are defined. Lastly, the scope and the thesis' structure are presented.

1.1 Background and motivation

According to Hamza et al. (2022), low productivity is one of the construction industry's most critical challenges. Labor productivity significantly affects the profitability of construction companies. Understanding factors that affect worker productivity can help develop strategies to reduce inefficiencies and manage the workforce in the construction industry. In addition, it will make the firms more competitive and increase the chance of survival within a highly competitive sector (Hamza et al., 2022). Better labor utilization leads to increased productivity, which is becoming increasingly scarce and relatively expensive. Many research articles discuss the construction industry and its productivity. Still, due to local differences, there are significant differences in what and to what extent different parameters affect the performance (Vidaković et al., 2020). Figure 1 shows how labor productivity in Norway has developed in the period 2000 to 2015. As shown, on-site labor productivity has mostly declined. The construction industry in Norway needs more research, and this thesis can contribute to new knowledge and help change this trend.



(a) Off-site and on-site labor productivity.

(b) On-site, construction industry and all industries labor productivity.

Figure 1: Labor productivity in the construction industry (in total, on-site and off-site) and other industries in Norway. Adopted from Ahmad et al. (2020).

Employees in physical occupations such as the construction industry have an increased risk of absence, disability pension, and early retirement (Labriola et al. (2009); Sundstrup et al. (2018)). In addition, they are exposed to musculoskeletal disorders (Davis and Kotowski (2015); Umer et al. (2018)) that affect their ability to remain in work until retirement age (Järvholm et al. (2014); Jebens et al. (2014); Jensen et al. (2012); Oude Hengel et al. (2012)). The increased risk has become particularly important to explore as the retirement age has increased in many countries (Merkus et al., 2019).

Labor productivity is crucial to the profitability of most construction projects. Extensive studies that have examined factors that affect labor productivity in the construction industry have identified that experience and skills are highly influential (Khanh et al., 2021). Hewage and Ruwanpura (2006) also found that skill level differences in the labor force affect construction productivity.

Norwegian working life, especially in the construction industry, is becoming increasingly internationalized and, to a greater extent, multilingual. After record-high labor immigration in the years after 2004, language difficulties have been a recurring theme without any particular results. Some of the problem areas related to communication difficulties in a workplace are linguistic misunderstandings, which in the worst case can lead to danger to life and health, foreign workers who may be more vulnerable to exploitation due to little knowledge of their rights or that they do not understand the given information that, and complicated working relationships between colleagues because they are unable to communicate (Ødegård and Andersen, 2020).

1.2 Research questions and objectives

This thesis aims to investigate how construction workers' characteristics, especially age, education/ experience, and language/ nationality, affect performance in a construction project, especially the construction of a cabin. The first sub-goal is reviewing the literature to find hypotheses that can be tested on real-life data. The next sub-goal will then be to determine whether the hypotheses are true. The final sub-goal is to find out what characterizes a good team composition for the best possible performance based on the carpenters' age, experience, and language/nationality and whether any team compositions should be avoided.

Research question 1: How does the carpenters' age impact the performance of cabin construction?

Research question 2: How do the carpenters' experience and education impact the performance of cabin construction?

Research question 3: How do the carpenters' language skills and culture impact the performance of cabin construction?

In all research questions, performance refers to the number of construction days and man-hours used by a carpentry team on a project. With cabin construction, reference is made here to the actual construction phase of a construction project and not all phases (more detailed in the next sub-chapter, research scope).

1.3 Research scope

This thesis will focus on the Norwegian construction industry, especially house and cabin construction. Figure 2 shows a rough overview of the phases of a construction project developed by and for the construction industry in Norway (Bygg21, 2019). As shown, a construction project consists of many phases, and this thesis will focus on phase 5 production.

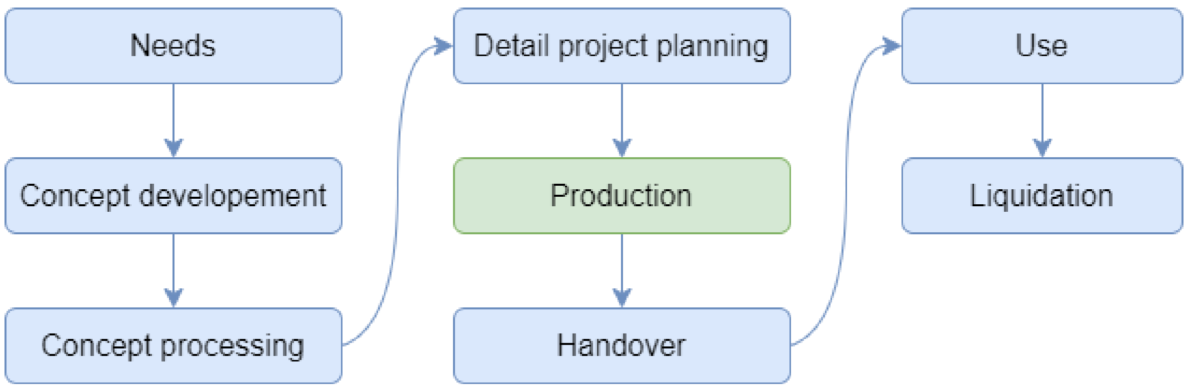


Figure 2: A rough overview of the phases of a construction project. A translated version based on a figure from Bygg21 (2019).

The thesis focuses on the construction industry in Norway, mainly because the construction industry characteristics can vary significantly from country to country, and the collected data analyzed in this thesis are cabin projects in Norway. The theory chapter is mainly based on the construction industry as a whole (not carpenters only) and is not limited to research in Norway. Therefore, many of the theoretical findings can be relevant to the construction industry in large parts of the world.

1.4 Research outline

Chapter 1 Introduction	The introduction chapter presents the background and motivation, the research questions and objectives, the scope, and the thesis structure.
Chapter 2 Literature study	The literature study chapter presents relevant literature that contributes to answering the research questions.
Chapter 3 Case	The case chapter introduces the case company.
Chapter 4 Methodology	The methodology chapter describes the methods and the research models used in the thesis.
Chapter 5 Data analysis and results	In this chapter, the analysis is conducted, and the results are presented.
Chapter 6 Discussion	The discussion chapter presents the main findings, limitations, and proposals for further work.
Chapter 7 Conclusion	The conclusion summarises the study's results, discusses limitations, and proposes further research.

2 Literature study

This chapter presents some relevant terms within the construction industry and performance and gives the theoretical background to answer the research questions. The first section presents a brief overview of different types of buildings. The following section briefly explains a construction project and goes through the various phases of the construction process. Furthermore, there is an overview of which factors previous literature has found to affect performance. Next, the characteristics of the construction industry in Norway are presented. Furthermore, the different characteristics, age, education and experience, and language and nationality are examined. Then the theory of the analysis method, multiple regression analysis, is reviewed. Finally, there is a summary of the findings from the literature study.

2.1 Different types of buildings

The use of a building has a lot to say about the design of the building, both in terms of size, requirements for insulation and security, etc. (Frøstrup, 2012). There are several ways to divide buildings. Frøstrup (2012) divide them into main types according to what they are used for. Some of them are:

- Residences
- Schools, kindergartens
- Buildings for industry, office buildings
- Hospital
- Sheds, work barracks, residential barracks
- Agricultural buildings

Residences can again be divided into several categories, where Frøstrup (2012) has divided them into small houses and large residential buildings. Small houses are often used as a collective term for smaller attached or detached residential buildings (generally, the house is up to 9 m high). Large residential buildings are often used as a general term for residential buildings with three or more floors or more than four apartments with a common entrance.

The following sub-chapter goes into more detail about what a construction project is and what phases it contains. As the data for this thesis is cabin projects, it will be reviewed as a residential building project (as this is similar to cabin projects).

2.2 Construction project and its phases

Table 1 shows an overview and a description of the main parts of a construction project. As this thesis focuses on the on-site part of a construction project, the main focus of this sub-chapter will be on the construction work phase.

Table 1: The phases of a construction project (Borgersen, 2016).

Idea	
Programming	In this phase, the functions and qualities of the building are worked out. The architect makes sketches of the building.
Preliminary project	In this phase, one makes drawings and calculates, e.g., how much ventilation, air, and energy is needed. The dimensions are determined. Investment costs and costs related to administration, operation, and maintenance for the solution chosen must also be covered.
Project planning	
Detailed planning	Detailed drawings are made. Contracts with contractors are also made.
Performance	
Construction work/ assembly/ installations	The building is erected, furnished, and technical installations are installed.
Taking over	A final inspection is carried out, and time is given to correct any errors or deficiencies. The building is then handed over to the builder (the person who will receive the building), and the claim period starts.
Operation and maintenance	
Complaint period	The house owner can demand that errors and defects that are discovered must be rectified if it can be proven that the defects are due to negligence on the part of the contractor. Alternatively, they can demand compensation for the deficiency. The complaint period lasts for five years.

Grønvold (2012), an online workbook associated with Sekkingstad and Svellingen (2012)'s textbook, follows the construction of a single-family home from foundations and foundations wall via joists, external walls, roof, exterior and interior cladding to completion according to a set progress plan. Figure 29 gives a relatively good overview of the various phases in a construction process (the construction of the building itself). The order and type of some of the tasks may vary somewhat from project to project depending on the kind of building or that several of the tasks may be done simultaneously or independently of other tasks.

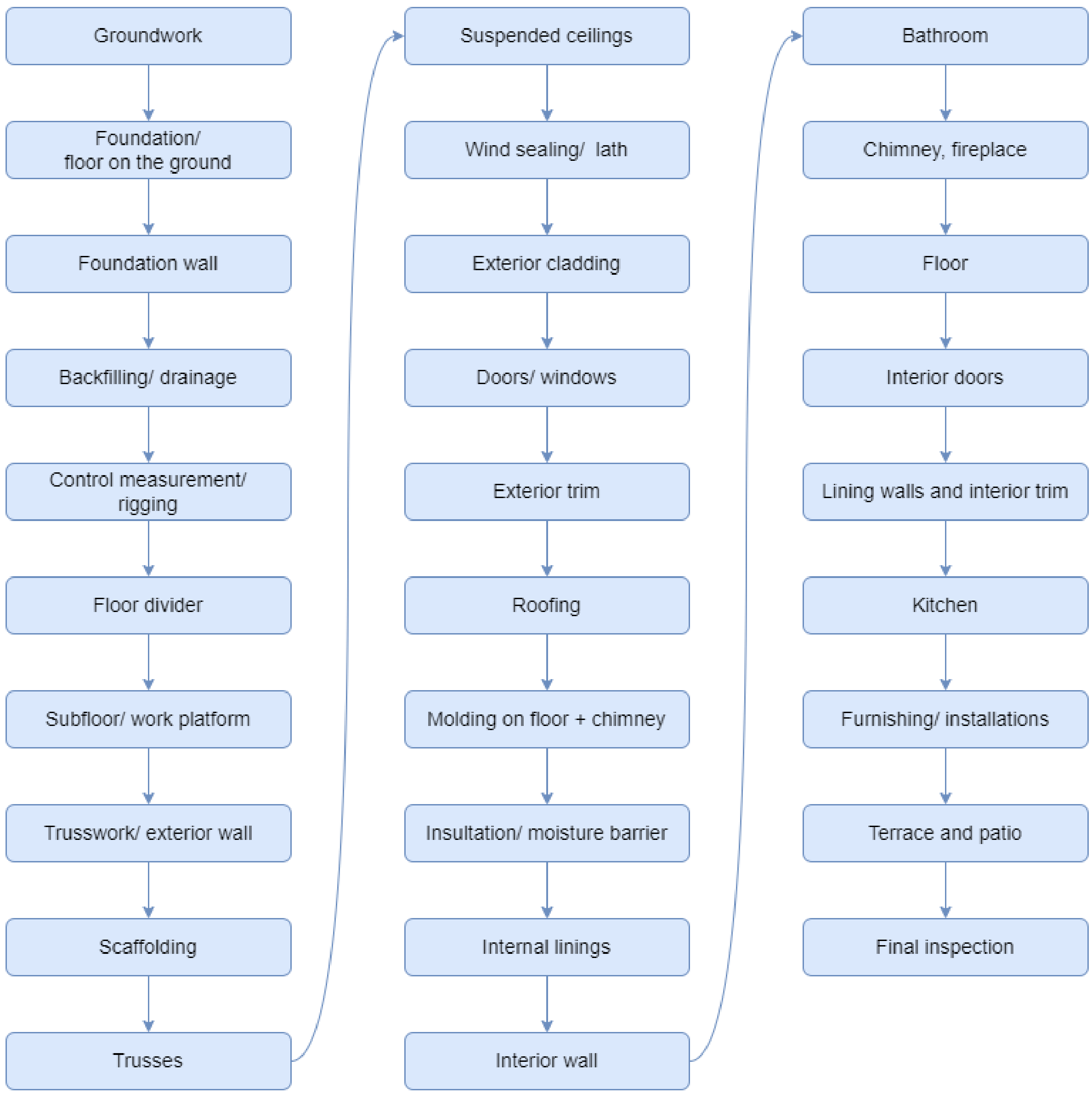


Figure 3: An example of a construction process. Made from Sekkingstad and Svellingen (2012) and Grønvold (2012).

2.3 Factors affecting performance

This sub-section is based on an early version of this thesis, Odland (2022). Factors affecting performance vary from country to country. Table 2 shows some of the factors that previous studies have found to affect performance in the construction industry. As this thesis mainly looks at the construction industry in Norway, factors typical for developing countries and countries at war are considered irrelevant and omitted from the overview.

Table 2: Factors affecting productivity in the construction industry.

Factors	**References**
Material shortage or quality	Hasan et al. (2018), Mahamid (2013), Alinaitwe et al. (2007), Enshassi et al. (2007), Pornthepkasemsant and Charoenpornpattana (2019), Jarkas and Bitar (2012), Shoar and Banaitis (2019), El-Gohary and Aziz (2014), Anojan and Siriwardana (2021), Dai et al. (2007), Dixit et al. (2019), Rathnayake and Middleton (2023)
Skill/ experience shortage	Hasan et al. (2018), Tammy et al. (2019), Mahamid (2013), Alinaitwe et al. (2007), Enshassi et al. (2007), Pornthepkasemsant and Charoenpornpattana (2019), Jarkas and Bitar (2012), Shoar and Banaitis (2019), El-Gohary and Aziz (2014), Anojan and Siriwardana (2021), Dai et al. (2007), Rashid (2015), Dixit et al. (2019)
Tool shortage or quality	Hasan et al. (2018), Alinaitwe et al. (2007), Enshassi et al. (2007), Pornthepkasemsant and Charoenpornpattana (2019), Jarkas and Bitar (2012), Shoar and Banaitis (2019), Anojan and Siriwardana (2021), Dai et al. (2007), Rashid (2015), Dixit et al. (2019), Rathnayake and Middleton (2023)
Poor communication	Hasan et al. (2018), Tammy et al. (2019), Mahamid (2013), Alinaitwe et al. (2007), Enshassi et al. (2007), Pornthepkasemsant and Charoenpornpattana (2019), Jarkas and Bitar (2012), El-Gohary and Aziz (2014), Dai et al. (2007)
Rework	Hasan et al. (2018), Mahamid (2013), Alinaitwe et al. (2007), Enshassi et al. (2007), Pornthepkasemsant and Charoenpornpattana (2019), Jarkas and Bitar (2012), Shoar and Banaitis (2019), Anojan and Siriwardana (2021), Rashid (2015), Dixit et al. (2019)
Weather conditions	Hasan et al. (2018), Mahamid (2013), Alinaitwe et al. (2007), Enshassi et al. (2007), Jarkas and Bitar (2012), Shoar and Banaitis (2019), El-Gohary and Aziz (2014), Rashid (2015), Rathnayake and Middleton (2023)
Lack of training	Hasan et al. (2018), Alinaitwe et al. (2007), Jarkas and Bitar (2012), Shoar and Banaitis (2019), El-Gohary and Aziz (2014), Anojan and Siriwardana (2021), Dixit et al. (2019)
Labor turnover	Mahamid (2013), Alinaitwe et al. (2007), Enshassi et al. (2007), Rashid (2015)
Absenteeism	Mahamid (2013), Alinaitwe et al. (2007), Enshassi et al. (2007), Jarkas and Bitar (2012), El-Gohary and Aziz (2014), Rashid (2015)
Poor construction method	Mahamid (2013), Enshassi et al. (2007), Jarkas and Bitar (2012), Anojan and Siriwardana (2021)
Age of labor	Enshassi et al. (2007), El-Gohary and Aziz (2014)

2.4 Characteristics of the construction industry in Norway

The construction industry in Norway consists of around 153 000 workers, where figures 4 and 5 show the distribution by nationality and age. Most of them work as a carpenter, electrician, or engineer. 91% of the workers are men, against 54% in all industries, and 88% of the workers have upper secondary school or a shorter education, against 57% in all industries. The industry consists of clearly more men and generally has a low level of education. There is also a low degree of trade union organization in relation to all industries, 38% versus 57%. The construction industry consists of about 20% immigrants. In addition, many workers are registered for short-term residence in Norway. The industry consists of many small businesses, with over half of all registered businesses being sole proprietorships Statens arbeidsmiljøinstitutt (STAMI) (2023).

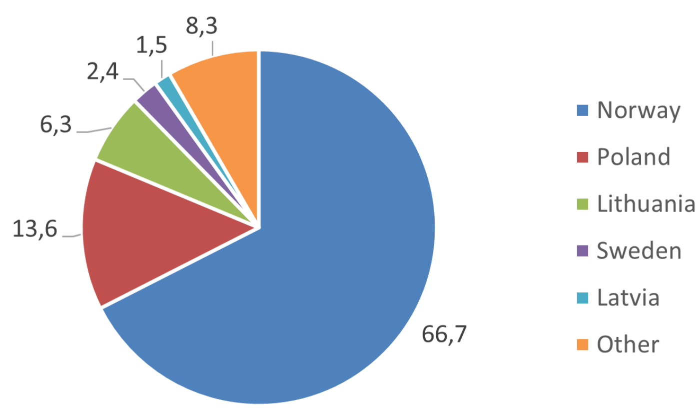


Figure 4: The workers in the construction industry, distributed by country of origin (in percent). Numbers from Byggenæringens Landsforening (2019).

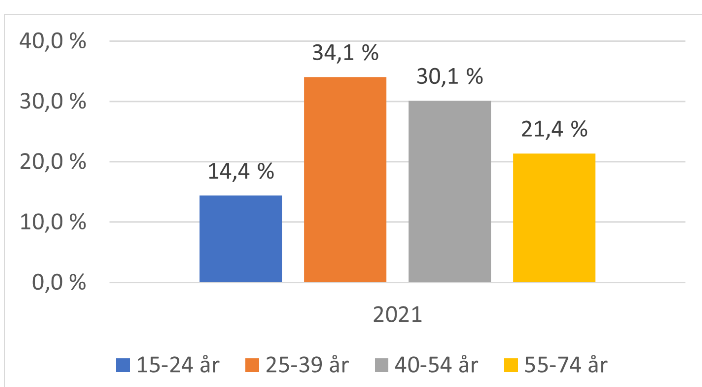


Figure 5: The workers in the construction industry, distributed by age. Numbers from SSB (2023b), table 07971.

Challenges within the construction industry

The working environment can be important in the causes of health problems and sickness absence. 3 out of 7 sickness absences in construction companies are related to work, which can often be prevented at the individual workplace.

The problems shown in table 3 increase the chance of problems, injuries, illness, and absenteeism. The construction industry is among the top 6 industries with the most registered occupational injuries, with 12,8% of all reported occupational injuries in Norway in 2021, and among the top 7 industries with the most occupational deaths (in Norway) (SSB, 2023b).

Table 3: Comparison of challenges related to the working environment in the construction industry against all industries in Norway. Numbers from Statens arbeidsmiljøinstitutt (STAMI) (2023).

Problem	**Construction industry**	**All industries**
Inhale dust or chemicals	48%	23%
Experiencing the risk of an occupational accident	28%	14%
Works with hands above shoulder height	49%	14%
Must perform work on the crouch or knees	49%	18%
Performs lifting in uncomfortable positions	26%	13%
Is exposed to loud noise	16%	9%
Work-related leg pain (total leg pain)	20% (34%)	12% (34%)
Work-related arm pain (total arm pain)	18% (26%)	11% (18%)

In 2018-2022, 143 occupational deaths were registered across 21 industries. The construction industry had the most deaths and accounted for 26,6% of them Arbeidstilsynet (2023b). The statistics are for both building and construction activities, and 3/4 of accidents in building activity in 2021 were occupational deaths because of falls. The last accident in building activity and 3/5 in construction activities were squeezing.

Norway has a government agency called the Norwegian Labor Inspection Authority, which, among other things, has the task of inspecting businesses to ensure that they meet the requirements of the working environment regulations (Arbeidstilsynet, 2023a). The Norwegian Labor Inspection Authority carried out 22 660 inspections in the construction industry in 2018-2022, of which 56% led to a reaction. Stopping in case of imminent danger is a type of reaction and was used in 17,8% of all inspections and 31,8% of all inspections with responses. Examples of situations where the labor inspectorate can decide to stop the work, partly or entirely, are if a business does not comply with an order (to correct a breach of the rules) within the deadline that has been given (the most common decision) or if there is an immediate danger to the employees' life and health. An example of an immediate danger to the workers' lives and health is if, under an inspection, they see that the company has not secured the workers well enough when working at height or when using machines (Arbeidstilsynet, 2023c).

2.5 Age

This sub-chapter reviews the literature on factors that are affected by age. Topics such as injuries and absence, work capacity and work ability, disability pension, and companies' attitudes towards senior workers are examined.

Injury and absence

Figure 6 shows the distribution of absenteeism and the risk of fall injuries among the various age groups, with the percentage of injuries divided by the age group's percentage in the industry. The graph shows a clear U-shape where the youngest age groups, in particular, are overrepresented among the injured. If injuries had not been affected by age, the graph would have been even at 100% (the same proportion of the injured as the proportion of employees in the industry). One can see that the youngest groups have a majority of shorter absences (1-3 days), while the older groups have a majority of long absences (over three days). This finding suggests that the youngest age groups suffer lighter injuries. The construction industry is among the industries with the most occupational injuries in Norway and accounted for between 11,7% and 12,8% of all occupational injuries in Norway from 2014 to 2021.

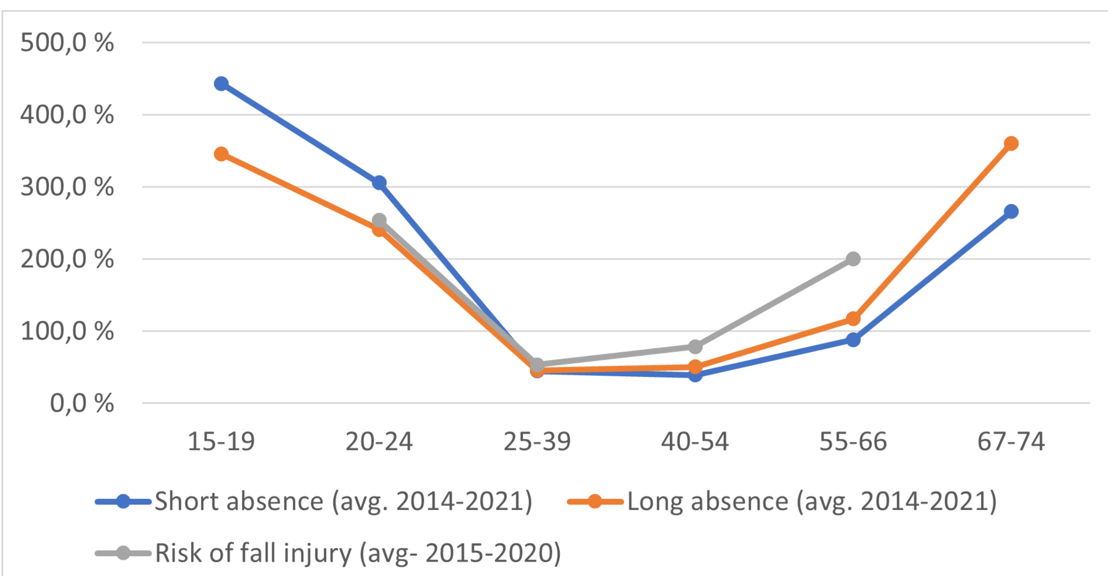


Figure 6: Short absence, long absence, and risk of fall-injury by age. Numbers from ssb and Mostue et al. (2022)

Breslin et al. (2003) results show that the youngest workers injure themselves the most. They believe an explanation may be a combination of general risk factors, such as occupational hazards, and unique risk factors, such as the maturity stage. Kjestveit et al. (2008) state that age is less important and that young workers have good knowledge and attitudes towards health, safety and environment (HSE). On the other hand, young age combined with little practical experience means they could be better at seeing the consequences of their actions in different work situations. Young age, therefore, negatively affects the understanding of risk. Low risk perception can, for example, contribute to them taking more shortcuts than older, experienced workers who have seen the consequences of their behavior. Young workers are also influenced to a greater extent by the working environment. Thus, they are more dependent on people around them focusing on risk and safety for them to focus on it themselves. Holte et al. (2010) found that young workers, to a greater extent, report physical strain, which suggests that the young are put to incapacitating heavy and more risk-exposed work. This type of work, combined with a lack of experience and understanding of risk, contributes to young workers being more often involved in accidents. The study also mentions that younger workers have higher short-term absences and mentions a different absence culture as a possible explanation in addition to the explanations mentioned earlier in this study.

Breslin and Smith (2005) found that young workers reported above-average physical exertion at work compared to older workers. They also found that young workers reported minor injuries such as cuts, scrapes, burns, and bruises, while older workers reported more severe injuries such as twists, sprains, and strains. The study also shows that younger workers were twice as likely to report an occupational injury than older workers. Laflamme and Menckel (1995) states that younger and older workers have different types of injuries and that older people are less exposed to accidents that can be prevented by reasonable judgment. In contrast, younger people are less exposed, and a quick response can prevent them.

According to Mostue et al. (2022), fall injuries are the most frequent injury among workers in the construction industry. Figure 6 show that the oldest group is most affected. Mostue et al. (2022) believes that one explanation for this age distribution is that experience does not affect fall injuries as much but that reaction time and balance can play an important role. In addition, injuries often become greater the older you are due to lower tolerance. Holte et al. (2007) findings show that fall injuries are more common among older workers than younger ones and that you are more exposed to back and neck injuries with age. Inadequate protection seems to be the dominant cause of accidents/injuries, and the increasing trend with age indicates that the older is worse at safety measures.

Kenny et al. (2008) state that functional work ability declines with age, starting in the 30s and more clearly in the 60s and 70s. A part of the decline in physical ability is due to lower maximal cardiac output, a decrease in oxygen-carrying capacity, and inhibited pulmonary abilities. The decline is led by slower changes in motor control and muscle composition, leading to muscle mass, strength, and speed reductions. With age, bone density also decreases, which increases the risk of bone fractures. On the other hand, the decline in these systems can vary from worker to worker and is influenced by genetics and lifestyle, among other things. Underthun et al. (2021) agree that diet and physical activity can play a big role. Because of these physical changes, more workers may find themselves working closer to maximum capacity, increasing the risk of musculoskeletal injuries and chronic fatigue (Kenny et al., 2008). Peng and Chan (2020) found that older workers suffered from declining health conditions and that physical work capacity and physical and mental health were critical factors affecting their job security. Holte et al. (2007) state that the development of skills and an increased degree of mastery should be the focus of younger employees, while not overestimating one's skills and taking into account one's own age and physiological/physical consequences should be the focus for the older workers.

Work capacity and work ability

Hamberg-van Reenen et al. (2009) results suggest that there are age-related differences in isokinetic [1] lifting strength and static muscle endurance in the back and neck/shoulder musculature. The results showed that the younger workers had a higher performance in isokinetic lifting strength than the older workers. The results were the opposite for static endurance of the neck and shoulder muscles. However, after three years of follow-up, all ages had reduced static muscle endurance. Merkus et al. (2019) results show, on the other hand, that physical strength was relatively similar for younger (< 44 years) and older workers, while older workers had lower aerobic capacity (endurance). They state that the balance between capacity and demands is the key for older workers to cope with physical demands.

Hamberg-van Reenen et al. (2009) results show that younger workers who participated in sports for 3 hours or more per week had the best muscle capacity and that older workers who participated in sports for 1-3 hours had better muscle capacity than those who were inactive or participated in sports for more than 3 hours each week. These results suggest that younger workers gain better muscle capacity with more exercise, while older workers should be active while being careful not to exercise too much. Kenny et al. (2008) agree that regular physical activity can improve work capacity by slowing the decline in aerobic and musculoskeletal systems. Gram et al. (2012) found that 20 min of aerobic capacity training three times a week in 3 months significantly increased the maximum oxygen consumption, which is likely to provide clinically relevant decreases in cardiovascular and metabolic disorders. They also state that workers with high physical work demands and low maximum oxygen consumption are shown to have an excessive risk for cardiovascular mortality. Jebens et al. (2015) found that senior workers had a decline in physical fitness compared to the younger. The level was still satisfactory for the work, and they were more exposed to overload. Reduced workload or training is therefore important for seniors to stay in the workforce.

[1] the speed of movement in the joint is constant when doing strength training (Mæhlum, 2020)

Van den Berg et al. (2011) state that workers who experience a decrease in Work ability index (WAI) also experience productivity loss. WAI is a tool to assess work ability during health and workplace examinations. The index's basis is answers to several questions about the work requirements, the worker's state of health, and resources (Ilmarinen, 2007). The index is a score between 7-49 and is divided into poor (7-27), moderate (28-36), good (37-43), and excellent (44-49) (Van den Berg et al., 2008).

Galati et al. (2020) state that the lower WAI a worker has, the higher the chance of an occupational injury. Sell et al. (2014) found that workers with good WAI and musculoskeletal pain led to reduced productivity. In contrast, low WAI and musculoskeletal pain did not have the same association with reduced productivity. Since 2005, WAI has been part of the standardized routine health examination for construction workers in the Netherlands (Hoonakker and Van Duivenbooden, 2012). The results of the study show that the WAI predicts long-term absence better than many other variables such as lifestyle characteristics, job characteristics, and health complaints, including objective assessment of these health complaints (COPD) and risk of future complaints (cardiac events). They also found that apart from WAI, only age, job category, musculoskeletal disorders, and lack of autonomy can predict long-term absence. Table 4 shows Hoonakker and Van Duivenbooden (2012)'s relationship between WAI and long-term absenteeism. The risk is compared to workers with excellent WAI, which means that the workers with poor WAI have almost twice the risk of long-term absenteeism within four years than the workers with excellent WAI.

Table 4: Long-term absenteeism from work in relation to WAI. Numbers from Hoonakker and Van Duivenbooden (2012).

WAI	**Experienced long-term absenteeism within 4 years**	**Risk of long-term absenteeism within 4 years**
Poor	31%	1,92
Moderate	33%	2,27
Good	27 %	1,60
Excellent	20%	1,0

Costa and Sartori (2007) found a decreasing trend in WAI for a group of 386 Italian men with heavy manual work, shown in figure 7. Their findings show a strong interrelation between job activity and perceived work ability. They also believe that WAI is significantly reduced with a steeper trend, the higher the physical workload and lower job control.

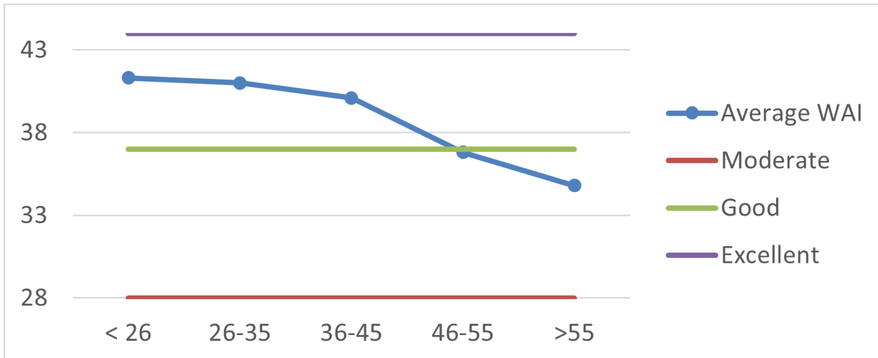


Figure 7: WAI for heavy manual workers by age. Numbers from Costa and Sartori (2007).

Jebens et al. (2014) found a similar trend in WAI tested on 87 employees in a medium-sized Norwegian construction company, see figure 8. They believed, however, that the trend was a weak and insignificantly decreasing tendency with age. On the other hand, the study of Norwegian construction workers is based on fewer workers, and it is significant individual differences at all ages. Eaves et al. (2016) found that workers who experienced aches and pains due to their work did not have reduced work ability, which supports the findings of good work ability of Norwegian senior workers (Jebens et al., 2014).

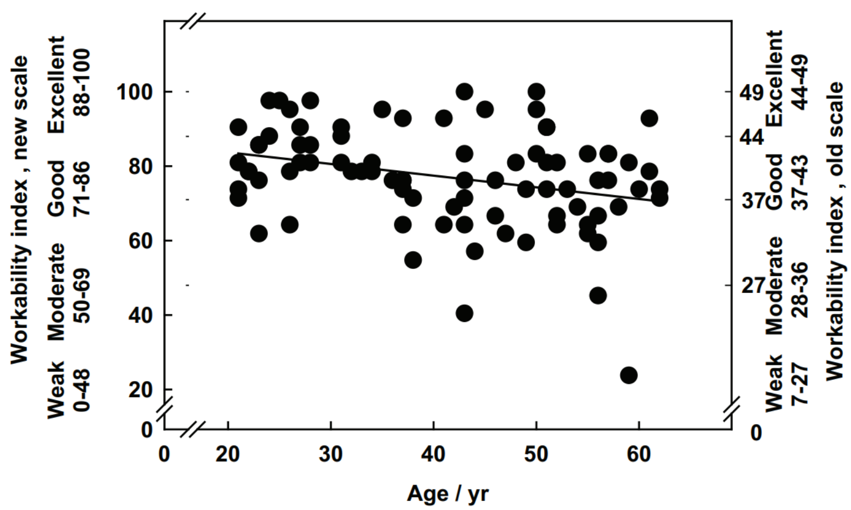


Figure 8: Self-reported WAI by age. Adopted from Jebens et al. (2014).

Ilmarinen et al. (1997) found a significant decline in WAI in 11 years for all ages, especially for people with physically demanding work. Figure 9 shows WAI measurements for men with physically demanding work in the age group 45-51 in 1981 and WAI for the same group 10 years later. As shown in the figure, most had good WAI at the first measurement, and all had fallen to moderate WAI at the second measurement. The study concludes that measures to promote work ability should start before age 51, especially for physically demanding industries such as the construction industry. Skirbekk (2008)'s results also indicate that productivity often declines with age, but that varies according to the sector one works in. They state that the productivity potential of older people is likely to increase over time as several professions are less dependent on seniors' strength, cognitive abilities, and health.

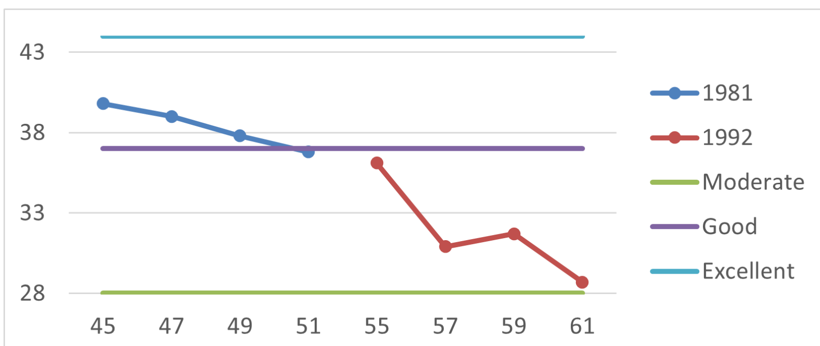
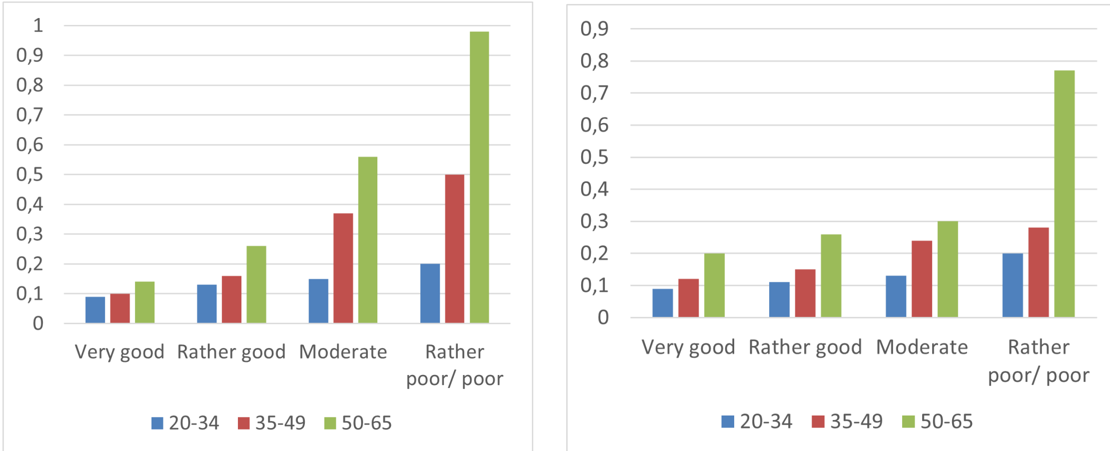


Figure 9: WAI by age in 1981 and 1992. Numbers from Ilmarinen et al. (1997).

Palmlöf et al. (2019) found that self-reported physical work ability in relation to work demands is associated with long-term sickness absence during the subsequent ten years. Figure 10 shows this relationship and that the trend increases with age and poorer work ability. Figure **??** shows a similar trend, except for moderate WAI, which Hoonakker and Van Duivenbooden (2012) results show gives a greater chance of long-term absenteeism than poor WAI does.



(a) Physical work ability.

(b) Mental work ability.

Figure 10: Associations between self-perceived physical work capacity and mental work capacity and the outcome long-term inability to work between 2003 and 2012. Numbers from Palmlöf et al. (2019).

Ilmarinen and Ilmarinen (2015) state that work ability is an essential human capital for workers throughout their careers. The study is based on the Finnish population and shows a similar tendency as Jebens et al. (2014) with significant variations in WAI within the different age groups. Although the survey includes all types of work, the results showed a slight decline in WAI with age. The results also showed more variation in the WAI score with age. Figure 11 shows how health, functional capacity, and competence develop with age. As these results are also based on all types of occupations, one can assume that the health and functional capacity would be somewhat lower for workers with physically demanding work than for construction workers. The variation, especially regarding health challenges, makes it difficult to assess whether one can compensate for workers' health challenges with increased competence, which varies a lot from person to person. The following sub-chapter returns to how experience affects performance.

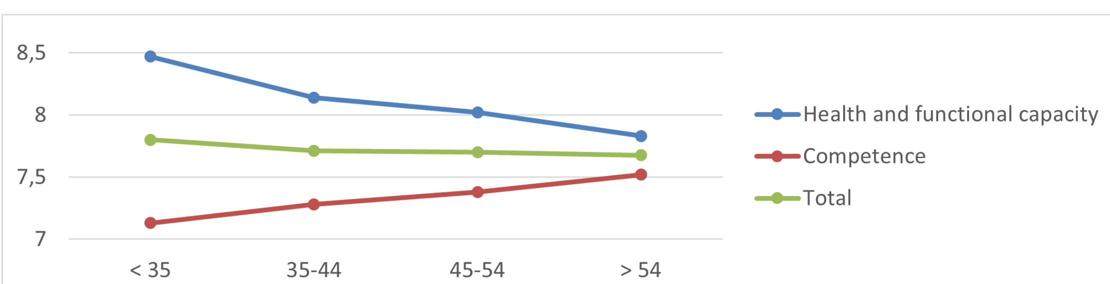
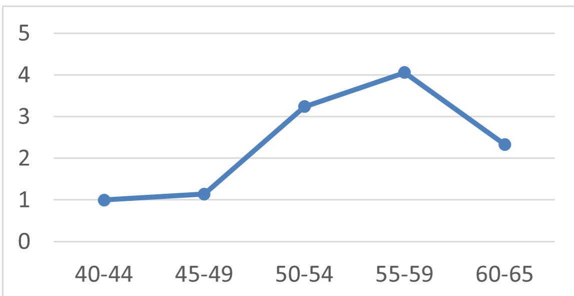


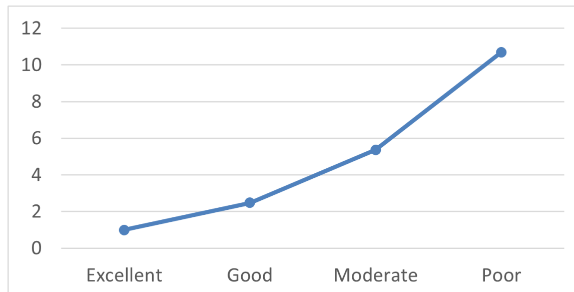
Figure 11: Health and functional capacity and competence by age. Numbers from Ilmarinen and Ilmarinen (2015).

Disability pension

Liira et al. (2000) found that moderate and poor WAI were significantly predictive of disability pensions during a followup. As shown in figure 12 (a), the risk of disability pension is lower for the oldest group than for the two previous age groups. This lower risk may indicate that companies and workers are better at taking age into account after age 60 but that they should consider taking measures already after age 50. Figure 12 (b) shows a similar trend to Palmlöf et al. (2019)'s prediction of long-term inability to work and agrees that WAI is a good way to anticipate these types of "problems".



(a) Risk of disability pension by age.



(b) Risk of disability pension by WAI.

Figure 12: Risk of disability pension by age and WAI. Numbers by Liira et al. (2000).

Tuomi et al. (1997)'s results show that although the retirement age was low (63 years, in some cases 55 years), just over one-third of the municipal workers who participated in the study would continue working until old age retirement. These results were lower than they had expected from the theoretical knowledge of aging. They found that factors related to physical work reduced work ability the most and caused more participants to leave working life. Few worked throughout the follow-up, and several had switched to less physical occupations.

Companies' attitudes towards senior workers

According to Midtsundstad (2007), 7% of companies in the construction industry plan to reduce early retirement. Part of the explanation for the low proportion may be that there is a large supply of Eastern European labor. Slagsvold and Solem (2005) support this teory. Midtsundstad (2007) results also show that nine out of ten Norwegian companies conduct regular employee interviews. On the other hand, construction is among the industries where this is the least common. These meetings are used to map the employees' needs, especially older employees' need for accommodation. These figures suggest that the construction industry, to a small extent, focuses on employees' needs for accommodation at different ages. Even though close to 75% of the construction industry companies had a shortage of people, only 40% considered employing workers over 55. 22% of companies believe that they have an early retirement problem. One explanation for the greater problem with early retirement than the focus on making arrangements for older workers may be that the work is physically demanding and that several managers feel it will be challenging to get someone to work after age 62, regardless of measures. Midtsundstad (2018) found that about 60% of the asked managers in the construction industry thought it was out of the question or challenging to have older workers part-time, against 14-20% in industries like education or public administration. Underthun et al. (2021) state that one of the challenges with older workers is that they often have lower education and a lack of formal qualifications, making it difficult to enter a new role. Several managers in the construction industry expressed that they wanted to keep seniors as long as possible but that it was difficult to find work tasks when they could no longer perform manual work as skilled workers. They also mention that more people try to bring in seniors if they lose experienced workers, partly because customers have experience as a criterion.

2.6 Education and experience

This sub-chapter reviews the literature on factors affected by education and experience. Topics such as education level, experience, HSE in education, and injuries are examined.

Education level

Figure 13 show an overview of the highest completed education among active workers in the construction industry in Norway. As reviewed in the sub-chapter on characteristics of the construction industry in Norway, around 1/3 of the workers are foreign workers. Andersen and Jordfald (2016) state that it is difficult for foreign workers to get their education approved in Norway, which means that there is a high chance that several people who are registered with primary/ lower secondary as their highest education have upper secondary school or higher education.

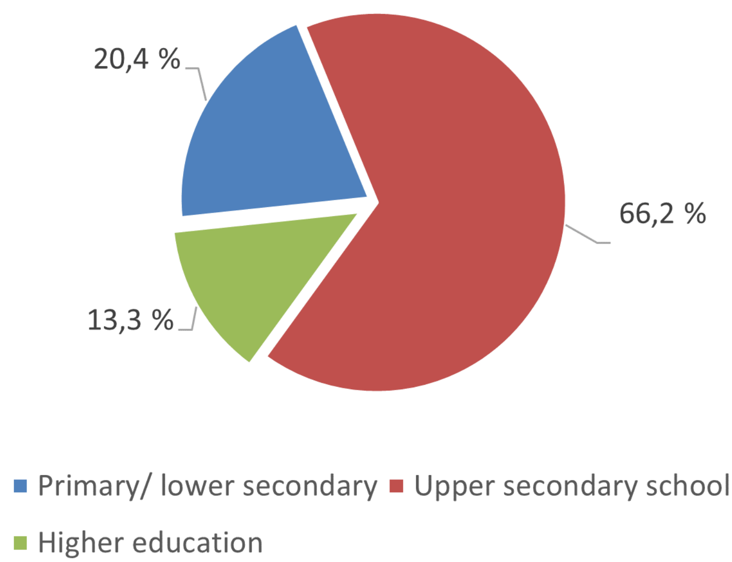


Figure 13: Highest completed education in 2020. Numbers from SSB (2023b), table 08415.

Following Andersen and Jordfald (2016)'s report, NOKUT, a Norwegian state directorate for ensuring quality in education, has opened up the approval of professional and journeyman certificates from several countries. Figure 14 shows that most European workers who come to Norway work as craftsmen, except for workers from Nordic countries. Even though the statistics are somewhat old, there is reason to believe that there is a similar tendency today as SSB (2023b)'s statistics for highest completed education were quite similar in 2014 as in 2020. The difference was a slightly higher proportion of primary/ lower secondary with around two percentage points higher.

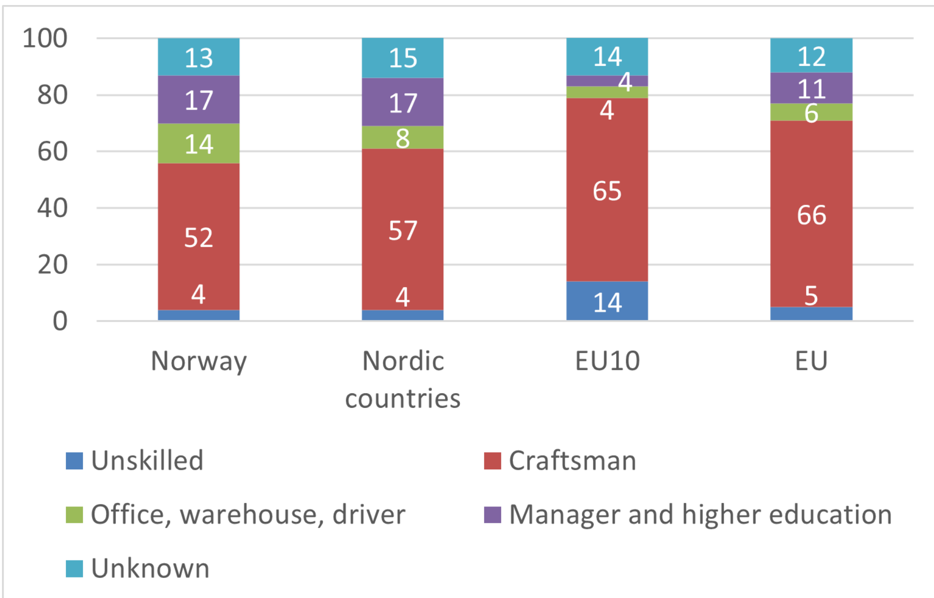
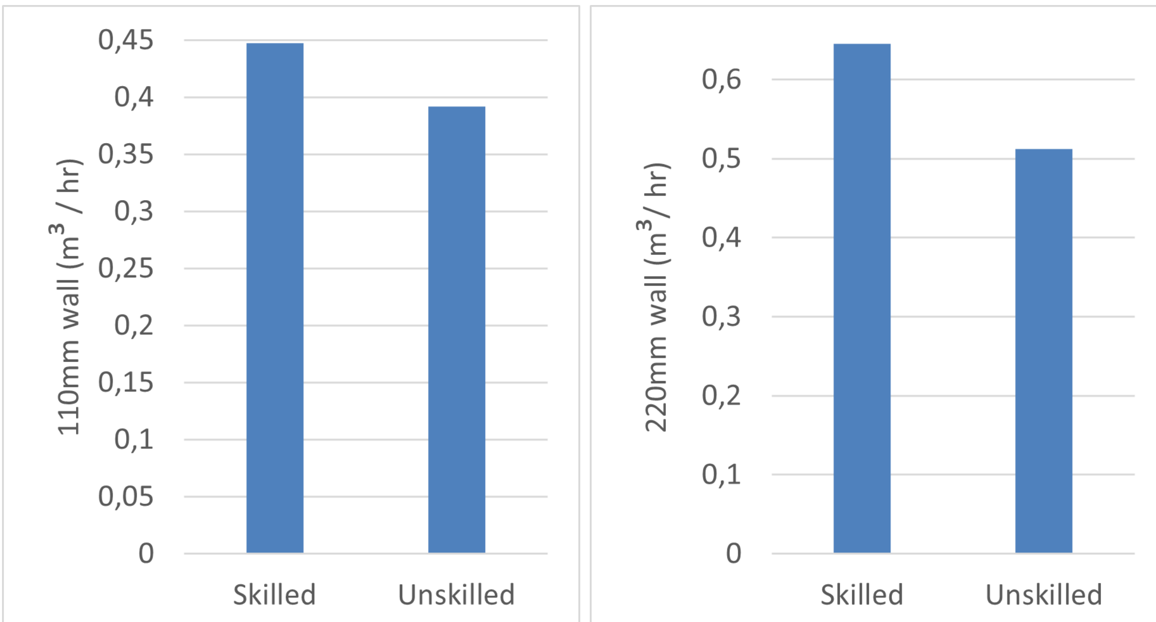


Figure 14: Occupational structure by country of origin in 2014. Numbers from Andersen and Jordfald (2016).

Statistics from SSB (2023b) shows that the proportion of workers with secondary school as their highest education has fallen by around 26%, leading to an increase of around 3% in high school and 44% in higher education from 2008 to 2020. According to Andersen and Jordfald (2016), 59% of the active workers in the construction industry have upper secondary school as their highest level of education, where the largest area is carpentry with 11% of the industry.

Mistri et al. (2019) found that lack of education negatively impacts a project's overall performance. Khanh et al. (2021) investigated the performance of skilled (educated) and unskilled masons. As shown in figure 15, the skilled workers had better performance, specifically 12,3% for the 110mm wall and 20,6% for the 220mm wall. Hussain et al. (2020) investigated the influence of skilled and unskilled workers and concluded that skilled labor has a significant positive impact and unskilled labor could have a significant negative impact on performance.



(a) Productivity based on workers' skill for 110mm wall.

(b) Productivity based on workers' skill for 220mm wall.

Figure 15: Brick masonry productivity based on workers' skill for 110mm and 220mm wall. Numbers from Khanh et al. (2021).

Ding et al. (2023)'s results show that inexperienced workers do not have sufficient skills to work on construction projects and that the lack of skills has a direct impact on performance in the construction industry. Vidaković et al. (2020) found that education had a strong (positive) and dexterity very strong impact on workers' productivity. Tammy et al. (2020) also found that the education level of the workers affects their performance. Both Vidaković et al. (2020) and Tammy et al. (2020)'s results, on the other hand, showed that experience had both a greater positive effect and a greater negative effect (in the case of a lack of experience) than education had.

Experience

Figure 16 shows Ha et al. (2020)'s result of the relationship between experience and productivity. The study found that it is linear from 0 to 12 years of experience before it flattens out. However, the study has no measurements of experience after 20 years. Khanh et al. (2021), however, found no significant difference in experience in their investigations where they looked at the performance of workers with < 10 years, 10-20 years, and > 20 years of experience.

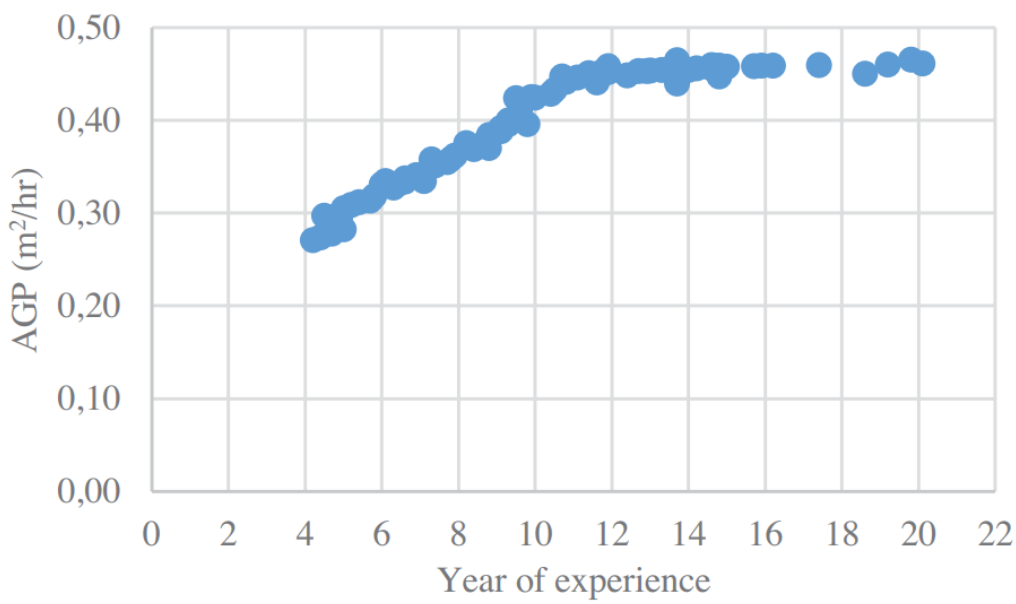


Figure 16: The relationship between productivity and years of experience. Adopted from Ha et al. (2020)

Figure 17 shows the increase in productivity of a typical Italian concrete worker based on experience. The results show a similar tendency to Ha et al. (2020) in that productivity stabilizes after 10-15 years of experience. On the other hand, it stands out by having a steeper increase in productivity in the first years before it gradually stabilizes.

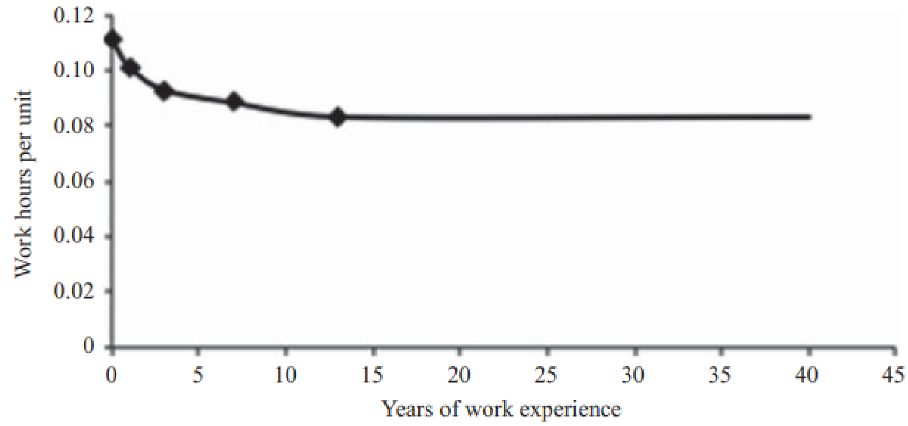


Figure 17: Productivity gains of a typical worker according to work experience. Adopted from Pellegrino and Costantino (2018).

Mtotywa and Mdlalose (2023) found a direct link between productivity and labor training and therefore stated that labor training significantly impacts construction companies' productivity. Further, they state that practical and theoretical training is essential to improve productivity. Finally, they add that labor training is crucial for the construction industry as it is a demanding and changing industry affected by digitization and technological growth. Ding et al. (2023) state that inexperienced workers lack technical knowledge, planning skills, and extensive skills to work on construction sites.

Dokko et al. (2009) investigates how prior work experience outside a given company affects the performance of a new company. Their results show that previous professional experience positively affects performance in terms of knowledge and skills. However, they also found that it could lead to negative effects such as behavioral and cognitive rigidities. Their analysis also showed that workers have different portfolios of knowledge and skills gained from prior work experience and that these portfolios contribute differently to a worker's current job performance.

Alwasel et al. (2017) analyzed masons of varying experience and found that experience significantly affects productivity, as the most experienced masons were twice as efficient as the least experienced masons. Figure 18 shows some of the results from the analysis. In addition to increased productivity with experience, one can see that the least and most experienced masons carry lower joint forces and moments compared to the workers with 1-3 years of experience. The results suggest that experienced masons develop techniques and work methods that are more productive while reducing the strain on muscles compared to the less experienced. Such working methods are essential for a long-term career in a physically demanding profession.

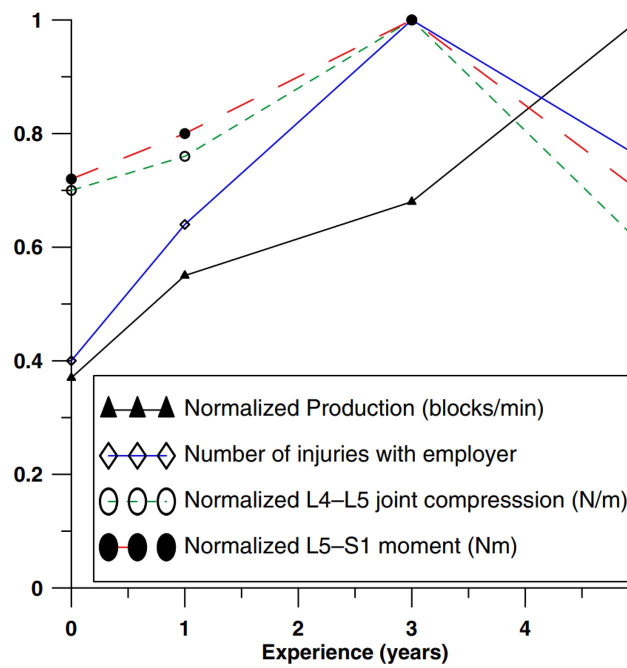


Figure 18: The relationship between productivity and injuries with years of experience. Adopted from Alwasel et al. (2017)

The learning curve theory states that every time the production quantity of a product doubles, the labor hours decrease by a certain percentage of the previous unit. This percentage is called the learning rate and identifies the learning achieved in the process. The lower the learning rate, the greater the learning achieved. A learning rate of 100% indicates that no learning is taking place (Thomas et al. (1986); Lutz et al. (1994)). Jarkas and Horner (2011) analyzed 45 buildings having recurring floor configurations. They found no significant changes in labor inputs as the cycle number increased. Based on the findings from the analysis, they claim that one can expect a minimal benefit from the effect of repetition for skilled and well-experienced operators. Furthermore, they believe that such an advantage can be linked to workers still learning their trade and that any productivity improvement achieved in the process can be related to the experience developed. Jarkas (2010) analyzed 21 residential building projects to investigate the learning curve theory, but, like Jarkas and Horner (2011), did not experience any decline over time. Mályusz and Varga (2017) found that learning effects can cause a 1-3% reduction in project duration. It will be a matter of a couple of days to a week shorter for cabin construction.

Pellegrino and Costantino (2018) analyzed 11 similar (but not identical) multi-story concrete structures. Figure 19 shows the productivity development of the various projects. Despite variations, the productivity pattern is almost the same in each structure. The results confirm that repetitive work provides opportunities for increased productivity. That is the time and effort used to complete repetitive activities decreases as the number of repetitions increases. Malyusz (2016) state that the learning rate is between 85-95% in the construction industry. They also state that the learning curve effect is not always applicable. It is necessary that the process is repetitive, that there is continuity for the workers, and that there must not be an abrupt stop during the production process.

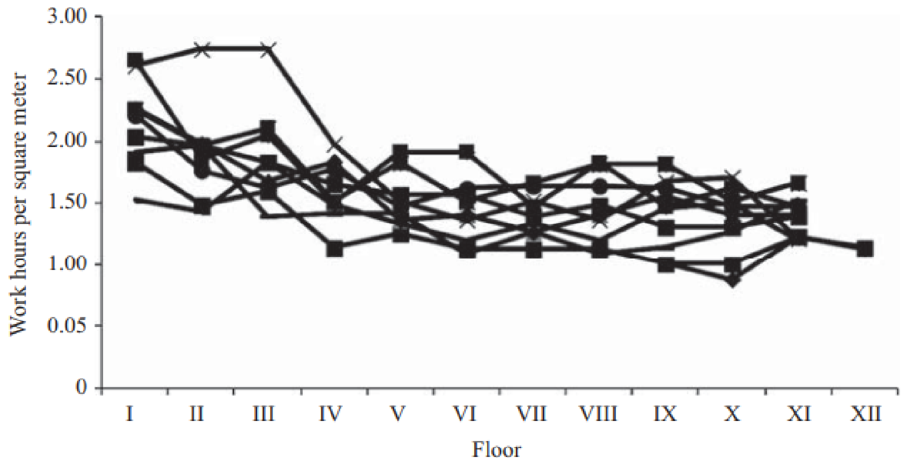


Figure 19: Productivity gains in 11 multi-story buildings in Italy. Adopted from Pellegrino and Costantino (2018).

HSE in education

Lysberg et al. (2012) found that the teaching in the construction industry in Norway covers the primary and general training when it comes to the use of protective equipment, machines, and tools but that there is less focus on showing the challenges of working in large companies and on building and construction sites. HSE is a topic in the curriculum within the vocational education program, where it is up to the individual school to design the training. Therefore, the degree of competence and attitudes towards HSE training in upper secondary school will vary. The Norwegian Labor Inspection Authority has prepared informational videos and held lectures and training for teachers, students, and staff at the training offices. Holte et al. (2009) state that HSE training in the school is perceived as relevant for half of the apprentices and mainly for those who work in small companies, which indicates that there should be more focus on the use of HSE in larger companies. Laukkanen (1999) found a fundamental need for training in recognizing hazards in the construction work environment.

Injuries

Figure 20 shows the risk of fall injuries by occupational group. The unskilled group has more than twice the risk of being hit by a fall injury than the average of 2,7, which shows that targeted fall prevention work must be largely aimed at unskilled workers within the industry. Mostue et al. (2022) analyzed 111 fall accidents and examined which factors influenced them. They found that competence, education, experience, and training was contributing factor in 23% of the accidents.

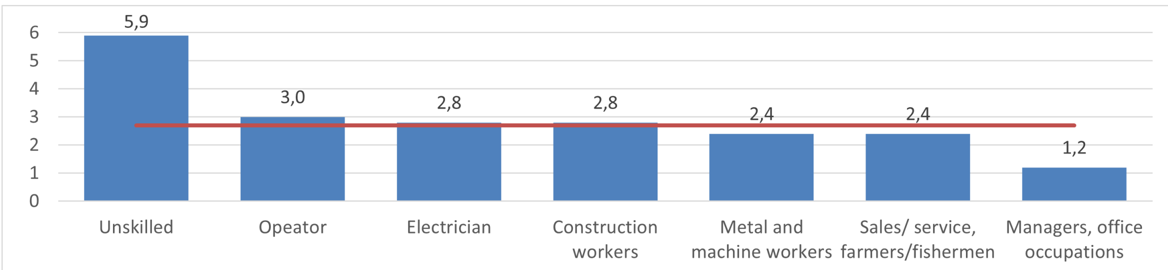


Figure 20: Risk (per 1000 employees) of fall injury by occupational group. Numbers from Mostue et al. (2020)

As mentioned in the subsection on age, several have found that younger workers are overrepresented in injury statistics. On the other hand, several studies believe this has nothing to do with age but that they are new to the job and have different experience and knowledge than those with more experience. Morassaei et al. (2013) found that all new employees have an exceptionally high risk of injury in the first month, regardless of age and experience, but this risk decreases with longer employment. Breslin and Smith (2006) had similar findings in that all age groups had a significantly higher injury percentage in the first month. However, their results also showed that younger workers (> 25 years) had a significantly higher risk than the older age groups. Rasmussen et al. (2011) results show that being an apprentice increased the risk of experiencing an accident at work by five times.

Breslin and Smith (2006) found that all workers have an increased risk of experiencing injury when they are new to a job. The results show that workers with less than one month in their new job have over four times the risk of injury compared to those who have worked there for over one year. Figure 21 shows the decreased risk of lost-time claims to months on the job. Morassaei et al. (2013) also examined the injury rate for newly employed workers and found the same tendency. Their study shows that newly employed workers have a higher risk the older they are, but all age groups end up at roughly the same level after around 13 months.

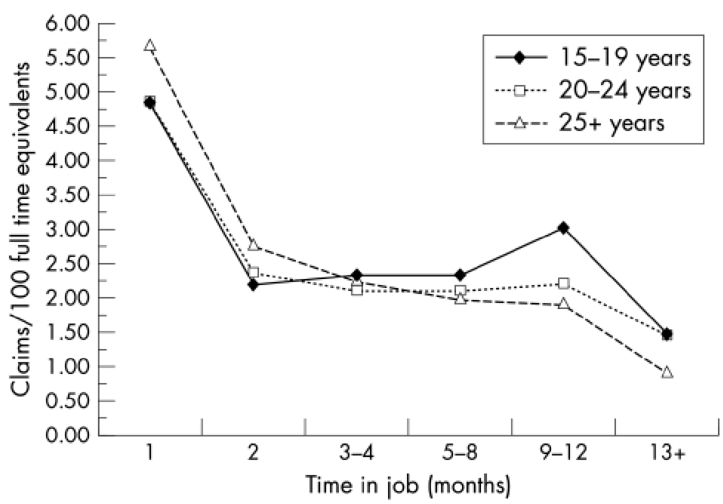


Figure 21: Lost-time claims to months on the job. Adopted from Breslin and Smith (2006).

2.7 Language and nationality

This sub-chapter reviews literature on challenges that can arise and factors that can affect multicultural and multilingual workplaces. Topics such as language barriers, type of employment, workers' connection to Norway, cultural differences, safety and injuries, quality of work, and productivity differences between countries are examined. Figure 22 shows a simple overview of some of the problems that can arise due to challenges related to language and culture.

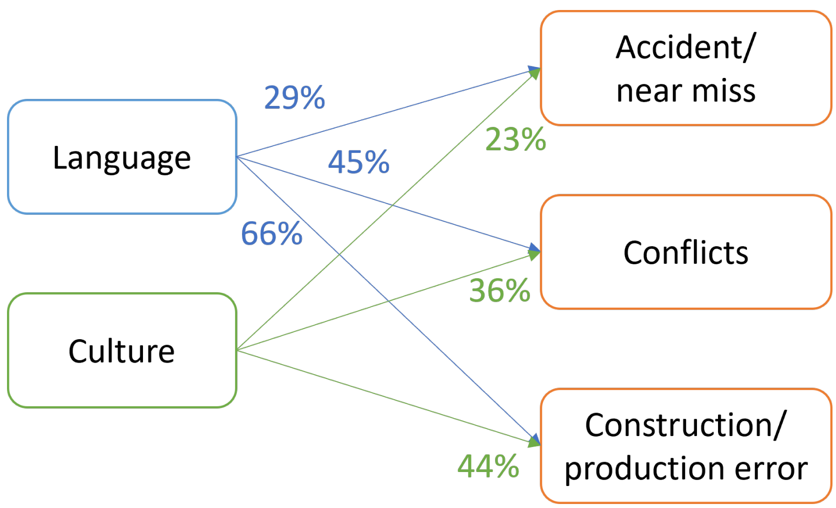


Figure 22: Proportion which said that challenges related to language and culture had consequences for safety, the working environment, and work quality. Translated version from Kilskar et al. (2017).

Language

The world's largest private education company, Education First (EF), conducts a yearly survey that ranks countries and regions by their English skills. Figure 23 shows that all the largest foreign groups in the construction industry in Norway have a high score on the test, ref table 5. They also state that a moderate or higher score should be sufficient to collaborate efficiently across borders, which suggests that communication between workers from these countries should work well. However, they started to rank various industries in 2018, where the engineering and construction industry was ranked moderate. In 2019 they also received a moderate score, but after a change in the index from 2020, they got a consistently low score of around 470-485 (Education First, 2022b).

Table 5: EF English Proficiency Index (EPI). Numbers from Education First (2022a)

Score	Value
Very high	600+
High	550-599
Moderate	500-549
Low	450-499
Very low	< 450

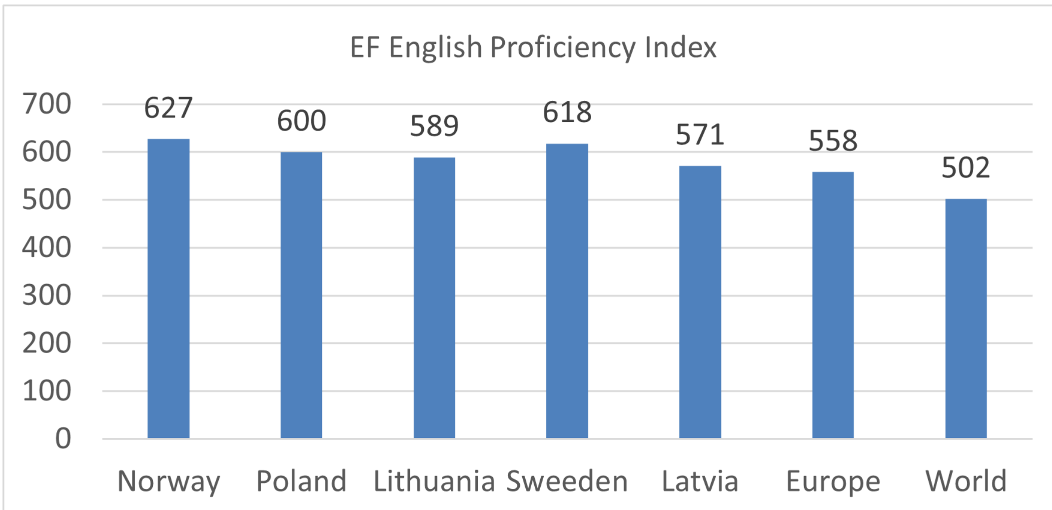


Figure 23: EF English Proficiency Index. Numbers from Education First (2022c)

In the construction industry, poor language skills can lead to dangerous situations for the employee and colleagues. It has therefore become common to divide work teams according to nationality to ensure that everyone understands each other (Ødegård and Andersen (2020); Wasilkiewicz et al. (2016); ; Kilskar et al. (2017)). However, this is a bad solution as it prevents cooperation and learning across nationalities (Kilskar et al. (2017); Ødegård and Andersen (2020)). Working side by side can be an effective way to learn, both when it comes to working methods, HSE, culture, language, and how working life in Norway works and is organized (Ødegård and Andersen, 2020). Wasilkiewicz et al. (2016) found that the level of integration at work and in society was seen as having a significant influence on the Poles' Norwegian skills.

The language problems and division by nationality also extend beyond the working environment. Norwegian workers, in particular, find multilingual workplaces troublesome, which may be because they feel that the workplace has changed and that "not everything is as it used to be". There may also be concerns that the job is carried out in an unfamiliar way, about future recruitment, or that one will be given different tasks than before (Ødegård and Andersen, 2020).

Several Norwegian workers experience being in the minority in the workplace or that workers from other countries are increasingly employed (Ødegård and Andersen, 2020). Some articles have expressed concern about the decline in the employment of young workers and lower numbers of applicants for carpentry and other vocational courses in secondary school (include Andersen and Jordfald (2016)). Andersen and Jordfald (2016) state that the proportion of employed people under 23 decreased between 2008 and 2014. Numbers from SSB (2023b) support the decrease and show that the proportion of employed people under 25 has decreased by 22% from 2008 to 2022 (from 18% to 14%).

From 2006 to 2009, there was an increase in the proportion of company managers who said that Eastern European workers cause language problems in the workplace (from 60% to 78%) (Bråten et al., 2012). A survey of migrant workers from Poland and Lithuania showed that less than half speak Norwegian as their primary language at work. In addition, almost 40% answered that they did not speak any or very little Norwegian. The oldest employees (over 50) and employees in construction were the ones who rated their Norwegian skills the worst. Workers with children in Norway had better Norwegian skills than those without, but longer residence in Norway had no significant effect on the Polish group but was shown to increase Norwegian competence among the Lithuanians. Three out of ten Polish and seven out of ten Lithuanian migrant workers had attended a Norwegian course. Still, they did not rate their knowledge of Norwegian as better than those who had not participated in a course (Ødegård and Andersen, 2021a).

Another study on Polish workers in Norway shows that Norwegian and English skills vary widely. They found that English skills highly depended on the interviewee's age, with the younger workers generally having better English skills. On the other hand, Norwegian skills were more dependent on the plan to stay in the country and the work contract. Those who spoke no Norwegian lived in Poland and commuted to work every other week. They saw no reason to learn Norwegian as they mostly worked 12-hour shifts and did not need to speak Norwegian outside of work. They had someone who could translate for them at work, or they knew a few basic words to do their job. The interviewees who planned to work for a few years to improve their finances knew some Norwegian. Those who had moved to Norway with their family could speak Norwegian at a higher level, even after a few years. Several interviewees had been on language courses but found it demanding and time-consuming, mainly because the courses took place in the evening after work (Wasilkiewicz et al., 2016).

Wasilkiewicz et al. (2016) also found that Norwegians perceive the language barrier as a greater risk than Polish workers. Many Polish workers thought communication at work was going well and that they knew enough Norwegian to do their job, but that it would have been helpful to know more. The Polish workers were also clear that communication became more manageable and the language barrier smaller when they knew each other and had worked together before. Kilskar et al. (2017) state that the opportunity to get to know each other can influence whether one communicates well about the work to be done daily, which, in turn, can positively impact the working environment and safety.

Type of employment

Several studies state that the type of employment, full-time, part-time, or contracted/ commuting, is of greater importance than nationality when it comes to the challenge of multicultural workplaces (include Kilskar et al. (2017); Ødegård and Andersen (2020)). Kilskar et al. (2017) states that people hired from staffing agencies learn the language less often and that there is less focus and investment in language training. Contracted labor also seems to have a poorer understanding of how their culture, especially related to hierarchy and power distance, can create misunderstandings and challenges in the workplace. How culture can influence will be further discussed later in the subsection. Foreign-hired workers also feel more discriminated against and accept unfair working conditions to a greater extent as they are afraid of not getting more work.

As discussed, relationship duration can help ensure safety and a good working environment. The length of the employment relationship also affects how much the employer invests in the worker, for example, when it comes to training and skill building, which, in turn, can affect the worker's prerequisites for working safely and by the expectations of the employer and other colleagues (Kilskar et al., 2017).

Connection to Norway

Figure 24 shows how many foreign commuters work in the construction industry in Norway. The proportion of other residents equals Norway's proportion in figure 4, which means that the foreign workers in the construction industry mainly come to Norway to work and that almost half of them do not live there. To check the connection these workers have to Norway, one looks at how many commuters are still commuters and how many have settled. In 2021, 53% were still commuters, and only 16% had settled down; the rest are unknown.

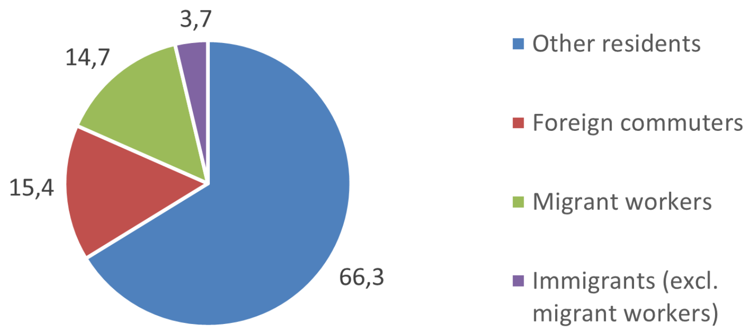


Figure 24: Workers in the construction industry in Norway divided by type, in 2020 (in percent). Numbers from SSB (2022).

A survey of 2,000 companies in the construction industry asked showed that 20% had used contracted labor from staffing companies in the last two years. For small companies (1-9 employees), the proportion was 13%, while for larger companies (more than 50 employees), the proportion was 73% (Bråten and Andersen, 2017). According to Bråten et al. (2012), the main reason Norwegian employers use foreign labor is the lack of labor. A survey of migrant workers from Poland and Lithuania showed that the workers' main motivation for coming to Norway was earning more money than at home. 17% of the Polish and 14% of the Lithuanians came to Norway because they were unemployed. Most respondents had lived in Norway for many years, and a large proportion had established themselves with family. However, yet 24% of the Lithuanians and 18% of the Polish considered returning to their home country within the next five years. The majority would continue to live in Norway if they had a job. The migrant workers with children had the greatest interest in staying. The most important factors to continue living in Norway were satisfactory living conditions and good treatment at work (Ødegård and Andersen, 2021b).

Cultural differences

As mentioned, language problems can lead to not exchanging knowledge across nationalities. Cultural differences can also prevent this, as many foreign workers have a different relationship with managers and do not dare to propose their methods, leading to more effective methods not being carried forward. In addition, Kilskar et al. (2017) reports that 23% have experienced accidents or near-miss, 36% have experienced conflicts, and 44% have experienced construction or production error due to challenges related to culture, see figure 22.

After several years of labor immigration, many have researched and found several differences in culture and attitudes, especially around hierarchy and security (include Bråten and Andersen (2017); Ødegård et al. (2007); Wasilkiewicz et al. (2016)). Eastern European workers often have a different relationship with their superiors than usual in Norwegian working life. Typically, the foreign worker does not dare to admit that he has not understood the message or to question whether it is correct and safe to perform the task. If a superior has given a message, do what you have been ordered to (Ødegård et al., 2007). Bråten and Andersen (2017) and Wasilkiewicz et al. (2016) agree that managers have a different authority for the Poles and that they follow instructions instead of discussing. Bråten and Andersen (2017) also add that it can be a major safety challenge if workers do not assess the risk themselves. Wasilkiewicz et al. (2016) found, in contrast to other articles, that the interviewed Poles usually asked if there was something they did not understand. However, they also stated that Polish workers have different kinds of "yes", where the tone was decisive for what the person meant to say.

Kilskar et al. (2017) research shows that construction managers believe that Norwegians are significantly more independent than foreign workers. Kilskar et al. (2017) in-depth interviews with the manager showed that some thought it was clear to see that foreign workers were used to working in pairs, that they needed more help to get started with work, and that they had a higher threshold for asking for help. One of the foreign workers explains that he does not ask for help if he does not know the people he works with because he feels he should have understood. Norwegian interviewees observed that Poles needed more specific orders to do their work, while the Norwegians were more independent. On the other hand, the Poles believed they were more observant and solution-oriented and thus could find good solutions without a superior's order (Wasilkiewicz et al., 2016).

On the other hand, the Norwegians and the Poles agreed that they were poor at reporting deviations and did not like it because they perceived it as snitching. Kilskar et al. (2017) conducted a survey that found that 70% agreed that the Norwegians were good at reporting dangerous or unsafe conditions, against 10% of the foreign workers. That foreign workers are bad at reporting incidents may suggest dark figures in several statistics. Ødegård et al. (2007) and Kilskar et al. (2017) agree that workers who need a clear command line come from a culture of high loyalty to workers and workers, therefore, do not want to speak up about critical matters. Wasilkiewicz et al. (2016) state that several Poles mentioned that this had improved when they had been in Norway for a while and got more focus on HSE.

Kilskar et al. (2017) state that many managers consider their Eastern European workers more willing to work. Their survey also shows that twice as many foreign workers are positive for overtime than the Norwegians. A Polish worker also states that they want to finish their work faster and drop planning, while the Norwegians want to plan before they start.

Safety and injuries

Many reports have been written about HSE and foreign workers after labor immigration accelerated after the EU enlargements in 2004 and 2007. Nevertheless, Kilskar et al. (2017) reports that 29% have experienced accidents or near-miss due to challenges linked to language and 66% due to challenges related to culture, see figure 22.

Bråten et al. (2012) results show that there was an increase in the number of managers that believed workers from new EU countries lacked knowledge about HSE from 2006 to 2009 (51% to 69%). On the other hand, the results show a decrease in the number of managers who say that language and communication problems have led to more accidents (from 17% in 2006 to 9% in 2009).

A collective study of 72 studies worldwide concluded that foreign-born workers had worse working conditions than native-born workers. Based on 31 studies, foreign workers had a 2,13 times higher risk of occupational injury than native-born workers. However, the study showed that the risk was very variable. In some countries, the foreign workers' risk was ten times as high; in other countries, it was below the natives, and some studies showed that it started higher than natives but decreased to below level after five years (Salminen, 2011). Gravseth et al. (2018) state that there are more foreign than Norwegian workers in the construction industry who rate their health as poor (Relative Risk (RR) = 2,4), have work-related absence, 14 days or more (RR = 2,3), and experienced work-related injuries with absence beyond the day of the accident (RR = 3,9).

Mostue et al. (2022) reports the number of occupational deaths and employees in the construction industry from 2012 to 2021. Based on these numbers, it is found that foreign workers had an average RR of 1,7. However, the foreign workers' risk was not significant in any of the years, and the risk varied from 0,3 to 3,5. Although most studies do not conclude with a significant difference, the risk of both occupational injuries and occupational deaths is somewhat higher for foreign workers, and several studies conclude that foreign workers are overrepresented (include Assum and Nordbakke (2013); Mostue et al. (2022); Arbeidstilsynet (2018); Arbeidstilsynet (2017)). Arbeidstilsynet (2018) found that the workers from Eastern Europe had a significantly higher risk of occupational death (RR = 1,7) than the Norwegian workers. Assum and Nordbakke (2013) state that foreign workers work in the most accident-prone jobs, have challenges with communication due to language problems, have poor training, feels a pressure to work more, and are often short-term employees, but that it seems to decrease with longer residence in Norway. Wasilkiewicz et al. (2016) agrees that foreign workers change their attitudes and behavior after being in Norway for a while.

Kilskar et al. (2017) state that some contracted workers experience having to accept unreasonable working conditions for fear of not getting more work. Bråten et al. (2012) mentions work time as a challenge when using staffing agencies because it makes it difficult to check that employees do not work more than is reasonable. Winge et al. (2015) state that there are more injuries among those who worked a long week (more than or equal to 45 hours per week). Winge (2012) state that many injured foreigners did manual work, while Norwegian workers often operated machines. Arbeidstilsynet (2017) agree that foreign workers perform more risky jobs. Wasilkiewicz et al. (2016) state that some Polish workers had experienced higher expectations towards him performing risk-related work. They think the expectations have come from people becoming used to the Poles doing everything, which they often do because they fear losing their jobs. Wasilkiewicz et al. (2016) state that there are somewhat looser rules in Poland, which may be why they often accept behavior that breaks with the rules, such as saving time. On the other hand, the Norwegians and the Poles said that they followed the rules if someone spoke out, as they were afraid of losing their jobs, which was often the main reason, followed by their safety.

As mentioned under experience, several studies explain that younger people's higher risk of injury is caused by the fact that they are new to the job and that it decreases with employment. This explanation may also be part of the explanation for the foreign workers as, as mentioned earlier, they are often young and less experienced.

Ødegård et al. (2007) found that 35% of the interviewed managers believe that using Eastern European labor can create dangerous citations in workplaces, and 17% believe language and communication problems have led to more accidents. The article also states that an inspector from the Norwegian Labor Inspection Authority believes that the official statistics are characterized by under-reporting as he thinks it is strange that no more accidents are reported when he is out in the field and observes the safety standard. Friberg and Eldring (2011) found that 34% expected to lose their job or have serious problems if they talk to the Norwegian Labor Inspection Authority, which can help build up under the inspector's claim. Ødegård et al. (2007) found that 86% needed training in HSE and Friberg and Eldring (2011) found that 44% had not received training in HSE, which may indicate that more foreign workers receive training in HSE. Friberg and Eldring (2011) found that 58% of the Polish workers in Oslo had to do dangerous things in their job in Poland, and 28% of the workers had also had to do dangerous work in Norway. Ødegård and Andersen (2021b)'s survey on working and living conditions for resident migrant workers from Poland and Lithuania states that one out of ten has had to perform dangerous work against his will.

In a corporate survey from 2006, managers were asked if workers from new EU countries have lower sick leave than Norwegian workers. 80% of the construction industry managers responded that they agreed (Ødegård et al., 2007). The conclusion is that the absence is probably lower as largely young workers come to Norway to work. They also state that lower sick leave may be due to better work ethic, less knowledge of rights, sick pay, or fear of losing their jobs. It is not good for the HSE if it turns out that foreign workers come to a greater extent to work even if they are ill. Andersen and Ødegård (2017)'s research shows that the proportion who fully or partially agreed that Eastern European workers have lower sickness absence than Norwegian workers has decreased from 58% in 2009 to 42% in 2017. One explanation for the decline could be that more workers know their rights concerning sick leave.

Quality of work

Almost half of the workforce from Eastern Europe lacks registered education as it has been difficult to get their vocational education approved in Norway (Andersen and Jordfald, 2016). Andersen et al. (2009) state that 34% of the workers from Eastern Europe performed less skill-intensive work and that 24% performed their work worse than the Norwegian workers. Kilskar et al. (2017) have asked several Norwegian building managers about the extent to which Norwegian and foreign labor deliver good quality in their work. Overall, the construction managers are more satisfied with Norwegian workers. But if one look more thoroughly at the answers, smaller companies without foreign labor are the most positive about Norwegian labor and the most negative about foreign labor. The difference in these articles may be that employers have become less skeptical or prejudiced toward foreign workers.

Productivity differences

The production index measures added value and is used in the construction industry to measure development SSB (2023a). Figures 25 and 26 show the development in productivity in the construction industry for the largest nationalities in the Norwegian construction industry, respectively, per quarter and an average of the annual productivity to see a clearer trend over a longer period. Figure 25 shows that the Eastern European countries have more significant fluctuations than the Nordic countries during the year.

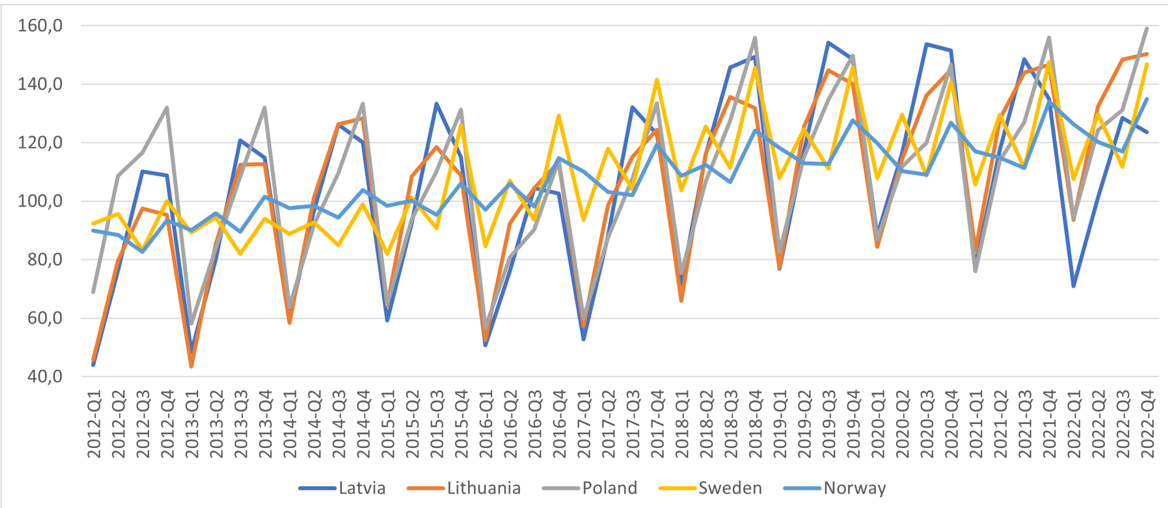


Figure 25: Quarterly production index by country. Numbers from Eurostat (2023), ei_isbu_q.

Figure 26 shows that all the countries have had a similar trend after 2010. If one disregard the decline in Latvia, the remaining countries have similar productivity, where the country with the lowest index (Sweden) achieves 94,5% of the productivity of the country with the highest index (Lithuania). Lativa, on the other hand, performs only 80,8% of the productivity of Lithuania.

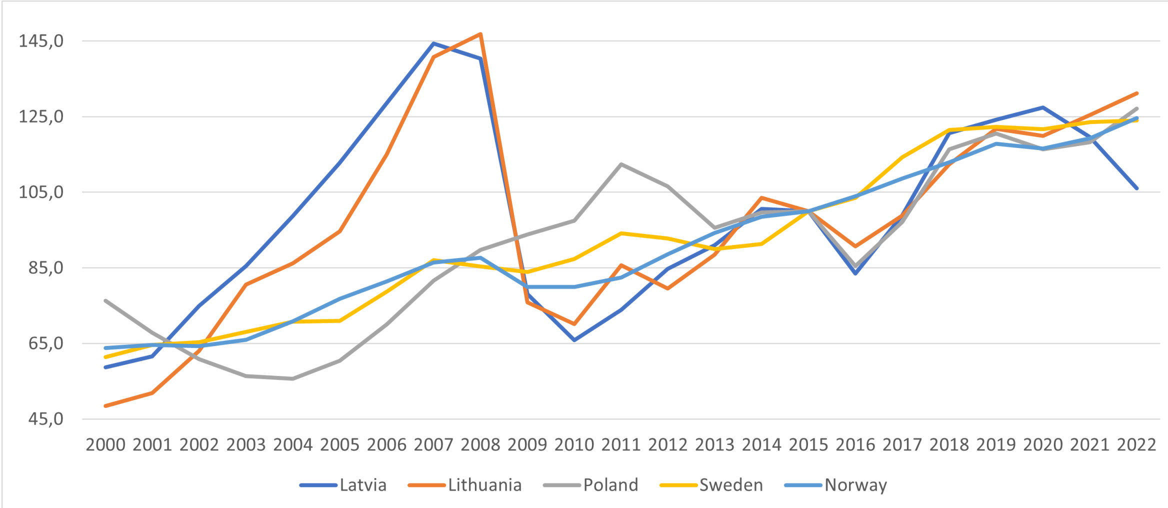


Figure 26: Average yearly production index by country. Numbers from Eurostat (2023), ei_isbu_q.

2.8 Multiple regression analysis (MRA)

Today, companies can collect data to improve their decisions. Some of it can be analyzed and understood by simple statistics, and sometimes that involves taking three or more sets of data into account, which requires more complex, multivariate statistical techniques to convert data into knowledge (Hair et al. (2010); DX Adobe (2021)). It is an increasingly used method to analyze complex datasets (Tabachnick et al., 2013).

2.8.1 Regression equation

"Multiple regression analysis is a statistical technique that can be used to analyze the relationship between a single dependent (criterion) variable and several independent (predictor) variables.", (Hair et al., 2010). The objective is to use the known and independent variables to predict an unknown dependent variable (Hair et al., 2010). The independent variables are the different characteristics the subjects bring into the research situation (Tabachnick et al., 2013). The regression analysis procedure weights them to ensure maximal prediction from the independent variables. The weights indicate the relative contribution of each independent variable. These variables form the regression variation, a linear combination of the independent variables that best predict the dependent variable (Hair et al., 2010). The multivariate regression analysis model is formulated as follows:

$$y = \beta_0 + \beta_1 x_1 + ... + \beta_n x_n + \epsilon$$

y – dependent variable

x_i – independent variable

β_0 – y-axis intercept, the value of y when all other parameters are set to zero

β_i – parameter

ϵ – error

2.8.2 Different types of variables

When using statistical techniques, it is essential to consider the type of measurement and the correspondence between the numbers and the events they represent. In multivariate analysis, the distinction is among continuous, discrete, and dichotomous variables. Continuous variables are measured on a scale and can take on any values within the range of the scale. Some examples of continuous variables are distance, age, and temperature. The discrete variables are often referred to as category variables. It is a finite and usually small number of values they can take. One example of a discrete variable is the year's season (winter, spring, summer, or fall) (Tabachnick et al., 2013). Dichotomous variables are variables that only have two categories or values. Some examples of dichotomous variables are gender (male or female) and categories where the possible values are yes or no, such as owning a house (statistics, 2023).

In some cases, discrete variables are used as if they were continuous in multivariate analyses. These are cases where there are many categories, and the categories represent a quantitative attribute. For example, a variable representing different age groups (e.g., variable 1 for 0-5 years, 2 for 6-11 years, 3 for 12-17 years, etc.) can be used because there are many categories and the numbers indicate a quantitative attribute (increasing age). On the other hand, numbers used to indicate different building construction types are not in a suitable form for analysis for many of the techniques as building construction types do not fall along a quantitative continuum (coherent/ continuous quantity) (Tabachnick et al., 2013).

In other cases, discrete variables of different categories are changed to two-level variables (e.g., carpenter versus non-carpenter). This conversion to dichotomous variables is called dummy variable coding and is done to limit the relationship between the dichotomous variables and other linear relationships (Tabachnick et al., 2013). In cases where a variable can take $N > 2$ levels of nonmetric values, $N - 1$ dummy variables are needed (Hair et al., 2010).

2.8.3 Assumptions for linear regression

When performing multiple linear regression, there are several assumptions about the relationship between the independent variables and the dependent variable, as well as the model's prediction error (Hair et al., 2010). To avoid, among other things, under or over-fitting, testing the assumptions is an important part of all statistical techniques (Williams et al., 2013). Hair et al. (2010) proposes the following assumptions; linearity of the phenomenon measured, constant variance of the error terms, independence of the error terms, and normality of the error terms distribution. Figure 27 shows the null plot of the residuals where all assumptions are met.

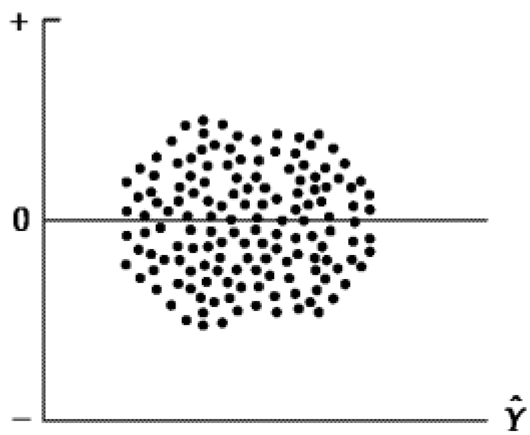


Figure 27: Null plot, the plot of residuals when all assumptions are met (Hair et al., 2010).

Linearity of the phenomenon measured

The linearity of the relationship between the independent and the dependent variables represents the extent to which a change in the dependent variable is associated with the independent variable. The regression coefficient is constant for all the values of the independent variable. The concept of correlation is based on a linear relationship, which makes it a critical issue in regression analysis. To examine the linearity of a given relationship, one can use residual plots, where the independent variable is plotted against the residuals or partial residuals in cases with multiple variables (Hair et al., 2010). To visualize potential trends in the data, one can estimate a non-parametric regression model, where locally weighted scatterplot smoothing (LOESS) is widely used (Fox and Weisberg, 2018).

Constant variance of the error terms

Hair et al. (2010) state that the presence of unequal variances, also known as heteroscedasticity, is one of the most common assumption violations. To identify this problem, one can plot the residuals (studentized) against the predicted dependent values and compare them to the null plot, where there is a consistent pattern if the variance is not constant (Hair et al., 2010).

Independence of the error terms

In regression, one assumes that each predicted value is independent, which means that the predicted value is not related to any other prediction and that they are thus not sequenced by any variable. Such an occurrence can be identified by plotting the residuals against any possible sequencing variable. If the residuals are independent, the pattern should appear random and similar to the null plot of residuals. Violations will be identified by a consistent pattern in the residuals (Hair et al., 2010).

Normality of the error terms distribution

According to Hair et al. (2010), nonnormality of the independent or dependent variables (or both) is one of the most frequently encountered assumption violations. The simplest method for testing normality is to plot a histogram of residuals and do a visual check for a distribution that approximates the normal distribution (Hair et al., 2010).

2.8.4 Estimate the regression equation

There are several different methods for estimating the regression equation, of which Ordinary Least Squares (OLS) is the most common method. OLS aims to minimize the sum of squared error (SSE) in the regression model. That is, minimizing the difference between the observed and the estimated values (Hair et al. (2010), Craven and Islam (2011)).

To assess how well a model fits the data, the coefficient of determination (R^2) is used. Hair et al. (2010) explains R^2 as a measure of how much of the variance of the dependent variable is explained by the independent variables. The coefficient varies between 0 and 1. The larger the R^2 value, the larger proportion of the variance is explained and the better the estimate of the dependent variable (Hair et al., 2010). However, R^2 is not the same as the correlation coefficient (r), also known as Pearson's correlation coefficient. The correlation coefficient describes the relationship between two variables and varies between -1 and 1, where 1 indicates a perfect linear relationship, 0 indicates no relationship, and -1 a perfect negative relationship Hair et al., 2010.

2.8.5 Examining the statistical significance of the model

Statistical significance testing for coefficients estimated by regression analysis is necessary when the analysis is based on a sample of the population rather than a census. Significance testing of regression coefficients is a probability estimate of whether the estimated coefficients will be different from zero. A confidence interval is established around the estimated coefficients. If the confidence interval to a variable does not include zero, the variable is statistically significant. To establish a confidence interval one have to look at three concepts:

- Establish a significance level (α), which is commonly known as the level of statistical significance and is the probability of the estimated coefficients. The most common level is $\alpha = 0,05$ (Hair et al., 2010).
- Sampling error, the cause for variation in the estimated regression coefficients for each sample drawn from a population. The sampling error is larger for small sample sizes and the estimated coefficients will most likely vary widely from sample to sample. For larger sample sizes the samples become more representative and the variation becomes smaller.
- Standard error, the expected variation of the estimated coefficients due to sampling error. It acts like the standard deviation of a variable by representing the expected dispersion of the coefficients estimated from repeated samples of this size.

2.9 Findings from the literature study

This sub-chapter summarizes the most important findings from the theory parts about the selected characteristics of carpenters. For each characteristic, the summary ends with hypotheses based on the findings.

Age

In the sub-chapter about age, chapter 2.5 reviewed factors influenced by a worker's age, including injuries, work capacity, and work ability. The findings show that most studies believe younger workers generally injure themselves more often and, in most cases, minor injuries than older workers. Most of them agree that one reason for this tendency is that younger workers have other types of tasks and a lack of experience. Some stated that older workers were less likely to report injuries, especially minor injuries. The findings also show a consensus that work capacity decreases with age and that training and adapting work tasks is essential to keep older workers at work. Based on this, the following hypotheses are proposed:

- H1.1: There is a relationship between age and man-hour consumption in cabin construction.
- H1.2: There is a relationship between age and construction days in cabin construction.

Education and experience

In the sub-chapter about education and experience, chapter 2.6 reviewed factors influenced by a worker's education and experience, including HSE in education, injuries, experience impact on performance, and level of education. The findings show that around 80% of the construction industry workers have a minimum education level at upper secondary school and possibly even more, as it can be difficult for a foreign worker to get his education approved in Norway. Most people who come to Norway and work in the construction industry are craftsmen.

Several studies found that experience and education played a significant role in performance. They found it to influence both positively and negatively (if it was not present), with experience influencing the most. More people had found that experience was more important than education but that a person with both education and experience performed better than one with equivalent experience and no education.

Some studies stated that experience increases performance each year throughout the career. Others, on the other hand, have found that experience affects performance increasingly up to around 12-15 years of experience, which remains at the same level throughout the career.

When it comes to experience and injuries, several have found an increased chance of injuries in the first year in a new job, regardless of whether one is a recent graduate. Statistics showed that unskilled workers had a higher risk of fall injuries. Some have also found that graduate workers have an increasing trend of injuries in the first years before they learn better working methods and techniques that reduce muscle strain. Findings also show that HSE is deficient at school, especially around risks on the construction site.

The learning curve studies were divided, with some showing improvement in performance and others no difference. On the other hand, those who found a difference believed that certain requirements had to be present for the learning curve theory to fit, which may be the case with the studies that did not show a difference. The studies that showed improvements are mainly based on larger construction projects, i.e., buildings with many floors, and that cabin construction is too small a scale to fit the theory. Based on this, the following hypotheses are proposed:

- H2.1: The number of man-hours in cabin construction decreases with the carpenters' experience.
- H2.2: The number of construction days in cabin construction decreases with the carpenters' experience.

Language and nationality

In the sub-chapter about language and nationality, chapter 2.7 reviewed factors affecting multicultural and multilingual workplaces, including language barriers, cultural differences, and safety and injuries. Several Norwegian research was found on this topic, mainly as a cause of Norway receiving a lot of foreign workers after EU enlargements. One of the surveys found that 29% had experienced language-related problems that had led to accidents or near misses, 45%

The survey from the EF showed that the population of all the largest foreign nationalities and the population in Norway had good English skills. The construction industry, on the other hand, received a low score. Findings also showed that dividing work teams according to nationality was common due to low language skills and the dangers that can lead to. Another study showed that the proportion of company managers who believed that language was a problem had increased. A third study found that Norwegians experience language problems more challenging than foreign workers.

Several studies found that cultural differences led to dangerous incidents. Among other things, Poles did as they were told without thinking of the risks. Several also believed that Poles often say yes even if they do not understand the message or that they do not dare to ask if there is something they do not understand. Some of the Poles believed that it was about not knowing the person and felt that they should understand or that they have different ways of saying yes, where the tone determines whether they understood the message.

The findings also showed that Poles needed to improve at reporting deviations. The report situation led several studies to believe that the injury statistics have large dark figures. Another study found an increase in company managers who believed foreign workers lacked HSE training. Several studies also focused on injury statistics, where most found that foreign workers were somewhat overrepresented and had a higher risk of occupational injuries. Some believed this was because the foreign workers performed more risky work, either because it was expected of them or because they feared losing their jobs.

Finally, the sub-chapter investigated whether there were differences in the quality of the work of the foreign workers compared to the Norwegian ones. Here, most company managers believed that it was pretty similar and that better and worse workers were found among the Norwegian and the foreign workers. The production index in the various countries supports this, as all major foreign nations apart from Latvia had approximately the same index. Based on this, the following hypotheses are proposed:

- H3.1: The more carpenters with a common language, the lower the man-hour consumption in cabin construction.
- H3.2: The more carpenters with a common language, the fewer construction days in cabin construction.

3 Case

The case company was founded in 1979 and has built over 8000 cabins both in the mountains and by the sea. They are a part of one of Scandinavia's largest companies in the construction industry, with over 300 member companies, 220 building material stores, and a turnover of about NOK 20 billion, about EUR 1,8 billion, in 2022.

Figure 28 show some of their cabins. At the time of writing, their catalog contains 25 cabins divided into nine series, where the smallest is around 50-60 square meters and the largest 120-130 square meters (Gross Floor Area). The cabins are priced between NOK 1,6 million (EUR 142 000) and NOK 4 million (EUR 350 000).

Figure 28: Some of the case company's cabins.

All the cabins are produced as building kits. They can be installed and sealed on the building site within a few days and therefore avoid being exposed to the weather for a long time while construction is in progress. The cabins are delivered in four levels of completion; as a building kit, externally mounted, electrically ready cabin, and turnkey cabin; see figure 29 for an overview of the various steps in the construction process.

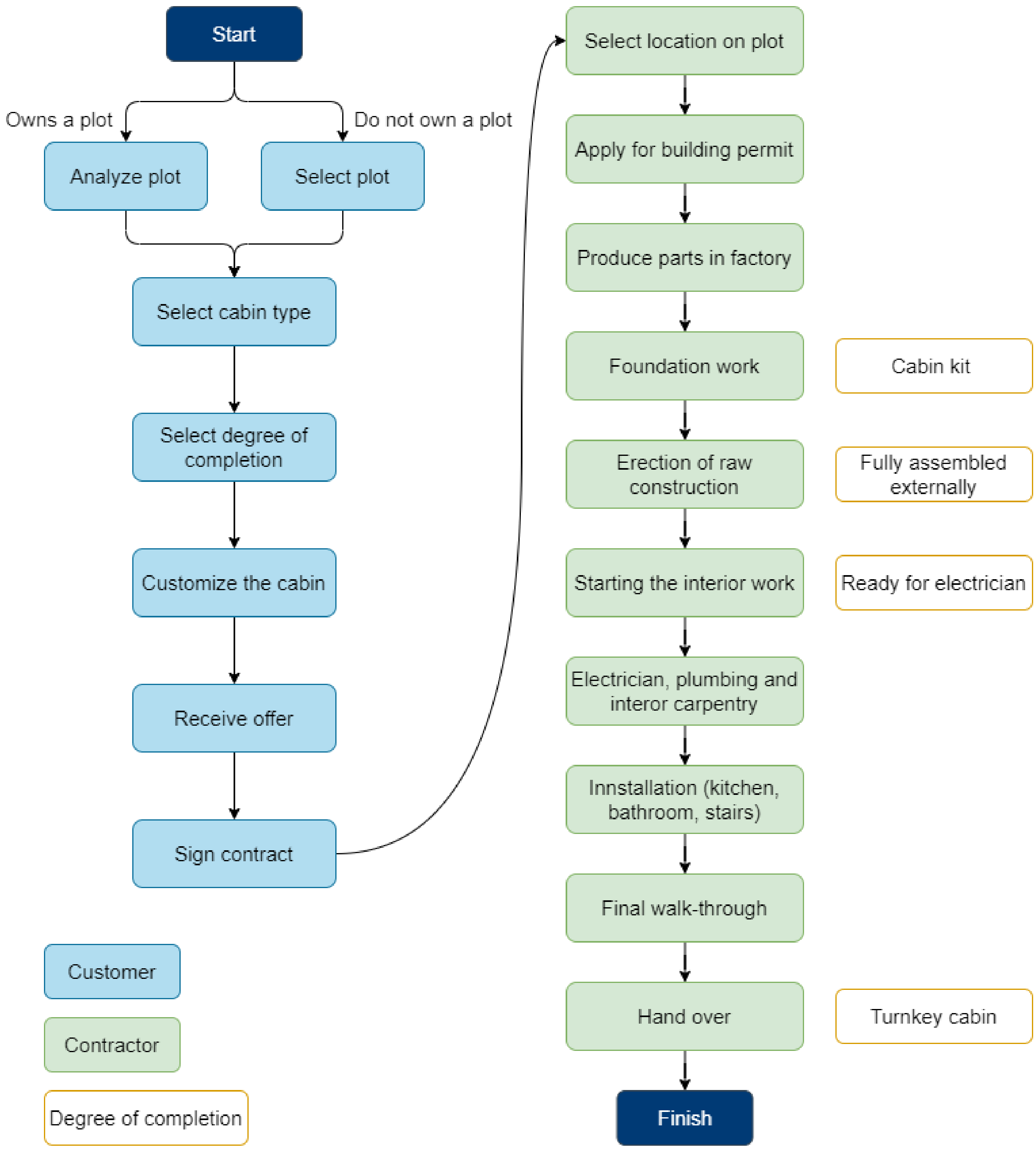


Figure 29: The phases of cabin construction, constructed from.

Table 6 shows an overview of the main phases of the case company's turnkey cabin projects. The projects with no man-hours in one or more of these phases were removed from the dataset, as explained under section 4.2, Case study (Preparation of data).

Table 6: The main phases of the case company's projects. Based on the data received.

Phase	Name
0	Concrete/ foundation [a]
1	Element assembly
2	House wrap
3	Roofing
4	Completion
5	Installation preparation
8	Panel
9	Doors and floors
10	Interior trim

[a] Mostly carried out by other companies, therefore not included as one of the main phases in the analysis

Table 7 shows an overview of phases that some projects must carry out due to the season (snow removal), due to errors/ deficiencies (complaint, additional work), or the size/ height of the cabin (scaffolding).

Table 7: Some of the extra phases of the case company's projects. Based on the data received.

Phase	Name
16	Reclamation
18	Additional work
151	Snow removal
152	Scaffolding

4 Methodology

A critical review of the methodologies used is essential when conducting literature research. Methodological literature indicates why a particular research design may be appropriate for investigating a topic (Cronin et al., 2008). Research methods are all the methods/techniques used to carry out research. These are the methods researchers use to carry out research operations. Research methodology is a systematic way of solving a research problem. Research methods are thus part of the research methodology. Still, the research methodology also contains the logic behind the methods used in the context of the research study and argues for the methods used (Kothari, 2004).

4.1 Literature study

"A literature review is an objective, thorough summary and critical analysis of the relevant available research and non-research literature on the topic being studied", (Hart, 1998). It is important in identifying and clarifying research topics and questions (Croom, 2010). The goal is to update the reader on current literature on a topic and form the basis for a new goal (Cronin et al., 2008).

Cronin et al. (2008) use the following steps when conducting a literature review:

1. Selecting a review topic
2. Searching the literature
3. Gathering, reading, and analyzing the literature
4. Writing the review
5. References

In this thesis, the literature searches used the search engines Scopus, Oria (NTNU's library search engine), and Google Scholar with the keywords listed below. Several of the conducted searches were in Norwegian, as several studies on the Norwegian construction industry are written in Norwegian. Language challenges, in particular, have been extensively researched after the EU enlargement in 2004. The literature search also includes a search among learning textbooks for the construction industry (apart from the searches listed) to find out how construction sites in Norway are structured and operated. Statistics Norway (Statistics Norway) and Eurostat are used as sources for public data on the construction industry in Norway and Europe.

- construction industry in Norway performance OR productivity
- Arbeidstakere byggebransjen
- Utdanningsnivå byggebransjen
- Bygg og anlegg farlig arbeid
- Eldre arbeidere i bygg og anlegg
- Work capacity construction
- Work ability construction
- Physical work ability construction
- Age productivity construction
- Job performance construction productivity
- Experience construction industry

For all relevant studies, snowballing was used to find more articles on the relevant topic. Snowballing means scrolling through an article's reference list or citations to identify additional articles (Wohlin, 2014). Furthermore, articles found by search and snowballing were examined to see if they used other terminologies than the original search, and then new searches were made with these terminologies.

4.2 Case study

Yin (2018) describes a case study as an empirical method that investigates a contemporary phenomenon, a case, in-depth and within a real-world context. According to Yin (2018), a case study is relevant if the research questions attempt to explain why or how something is connected.

Multiple regression analysis was chosen as the research method to investigate the relationship between the carpenters' characteristics and construction performance. The research models are shown in figure 30 and 31. The models include some control variables to increase the explanatory strength of the regression models.

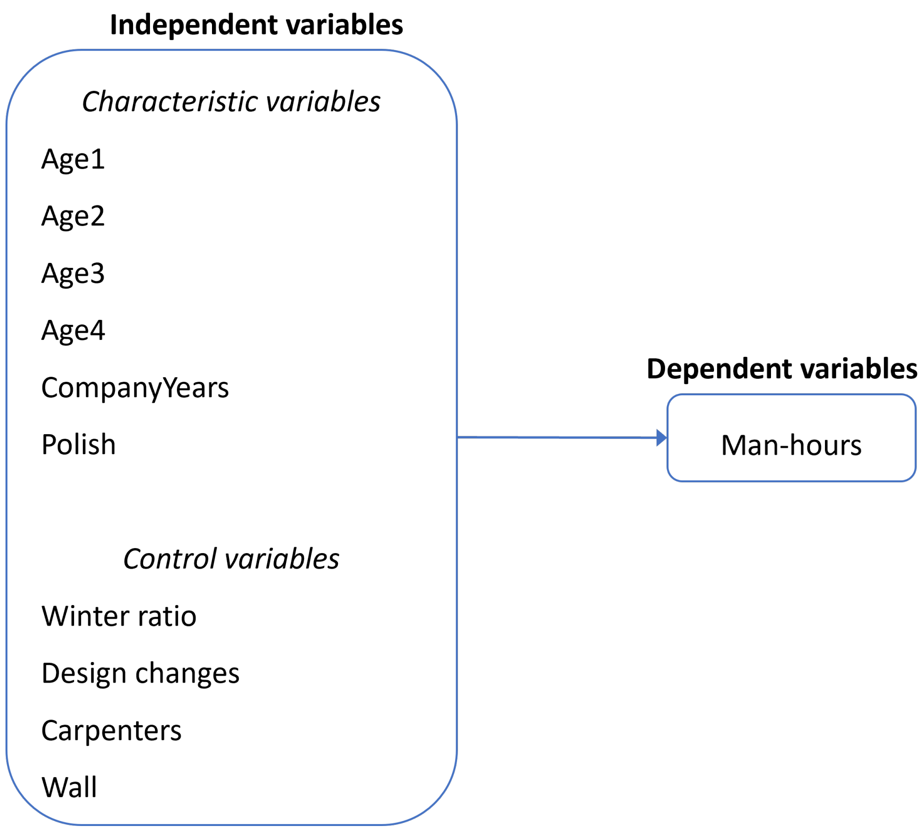


Figure 30: One of the research models for this thesis.

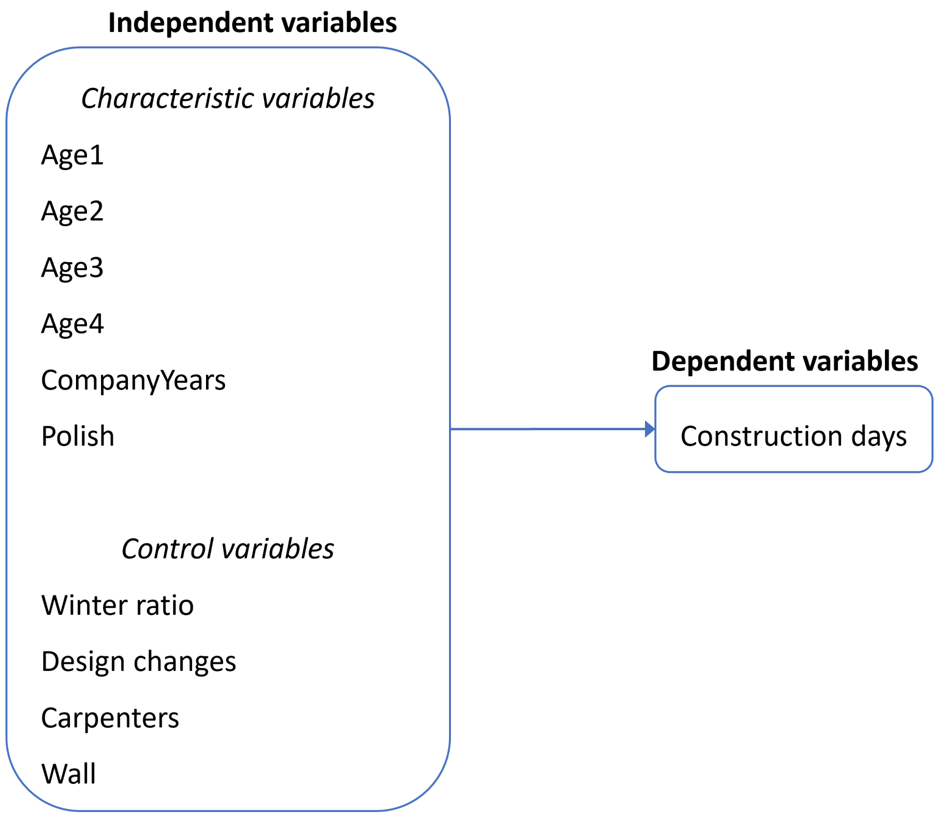


Figure 31: One of the research models for this thesis.

Hair et al. (2010) comes up with three points the researcher must consider before multiple regression can be applied to a research problem: the research problem must be suitable for multiple regression, specification of a statistical relationship, and selection of dependent and independent variables.

First, regarding suitable research questions, multiple regression was used to explain and investigate the relationship between carpenters' characteristics and construction performance. The significance, magnitude, and sign of the independent variables were interpreted to examine this relationship.

Secondly, a statistical relationship must be specified. To specify a statistical relationship, one must check whether a relationship between two statistically significant variables exists. If there is a significant relationship between two variables, one must change or remove one of the variables.

Finally, one has to select the dependent and independent variables. In this thesis, widely used measures of construction performance are chosen as the dependent variables. The independent variables are divided into two categories: characteristic variables that will help answer the research questions and the control variables that have been chosen according to what Christensen (2022) found significant.

Variables

Table 8 shows the variables used in the data analysis. The variables are classified as independent (x) or dependent (y) and metric or nonmetric. As this thesis, to some extent, builds on Christensen (2022), all the variables that Christensen (2022) found significant (i.e., the contract sum, number of changes to the standard design, winter conditions, date of construction start, and construction team) were assessed.

The data used in this thesis has been changed and updated after the analysis by Christensen (2022) and no longer contains the team variable. In an early version of this study, the start variable was included as a control variable as Christensen (2022) found it significant. However, it was removed as it had little effect and acceptable Variance Inflation Factor (VIF)s, and little suggested that it had a significant impact. Much of the efficiency at the start is most likely explained by the variable years in the company. Removing the start variable also makes reservations about the correlation between these variables.

In this thesis, the contract sum is also replaced by meters with meters wall (hereafter referred to as wall), as it is uncertain what the contract sum contains. If, for example, the contract sum includes electrical and plumbing work, and thus can be identical for the carpenters but have different prices. In Christensen (2022), contract sum was used as a control variable to measure scope and complexity. The area was the first thought as a variable for size/ scope, but an analysis with this variable showed that it did not affect man-hours or construction days to any significant degree. The wall variable (including both internal and external walls) is another measure for size/ scope and was found to be significant.

Table 8: Description of the variables. The independent variables are noted as x and the dependent y.

Notation	Variable	Variable type
The dependent variables		
y_1	Man-hours	Metric
y_2	Construction days	Metric
Carpenters characteristics		
x_1	Age1	Metric
x_2	Age2	Metric
x_3	Age3	Metric
x_4	Age4	Metric
x_5	CompanyYears	Metric
x_6	Polish	Metric
Control variables		
x_7	Winter ratio	Metric
x_8	Design changes	Metric
x_9	Wall	Metric
x_{10}	Carpenters	Metric

The dependent variables

y_1	Man-hours	The total number of hours carpenters have worked on the on-site part of the project.
y_2	Construction days	The number of working days from the start to the end of the on-site construction phase.

Carpenters characteristics

x_1	Age1	The percentage of work done by workers in the age group 16-25
x_2	Age2	The percentage of work done by workers in the age group 26-35
x_3	Age3	The percentage of work done by workers in the age group 36-45
x_4	Age4	The percentage of work done by workers in the age group 46-55
	Age5	The percentage of work done by workers in the age group 56-65*
x_5	CompanyYears	A weighted average of the years in the company of all the carpenters who worked on the project. The weighting is the percentage of man-hours for each worker. $CompanyYears = sum(yearsInCompany_i * manhours_i / projectManhours)$
x_6	Polish	The proportion of carpenters on a project whose mother tongue is Polish (measured in %).

* Not included because it is redundant

Control variables

x_7	Winter ratio	Describes the number of winter days on the project (winter days / total days). A ratio from 0 to 1 where: 0 = summer (April - September) 1 = winter (October - March)
x_8	Design changes	The number of changes made to the standard cabin design.
x_9	Wall	Number of meters wall. Used to measure the size of the cabin.
x_{10}	Carpenters	Number of carpenters who have worked on the project.

Preparation of data

Table 9: Overview of the datasets received.

Name	Description	Rows
Prosjekter 20230516	Contains information on all the case company's construction projects from 2019 to April 2023.	796
Timer ført på prosjekt 20230516	Contains all man-hours carried out by carpenters on the various projects.	100338
Ansatt info 20230516	Contains information about the carpenters	304

Table 9 shows an overview of the data received from the case company. Several actions were taken before the data were used in the analyses. The datasets were reviewed to ensure that the projects used in the analysis had all the necessary information and were relevant to the scope. The actions performed were:

- Projects that lacked necessary information, i.e. a variable or value(s) needed to calculate a variable, were removed.
- Other building projects, such as houses and annexes, were removed (by looking at the model name).
- Projects where the customer was in charge were removed.
- Cabins that were not of the type of turnkey cabins were removed.
- Projects where some of the main phases (ref table 6) missed logged man-hours were removed to try to weed out projects where other contractors were involved. The following page reviews how the main phases were selected.
- Analyze the data and look for outliers. If a point is more than the mean value plus four times the variable's standard deviation, consider removing this point, as this might be a special case.

The initial dataset consisted of 796 projects; after the review, 302 projects remain. For the remaining projects, all the variables were extracted or calculated and saved in a new file that was used in the analysis.

Table 10 show an overview of all phases with logged man-hours. The last column (Number of projects) is the number of projects with some man-hours in that phase. As shown, more projects have man-hours in phases 1-11 and 15. Considering this and the names of the phases, they are classified as the main phases in this thesis and are something that all projects should have. In addition, the man-hours in phases 16, 18, 151, and 152 are included. 16 and 18 are to include hours on correcting errors and deficiencies made during the project, 151 to take account of the season, and 152 as this may be affected by the size/height of the cabin.

Usually, Phase 00 Concrete/ foundation (102) would also be counted as one of the main phases, as this is also something that all construction projects have to do. But as shown in the table, most projects do not have any man-hours in this phase, meaning they mostly get others to do this job.

Table 10: All phases with man-hours in the dataset.

Phase	Name	Number of projects
1	Phase 01 Element assembly	367
2	Phase 02 House wrap	347
3	Phase 03 Roofing	363
4	Phase 04 Completion	367
5	Phase 05 Installation preparation	368
8	Phase 08 Panel	365
10	Phase 09 Doors and floors	362
11	Phase 10 Interior trim	354
12	Phase 11 Fixed furnishings	245
13	Terrace	171
14	Log cabin decor (Stavlaftdekor)	12
15	Rigging and operation	400
16	Reclamation	201
18	Additional work	111
20	Final cleaning	12
22	Course/training	16
102	Phase 00 Concrete/ foundation	96
151	Snow removal	66
152	Scaffolding	95
153	Building meetings	19

5 Data analysis and results

In this sub-chapter, the multiple regression analysis is conducted. In all the tests carried out in this thesis, the significance level used was 0,05, and the analyses were performed with the IBM SPSS Statistics software version 29.0.0.

5.1 Preliminary examination

This section uses univariate and bivariate examinations to understand and explore the data.

5.1.1 Univariate examination

Univariate analysis is a method used to describe the data, find patterns, and summarize the data (To, 2023b). With the help of this analysis, it is easy to detect abnormal data. In earlier versions of the analysis, for example, both man-hours and construction days were 0, which gives reason to review the data again.

Table 11: Descriptive statistics for the data and variables included in the regression analysis (N=288 cabins)

	Min	Max	Mean	SD
Dependent variables				
Man-hours	584	2991	1289,98	395,77
Construction days	34	162	75,09	21,24
Independent variables				
Age1	0	,58	,08	,13
Age2	0	1	,28	,26
Age3	0	1	,40	,27
Age4	0	1	,22	,23
Age5	0	,50	,01	,07
CompanyYears	0	6,41	2,09	1,55
Polish	0	1	0,86	0,23
Winter ratio	0	1	0,55	0,29
Design changes	1	11	3,30	2,27
Wall	29	86	44,38*	7,68
Carpenters	2	23	9,25	4,86

* 44 meters wall corresponds to around 100 square meters (see appendix A).

5.1.2 Bivariate examination

Bivariate analysis is used to check if there is a relationship between two sets of values (To, 2023a). In MRA, it is used to assess correlations and multicollinearity. Table 12 shows the calculated Pearson's correlation coefficients. Even though some of the variables are significantly correlated with each other, all the independent variables' VIF obtained in the regression calculations turned out to be below 1,401, which is well below Hair et al. (2010)

's recommended cutoff. Therefore, the regression coefficients can be considered relatively reliable.

Table 12: Pearson's correlations for the data and variables included in the regression analysis (N = 288 cabins)

	Man-hours	Construction days	Age1	Age2	Age3	Age4	Age5	CompanyYears	Polish	Winter ratio	Design changes	Wall	Carpenters
Man-hours													
Construction days	,887**												
Age1	,088	,096											
Age2	0,084	0,093	-,155*										
Age3	-,123*	-,132*	-,276**	-,503**									
Age4	-,015	-,011	-,112	-,418**	-,390**								
Age5	,048	,023	,164**	-,072	-,154**	-,128*							
CompanyYears	-,281**	-,237**	-,172**	-,164**	,218**	,079	-,180**						
Polish	,075	,066	,075	-,069	-,028	,091	-,084	-,272**					
Winter ratio	,119*	,042	,036	,039	-,080	,041	-,043	-,044	-,003				
Design changes	,234**	,217**	,040	-,026	-,011	-,007	,090	-,028	-,058	-,052			
Wall	,482**	,468**	-,017	,133*	-,087	-,033	-,015	,051	-,004	-,022	,254**		
Carpenters	,393**	,424**	,163**	,070	-,088	-,063	-,010	-,255**	,190**	-,079	,135*	,304**	

* Correlation is significant at 0,05 (2-tailed).
** Correlation is significant at 0,01 (2-tailed).

5.2 Regression calculations

5.2.1 Model summary

Table 13 shows an overview of some fit statistics for the two regression models. R^2 represents the proportion of variance in the dependent variable explained by the independent variables. The R^2 adjusted is a version of R^2 that is adjusted to take the number of predictors (independent variables) into account (Academy, 2020).

Table 13: Summary of the two regression calculations.

	Dependent variable	R^2	R^2 adjusted
Model A	Man-hours	,388	,366
Model B	Construction days	,354	,330

Sample size = 288 in both cases. R^2 = coefficient of determination

Table 14 and 15 provide a summary of the two regression calculations performed to test the hypotheses listed in section 2.9, Findings from the literature study. The unstandardized regression coefficient (b) provides estimates of the expected change in man-hours and construction days for each unit of change in the independent variable. The standard error of the unstandardized regression (ϵ) estimates the variability of the coefficient. The standardized regression coefficient (β) allows us to compare the relative importance of each independent variable to the dependent variable. The t-values are b/ϵ and are used to test the statistical significance of the coefficients. The p-value (Sig.) indicates the probability of obtaining the observed estimate. All variables with a p-value below the significance level 0,05 are statistically significant Academy (2020).

Table 14: Coefficients and significance of model A (man-hours).

Variable	b	ϵ	β	t	Sig.
Age1	,616	311,226	,000	,002	,998
Age2	-56,892	263,050	-,040	-,216	,829
Age3	-28,237	262,786	-,021	-,107	,915
Age4	6,962	263,884	,005	,026	,979
CompanyYears	-58,281	12,442	-,251	-4,684	<,001
Polish	-44,436	77,622	-,029	-,572	,567
Winter ratio	170,038	58,360	,139	2,914	,004
Design changes	15,473	7,797	,098	1,984	,048
Wall	19,410	2,431	,414	7,986	<,001
Carpenters	15,350	3,913	,208	3,923	<,001

b - Unstandardized regression coefficient; ϵ - Standard Error of b; β - Standardized regression coefficient; t - t-value; Sig. - p-value

Table 15: Coefficients and significance of model B (construction days).

Variable	b	ϵ	β	t	Sig.
Age1	8,483	18,877	,051	,449	,654
Age2	4,022	15,955	,048	,252	,801
Age3	3,032	15,939	,038	,190	,849
Age4	6,811	16,006	,075	,426	,671
CompanyYears	-2,651	,755	-,193	-3,512	<,001
Polish	-3,149	4,708	-,035	-,669	,504
Winter ratio	4,515	3,540	,062	1,275	,203
Design changes	,761	,473	,081	1,609	,109
Wall	1,053	,147	,381	7,144	<,001
Carpenters	1,117	,237	,256	4,706	<,001

b - Unstandardized regression coefficient; ϵ - Standard Error of b; β - Standardized regression coefficient; t - t-value; Sig. - p-value

5.2.2 Hypothesis tests

Table 16 summarises the main results from the analyses.

Table 16: Summary of this thesis hypothesis test results.

	Hypothesis	Result
H1.1	There is a relationship between age and man-hour consumption in cabin construction.	Rejected (p = ,998; p = ,829; p = ,915; p = ,979)
H1.2	There is a relationship between age and construction days in cabin construction.	Rejected (p = ,654; p = ,801; p = ,849; p = ,671)
H2.1	The number of man-hours in cabin construction decreases with the carpenters' experience.	Supported (p < ,001)
H2.2	The number of construction days in cabin construction decreases with the carpenters' experience.	Supported (p < ,001)
H3.1	The more carpenters with a common language, the lower the man-hour consumption in cabin construction.	Rejected (p = ,567)
H3.2	The more carpenters with a common language, the fewer construction days in cabin construction.	Rejected (p = ,504)

5.2.3 Additional analysis

The case company made a change from 1 December 2022, where they introduced assembly instructions (for one model, it was introduced on 1 January 2022). As this change is so recent, only 15 cabin projects have used the assembly instructions in the dataset (that also passes the criteria described under section 4.2, data preparation).

As the proportion of projects that have used the assembly instructions is so small, and all the projects that have used it were of the same cabin model, you can get an indicator of how the assembly instructions affect man-hours and construction days by running a separate analysis on this cabin model. Due to the small number of projects, only the wall variable is included as a control variable, as this variable influenced the most. Table 17 shows the result of the analysis, where one can see that the assembly instruction was not significant for either man-hours ($p = ,345$) or construction days ($p = ,191$).

Table 17: Regression analysis of assembly instructions (N = 26).

Dependent variable	Coefficient of determination		Independent variables	
	R^2	R^2 adjusted	Wall	Assembly instructions
Man-hours	,223	,155	b = 24,974	b = -114,967
			p = ,04	p = ,345
Construction days	,28	,217	b = 1,712	b = -10,019
			p = ,025	p = ,191

5.3 Quality of the analysis

In this section, the assumptions for multiple regression described in section 2.8.3 are tested.

Linearity of the phenomenon measured

As described in the theory chapter, the linearity can be examined by plotting the independent variable against the partial residuals. A LOESS curve was added to highlight trends. The plots are presented in appendix B and C.

For both models, the age variables have a clear linear trend. There are some more variations, but a fairly clear trend for the variables companyYears, polish, winter ratio, design changes, wall, and carpenters.

Constant variance of the error terms

As described in the theory chapter, the variance of error can be examined by plotting the residuals (studentized) against the predicted dependent values and comparing them to the null plot, where there is a consistent pattern if the variance is not constant. The plots are presented in appendix D; as shown, they are similar to the null plot. In addition, the White test was conducted, concluding that there was no problem with heteroscedasticity for either model. In cases where heteroscedasticity is present, it may cause biased p-values.

Independence of the error terms

As described in the theory chapter, the independence of the error can be examined by plotting the residuals against any possible sequencing variable. If the residuals are independent, the pattern should appear random and similar to the null plot. This thesis has several sequencing variables, namely winter ratio and companyYears. The plots are shown in appendix E and appear random and similar to the null plot, which means that the error terms are independent of one another.

Normality of the error terms distribution

As described in the theory chapter, the normality of the error can be examined by plotting a histogram of residuals and doing a visual check for a distribution that approximates the normal distribution.

The histograms are plotted in appendix F, showing that the error terms are not perfectly normally distributed. The Kolmogorov-Smirnov and Shapiro-Wilk tests concluded that the error terms are non-normally distributed. These statistical tests are increasingly sensitive for larger sample sizes, which can explain the detection of non-normal distribution. If one look at the q-q plots (appendix G), it seems, despite some displacement in the histogram, reasonable to conclude with an approximately normal distribution. If the error terms are non-normally distributed, it would not have biased the regression coefficients, but the p-values would be skewed (Hair et al., 2010).

6 Discussion

This section will discuss the various research questions using the three variables; age, education/ experience, and language/ nationality. Then the control variables will be reviewed, and finally, a brief discussion of the findings from the additional analysis.

6.1 Age

Age proved challenging to test, especially as the theory pointed to a U-shaped relationship between age and man-hours and age and construction days. In addition, there are many carpenters per project where some work more than others which might be challenging to take into account. Several methods were explored along the way, including weighted average (weighted in relation to the percentage of the hours the different ages had), both with and without an associated quadratic variable (to test the relationship had a u-shape), an estimated u-shaped function, $f(age)$, which replaced the various ages in the weighted average and finally the chosen solution, with variables for age groups that kept track of what percentage of man-hours had been worked by the carpenters in the age group. There are several problems with the chosen solution, so this should be explored further.

A problem with the method presented is that it takes a lot to achieve significance for the various variables. Nevertheless, it is very likely correct that age is not significant in the analyzes carried out in this thesis, as R^2 has been compared for the analysis with and without age, where there is almost no difference, which means that age minimally helps to explain the variations in man-hours and construction time. In addition, the graphs of the relationship between age and man-hours and construction days, see appendix H, show that there are minor differences between top and bottom both for man-hours and construction days, especially if you compare with the significant variables. Representatives from the case company also think the results seemed correct and even had the impression that the eldest performed best.

Should age turn out to be significant in later analyses, it is helpful to investigate the reasons for this. With a few data points, individual differences can have a significant effect and be a cause. It may also be the case that carpenters of different ages have different tasks, with some being more demanding than others. Especially when it comes to older carpenters, it is essential to look at the tasks in order to be able to keep people at work longer.

6.2 Education and experience

The findings from the analysis show that the number of years in the company is of significant importance, which was expected. In the database, most carpenters had less than one year in the company (see appendix J), which suggests that many are new to the company. The average of 2,1 years in the company also suggests that they cannot keep the carpenters for more than a few years. As this variable strongly influences the number of man-hours and construction days, more focus should be placed on retaining the carpenters. According to the case company, most of the Polish workers came to Norway to work for 4-5 years before returning, which makes it challenging to keep them longer. They also believe that part of the effect in the first years is that those who do not perform disappear after a couple of years.

Furthermore, it is particularly interesting to explore experience in the company with the total experience, as some findings in the theory state that years in the company have significance independent of total experience. It is also interesting to see the development in the longer term, as findings in the theory believe that the influence of experience levels flattens after 10-15. In these analyses, however, the total experience is unknown, which means that, in theory, one can see a decrease due to many of the carpenters having little total experience. On the other hand, if one look at the age distribution of the carpenters, appendix I, the average is around 35, which suggests that most should have over 15 years of total experience. Findings then indicate that experience does not flatten after 10-15 years or that experience in the company plays a role. In these analyses, there was also a lack of data on the carpenters' education. Part of the reason for this is that many of the foreign workers' education is not approved in Norway. In recent years, on the other hand, there has been a development in the approval of foreign diplomas, which in the coming years can make it possible to explore whether education plays a role.

Figure 32 shows the relationship between years in the company and the number of man-hours. The cubic supply fits somewhat better than the linear fit, which may indicate that the number of years in the company is more critical in the first years and that it flattens out later. These theories may be interesting to explore further.

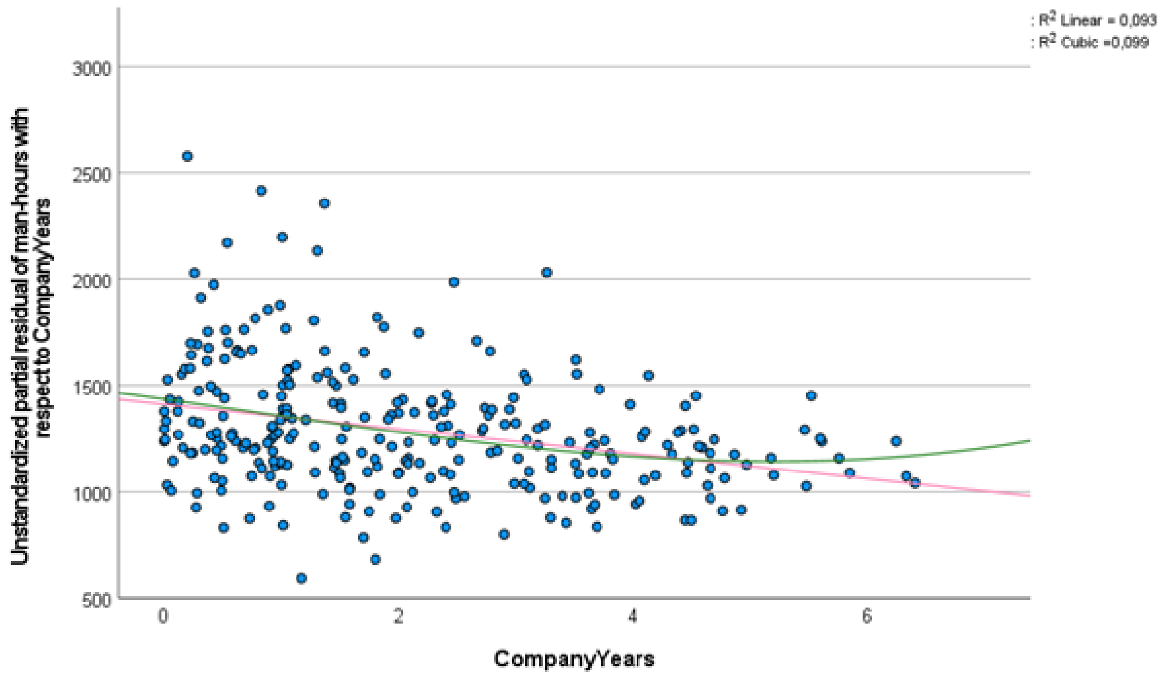


Figure 32: Unstandardized partial residuals plot for man-hours with respect to years in the company

Figure 33 shows the relationship between years in the company and the number of construction days. This graph is also somewhat more cubic than linear, but it may be controlled by a few points on the right (several years in the company). On the other hand, it indicates that years in the company for construction days have the most say in the first years, but after a few years, the effect flattens out.

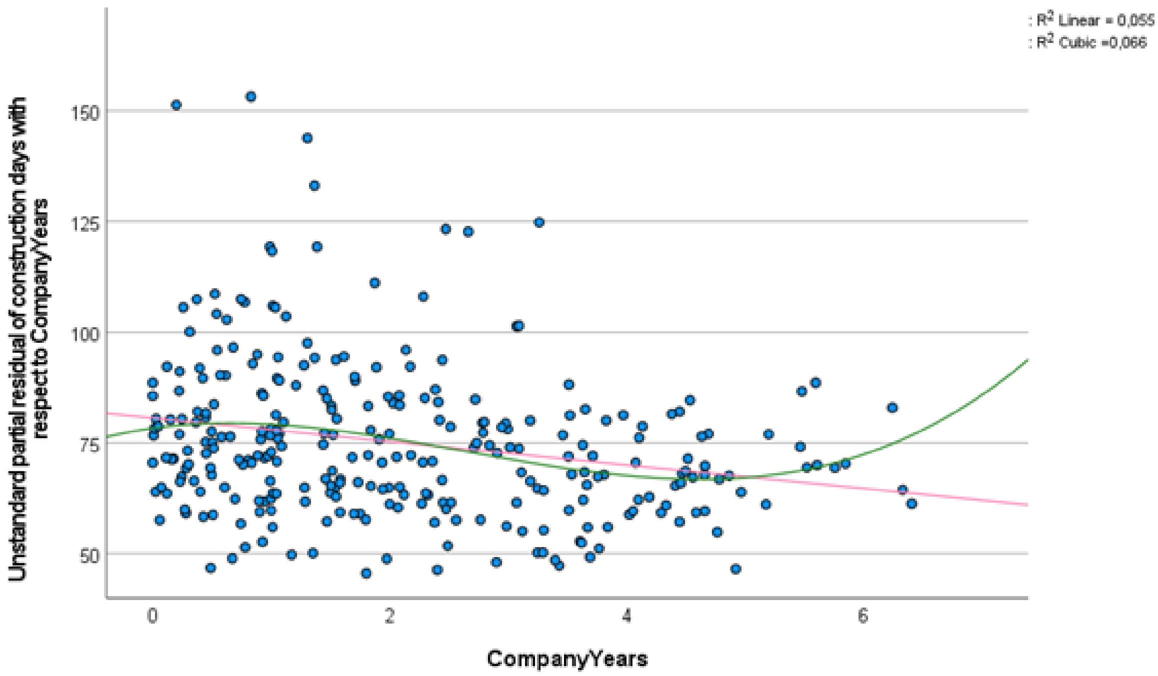


Figure 33: Unstandardized partial residuals plot for construction days with respect to years in the company

6.3 Language and nationality

In this thesis, it was decided that the most appropriate thing was to use a percentage of Polish workers in order to be able to test; (1) whether nationality had a say, i.e., whether the Polish turned out to be better/ worse than the other nationalities represented in the dataset, and (2) whether it was better to have a high percentage of workers with the same nationality/mother tongue (to avoid language barriers). The decision was made because the Polish workers accounted for 227/269 (84,4%) of all the workers who had worked on the projects included in the analyses. The descriptive statistics also show that the Polish workers, on average, accounted for 86% of the workers on the various projects.

As expected, this variable was not significant, as findings in the theory suggested that it did not seem to be performance differences between the different nationalities. On the other hand, it was expected from the theory that there was a difference in whether the workers spoke the same language. The findings were also as expected by the case company as they have the impression that communication between the carpenters is not a problem. The dataset used in this thesis had only information about the carpenters' nationality and not all languages spoken by the various workers. That is, it is possible that even if the % of Polish workers was low, those who needed to communicate with each other spoke a common language. Although this variable was not found to be significant, it may be interesting to investigate further whether it affects the project's performance if several nationalities work together, as this was tested to a small extent with the dataset used in the analyses.

6.4 The control variables

As mentioned under method, contract sum was used as a control variable in Christensen (2022) replaced by meters of wall due to uncertainty about what the contract sum variable contained. However, this change led to us losing a variable that could help say something about the complexity of the various projects. Further research should try to find an appropriate variable to account for complexity.

Another thing worth mentioning is that the start variable, as mentioned in the method, was removed as companyYears can explain the effect to a greater extent. The start variable could help capture the effects of the corona, which companyYears cannot. The construction period for the cabins included in the analysis is January 2021 to April 2023, so the coronavirus may have affected the projects somewhat. The scope, on the other hand, is difficult to say anything about. However, one effect it may have had is somewhat longer construction time as a cause of higher absenteeism (as a cause of quarantine and isolation).

Winter ratio

The winter ratio was found to be significant for man-hours and not for construction days. That is the same result as Christensen (2022) and strengthens the results as at least 44,6% of the projects included in this analysis are different from those analyzed in Christensen (2022). It was also in line with what the case company expected, as they operate with cabins built in winter use 200 more hours. Figure 35 shows the relationship between winter ratio and man-hours, and as shown, the cubic approximation fits somewhat better than the linear one and may be interesting to explore further.

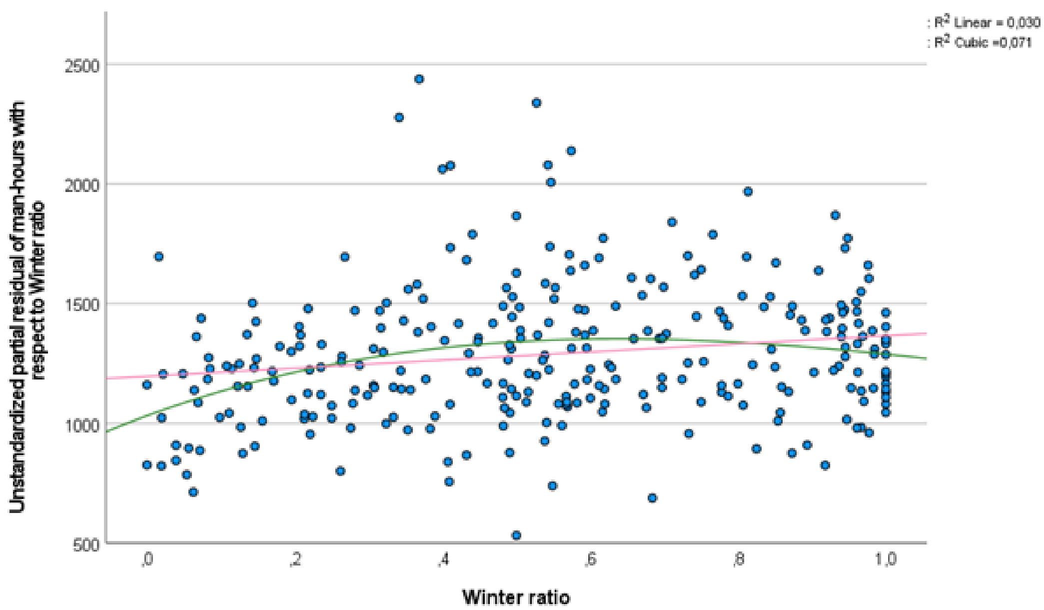


Figure 34: Unstandardized partial residuals plot for man-hours with respect to winter ratio

Design changes

For the design changes, it is the same case as for the winter ratio; only man-hours became significant, which agrees with Christensen (2022). The relationship to man-hours, shown in figure 35, also shows a tendency for a cubic approximation to fit better, although it is a minor difference and possible adaptation to a few points. It may still be interesting to explore the tendency in further studies.

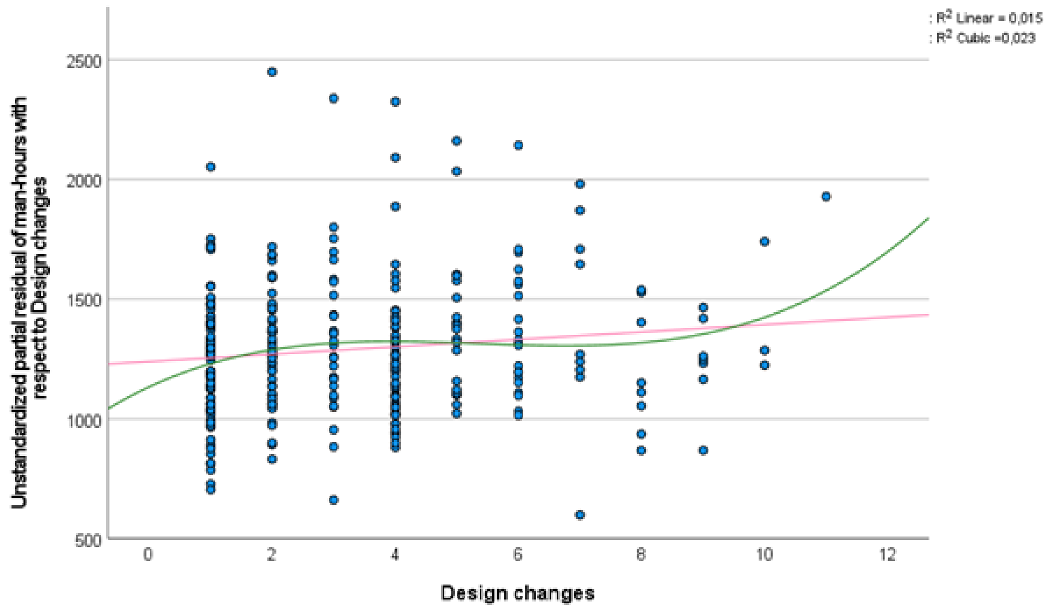


Figure 35: Unstandardized partial residuals plot for man-hours with respect to design changes

Wall

The new control variable, wall, was found to be highly significant in both models, which makes it a good candidate as a control variable for analyses related to construction projects. The area was also tested for this variable, but it was not found to be significant. An analysis was also run with ln(wall) to check whether the relationship between wall and the dependent variables was logarithmic (due to large-scale advantages), which was found to be significant. Figures 36 and 37 of the conditions also show that a cubic approximation fits better than the linear one, making exploring the conditions relevant. The case company also thinks these findings were in line with the expectations and added that the more complex cabins typically have more walls, which may explain why walls are more significant than the area.

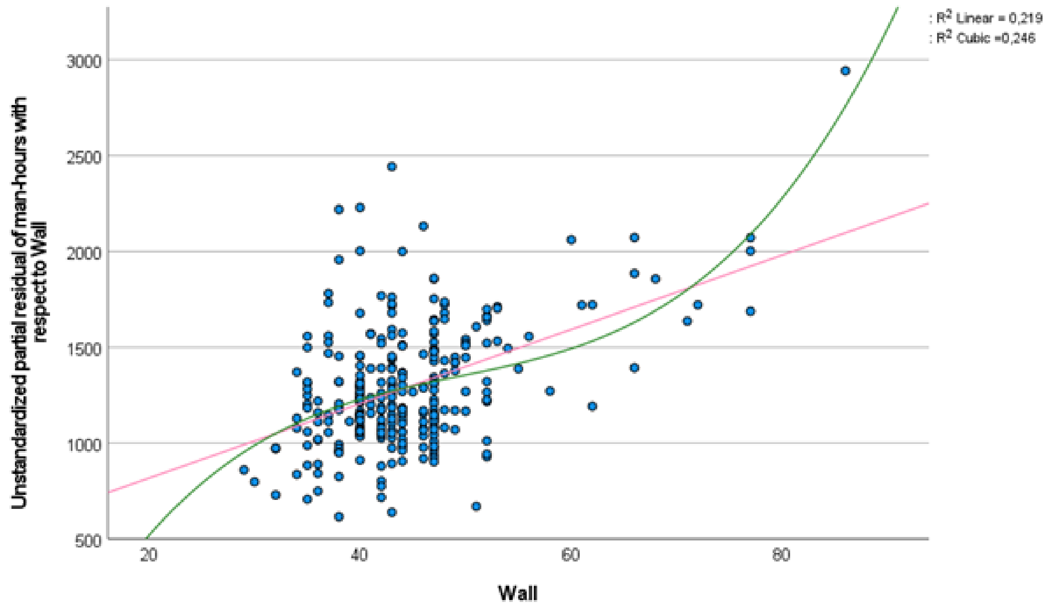


Figure 36: Unstandardized partial residuals plot for man-hours with respect to wall

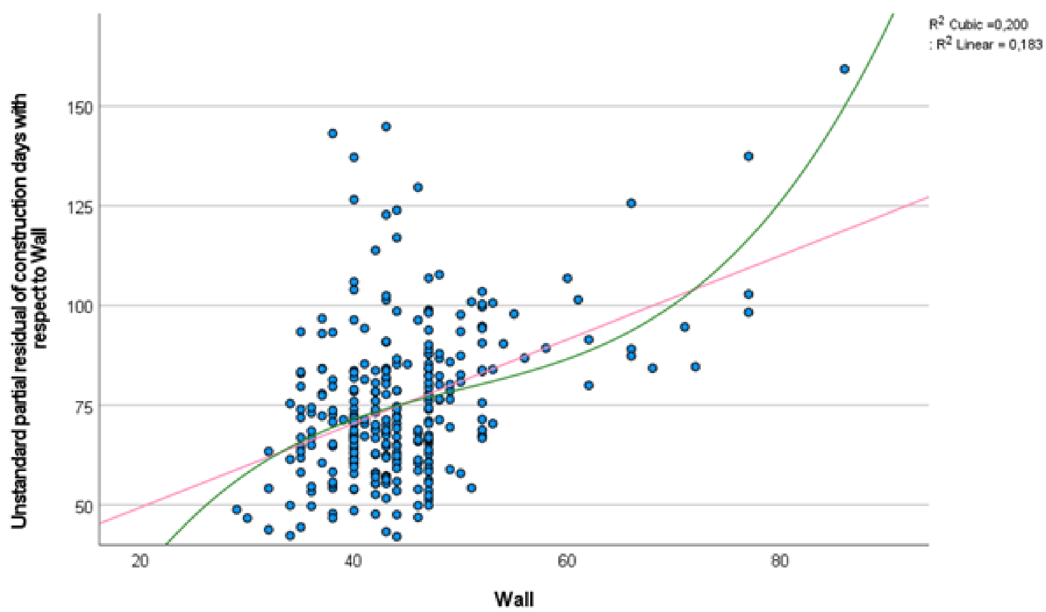


Figure 37: Unstandardized partial residuals plot for construction days with respect to wall

Carpenters

The number of carpenters was found to be significant for both man-hours and construction days. This result deviates from the results from Christensen (2022), where the variable was not found to be significant in any of the models. The reason why it was now found to be significant may be due to some different datasets where, among other things, the current dataset has 2-23 carpenters per project and an average of 9,25, compared to 2-18 carpenters and an average of 7,83 in Christensen (2022). The points over 20 carpenters are also clearly above the average for both models, which may make the variable significant. If one looks at the figures 38 and 39, one sees that these conditions also have a somewhat improved fit by cubic approximation, possibly because of the points over 20 carpenters, but still interesting to explore further. It is somewhat surprising that more carpenters lead to more construction days. The findings suggest that a level can be reached where having more carpenters on the project is no longer profitable.

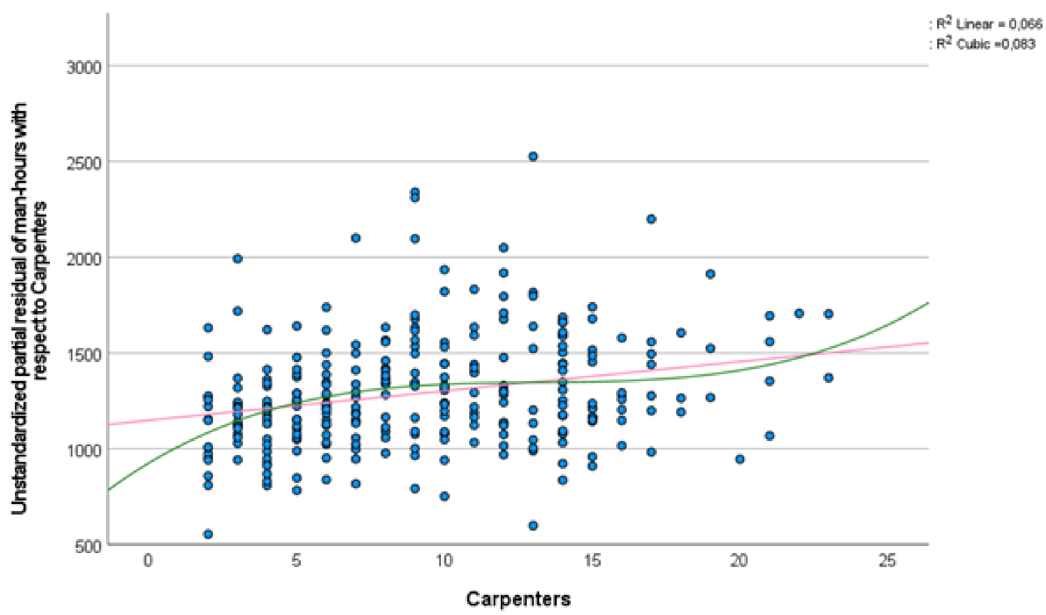


Figure 38: Unstandardized partial residuals plot for man-hours with respect to carpenters

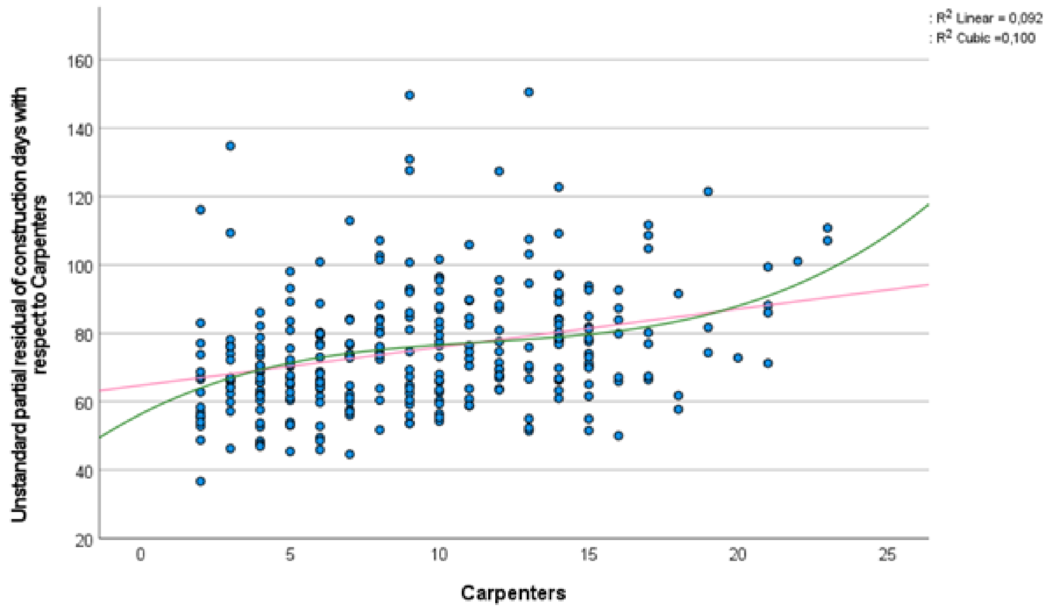


Figure 39: Unstandardized partial residuals plot for construction days with respect to carpenters

6.5 Assembly instructions

Although the assembly instructions were not significant, the results are interesting. For man-hours, the results show that the cabins that used assembly instructions, on average, used 115 fewer man-hours. For construction days, the results show that the cabins that used assembly instructions used an average of 10 days less. To put that into perspective, this means that the assembly instructions resulted in projects using an average of 8,8% fewer man-hours (based on average man-hours used) and 13,1% fewer construction days (based on the average number of construction days). One reason this variable was not found to be significant may be the size of the dataset, as it only consisted of 26 cabins, where 15 of them had used assembly instructions.

7 Conclusion

This chapter will present the main findings, the contribution to knowledge, some limitations of the thesis, and suggestions for further research.

7.1 Main findings

This thesis has explored how the carpenters' age, education/ experience and language/nationality can affect the performance of cottage projects. These topics were first explored in the literature; then, some hypotheses were formulated and tested on data from the case company.

The most important findings from the analysis are that experience in the company is of significant importance, while the age and nationality of the carpenters do not seem to have anything to say. In addition, analyses were carried out suggesting that assembly instructions contribute to fewer man-hours and construction days.

The thesis has also contributed to strengthening the credibility of the control variables, as well as coming up with a new control variable that was highly significant and which can contribute to a greater degree of explanation in further research.

7.2 Limitations

One limitation is that large parts of the theory chapter are based on foreign studies on the construction industry, which vary widely from country to country. Another limitation is that multiple regression analysis can only determine average values, which is not feasible in the construction industry (Tangen, 2005).

A third limitation is that several of the variables look at characteristics of the carpenters that can be influenced by individual differences and which can have significant impacts with smaller datasets. A more considerable amount of data can produce results that are less dependent on individual differences. In addition, there was a lack of data to test all the findings from the theory. For age, one can see from appendix I) that the dataset mainly consists of carpenters between 20 and 50, which means that the impact cannot be tested for all ages. The same applies to years in the company (see appendix J), where over 80% of the carpenters have worked in the company for less than two years. For experience, there was also a lack of data to test differences in performance for educated versus uneducated carpenters and data on how many years they have been in the industry (in total). For language/nationality, there was also a clear majority of one nationality and no data on any other language skills apart from the mother tongue.

7.3 Further research

Based on this study and suggestions from representatives from the case company, a list of suggestions for further research has been made.

- Find a better model to investigate whether the age of carpenters affects performance.
- Explore how total experience (not only experience in the company) and education affect performance. In addition, it may be interesting to investigate whether experience flattens out after some years.
- To more thoroughly check whether language skills affect performance, one can check whether workers who work together speak the same language. In this thesis, entire projects were looked at where there could be up to 23 carpenters who had worked on the project, which means that not everyone needs to understand each other as they work in smaller groups.
- Furthermore, explore the control variables and investigate whether some non-linear relationships better fit the data.
- Further explore the assembly instructions for several projects.
- Examine the assembly instructions against the carpenters' experience.
- Explore other factors that can affect performance, as the models presented in this thesis had R^2 values of 0,366 and 0,330, which means they can explain 36,6% and 33% of the variations for man-hours and construction days.
- Exploring whether language and nationality can affect communication between disciplines (e.g., plumbers or electricians).
- Exploring whether language and nationality can affect the communication between carpenters and managers.
- Exploring the effects of a change of construction manager during a project.
- Explore whether there is a connection between the presence/time spent by the construction manager and project performance.

- Investigate to what extent and how the assembly instructions are used and whether this impacts performance.
- Examine the ten best and ten worst projects (measured in man-hours and construction days) and look at what characterizes them.
- Exploring the effects of a newly introduced logistics system.

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Appendix

A Relationship between wall and area

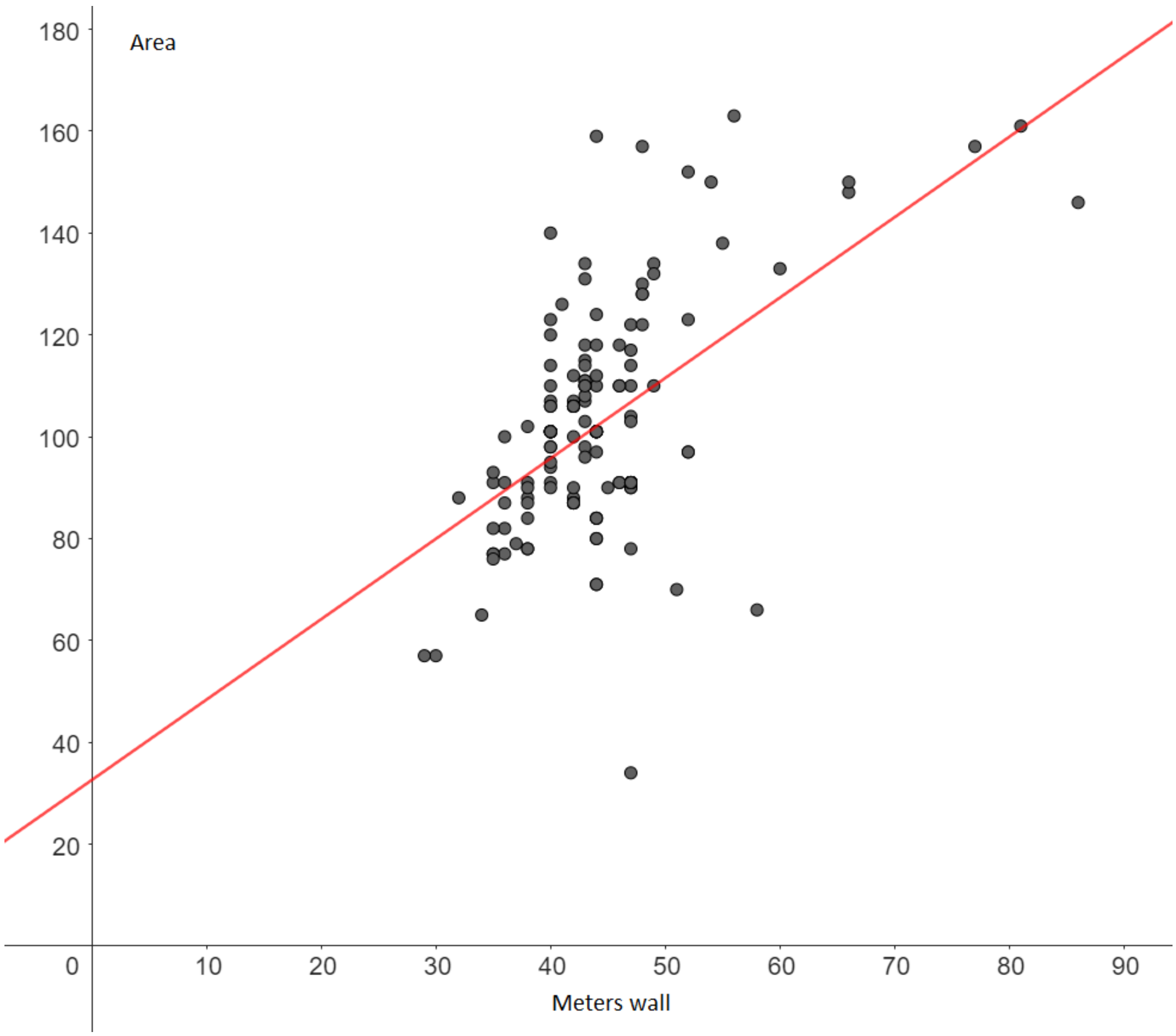
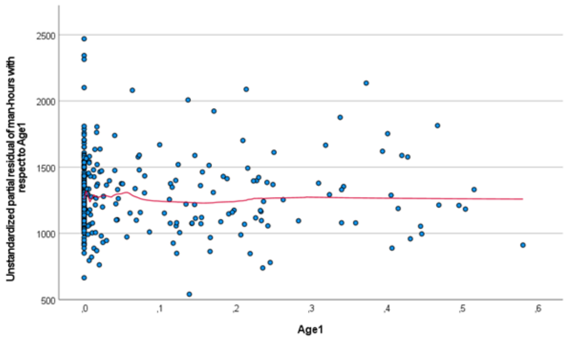
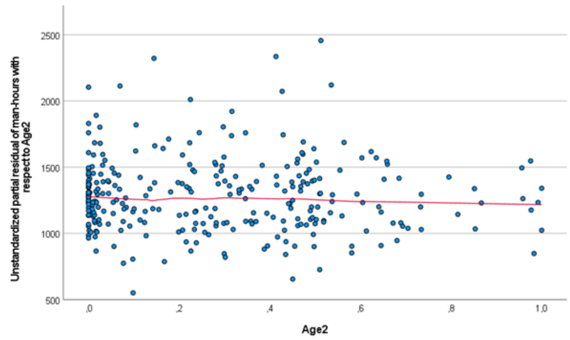
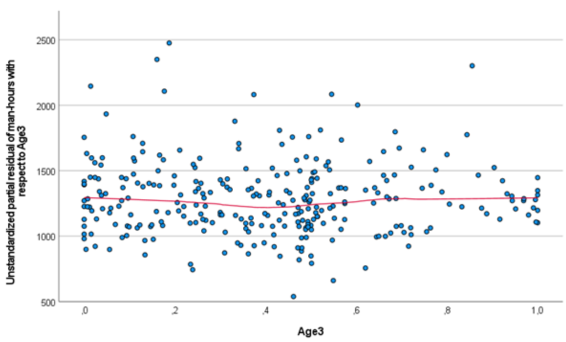


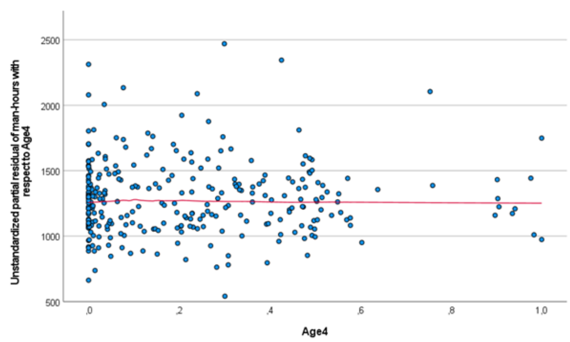
Figure 40: Relation between wall and area, where the x-axis is wall and the y-axis is area.

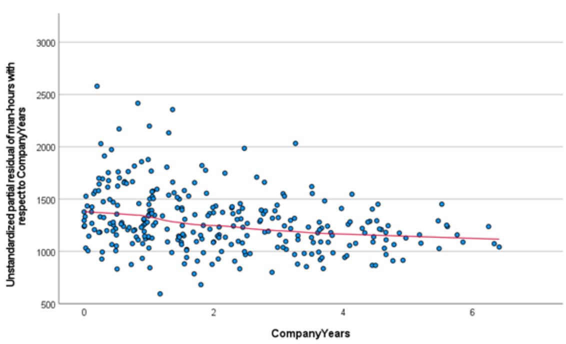
B Partial residual plots of man-hours

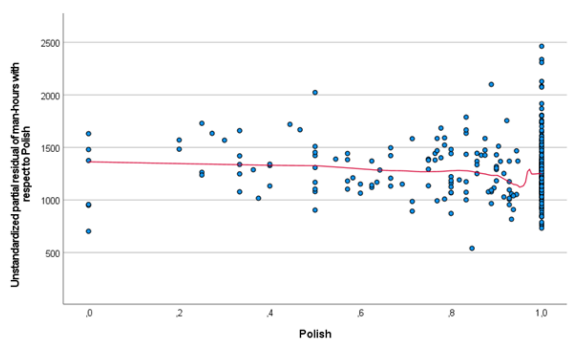


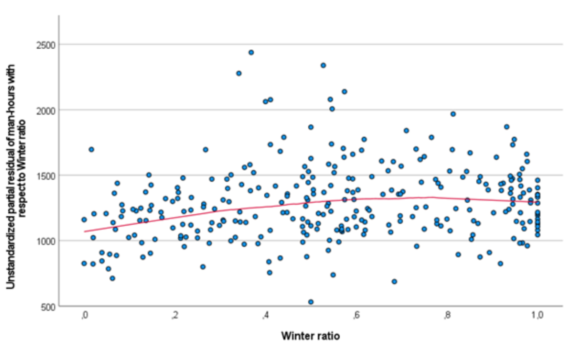


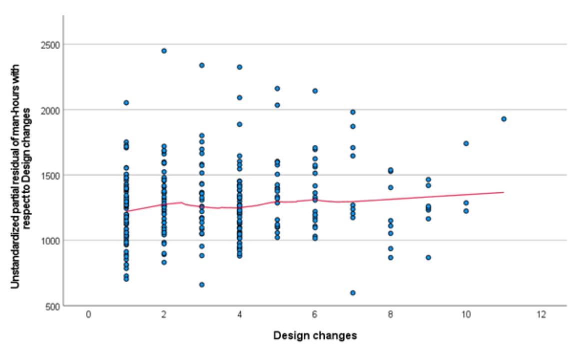


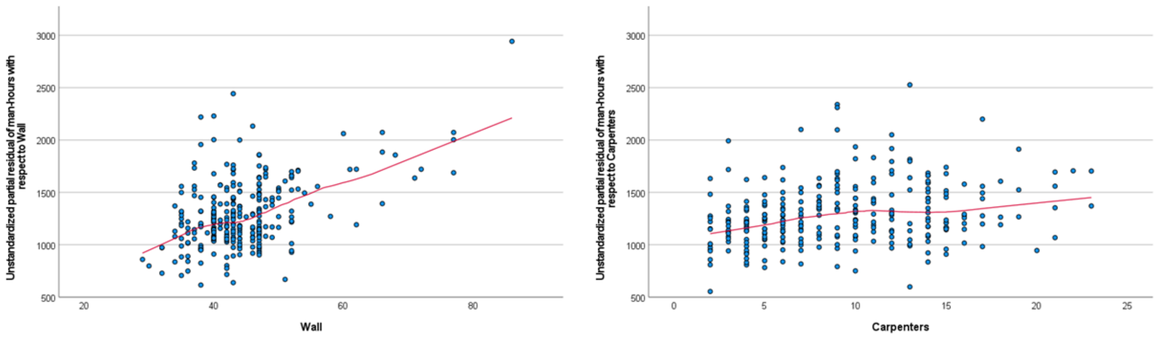




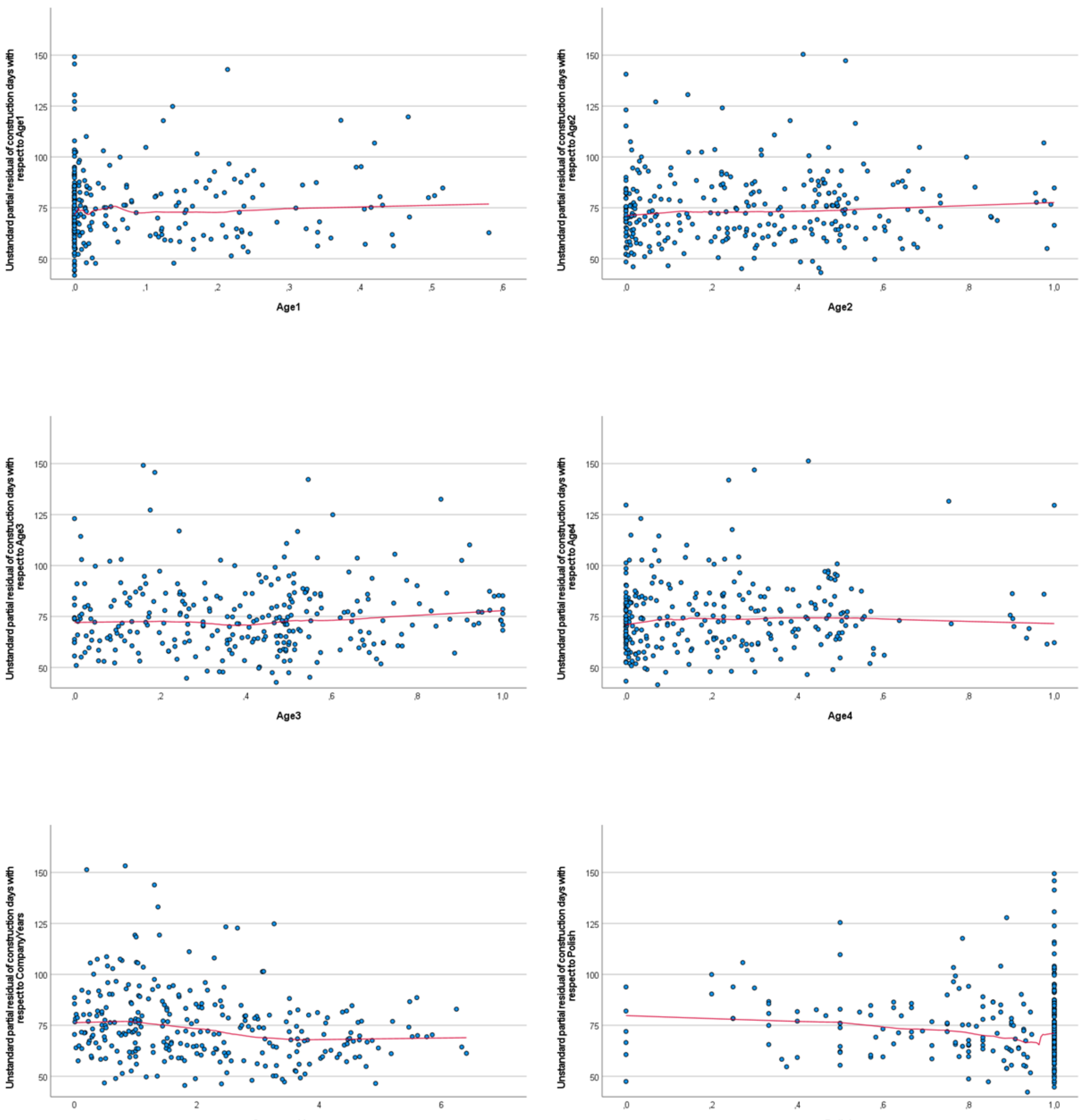


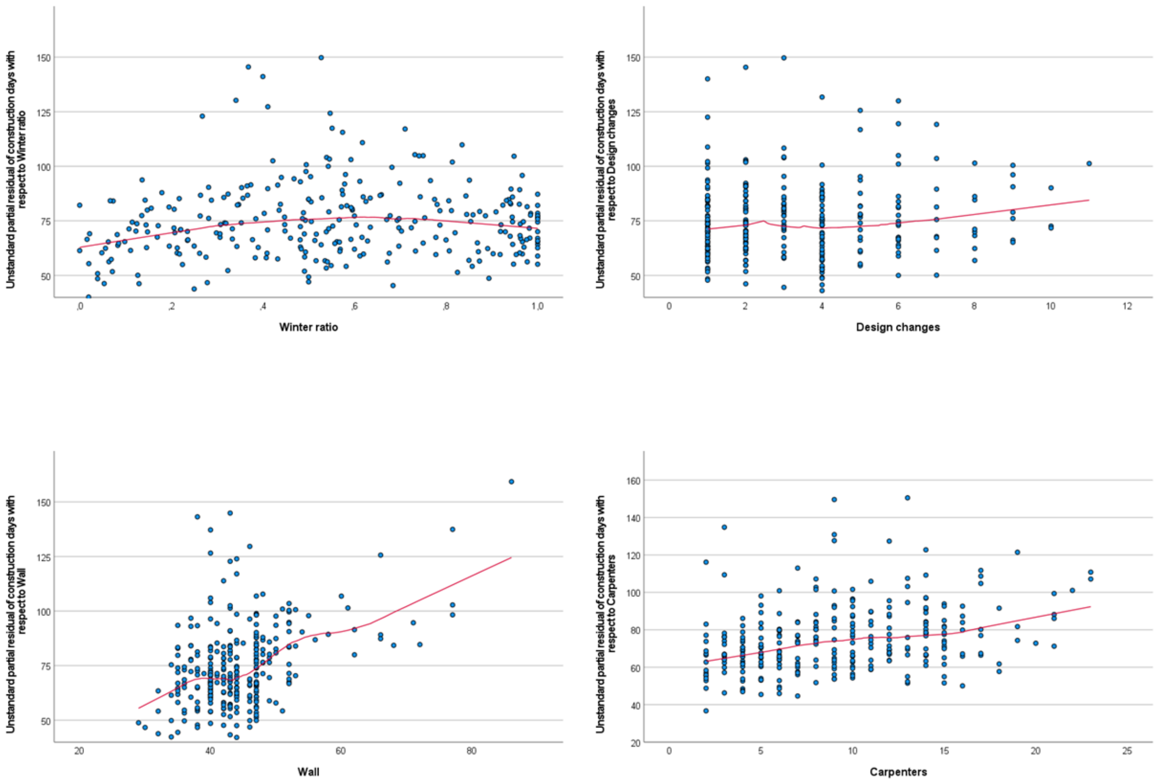




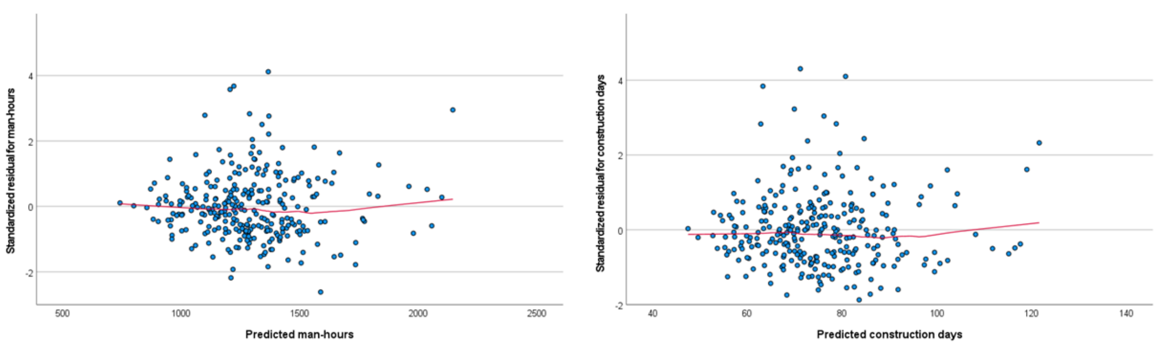


C Partial residual plots of construction days

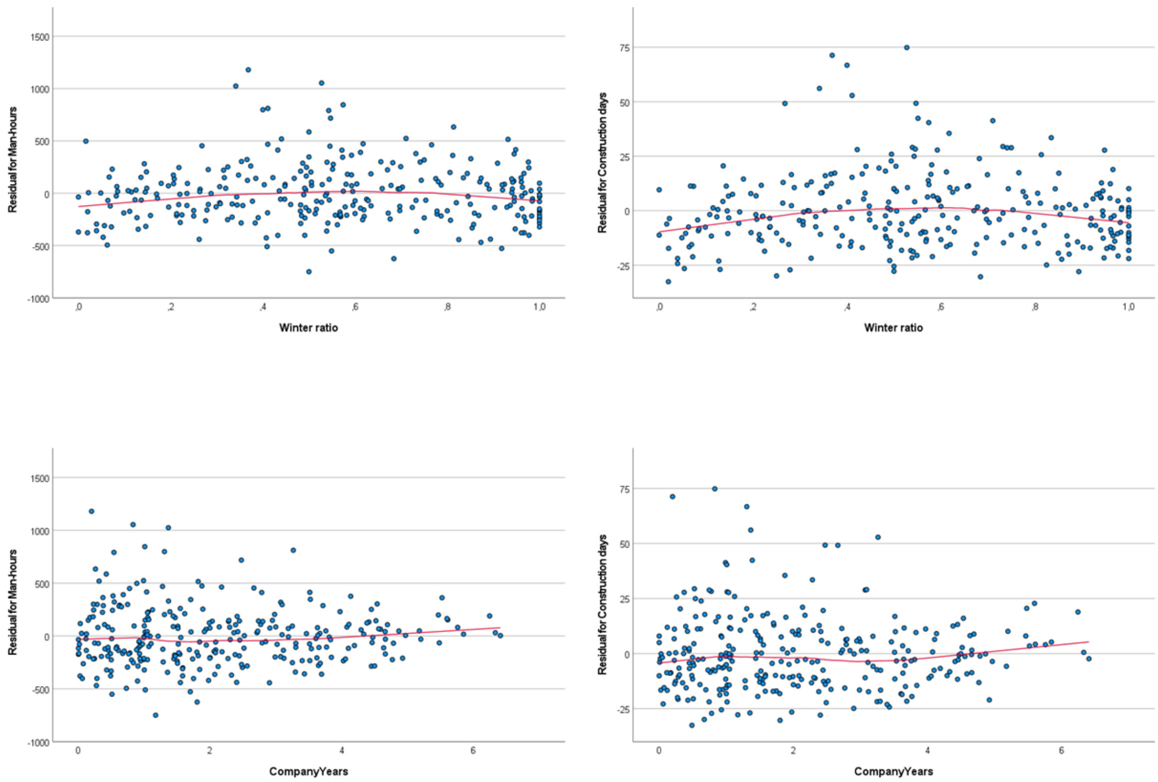




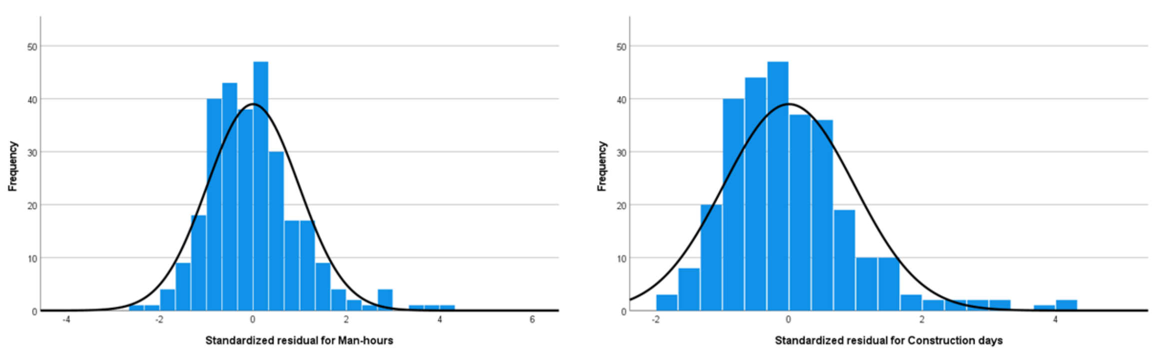
D Predicted values plotted against the standardized residuals



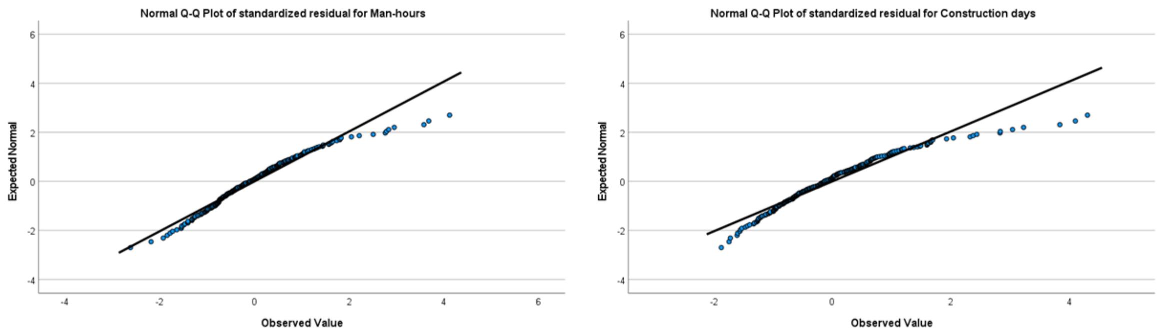
E Sequencing variable plotted against residuals



F Histogram of residuals



G Normal Q-Q plot of residuals



H The effect of age on man-hours and construction days

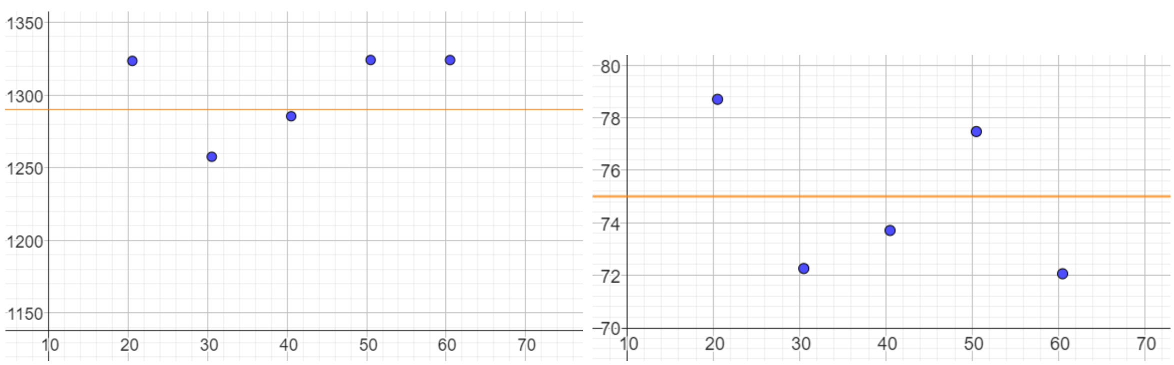


Figure 41: The relationship between age and man-hours (left) and construction days (right).

I Age distribution in the dataset

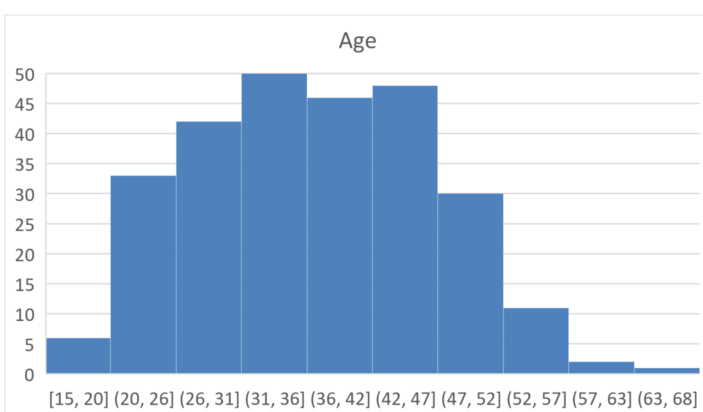


Figure 42: Age distribution in the dataset

J Years in company distribution in the dataset

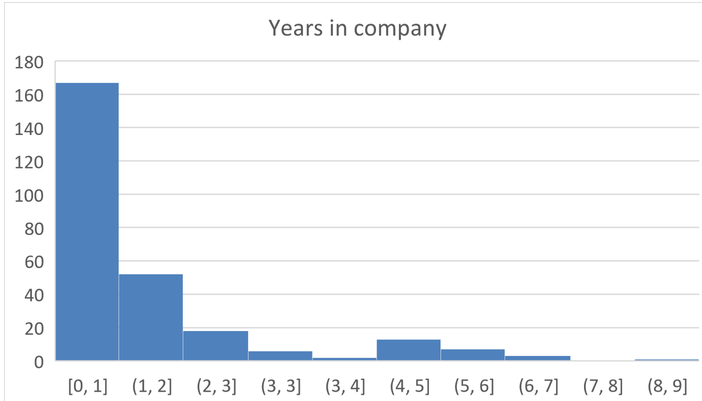


Figure 43: Years in company distribution in the dataset

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