COST REPORT OF FAÇADE WOODWORK

Case As Oy Espoon Tähtirikko

HAMK
UNIVERSITY OF APPLIED SCIENCES

Bachelor's thesis

Degree Programme of Construction Engineering

Visamäki, spring 2015

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ABSTRACT

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ABSTRACT

This Bachelor's thesis was commissioned by YIT Rakennus Oy's Residential Buildings Unit of Southern Finland. The object of the thesis was As Oy Espoon Tähtirikko, which consists of six row houses made of prefabricated elements. The background of the thesis was that in previous similar projects there were big overruns of the budget. Thesis consists budget consideration of façade woodworks, roof woodworks, balconies, balcony roofs, balcony's woodwork, entrance canopies and doorjambs.

The aim was to find out the main reasons for the actual costs for the commissioner. Six of the As Oy Espoon Tähtirikko's row houses were compared to each other and actual working hours of the work phases were collected. The aim was to produce data in man-hour and in Ratu-card form to the quantity engineers in YIT and to take into account the special characteristics of the site and the buildings that have an effect on the results. The main sources of information were RT-cards, visits to the site and interviews with YIT personnel.

As the work proceeded, it was noticed that many factors have an effect on the façade woodworks. At the start of the work phase, meeting between the foremen and the carpenters, have a big effect on the cost performance of the work. The planning of the work phase and the logistics of the site and agreeing of the working order help organizing the whole work phase. According to the site foremen and data from previous projects, it is noted that piecework as a working method is recommended, where costs of work remain predictable and the scheduling of work becomes easier.

Keywords cost report, façade woodworks, estimation

Pages 49 p. + appendices 8 p.

TIIVISTELMÄ

VISAMÄKI
Rakennustekniikan koulutusohjelma
Teräsrakentaminen

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TIIVISTELMÄ

Opinnäytetyö on tehty YIT Rakennus Oy:n asuntorakentaminen Etelä-Suomen yksikölle. Työn kohteena oli As Oy Espoon Tähtirikko, joka koostuu kuudesta, elementtirakenteisesta rivitalosta. Opinnäytetyön valintaan vaikutti aikaisemmissa kohteissa havaitut suuret ylitykset julkisivun puutöissä kustannusarvion ja toteutuneiden kustannusten välillä.

Työn sisältöön kuuluivat kohteen julkisivun puutöiden, vesikaton puutöiden, parvekkeiden, parvekekattojen, parvekkeiden puutöiden, sisäänkäyntikatosten, ovenpielien lautojen asennusten ja tasoerojen puutöiden tarkastelu.

Työn tavoitteena oli selvittää tilaajalle suurimmat syyt kustannusten ylittymiseen. Työssä vertailtiin kuutta As Oy Espoon Tähtirikon rivitaloa keskenään ja pyrittiin selvittämään toteutuneet työntekijätunnit eri työvaiheista. Tavoitteena oli tuottaa tietoa YIT:n kustannuslaskijoille työmenekki per yksikkö ja Ratu-kortiston tyylisissä muodoissa ja huomioida kohteen ja eri talojen erikoispiirteet, jotka vaikuttivat tulokseen. Päälähteinä käytettiin RT-ohjekortteja, työmaavierailuja ja YIT:n henkilökunnan haastatteluita.

Työn edetessä havaittiin, että useat eri seikat vaikuttavat julkisivun puutöiden tekemiseen. Työvaihetta aloittaessa, työnjohdon ja työntekijöiden välisellä aloituspalaverilla on suuri vaikutus työstä aiheutuviin kustannuksiin. Työvaiheen ja työmaalogistiikan suunnittelu sekä työjärjestyksestä sopiminen helpottavat koko työvaiheen organisointia. YIT:n työnjohtajien haastattelujen ja aikaisempien työmaiden toteutuneita kustannuksia tarkastelemalla voidaan julkisivun puutöissä käytettäväksi urakkatyömuotoa, jolloin työn kustannukset pysyvät ennakoitavissa ja työvaiheen aikatauluttaminen helpottuu.

Avainsanat kustannusraportti, julkisivun puutyöt, kustannusarvio

Sivut 49 s. + liitteet 8 s.

CONTENTS

1. INTRODUCTION

1.1. Background

This thesis deals with façade woodwork on the construction company YIT's building site in Espoo. The purpose of this thesis is to gather information on how costs accumulate in the work phase of façade woodwork. The main reason why this thesis topic is assigned was that the costs of the work phase in the past projects have overrun the estimated value. A significant share of the buildings that this YIT's unit is producing on a yearly basis are assembled from elements. This is what the thesis discusses.

The aim was to produce data in a similar form as it is in the Finnish Ratu-kortisto, man-hours per unit. With this data, knowledge and information of the work phase and cost estimations of the future projects can be estimated more precisely. As YIT utilizes findings and data collected in this thesis, it is able to significantly save time and money spent on this work phase.

1.2. Thesis objectives and framework

On the site there are a total of six buildings and in total 30 two-story apartments and car ports. Apartments are row houses with two buildings consisting of seven apartments, one of five apartments, two of four apartments and one building of three apartments.

Buildings are made of pre-fabricated elements, which are assembled on site. In buildings with five to seven apartments, the frame is made of concrete and in buildings with three to four apartments, the frame is made of timber. Due to this element based building method, the junctions of wall elements are left without wooden panels, as seen in figure 9 (page 10).

This thesis also gives important data to site managers, to help them evaluate how much time and money is used and facilitates scheduling of the work phase. In this thesis only facades woodwork, woodwork of the roof and additional work phases explained in chapter 3.4., are considered. Therefore, woodwork of the roof that are done by the subcontractor and the façade woodwork of the car ports are not included.

1.3. Research methods

Information is searched for and gathered by monitoring the work phase during several visits to the sites. The site considered is in a steep location, which also enables to compare different buildings to each other. Research is also conducted on whether the working method that is usually used is the best alternative.

The work phase is analyzed in its specific details i.e. the most time consuming work, material transports and logistics, working with passenger crane, climate conditions and working areas effect on the job. Data that site supervisors are updating to the cost estimation software is utilized.

2. STRUCTURES AND DETAIL DRAWINGS

2.1. ART-unit and element factory

YIT's ART-unit produces from 250 to 300 apartments on a yearly basis. The number of apartments produced annually varies according to the size of the apartments. The distribution between blocks of flats and detached houses is the following: 60% of the annually produced apartments are block of flats. ART-unit employs approximately 120 people, of whom 50 are engineers. (Kuusela, email 9.2.2015)

The YIT's element factory is located in Ratasniitty area in Hämeenlinna. The factory employs 4 engineers and 15 carpenters. The main products of the factory are outdoor wall elements. With a full capacity, it produces yearly material roughly 24000 brm³, which equals to 1200 pieces of wall elements annually. The factory also produces cold walls for warehouses and shelters, intermediate floor elements, fire seal elements, balconies, roofs of balconies and warehouses, terraces and fences. (Alanen, email 29.12.2014)

The design process of elements is done at the factory, three engineers are designing the elements to be built. The designing of elements happens on the basic facts given by the architect, construction designer and HPAC-designer. In 2013, 43% of the production was sold out to other companies and 57% was sold to YIT. The share of ART-unit of the figure was approximately 30%. The element factory's annual turnover in 2013 was approximately 3,3 million euros. (Alanen, email 29.12.2014)

2.2. Literature

A very limited amount of literature can be found about façade woodwork. Literature about façade woodwork of element based buildings was not found at all. Finnish Ratu and RT-cards do offer information about the subject. Ratu-project is led and funded by Finnish construction industry, aiming at safe, productive and improving high quality building, involving different sides of construction industry. (http://www.ratu-hanke.fi/). RT-cards are provided by Rakennustieto Oy, which is a limited company owned by RTS, Rakennustietosäätiö. RTS is an independent and non-profit foundation aiming to promote good methods of construction. (https://www.rakennustieto.fi/index/rakennustieto.html)

2.3. Ratu-card 0424, Wooden element walls

Ratu-card number 0424 deals with work consumptions and methods of wooden element walls. In this document we can find raw estimations of labor inputs during the installation phase, including possible accelerating and slowing facts and effects on the work phase. With these parameters it is possible to come up with a raw estimation of the length of the process, which eventually leads to the expenses of work phase.

According to the Ratu-card 0424, quality control during the assembly of elements includes a dimensional accuracy. This controlling includes element seams, horizontal and vertical straightness and racking and curving of the elements. The dimensional accuracy is a very important factor and has a great effect on façade woodwork if it is not accurate enough.

The document deals with the tolerances of assembly, as we can see from Table 1. The building type considered is a residential building. Therefore, class two (luokka 2) is considered. In the table we can see that walls side position from the polar axis and free gap in between the wall elements have a tolerance plus minus eight millimeters. Also, the racking of the wall elements is allowed to be plus minus five millimeters. These three factors have a significant effect on façade woodwork.

Table 1. Assembly tolerances of wall elements (Rakennustieto Oy. 2014. Ratu 0424, Wood element building, walls)

SEINÄELEMENTTIEN ASENNUSTARKKUUDET [1)] [lähde: RunkoRYL2010, taulukko 721:T8]

Ulottuvuudet ja sijainti	Suurin sallittu poikkeama		
	LUOKKA 1 [2)]	LUOKKA 2 [2)]	LUOKKA 3 [2)]
Seinän sivusijainti perussuorasta	± 5 mm	± 8 mm	± 12 mm
Vapaa väli (vastakkaiset seinät)	± 5 mm	± 8 mm	± 12 mm
Seinän poikkeama pystysuorasta			
– korkeus enintään 3 m	± 3 mm	± 5 mm	± 8 mm
– korkeus yli 3 m	± 5 mm	± 8 mm	± 12 mm
Sauman leveys, poikkeama nimellismitasta	± 3 mm	± 5 mm	± 8 mm
Hammastus			
– ulkosauman hammastus, puuverhous	3 mm	5 mm	8 mm
– elementtien yläreunan hammastus	3 mm	5 mm	8 mm

Selitykset

Luokka 1: Rakennusosat, joilta vaaditaan erityistä mittatarkkuutta ja joille asetetaan erityisen korkeat ulkonäkövaatimukset.

Luokka 2: Asuin-, liike- ja toimisto- tai vastaavien rakennusten rakennusosat. Luokka 2 on yleisimmin käytetty asennustarkkuusluokka.

Luokka 3: Hallirakennusten yms. tilojen rakennusosat, joille voidaan sallia luokkaa 2 alhaisemmat mittatarkkuus- ja ulkonäkövaatimukset.

When considering the Tähtirikko site, the biggest buildings consist of seven apartments. Therefore, on one side seven elements are also assembled. If elements are assembled with maximum tolerances, the measuring difference at the end of the building can be up to 56mm, compared to the starting point. If this scenario happens, it will cause more work with woodwork. Also, if we consider that assembly tolerances are not in line with the first and second floor, similar difference can be found at the ends of the buildings.

As we can see in Figure 1, problems occurred with accurateness of the element assembly in E-building on Tähtirikko site. The studs and panels will be installed partially on top of the plinth. As we can see in the piece of wood placed hanging, there are differences in the placement of the studs. The studs on the first floor element are approximately 15 mm more inside than the studs on top of the plinth. If panels are installed straight down from the element face, there will be a bulge.

Figure 1 Assembly tolerances and accurateness. Ahokas M. 2014.

2.4. RT-card, façade woodwork

Façade woodwork is considered in RT-card 82-10829. The document includes regulations concerning façade woodwork according to the National Building Code, regulation E1. These regulations concern the fire safety issues of the wooden facades. The document also deals with quality standards of wood material.

According to the card, a ventilation gap, open from top to bottom, is left behind the cladding. To establish this gap, fastening supports for the façade panels are installed. Boards of 22mm times 100mm are most often used.

The RT-card 82-10829 also says that if possible, the extension of timber panels must be avoided. Extensions can be avoided using finger-jointed timber or by placing a covering panel on top of the joint. The nailing of possible extension is usually forced to be at the very end of the panel, the possibility of splitting of the board increases.

According to the RT-card, due to the ventilation gap, the outer edge of the panel is commonly about 50 mm or more out than the outer edge of the plinth. Technically the solution is preferable. The lower edge of the cladding must always be at least 300 mm above the ground. About 25 mm of the ventilation gap is left on the upper edge of the cladding. One or two of the highest panels are forced to be notched due to the roof trusses.

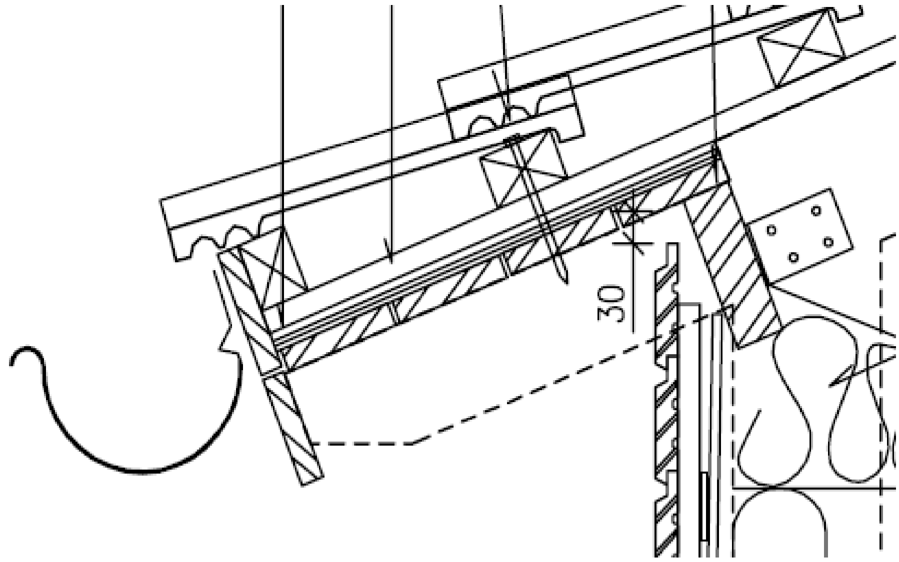


Figure 2 Detail drawing of the upper edge panels, without storm boards, on longer eaves. Nieminen A. 2014. Detail drawing 4.21b.

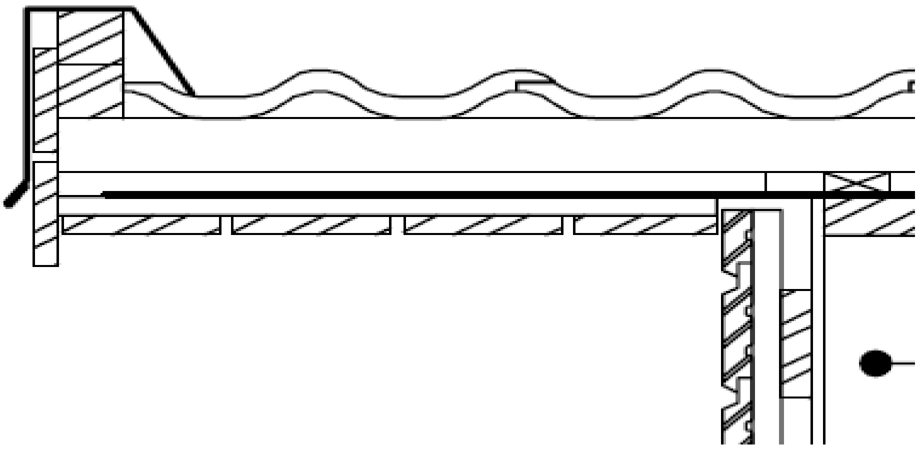


Figure 3 Detail drawing of the upper edge panels on short eaves. Nieminen A. 2014. Detail drawing 4.17.

As we can see from Figures 2 (page 5) and 9 (page 10), on longer eaves, there is a storm board to prevent frost snow to storm into the roof structures. The structure is ventilated from the wall and roof structure. We can see in Figures 3 and 10 (page 13), ventilation of the wall structure on shorter eaves happens in between the eaves soffit cladding.

RT-card says that traditionally thicker and wider boards are used on the corners. The usage of boards on the corners makes the work easier and speeds it up. As we can see in the Figure 4, boards on the corner are used.

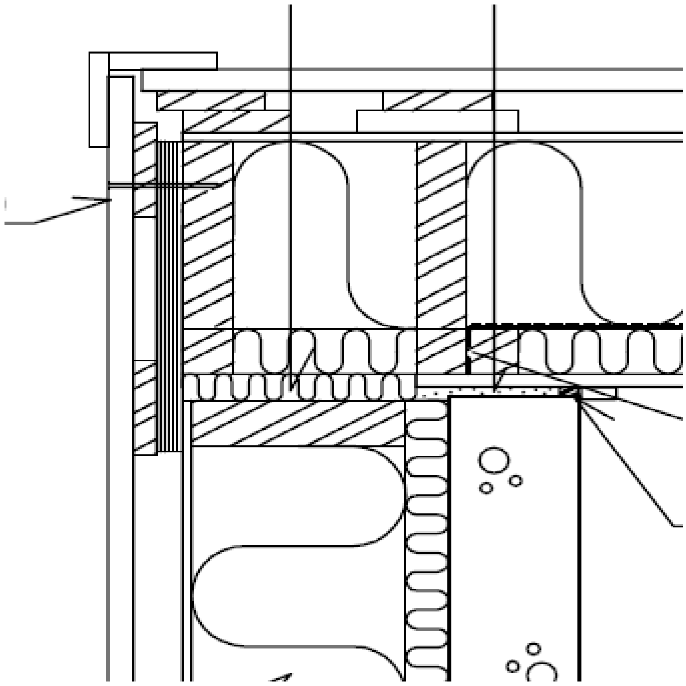


Figure 4 Structure on the corners, corner boards are used. Nieminen A. 2014. Detail drawing 5.12.

2.5. Ratu-card 0418, exterior cladding

Ratu-card 0418 gives guidelines to determine consumptions and quantities of façade woodwork. The document focuses more on actual façade woodwork and not element based buildings, but the effects of the variables during the construction phase can be utilized. The variables can be divided into two i.e. variables that account during the whole construction period and the ones that are variable during different work phases.

Storing materials is a variable of a construction site. It can extend the working input if the site is cramped and cut it if the site is spacious and the area plan is done well. Lifting and installation is a variable of wind and construction site, strong wind and cramped site extend the work input and not windy and spacious site cuts it down.

The transportation of materials is a variable, which is increased by long distances and plenty of single and additional transports. Short distances and well planned transports decrease the working input. The weather is a variable that increases the working input if a lot of weather guards are needed. The preparation for poor weather conditions is not adequate and if the weather conditions are constantly poor the working input increases.

Arrangements on the site can have an increasing effect on the working input, if storage facilities are messy and disorganized. Poor logistics, a lack of installation schedule and plan also have an increasing effect on working input. A very difficult cladding type, a lot of different kinds of shapes, different styles of cladding material and holes make work slower. The area of wall a have an effect too if no personnel hoist is needed and the wall type is a simple straight forward type, it work input decreases.

The hardest variable to estimate is the relation between site supervisors and the working crew. The crew, where carpenters are familiar to each other and have experience in the work, can manage under a more unexperienced supervisor. Also, a very experienced supervisor leads and plans the work phase better than a supervisor with less experience.

2.6. Ratu 1196-S Planning of the work phase

Ratu card 1196-S deals with a planning of the work phases of facades made of wood and from stone materials. This card we can find factors concerning how the amount of work affects to the work efficiency and how frost has an effect on the working efficiency.

In the Table 2 below, we can find that as the amount of façade woodwork rises, the work efficiency factor gets smaller. This is noticed in Tähtirikko, as the building's size varies from three to seven apartments. In the Table 6 we can also see the factors of frost that have an effect on work efficiency. As temperature falls the factor causing extension to the working time rises. This is a notable factor, as work is done in Tähtirikko during wintertime. The amount of snow during the construction period has a similar effect to frost. Snow clearing work can increase the working time by 15% and an effective working time can decrease.

Table 2. Effect on the amount of work on the efficiency and caused by frost. Rakennustieto Oy. Ratu 1196-S. Puu- ja kiviaineiset julkisivut, tehtäväsuunnittelu.

Suoritemäärän vaikutus työmenekkiin

Verhous	50 m^2	100 m^2	200 m^2	400 m^2	800 m^2
Kerroin	1,10	1,05	1,00	0,95	0,90

Talvihaitta- ja lisäprosentit (%)

Lämpötila, ˚C	0…-2,5	-2,5…-7,5	-7,5…-12,5	alle -12,5
Työajan lisäys	3 %	5 %	8 %	15 %

3. FAÇADE WOODWORK AT TÄHTIRIKKO SITE

3.1. Plot

The soil at Tähtirikko site consists mainly of silt moraine, rocks and bedrock. The plot itself has big differences in elevations. Steep bedrock is visible on the western corner of the plot. (Huokuna, Geotek Oy, 19.11.2012). Notable elevation difference can be seen most easily when comparing the first floors of buildings F and C. On the western side, buildings F, E and D are linked to the bedrock. The Storage area is not seen in this picture, it is on the northern point of the plot.

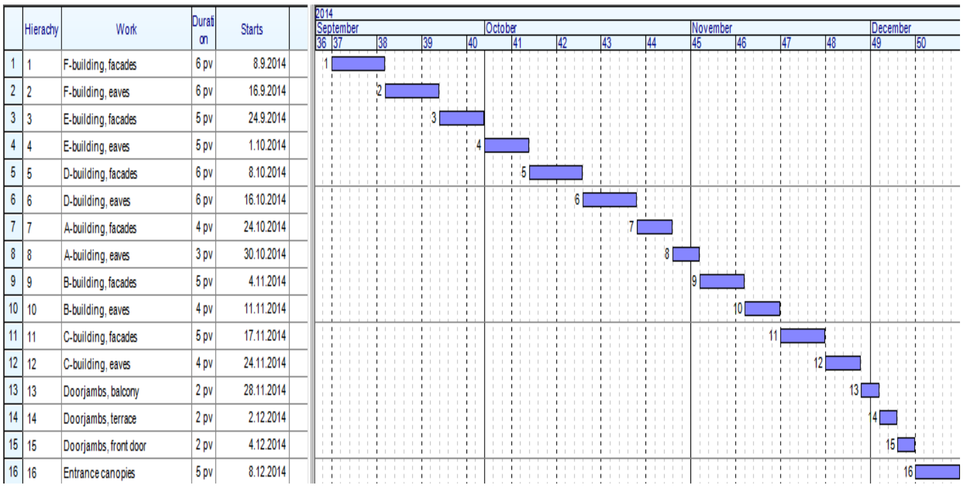
Figure 5 Picture of the plot. Konola A. 2014. General layout.

Figure 6 Visualization picture of Tähtirikko.

3.3 Course and scheduling of work

Before the actual work phase began, planning the course of work had been made by the author. A computer software called PlaNet+, was used to perform a linear time schedule with dates and duration. In these schedules and plans evaluations of durations and efficiency of the work were conducted according to the information given by the carpenter mainly responsible for the work and by the general foreman of the site. Both of the above have a long experience in façade woodwork and have been working together in many past projects.

With this preliminary schedule, as seen Figure 7, of the work phase we can estimate the last of the work phases would have been 70 days, starting from 8 Sep 2014 and finishing on 12 Dec 2014.



	Hierachy	Work	Duration	Starts
1	1	F-building, facades	6 pv	8.9.2014
2	2	F-building, eaves	6 pv	16.9.2014
3	3	E-building, facades	5 pv	24.9.2014
4	4	E-building, eaves	5 pv	1.10.2014
5	5	D-building, facades	6 pv	8.10.2014
6	6	D-building, eaves	6 pv	16.10.2014
7	7	A-building, facades	4 pv	24.10.2014
8	8	A-building, eaves	3 pv	30.10.2014
9	9	B-building, facades	5 pv	4.11.2014
10	10	B-building, eaves	4 pv	11.11.2014
11	11	C-building, facades	5 pv	17.11.2014
12	12	C-building, eaves	4 pv	24.11.2014
13	13	Doorjambs, balcony	2 pv	28.11.2014
14	14	Doorjambs, terrace	2 pv	2.12.2014
15	15	Doorjambs, front door	2 pv	4.12.2014
16	16	Entrance canopies	5 pv	8.12.2014

Figure 7 Preliminary schedule. Ahokas M. 2014.

As we can see in Figure 7, the most time consuming part estimated to be in total was façade woodwork. The work estimated to last in that work phase was 70 days in total. Buildings F and D are the biggest ones and identical to each other, both buildings containing seven apartments. The calculated duration of work with these buildings was the longest.

The course of work was planned to be started from building F, then continuing down the hill. As we can see in Figure 5, after building F come buildings E and D, then continuing with buildings A and B. The reason for this was that the building C was not yet built, so façade woodwork could be done.

As we can see from the schedule, the amount of time reserved for buildings A, B and C is smaller than in D, E and F buildings. This is because buildings mentioned above contain only four apartments and building A contains only three apartments. Therefore the amount of work is smaller with these buildings.

When comparing the quotation to this schedule we can see that the amount of work used for facades is more than two times less than estimated. This is because the preliminary schedule is conducted under the assumption that all of the work done is piecework. With the term piecework is meant that general foreman and carpenter have made a contract in which the carpenter has a deadline when the work must be ready. In piecework the wage paid to the carpenter is higher than regularly. As piecework is chosen to be the way to work, expenses are higher but time is saved and scheduling of work is easier.

4. CONTENTS OF FAÇADE WOODWORK

4.1 Dividing and classification of working classes

In calculating and monitoring the accumulation of money and keeping track of the cost evaluation in projects YIT has its own computer software, called TAS5. In this software all of the work phases have their own individual segments. In these segments there are several different sources included. These segments are divided into different classes, class one being work input, class two is material input, class 1-S is input of social costs of work, such as pension and insurance fees. Input for subcontractors work is class three, input for outsourced workforce is class 35. Machinery and tools linked to the work phase are in input in class four.

The software has different inputs for different kind of workers. Software divides workers into two different categories. An employee with more experience and who can carry out more demanding duties, is called a carpenter. An employee with less experience, has lower education level than the carpenter and carries out less demanding chores, he is called a construction worker. The carpenter has a higher input value for salary than the construction worker.

4.2. Inputs and work content of façade woodwork

The work content of façade woodwork includes the installation of missing façade panels, the installation of corner boards, fastening of doorjamb boards, fastening of elements and insulation of joints. In Figure 11 (page 14) we can see the starting point of the façade woodwork. There we can see that panels are missing from this point of the building, due to a horizontal seam on top of the element and vertical seam in between two elements. From the picture we can also see that the covers of the window's weathering strip, installed to protect them from damaging during transportation, are still in place.

As we can see in Figure 8, there are holes drilled into the wooden battens, near the horizontal seam. After installing the elements, bolts are drilled through these holes to fix the wall element to the concrete wall in between apartments. Anchors are drilled so that they are from center to center 1200mm and the height difference between two anchors is at least 150mm. With houses made of wood, the anchoring is seen in Figure 9. Wood screws are fixed to the separation wall and notched spikes are used to fix the wall into the studwork.

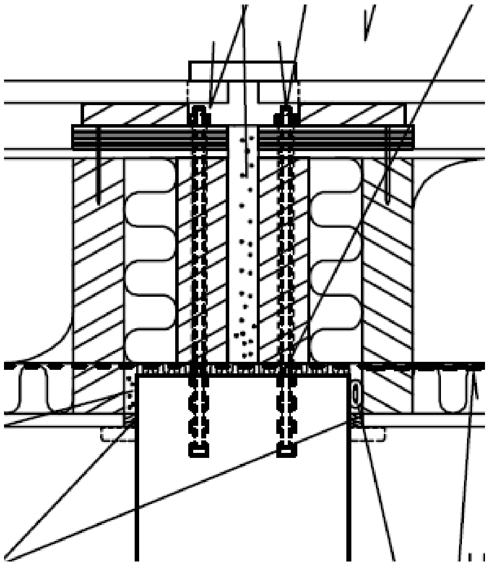


Figure 8 Wedge anchorage to the concrete wall. Nieminen A. 2014. Detail drawing 5.08.

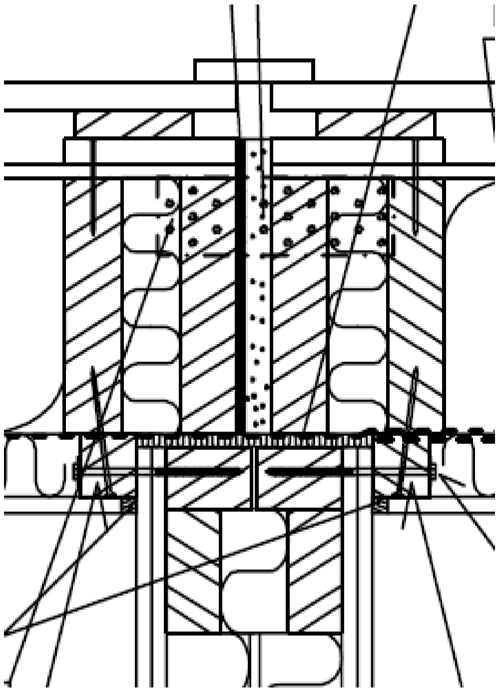


Figure 9 Anchoring to the wooden wall. Nieminen A. 2014. Detail drawing 5.07a.

Vertical seams must be insulated, to prevent any air leakages and cold bridges. As we can see in Figures 8 and 9, polyurethane foam is sprayed to the seam. A mineral wool strip is installed underneath the element, to prevent air leakages and heat bridges. At the seams of elements, elastic putty is installed.

In Figure 13 we can see the starting situation of façade woodwork at the ends of the buildings. As we can see, rows of panel are missing from the upper seam and rows of panel are missing from the lower seam. The starting point of installation of corner boards can be seen in Figure 11. In Figure 10 we can see the starting point of installation of doorjambs, as plain doorframe is visible.

Figure 10 Polyurethane foam sprayed into the vertical seam using a passenger crane. Ahokas M. 2014.

Figure 11 Starting point of façade woodwork. Ahokas M. 2014.

4.3 Inputs and work content of roof woodwork

Work content of roof woodwork includes the installation of eaves soffit boards on long and end eaves of the building. In Figure 13 we can see the starting point of roof woodworks at the ends of buildings. It is noticeable matter that there is no eaves soffit cladding installed by subcontractor.

The detail drawing in Figure 2 (page 5), explaining the assembly of the highest panels and on longer sides, can be seen in Figure 14 (page 16). The storm boards are not drawn into this figure, since they were not included during the design phase, they were installed due to orders of the client. The detail in Figure 3 (page 6), can be seen in Figures 14 (page 16) and 17 (page 17). Two boards on the face of eaves are installed so, that the roof sheet can be fixed to them.

Figure 12 Starting point of the roof woodworks. Ahokas M. 2014.

Figure 13 Starting point of the roof woodwork at ends of buildings. Ahokas M. 2014.

Figure 14 Storm boards and side eaves finished. Ahokas M. 2014.

Figure 15 The junction of eaves in building E. Ahokas M. 2014.

4.4 Additional content to thesis

During the construction period, difficulties and additional work that were connected to woodwork of buildings occurred. As per the instructions of the commissioning company, cost overruns of these actions were also included into thesis. This additional content in question was the installations of balconies and roof of the balconies, balcony woodwork and possibility to change the calculation method of installation of entrance canopies and additional work with the installation of storm boards.

4.5 Calculation method

Estimating the time and money needed for the work phase is done by a calculating engineer. Calculation process starts with a modeling of the building to be built. Quantity information is transferred from building information model into the quantity estimation program.

In the estimation software, every work phase has its own consumption for work and for materials. The consumptions of materials is based on the data from the building information model and consumption of work is based on the knowledge of previous projects. Software calculates different work phases in different units.

The woodwork of a roof includes different jobs, for example facing boards are calculated in meters and insulation materials are calculated in area. Everything that can't be calculated using the model in the software are calculated by hand. With terraced and single-family houses this calculation model can't be used as much as when calculating a block of flats. (Mero, email, 3.12.2014)

5. PAST PROJECTS

The façade and roof constructions at the Tähtirikko site account for 7,35 % of the whole construction budget. Although the percentage of the whole costs of the site is not significantly remarkable, the share of the working hours – the working input share, is. The percentual share of façade woodwork is 9,19 %. Roof construction equals to 9,55 percentages. As we can see in Table 3, as the share of manual labor is significant, it is noticed in previous projects that the costs of the work phases are prone to overrun the estimated.

5.1. Data from past projects

As we can see in Table 3, there are some big overruns in façade woodwork in ART-unit's past projects. Mainly in all of the projects listed are typical of ART-unit, containing two-story buildings. The overruns are not financially big as they are compared to the whole project's quotation, but are remarkable as percentual overruns.

In the table 1 we can point out project A, where work was done as piecework. Using piecework as a working method makes the forecasting of the actual costs of the project easier and more predictable. As we can see from this project, final costs of work match well to the estimated costs. The overrun of façade woodwork is 2,5% and the surplus of façade woodwork is 11,2%.

As we can see, there is no overrun in project B, as all of the buildings in this project were one-story buildings. This doesn't have an effect on the calculation method that was used in the project. Therefore façade woodwork was calculated as if the buildings had two stories. This makes the estimated costs not that accurate; therefore final costs are positive. As we consider the total costs of the roof woodwork, we can see that the realization of the budget is very imprecise. As we take a closer look at the cost evaluation program, we can see that the actual work done in this work phase is 16 hours. This points out the fact that all of the costs have not been precisely recorded by the site supervisor.

Total overruns in project C are very significant. As we look at the project more precisely, we can see that the money reserved for work in façade woodworks is overrun by 15,2 %, as in roof woodworks the overrun is 12,3%. What is remarkable is that in roof woodwork, the subcontractors work and the materials costs overrun significantly.

As we can see, also in project C, the overruns in façade and roof woodwork are significant. The cost overrun in façade woodwork materials and work is 16%. The characteristics of the plot made the work very difficult with a passenger crane to operate. Although there are big overruns in façade woodwork, the budget of roof woodwork holds. The main reason for this is that the materials cost significantly less than estimated.

The biggest single overrun in Table 1 was in project E, where the overrun in roof woodwork has been 1,5 times the estimated. This figure also includes also used materials, the lifting crane and subcontractors work. In this project, the work was done so that subcontractor made the roofs for all four one-story buildings. On the two-story buildings, roofs were done as an element on the ground level and then lifted in its place. This work was done by YIT’s carpenters. Apparently the main idea behind this was to ensure the building to be completely dry in a building phase. As we can see from the large overrun, using this working habit was not calculated the by calculating engineer in the quotation.

In project F, the estimated costs match to the actual costs of work well. This can be the case that the site supervisor responsible for the work phase has been tampering with the numbers to make them look better. As said earlier by the Calculating Engineer Mero, faulty usage of expense program can cause faulty results as the estimated costs are compared to actual costs. (Mero 3.12.2014)

The project G was ongoing on at the same time as Tähtirikko was built. The project G is located on a flat plot and consists one and two-story buildings. The façade and roof woodworks were done as a piecework, mainly by one carpenter. The estimated costs match well to the actual costs of the work.

As a conclusion we can say that the size and shape of the plot have a remarkable effect on the final costs, as these factors are not included in the calculating program. A big plot causes more logistics of the materials and transportation of the machinery and passenger crane, whereas rocky and tight plots make moving around with passenger crane difficult, causing frequent extensions of the boom and material logistics are more challenging to execute. On the other hand, a big plot ensures bigger facilities to store and move materials around as with smaller plot transportation of the passenger crane is minimal and materials can be placed on one spot for a longer period of time.

Table 3. Data from past projects

Project	Façade woodwork quotation / costs	Roof woodwork quotation / costs	Notice
A 26 apartments in nine buildings.	- 2,5 %	11,2 %	-Flat plot, three hillside buildings -Work was done as piecework, two carpenters
B 22 apartments in 11 one storey buildings.	7,1 %	59 %	Flat plot, buildings located tightly
C 23 apartments in 13 buildings. All two-storey buildings.	- 15,2 %	- 12,3 %	-Flat and big plot
D 26 apartments in 16 buildings. All two-storey buildings	-16 %	14,5 %	-Rocky and big plot
E 17 apartments in eight buildings. Four one-storey and four two-storey buildings	- 10 %	- 32,7%	Tight and flat plot
F 16 apartments in four buildings. All two-storey buildings	8,6 %	- 0,8 %	-Narrow plot -All hillside buildings
G 23 apartments, both one and two-story buildings.	4,2 %	0,5 %	-Flat plot -Work done as piecework by one carpenter

6. DATA COLLECTION AND ANALYSES

6.1. Data collection

At the beginning of the

thesis, one source of data collection would be a diary form sheet, which the carpenter fills in on a day-to-day basis. This method turned out to be ineffective, as the carpenter failed to write down the work done daily. An easier and more practical way that was used was frequent, weekly visits to the site. During these visits the carpenter was interviewed about weekly work input, time consumption per work phase and whether any difficulties that slowed down the work pace had occurred. During the visits, the following week's working schedule was discussed with the carpenter and the site supervisor and observations about possible difficulties could be evaluated. This way turned out to be effective, as places where the difficulties occurred could be visually seen.

One week was spent at the site, observing the work phase more closely. During this week, a clearer picture about the work phase as a whole was created than during the weekly visits. The week enabled to have constant communication with the carpenter, visually seeing all of the phases included in the work and getting involved with the process as a whole.

For detailed information data collected was submitted to the calculating manager of ART-unit. According to these weekly reports he was able to guide and tell, if the data input gathered was not sufficient.

The data gathered was the time consumption and work input during a specific work phase. As every work phase was separated and work inputs were recorded, it was possible to produce tables of the data gathered. In these tables we are able to notice which work phases took more time to execute than estimated, which were estimated correctly and which were estimated to take a longer time.

6.2. Analyses of facade and roof woodwork

The attachment of missing panels cause the single biggest difference compared to the estimation. Although the time reserved for the work phase is the largest, working time due to the various difficulties, runs out. As we can see in Figures 11 (page 14) and 13 (page 15), there is a lot of work done by hand; panels must be taken in, notched and cut to length in many places around the building. Different kind of machinery is used in all of these jobs mentioned above, which take time to move, transport, use and maintain.

The working input was divided into six different categories. Four of these categories are found in the estimation, woodwork, corner boards, and side and end eaves. The insulation of the joints and element fastenings were not considered in the estimation, but they were included in the analysis. Fastening of the elements is more closely considered in chapter 3.3. In estimation, this work phase is considered to be part of the frame-work phase, although it is done during the façade woodwork. Insulating of the vertical joints is done during the façade woodwork.

Due to the overlapping of the work phases, when working on the side eaves of the building, fall protection railings on the roof must be taken off. As wall elements are delivered to the site, the protection shields of windows are used to protect the weathering strip. The uninstallation of these weathering strips and fall protection railings are calculated in the work input of element fastenings. Railings and weathering strips can be seen in Figure 16.

6.2.1. A-building

Building A is located next to Miilukorventie road on a highest point of the plot. The building consists of three apartments. The location is the best on site concerning façade woodwork as there are no steep hills and geography near the building is good, except on the southern end, the location in between A and B buildings is narrow, only few meters. In this location, longer extensions of the boom are needed.

A special feature in A, B and C buildings is the level differences, since all of the buildings are located parallel to the slope. As we can see Figure 16, the level difference at the eaves is more laborious to be done than a straight eave. In building A, the level difference is situated between first and second apartments.

Figure 16 Level difference in A building. Problematic electrical cabling also visible. Ahokas M. 2015.

6.2.1.1. Division of working time in building A

As we take a look at the issues with A building, there were problematic electrical cables, as seen in Figure 16. The working time lost with the wiring is four hours. Wirings had to be placed in between the studwork and to be able to do that, studwork had to be cut. When paneling the wall, the carpenter had to be very careful, so that nails don’t penetrate the electric cables. This problem could be taken into account as elements are designed. A casing pipeline could be installed as element as it’s being manufactured, so that it is placed inside the studwork, to prevent this kind of problematic work phase on site.

Another problem concerning A building were too short studworks, as seen in figure 17. Extra studs had to be installed in between roof sheeting and panel. The reason why this problem occurred is either that the canopy is placed too low related to the wall element or that there has been an error when wall elements were manufactured. After all, studworks had to be extended to be able to have panel a proper fixed to the wall. The work input to fix the missing studwork was four hours.

A building is the smallest building on the plot, which increases the working time, as we can see in Table 2 (page 6). The working input per hour in every work phase are approximately on the average value due to the closeness of the circular saw and material storages. There is also a lot of room around the building and the terrain was in good condition to move around with a passenger crane. The work input per hour of the corner boards is the smallest of all buildings. This is due to reasons mentioned above and the closeness of the B building.

Table 4. Division of working time in building A

A-Building	Man-hour per unit
Joint insulations	0,16 m-h/m
Woodwork	1,39 m-h/m
Corner boards	0,08 m-h/m
Side eaves	0,38 m-h/m
End eaves	0,67 m-h/m

Figure 17 Studwork extensions on top of entrance canopy in A building. Ahokas M. 2014.

6.2.2. B-building

The building B is very similar to building A. The main differences are that building B consists of four apartments and the level difference is situated in the middle of the building. The terrain on side next to building E is very steep, as seen in Figure 18. With that side, long extensions of the boom are needed to be able to construct the eaves. The ends of the building are very narrow, buildings A and C are very close on each end. On the eastern side of the building, the terrain is in good condition.

Figure 18 The terrain on the western side of the building B and the eastern ends of buildings D and E. Ahokas M. 2014.

6.2.2.1. Division of working time in building B

Material storage facilities and the circular saw were in a close reach, which decreased the working input. Due to this reason, buildings B and C are not comparable to each other. Since the ends of the buildings are close to each other, time spent installing the missing panels and working with the end eaves is a utilized well. Transportations of the passenger crane are minimal and materials and machinery were distributed more close to the actual working area. Also, on the eastern side, there were no elements that slow down the construction process. The benefits of the location can be seen in every work phase. Man-hour per unit in façade woodwork, side eaves and end eaves are the smallest of all buildings.

Table 5. Division of working time in building B.

B-Building	Man-hour per unit
Joint insulations	0,11 m-h/m
Woodwork	1,26 m-h/m
Corner boards	0,09 m-h/m
Side eaves	0,33 m-h/m
End eaves	0,58 m-h/m

6.2.3. C-building

C-building differs from other buildings in that in the cellar of the building lies the air raid shelter. However this doesn't have an effect on the façade woodwork. The car port at the end of the building has a significant effect on the work, as seen in Figure 19. Due to the level differences at the site, at the end where also the car port lies, is a retaining wall that connects C building and the past project, Lehtorikko's outmost corner.

Figure 19 The southern end of the C building. Ahokas M. 2015.

As we can see in Figure 19, car port makes a difference in the façade woodwork so that some of the paneling is left out at the end. The height difference between the highest point of the building and ground level in front of the car port is approximately 11 meters. The level difference at the point also causes a long extensions of the passenger crane's boom. Stairs leading to the car port lie on the eastern side of the building. These stairs cause a problem with the passenger crane, paneling and side eaves of apartment 11 are possible to execute from eastern side of the building, but end eaves and paneling of the end of the building must be done from in front of the car port.

The western side of the building was very uneven during the paneling and as side eaves were done. This is because the earthwork subcontractor hadn't levelled the area. This caused the change of working process so that side eaves were done using balconies. As the work had to be done like this, the working input was bigger than in other buildings. The location on the eastern side of the building was also not optimal for side eaves.

6.2.3.1. Division of working time in building C

In the Table 6, we can see the actual man-hours per unit concerning C building. As in corner boards and both eaves, the man-hour per meter is in line with the average values. The value for façade woodworks is significantly higher than the average value. This is due to the factors pointed out earlier in chapter 6.2.3; remarkable amount of working time was lost due to the position of the building, especially in the southern end, as we can see in Figure 19. The man-hour per meter of end eaves is very high in comparison to the average value. This matter can be explained with the same reasoning as mentioned above.

Table 6. Division of working time in building C

C-Building	**Man-hour per unit**
Joint insulations	0,11 m-h/m
Woodwork	1,73 m-h/m
Corner boards	0,12 m-h/m
Side eaves	0,37 m-h/m
End eaves	0,77 m-h/m

6.2.4. D-building

Building D lies in a flat location and consists of seven apartments. The exception is the western end of the building, which is near to the slope. There is a steep climb up, as we can see in Figure 20, which makes working there more difficult. A carpenter cannot drive the passenger crane in that area in the end of building. The end must be done so that the passenger crane is driven right to the end of the building and the work is done with a fully extended boom or by changing the passenger crane. This increases the man-hour per unit or the rental costs of the new passenger crane.

Figure 20 The western end of building D. Ahokas M. 2014.

We can also see in Figure 20 that on the southern side of the building F, there are other buildings, too. These buildings limit the working area in the zone. As we can see in Figure 21, the southern side is also profiled by the earthwork subcontractor and due to that the area is not accessible to the passenger crane. Due to this poor scheduling of work, the façade on this side was not accessible with the passenger crane. The woodwork was done from wooden bridges, assembled in between the balconies. This method is slower, which increases the man-hour per meter and more importantly the work safety of the carpenter cannot be ensured as well as working from the passenger crane. The woodworks were done at the same time as the partition walls of balconies and other woodworks were done.

Due to the flat location, the northern and eastern sides of the buildings cause no difficulties and cause no extra time consuming work phases, i.e. work can be executed at a normal pace. As said before, the storage area on the site is located on the northern point of the plot. As we can see in Figure 5 (page 6), building D is located on the most southern point of the plot, therefore logistic arrangements are the most difficult and laborious on the site.

Figure 21 The southern side of building D. Ahokas M. 2014.

6.2.4.1. Division of working time in building D

As we consider working time in building D, we can see in Table 7 that all of the work phases are in line with the average values, except the façade woodwork. This is due to the factors pointed out in chapter 6.2.4; the logistics to the southern end of the plot and the poor scheduling of the work phase, as the southern side of the buildings' façade were had to be done using wooden bridges across the balconies.

Table 7. Division of working time in building D

D-Building	**Man-hour per unit**
Joint insulations	0,08 m-h/m
Woodwork	1,63 m-h/m
Corner boards	0,14 m-h/m
Side eaves	0,39 m-h/m
End eaves	0,69 m-h/m
Element fastenings	0,06 m-h/m

6.2.5. E-building

E-building is located on the steepest position of the plot. Its northern side has a soil pressure wall. As we can see in Figure 22, the western end of this building is very steep. During the façade woodwork of the end, the passenger hoist was located on the road between buildings F and E. The location of the crane was not optimal; the long boom had to be extended. The eastern end of the building is also steep, but easier to execute than the northern one. As we can see in Figure 15 (page 17), in this building there are studs and cladding on top of the plinth. The element edge is so high, where the cladding starts on western, that the crane must be used and on the eastern end work can be conducted from ground.

In E-building, on the soil pressure wall side, there is just one floor. Therefore, big part of façade woodwork could be executed from the ground level, without the passenger crane. As we can see in Figure 5 (page 9), buildings E and D are close to each other. When working on longer sides in between the buildings, the crane movement was minimal. This is a positive aspect on tight plots. Therefore, difficult logistic arrangements in front of D building also had an effect on E building.

6.2.5.1. Division of working time in building E

The most time consuming part of building E was the façade woodwork. During the installation of elements, a dimensional error occurred, which led into laborious fixing in this work phase. What happened was that the outmost element of the second floor and the element beyond it, had a gap that needed to be fixed in order to prevent the wall bulging at that point. With this fixing and reconstructing of the wall, estimated 10 to 20 working hours were lost. We can see that the wall in question in Figures 1 (page 4) and 22 (page 31). At the junction of concrete wall and wooden element, the gap between those two was approximately 15 mm or more. The fixing had to be done using a passenger crane due to the height of the position. This error really had an effect on the man-hour per meter of the façade woodwork of the building.

The most time consuming parts, the construction of side and end eaves and the installation of missing panels can be explained with the challenging position on the plot. Due to the tight position, logistic arrangements were difficult to carry out. On the other hand, no material transportations were needed when constructing buildings next to each other.

As we can see in Figure 22, on the western side of the building E, there is a special feature where the studs and paneling continue on the top of the plinth. This feature also happens on the western side of the building and is caused by the building's location on a steep slope. The estimation of the work phase included fastening the studding to the plinth and fastening the panels. This work phase estimation was very exact. Due to the position of the building, the northern side of the building is in one story. This has a big effect on every work phase, especially on the corner boards and side eaves, as half of them can mainly be done from the ground level, without the passenger crane.

Table 8. Division of working time in building E

E - building	**Man-hour per unit**
Joint insulations	0,10 m-h/m
Cladding and woodwork	0,24 m-h/m²
Woodwork	1,33 m-h/m
Corner boards	0,14 m-h/m
Side eaves	0,34 m-h/m
End eaves	0,73 m-h/m
Element fastenings	0,06 m-h/fastener

Figure 22 The location of building E, the western end. Ahokas M. 2014.

6.2.6. F-building

Building F lies on a decent place of the plot from the point of view of construction. The using of passenger crane is easy on every side of the building, except on the western end. As we can see in Figure 23, the condition of the end is not suitable for passenger crane to drive to. In this case, the façade woodwork has to be done from very long extended boom, which slows down the work pace. The work can be executed from the southern side of the building, as on a northern side, there is a limited area for the passenger crane to operate, due to the closeness of car ports.

On the southern side of the building, the closeness of the building E cuts down the working time, as the movement of the crane and material can be minimized. Although this is the case, the extension of the boom is significant as we can see in Figure 24. The passenger crane can be driven on a spot so that the right track of the machine lies on a bottom left corner in Figure 24, where we can see the wooden boards. This position is safe to be driven to, as the base is a drive path for cars. This ensures the safety of the work, as the stability of the crane is ensured as the boom is extended.

The most problematic area lies on the western end. The area is near to the rocks and it is very steep. Moving to the position with a passenger crane is very difficult, as we can see in Figure 23. On the northern side there is a big pile of snow and on the southern side the road doesn't continue far enough.

Figure 23 Building F, western end. Ahokas M. 2014.

Figure 24 Building F, southern side. Ahokas M. 2014.

6.2.6.1. Division of working time in building F

There were no significant problems in façade and roof woodwork in building F. The only problem concerned the western end, as pointed out earlier. Paneling and the end eaves at the western end were done using the same machinery as in other buildings. The snow pile and part of the slope at the north western corner was removed using a tractor excavator, to provide enough room to move around with a passenger crane. Paneling of the western end took six hours and the end eave six hours. In total this problem caused extra working input of six hours in comparison to similar end of the building in normal conditions.

As we compare buildings D and F, we can see that the working inputs are approximately the same in every work phase. In D building, the working input in woodwork is somewhat higher, due to the problems in the southern side of the building. The amount of work is the same in both buildings, and the problematic hill on the western side on both of buildings.

Table 9. Division of working time in building F

F - Building	Man-hour per unit
Joint insulations	0,08 m-h/m
Woodwork	1,23 m-h/m
Corner boards	0,13 m-h/m
Side eaves	0,36 m-h/m
End eaves	0,78 m-h/m
Element fastenings	0,06 m-h/fastener

6.3. Overall man-hour inputs of work phases

6.3.1. Man-hour per meter of the façade woodwork

In the façade woodwork, the man-hour per unit varies a lot between the buildings. The main causes for big differences are caused by the terrain around the building, closeness of other buildings and problems related to the poor scheduling of work.

We can point out few details in Table 10. Working in building B has been the most efficient and the least efficient in building C. These two buildings are similar in shape and size, but the work input difference is approximately 27 %. There is a 9 % difference in work input between buildings D and F, although they are also similar in size and shape. These two notable differences are mainly caused by the difficulty to operate with a passenger crane in the area. We can also point out the fact that both D and C are located on the far end of the plot, where the material transportations take a longer time and the transportation of the circular saw is the most laborious.

According to Table 10, in buildings B and E, the façade woodwork was the most efficient. This can be explained by the locations of the buildings; both of them are close to other buildings on two or more sides. This factor cuts down the material and transportations with the passenger crane. Both of these buildings are also at a good distance to storage areas of materials and the terrain in both of the buildings was in good condition.

In building A the work is below the average value but the amount of work is significantly smaller than in other buildings. One factor is that the building is located on a good position next to the material storage area and the terrain around it is in good condition, counterfeits the statistic. We can see In Table 1(page 3) that the amount of working area can reduce and raise the amount of working time, therefore the work input of building A should be higher. As we analyze building F, we can see that the work input is approximately the average. This can be explained by the information in Table 1(page 3), as the amount of work increases the working time decreases. The working time lost in the problematic western end of building is compensated by the closeness of storage area and trouble-free terrain to operate with a passenger crane. In Table 10, façade woodworks is analyzed without joint insulations and element fastenings.

Table 10. Man-hour per meter of façade woodwork, without work input of joint insulation and element fastening

Facade woodwork	Man-hour per meter
A	1,39 m-h/m
B	1,26 m-h/m
C	1,73 m-h/m
D	1,63 m-h/m
E	1,33 m-h/m
F	1,48 m-h/m
Average value	1,47 m-h/m

6.3.2. Man-hour per meter of the side eaves

The man-hour per meter of the side eaves doesn't differ much between buildings. The work phase turned into more laborious after the decision of the installation of storm boards. The work in every building was very slow, as we can see in Table 11; the working input on average was just 0,36 man-hour per meter.

In buildings B and E, the work efficiency was the biggest. With E building, this can be explained by the location of the building. Long sides of the building are next to the sides of buildings D and F. Because of this the working with a passenger crane and material transportation can be minimized. With B building, data can be explained by the terrain around the building, which was good apart from the part of the western side and with a closeness of the material storage area.

Table 11. Man-hour per meter of the side eaves

Building	Man-hour per meter
A	0,38 m-h/m
B	0,33 m-h/m
C	0,37 m-h/m
D	0,39 m-h/m
E	0,34 m-h/m
F	0,36 m-h/m
Average value	0,36 m-h/m

6.3.3. Man-hour per meter of the corner boards

In Table 12, we can see the man-hours per meter of the corner boards. As can be seen the values vary from 0,08 hours in A building to 0,14 hours in D building. The man-hour per meter is the smallest in A building. This can be explained by the size of the building, only three apartments and by the closeness of the circular saw and material storage facilities. There is also a lot of space on the northern side of the A building to move around with passenger crane.

As we see in Figure 5 (page 9), buildings A, B and C form a line, with a small distance between each other. This feature decreases the amount of work between the buildings, as moving the passenger crane is minimal, which decreases man-hour per meter. The amount of work increases and man-hour per meter decreases, as we compare A and B buildings.

A notable fact is that the amount of work is the same in B and C buildings. Nevertheless, the man-hour per meter is 12 % lower in B building. This is caused by the location of B building, both of its end are close to other buildings and to the material storage area, and the terrain in B building is better than in C building, therefore man-hour per meter is higher.

As we take a look at the D and F buildings, where the amount of work is same, we can see a lot of similarities. In both of these buildings, one side is close to E building, one end is near the rocks and one end is in a good position with a lot of space to move around with a passenger crane. What makes the little difference in these buildings, is the fact that the southern side of the D building was not in the condition for the passenger crane to drive.

The man-hour per meter in building E is not comparable to other buildings, as the building is partially in one-story. This decreases the working time as it can be done partially from the ground level, without the use of a passenger crane.

Table 12. Man-hour per meter of the corner boards

Building	**Man-hour per meter**
A	0,08 m-h/m
B	0,09 m-h/m
C	0,12 m-h/m
D	0,14 m-h/m
E	0,14 m-h/m
F	0,13 m-h/m
Average value	0,12 m-h/m

6.3.4. Man-hour per fastener of the element fastenings

Element fastenings in Table 13 are from concrete framed buildings D, E and F. The element fastenings and detailed drawing can be found in Chapter 3.3. Fastening of elements is not calculated separately in the estimation; work phase is included in woodwork work input. Man-hour per fastener is the lowest in building E, as fastening on one side can be made almost entirely from the ground level, as th building is partially in one story. The installation of fasteners is similar in both D and F houses, as they are very much alike. The man-hour per fastener is also the same in both of these buildings.

Table 13. Man-hour per fastener of the element fastenings

Building	Man-hour per fastener
D	0,063 m-h/fastener
E	0,056 m-h/fastener
F	0,063 m-h/fastener
Average value	0,060 m-h/fastener

6.3.5. Man-hour per meter of the joint insulations

Joint insulations are not calculated in the estimation. In this calculation are calculated the vertical element joints that are insulated during the façade woodwork paneling work phase. Insulating is done using polyurethane foam, sprayed into the joint.

As the insulating is done simultaneously as paneling is done, it is difficult to estimate the man-hour per meter in every building. The average man-hour per meter is 0,11 meters. In the joint insulation work phase, there are no clear variables that increase or decrease the man-hour per meter.

Table 14. Man-hour per meter of the joint insulations

Building	Man-hour per meter
A	0,16 m-h/m
B	0,11 m-h/m
C	0,11 m-h/m
D	0,08 m-h/m
E	0,10 m-h/m
F	0,08 m-h/m
Average value	0,11 m-h/m

6.4. Data collection of extra work

During the construction period, additional work phases were included in the thesis. This additional work consisted of the wooden structures on site that are laborious to manufacture. The main consideration in these additional phases was in balconies and balcony roofs. Other work phases under inspection were the installation of balcony woodwork, entrance canopies, the frames of the doors and windows.

6.4.1. Balconies

The balconies in Tähtirikko site were made of prefabricated elements. The elements must be lifted and transported to the site. Because of this there are few panels left uninstalled as they are brought to the site. Three to four panels must be installed on site and in case of the balcony of two apartments, an additional board to the balconies seam and to the vertical seam of wall elements must be installed.

The man-hour per balcony of two apartments can be calculated to be eight hours. In total there are 4 single balconies and 13 balconies of two apartments. We can estimate that the total work is 16 hours for single balconies and 104 hours for balconies of two apartments, in total 120 hours.

The quality of elements plays a big role in this work phase and it had a big effect as final boards were installed underneath the balcony. As can be seen in Figure 22, there is a 15 mm thick plywood inside the balcony, which is tilted at a rate 1:20, to ensure the possible rainwater to run off from inside the balcony. This plywood in some balcony elements has been installed wrongly i.e. it’s too long at the end. In this case, the water channel is impossible to install and cutting of plywood from a very tight position is very time consuming. Another time consuming work is to install the outmost panel to the balcony, as at the end, there is a beam girder made of metal. The problem is that nails cannot be used, fixing must be done using screws that go through the panel into the holes of the beam girder. The costs of the installing the final boards underneath the balconies were calculated as part of the façade woodwork.

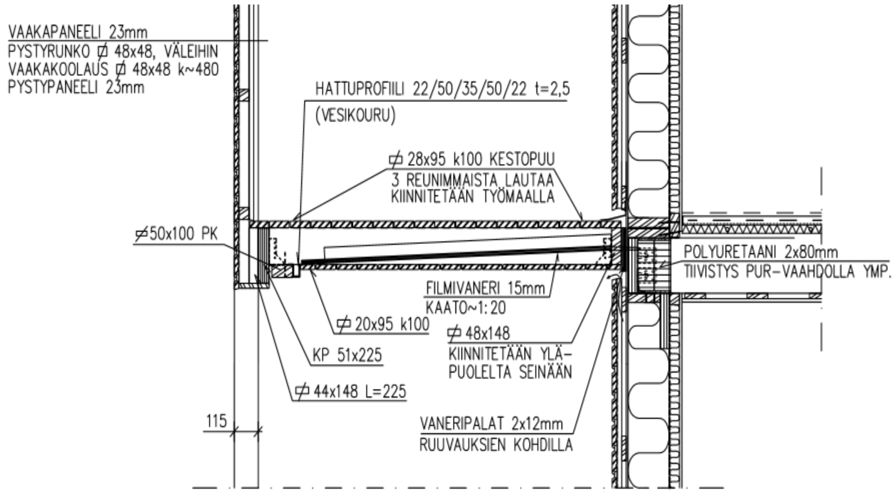


Figure 25 Detailed drawing of balcony. Nieminen A. 2014. Balconies in buildings A, B, C.

We can observe significant differences as man-hour per unit of balconies are compared to the estimation. The estimated time in single balcony installation per unit appears to be three hours over the actual man-hour. Due to this inaccurate estimation, the estimated value in total misrepresent the man-hour of the work phases This estimated work input is related to the man-hour of the double balcony's man-hours.

As we can see in Table 15, also estimated man-hour per unit of the double balconies is also slightly inaccurate. As noticed earlier in, there were no significant errors and delaying of elements during this work phase. The cause of this overrun can be explained by the terrain of the construction site and a fact that due to the narrow areas to it was difficult to operate with the lifting truck.

Table 15. Man-hour per unit of balcony installation

Work phase	Man-hour / unit	Estimated man-hour / unit
Balcony installation, single	4,00	7
Balcony installation, double	8,00	7,5

6.4.2. Balcony roofs

Balcony roofs were prefabricated elements, manufactured by YIT's element factory. Roof sheet panels are installed on the top side of the roof element. The structure of the element had been modified, and this caused a plenty of problems during the installation phase. In this model, there are no places for lifting lugs to place, therefore, that had to be done on site.

In Figure 26 we can see the detail drawing of the balcony roof. Plywood 12 mm in thickness was installed to the end of the roof element, but this had to be changed into thinner. On the face of the wall element there is also a plywood board. The outer surface of the wall elements can be seen on figure 9. The problematic part of the structure was the attachment of the joist to the beam installed into the wall element's outer surface. The plywood board had to be installed in between the beam and wall of the building.

Due to the modification of the roof element, the lifting became very difficult and inaccurate. The roof of two balconies are roughly 5,5 meters long and nearly two meters wide. Lifting of this heavy element in impractical lifting positions was also very slow as safe lifting must be ensured.

Due to the shape of the plot, the balcony roofs of the building D had to be lifted on the other side of the building. In this case a mobile crane was used. This was very slow work, as the driver of the crane had no visual contact of the roof element and the communication happened via radiophone.

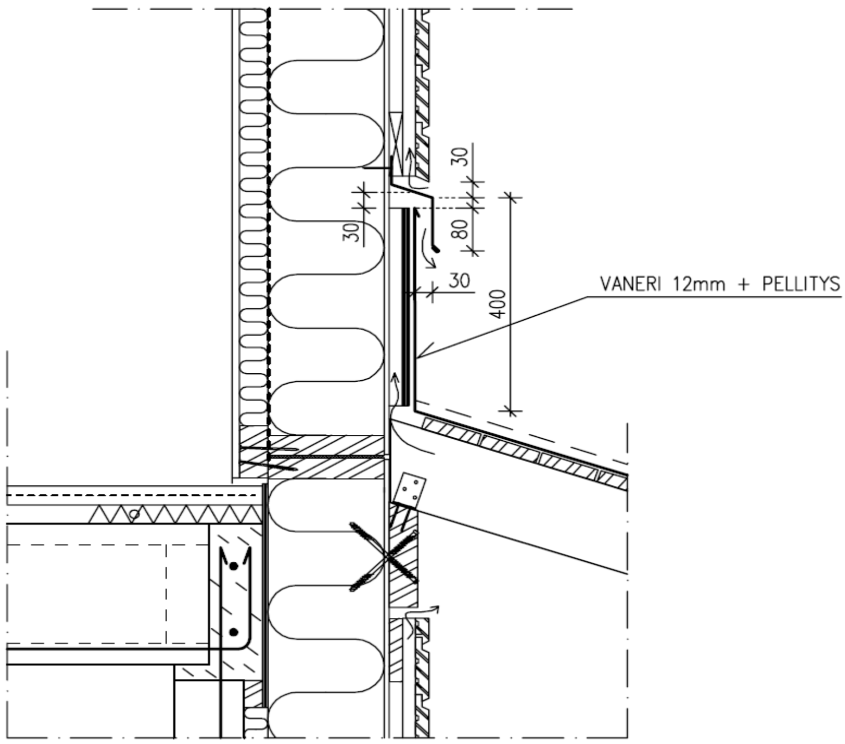


Figure 26 Detail drawing of the balcony roof. Nieminen A. 2014. Detail drawing 8.01.

Roofs were installed using the lifting crane of a truck. The installation work itself needed two carpenters and the driver of the truck. It is a noticeable fact that this is a very expensive work phase. During a visit to the site, it was observed that one double balcony's roof was installed in a way that three carpenters were involved the whole day. The total of 4 single balcony roofs for one apartment and 13 balcony roofs of two apartments were installed.

The overrun is transferred to the double balconies, as with them the installation was more problematic. Table 16 shows that the actual work input was one and a half time larger than estimated. As working hours reserved in the estimation for this work phase was not adequate enough, and if the costs of the lifting truck and the mobile crane are taken into account, it can be stated that the work phase was significantly overrun.

Table 16. Man-hour per unit of balcony roof installations

Work phase	**Man-hour / unit**	**Estimated man-hour / unit**
Balcony roofs, single	2,50	2,50
Balcony roofs, double	6,19	3,92

6.4.3. Balcony woodwork

Balcony woodwork includes the construction of a partition wall in case of a balcony for two apartments and frame and paneling of the end triangles. The frame of the partition wall of consist studding and a 12 mm plywood sheeting to achieve the fire safety class of 30 minutes. With one single, one apartment balconies, end triangles are only made. The work also consists of insulating of the vertical element seam with a fire seal urethane.

There were no big problems in this work phase, except the fact that the beam between two balconies was not in the same line as the partition wall. Therefore the beam was cut, so that the partition wall could be constructed straight all the way.

The overrun in man-hour per unit can be seen in the Table 17. Man-hour per unit overrun can be explained by the material transportations i.e. materials were cut to the size in a different location and then delivered to the balconies. The passenger crane was also used as paneling of the end triangles was done. As discussed the subject with the site supervisor, the work pace was very slow, compared to previous projects, as piece work was the working method. The normal time to finish this work should be much smaller.

Work phase	**Man-hour / unit**	**Estimated man-hour / unit**
Balcony woodworks, double	17,92	15,5

Balcony woodworks, single	7,00	7

Table 17. Man-hour per unit of balcony woodworks

6.4.4. Entrance canopies

The reason why entrance canopies are observed, was the idea to change the calculation method of installation from working hours into price per canopy. The installation was done in two parts: first the canopy was lifted using a lifting crane of a truck on its place. There it was fixed on the wall using head bolts and left leaning on a prop. The final fixing was done from a passenger hoist, using drawbars in D, E and F buildings and by columns in A, B and C buildings, as we can see in detail drawings in Figures 27 and 28.

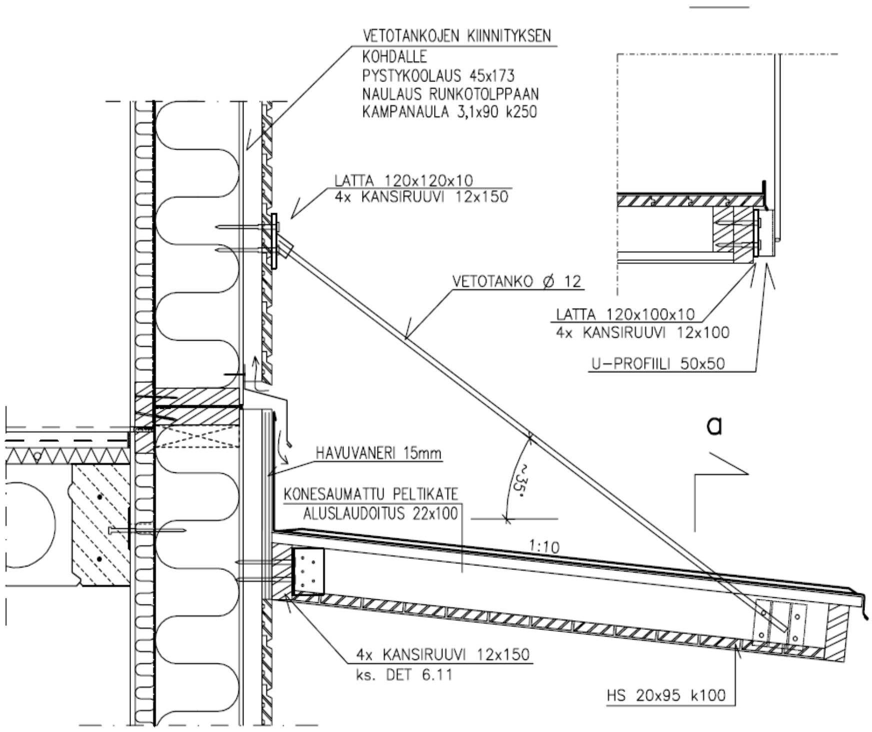


Figure 27 Detail drawing of a entrance canopy in D, E and F buildings. Nieminen A. 2014. Detail drawing 6.13.

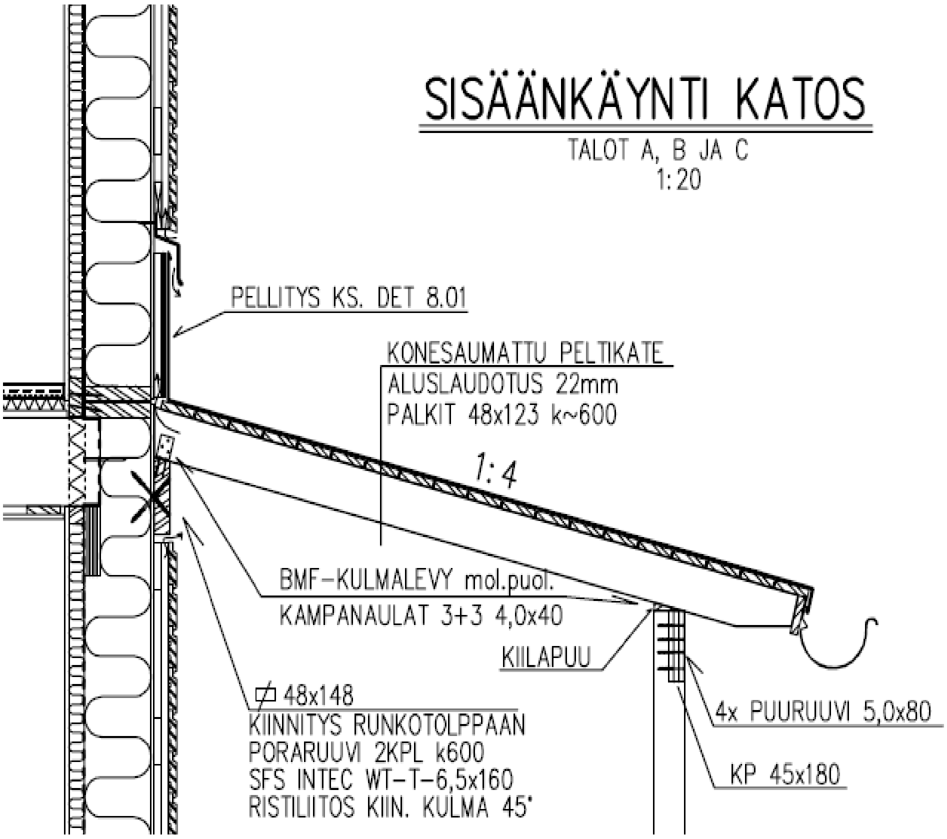


Figure 28 Detail drawing of an entrance canopy in A,B and C buildings. Nieminen A. 2014. Entrance canopy.

The first part of the work went really well, with two carpenters it took eight hours to install 15 canopies in D, E and F buildings. As a conclusion we can say that it takes roughly 30 minutes per canopy. Drawbars were installed using a passenger crane. As drawbars were installed and props could be removed with two carpenters, the final installation took roughly 30 minutes per canopy. As a conclusion we can say that the whole installation took 60 minutes, as 15 canopies in total were installed, using this as an average value, the total time spent was 22,5 hours.

Canopies were installed simply straight to the final position in A, B and C buildings. In this model, there is more preliminary work to be done as wooden beams and columns must be done and installed before the canopy can be installed. There are in total five double entrance canopies and one single canopy. The preliminary woodworks took 20 hours and the installation of the canopies eight hours. In total this work phase work input overran two and half hours. We can find the estimated value very exact and conclude that using drawbars as a fastening method, work input is roughly one hour per canopy and as columns are used, the work input is roughly five hours per canopy.

As all the work concerning entrance canopies was done, it was noted by YIT's quality engineer during a construction site visit that modifications must be done to the entrance canopies in F building. As we can see Figure 27, on the outer wall side of the canopy element, there is a 15 mm thick plywood sheet and on top of that there is a roofing sheet. The plywood sheet is also installed on the wall element, in the place where canopies are installed. As we can see in Figure 29, these two plywood sheets make the connection to the outer wall so that sheeting is 15 mm out of the wall line, to make this detail look and function properly, a piece of board is installed on the side of the canopy. The fixed connection can be seen in Figure 31.

These modifications are related to the sheet metal workers' job in the installation of sheets to the canopies in A, B and C buildings. As we can see in Figure 28, on top of canopies in question there was a large gap between the paneling and the roof sheet. It was noticed that wooden studs must be installed under the sheet to prevent it from twisting and to keep the ventilation gap open. As we can see in Figure 29, the fixed connection and the sheeting look and function well. This model could be transferred to use also in other YIT sites, where similar canopies are used.

Figure 29 Fixed canopy connection in building A. Ahokas M. 2015

Figure 30 Canopy connection before fixing in building F. Ahokas M. 2014.

Figure 31 Fixed canopy connection in building F. Ahokas M. 2015.

The man-hour per unit of entrance canopies without any modifications was very accurate. There we delaying factors as the entrance canopies were installed. All the modifications were simple to make and they were not a significant factor as the work input was calculated. As modifications are taken into practice in future, the estimation does not have to be modified.

Table 18. Man-hour per unit of entrance canopies

Work phase	Man-hour / unit	Estimated man-hour / unit
Entrance canopies	2,5	2,52

6.4.5. Doorjambs

The doorjambs of the terrace doors were installed at the same time as all of the buildings. The installation of doorjambs is a very systematic work phase as all of the doors are similar in size. All of the material can be cut beforehand and later just install in its place. Since the terrace doors are on the ground level, no lifting or usage of a passenger hoist is needed.

The installation of doorjambs to the balcony doors was more laborious. The balcony door frames were done at the same time as other woodwork on the balconies were made. Therefore, an exact work input is hard to evaluate. The longer time input can be explained on the material transportation i.e. boards must be carried by hand to the balconies.

The man-hour per unit of front doorjambs is approximately the same as in balcony doors. There is a special feature in the front doorjambs that slows down the work i.e. vertical boards must be notched from the low end. This feature slows down the work pace in doorjambs in comparison to the door frames of the terrace doors.

As we can see in Table 19, working inputs per doorjambs are the same in front doors and in balcony doors. The main idea to involve doorjambs under inspection was the possibility to change the estimation method from meters to pieces. As the work inputs of different doors vary, it is difficult to estimate a medium for work input to estimation.

Table 19. Man-hour per unit of doorjambs

Work phase	Man-hour / unit	Estimated man-hour/ unit
Doorjambs, balcony	0,73	1,1
Doorjambs, front door	0,73	1,1
Doorjambs, terrace	0,43	1,1

7. CONCLUSIONS

As a conclusion, we can say that façade woodwork at Tähtirikko site suffer from other work phases and a lack of planning the course of work. As this work phase is not considered to be the most crucial work to be done on the site it is not usually done systematically. The duration of the work phase grows, as it has been done in short parts. These short parts cause that the logistics of materials, movement of passenger crane and area of work have to be planned every time from the beginning.

As was pointed out, the work as a whole was not done systematically. This problem can be avoided by going through all the work phases before the work has begun. At YIT, it is instructed and strived to have a starting meeting before every work phase starts. In this meeting supervisors and carpenters together look at the possible difficulties during the work and look at the work safety aspects of the work phase. During this meeting it is easy to agree on the working method and sign the contract about piece work. It also helps both parties if the schedule of work is agreed on in this meeting.

As we take a look at the past projects, we can see that using piece work as a working method eases the evaluation of working input. As costs are fixed, the work phase generally is simpler to manage. As the carpenter’s wage is higher we can generally say that the working phase is quicker and they are more dedicated to their work, as they can achieve higher wages by working quicker.

The accurateness of the element assembly is a significant variable in façade woodwork. As the tolerances allow small differences, the actual fixing work is done in this phase. As said, in building E, a lot of time was wasted due to inaccurate element assembly.

The shape of the plot has a big effect on façade works. In Tähtirikko site, it had positive and negative effects. The tightness of the construction site causes fewer movements of materials and transportation with a passenger crane. The area where work is done stays the same longer periods. Therefore, no moving of materials and estimation of bearing capacity of the soil needs to be done. On the other hand, it causes tight and narrow paths to be crane to driven and long extensions of the boom. The closeness of the bedrock and nearby houses also caused difficulties.

The work was done during the fall and winter time of the year. The actual working time during winter is smaller than in summertime. Effective working time decreases due to possible snow removal and special needs of the machinery during frost. Because of these special arrangements of machinery, they worked properly and no breakdowns happened, but working time was lost.

It was noticed that in the past projects, site supervisors should pay more attention to the accurate usage of the cost evaluation and forecasting program TAS 5, of the work phases. Bad and inaccurate usage of TAS 5 causes inaccurate data as estimation and actual costs are being compared.

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