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COST COMPARISON BETWEEN PRE-FABRICATED PIPE RACKS AND OTHER IMPLEMENTATIONS

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ABSTRACT

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The purpose of this thesis was to create a cost comparison tool that can be used to compare the costs of the primary and secondary supports of the cooling water pipe system of engine power plants. This thesis was done for Wärtsilä's Energy Engine Power Plants department.

The cost comparison was created on Excel, where the costs of the three support options were specified from start to finish on separate sheets. Based on these sheets, the costs are linked to the comparison sheet, where the main costs of each of the three options are itemized.

The comparison tool was used in practice for a project being built in the Caribbean, which was implemented with Wärtsilä's standard secondary supports. The cooling system of the project was redesigned using prefabricated pipes, from which it was possible to create a cost comparison.

In the cost comparison, the standard option was the most affordable of these. The prefabricated options were slightly more expensive, but their quality is more consistent, and the installation time is shorter compared to the standard option. With the help of the cost comparison, it was possible to determine that the right option had been chosen for this project.

The Excel tool was found to be functional, and in the future, it will be possible to use it already in the sales phase of the projects, when the final costs of the options are known.

Keywords Prefabrication, cooling water piping, and cost comparison

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TIIVISTELMÄ

Tekijä	Jesse Viita-aho
Opinnäytetyön nimi	Kustannusvertailu esivalmistettujen putkitelineiden ja muiden toteutusten välillä
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Opinnäytetyön aiheena oli luoda kustannuslaskuri, jolla pystytään vertailemaan moottorivoimalaitosten jäähdytysvesiputkistojen primääri-, ja sekundäärituentojen kustannuksia. Tämä opinnäytetyö tehtiin Wärtsilän Energy Engine Power Plants osastolle.

Kustannuslaskuri luotiin Excel pohjalle, jossa kolmen tuentavaihtoehdon kustannukset eriteltiin alusta loppuun omille sivuillensa. Näiden sivujen perusteella kustannukset on linkitetty vertailutaulukkoon, jossa on kunkin kolmen vaihtoehdon pääkustannukset eriteltynä.

Laskuria koekäytettiin Karibialla rakennettavaan projektiin, joka on toteutettu Wärtsilän standardi tuennoilla. Projektin putkistot ja tuennat suunniteltiin uudelleen käyttäen esivalmisteputkia, josta pystyttiin luomaan kustannusvertailu.

Kustannusvertailussa standardivaihtoehto oli näistä edullisin. Esivalmistetut olivat hieman kalliimmat, mutta niiden laatu on tasaisempi ja asennusaika lyhyempi kuin standardi vaihtoehdossa. Kustannuslaskurin avulla pystyttiin toteamaan, että tähän projektiin oltiin valittu oikea vaihtoehto.

Excel laskuri todettiin toimivaksi, ja sitä pystytään tulevaisuudessa hyödyntämään jo projektien myyntivaiheessa, kun tiedetään vaihtoehtojen lopulliset kustannukset.

Avainsanat Esivalmistus, jäähdytysvesiputkisto, kustannusvertailu

CONTENTS

LIST OF ABBREVIATIONS

EPC - Engineering, procurement, and construction

EEQ - Engineered equipment

DN - Diametre nominal / Nominal pipe size

NDT – Non-destructive testing

HFO – Heavy fuel oil

MIG – Metal inert gas

MMA – Manual metal arc

TIG – Tungsten inert gas

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

This introductory chapter will give a summary of Wärtsilä, purpose and scope of the thesis, and the research plan that is used.

1.1 Wärtsilä

Wärtsilä provides advanced technologies and solutions for the marine and energy markets. The company was founded in 1834 and has since grown to become a global leader in its industry, with operations in over 240 locations in 79 countries with over 17,500 employees. The net sales were EUR 5.8 billion, in 2022. /12/

Wärtsilä Engine Power Plants provides customers with sustainable, reliable, and cost-effective alternatives to traditional energy technologies. The solutions are based on modern technology, deep expertise in the industry, and a commitment to sustainability. Wärtsilä offers flexible and efficient power plants with advanced digital solutions for customers. Global network allows the company to provide rapid support and service to its customers, no matter where they are located. /11/

Wärtsilä aims to help its customers decarbonize their operations by providing sustainable and flexible energy solutions. The company has set a goal to achieve carbon-neutral operations by 2030, and it offers a range of products and services that support renewable energy integration, energy storage, and energy efficiency. /13/ Wärtsilä has the resources and capabilities to fulfil contracts ranging from engineered equipment (EEQ) delivery to complete turnkey projects including engineering, procurement, and construction (EPC), which this thesis is also focusing on. /3/ EPC is a type of contracting where the contractor manages the entire project from start to finish and executes and delivers the project to the client within an agreed-upon budget and timeframe. This agreement covers all labour related to planning, engineering, procurement, construction, and installation, as well as the complete supply of materials and equipment. /5/

1.2 Purpose of the thesis

The purpose of the thesis is to create a cost comparison tool that would show the actual prices of pipe support materials and installations. The total installation costs and the time spent on site can be reduced by choosing the right option of the secondary supports. The cost comparison tool can be used as a guideline when choosing the right option, and it can be implemented for other project types in the future. There have been several studies on prefabricated solutions for pipe systems, but the prices of materials and installations have not been studied.

There are three secondary support options that this comparison focuses on. The first one is the on-site welded, which is widely used in projects. The prefabricated support is the second option, where the steel structure with pipes is delivered to the site ready for installation. The third option is an on-site assembled support where the parts are attached with screws instead of welding. This third option has not been used for cooling systems earlier.

The piping system for the project in the Caribbean was redesigned and compared using the comparison tool to see how it would have affected the final cost and installation time.

1.3 Scope of the thesis

This comparison is made for one power plant type which is 6xW18V50DF. The six Wärtsilä DF engine powerplant was chosen for this comparison because of its generality. The quantity of pipes and systems varies between projects, but for this comparison, certain sets of pipes that were included in installation were selected. The prices that have been used in this research originate from Wärtsilä internal, and supplier price lists. The installation times that are used in the comparison are from Wärtsilä pipe designers. The result of this thesis can be implemented also to other projects and systems.

1.4 Research Plan

Information for the thesis has been gathered through interviews with several Wärtsilä employees and subcontractors. During this thesis process, data and material has been collected in several meetings and interviews. The cost comparison of these three pipe racks has been done in Excel sheets, where all related information is collected and calculated.

2 MAIN TERMINOLOGY AND PROCESSES

2.1 Prefabrication

Prefabrication is a manufacturing process, generally taking place at a specialized facility, in which various materials are joined to form a component part of the final installation. The purpose of prefabrication is to make a specific assembly under controlled conditions so that installation at the power plant is as simple and uncomplicated as possible. /2/

Prefabricated pipes are designed in a way that the majority of the piping is delivered to the site fully constructed and with surface treatment applied. The installation of the piping is quick because the pipes only need to be installed in the brackets and the ends attached to each other.

The design of prefabricated systems takes about 30 to 50 percent more time than standard options design, but this will vary depending on the project. The result of a prefabricated design is a manufacturing package that is requested from subcontractors.

2.2 Welding

Welding refers to the uniting or fusing of pieces by using heat and/or compression that makes the pieces form a continuum. The source of heat in welding is usually an arc flame produced by the electricity of the welding power source.

The most used welding methods are MIG, TIG, and MMA welding. TIG welding method allows for producing extremely fine welding results, and therefore it is used in welds that will be seen or that require accuracy. MIG welding is a versatile welding method, in which the filler material does not need to be separately fed into the molten weld. Instead, the wire runs through the welding gun surrounded by the shielding gas straight into the molten weld. The oldest, most known, and still common process is MMA manual metal arc welding, which is commonly used in installation workplaces and outdoor sites that demand good reachability. /7/

The steel structure of prefabricated pipe rack is made at the workshop, and it is usually MIG welded, and the pipes are TIG welded. TIG welding is preferred when doing site welds to decrease welding splatters, but sometimes MIG is the way of working. Wärtsilä has a regulation that the first weld seams of pipes should be made with TIG weld. After the first clean seam, MIG can be used for its fast-welding speed. All pipe weld seams are NDT tested with liquid penetrant by professionals.

2.3 Pickling and Flushing

In the process of pickling a stainless steel, a thin layer of metal is removed from the surface of the steel. A mixture of nitric acid and hydrofluoric acid is usually used for pickling stainless steel. Pickling is a process used to clean heat-discoloured welds in the manufacture of stainless-steel products when the chromium content of the steel surface has been reduced due to oxidation. /1/

Flushing is pipe cleaning procedure, where pipes are flushed with compressed water, and the water usually contains some inhibitor that neutralize the pH value.

All the pipes must be cleaned after installations, so that the whole pipe system is as clean as possible. The pipes treated in the workshop can be flushed with smaller amounts of the substance compared to site welded pipes. When prefabricated pipelines are already cleaned and treated before being sent to site, the flushing process with them is quick. The flushing and pickling process of site welded pipes takes a lot of time and liquids, as the entire system is pickled at the same time.

2.4 Painting

The pipeline, its supports, and in general all bare metal used in power plants must be painted to prevent corrosion to extend their service life.

The painting of metal with protective paint systems is called corrosion protection painting. The purpose of corrosion protection painting is to protect the metal substrate against atmospheric corrosivity, i.e. rust, and to give the surface the designed appearance and texture. Corrosion is a physicochemical reaction occurring when a metal is exposed to its environment, which changes the properties of the metal and, in many cases, results in degradation of the metal, adjacent environment, or technical system. /10/

Unless otherwise agreed, Wärtsilä's power plant pipes are painted according to the ISO12944-5-2018 standard. The corrosion category depends on the project, and these category explanations can be seen in Table 1.

Table 1. Corrosivity categories. (Hilti corrosion handbook.)

Corrosivity category C	Corrosion level	Typical environments	
		Indoor	Outdoor
C1	Very low	Heated spaces with low relative humidity and insignificant pollution, e.g. offices, schools, museums.	Dry or cold zone, atmospheric environment with very low pollution and time of wetness, e.g. certain deserts, Central Arctic / Antarctica.
C2	Low	Unheated spaces with varying temperature and humidity. Low frequency of condensation and low pollution, e.g. storage, sports halls.	Temperate zone, atmospheric environment with low pollution (SO_2 < 5μg/m³), e.g. rural areas, small towns. Dry or cold zone, atmospheric environment with short time of wetness, e.g. deserts, subarctic area.
C3	Medium	Spaces with moderate frequency of condensation and moderate pollution from production processes, e.g. food-processing plants, laundries, breweries, dairies.	Temperate zone, atmospheric environment with medium pollution (SO_2: 5μg/m³ to 30μg/m³) or some effect of chlorides, e.g. urban areas, coastal areas with low deposition of chlorides. Subtropical and tropical zone, atmosphere with low pollution.
C4	High	Spaces with high frequency of condensation and high pollution from production processes, e.g. industrial processing plants, swimming pools.	Temperate zone, atmospheric environment with high pollution (SO_2: 30μg/m³ to 90μg/m³) or substantial effect of chlorides, e.g. polluted urban areas, industrial areas, coastal areas without salt water spray, or exposure to strong effect of de-icing salts. Subtropical and tropical zone, atmosphere with medium pollution.
C5	Very high	Spaces with very high frequency of condensation and/or with high pollution from production processes, e.g. mines, caverns for industrial purposes, unventilated sheds in subtropical and tropical zones.	Temperate and subtropical zone, atmospheric environment with very high pollution (SO_2: 90μg/m³ to 250μg/m³) and/or significant effect of chlorides, e.g. industrial areas, coastal areas, sheltered positions on coastline.
CX	Extreme	Spaces with almost permanent condensation or extensive periods of exposure to extreme humidity effects and/ or with high pollution from production processes, e.g. unventilated sheds in humid tropical zones with penetration of outdoor pollution including airborne chlorides and corrosion-stimulating particulate matter.	Subtropical and tropical zone (very high time of wetness), atmospheric environment with very high SO_2 pollution (higher than 250μg/m³) including accompanying and production factors and/or strong effect of chlorides, e.g. extreme industrial areas, coastal and offshore areas, occasional contact with salt spray.

All the prefabricated supports and pipes are painted in advance, which prevents them from corrosion during transportation. Since they are typically painted with primer, the final coat of paint is applied on site. The painting process is a task that takes time and resources at site. Pipes that have been prefabricated are already painted to the final coat, and this is a big benefit of prefabrication, but the paint surface may be damaged during delivery, and this can require some repair work.

In addition to preventing rust, paint also serves the important function of identifying the pipes by their colour. It is simpler to recognize which pipes belong to which systems because all pipe systems are painted on site with different colours. When prefabricated cooling pipes are delivered to a site, they are already painted green, which can be seen in Figure 1. This makes it easier for installers to identify the pipes that belong to the cooling water system.

Figure 1. Prefabricated cooling water pipes. (Wärtsilä 2022.)

3 IMPLEMENTATIONS

Implementations used in the comparison are discussed in this chapter.

In the first option Wärtsilä standard secondary supports are used with site welded piping. In the second option the rack and pipe segments are completely prefabricated and assembled by a subcontractor. The third option is a modular channel steel structure where the frame parts are pre-cut, and it is assembled at site with bolted connections. The pipes in this option are the same prefabricated pipe segments as in the second option, but these are installed to the rack at the power plant. To make the comparison as easy as possible the same dimensioning and setup is used for all three options. Figure 3 shows the typical appearance of cooling water pipes used in the project.

In all setups the section of piping consists of the following:

- 12 x DN200 Carbon steel piping for cooling
- 1 x DN100 Carbon steel pipe for HFO with insulation and trace heating
- 1 x DN50 Stainless steel pipe for water supply
- 1 x DN40 Stainless steel pipe for air supply

Figure 2. Pipe rack with insulated pipes. (Wärtsilä 2020.)

3.1 Wärtsilä Standard Secondary Supports with Site Welded Piping

In Wärtsilä built power plants, a secondary support with site welded piping is the original option and the option that has been used the most for the pipelines. This support option is suitable for all type of projects.

3.1.1 Standard Secondary Support

Vertical legs are prewelded, and horizontal beams are welded at site. Parts are prepainted, but require touch-up painting after welding. This support is made of S355J2 steel, and it weighs 258 kg.

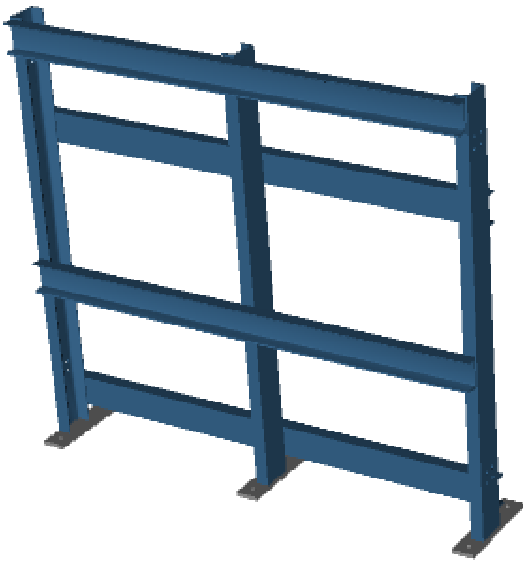


Figure 3. Standard pipe rack. (3D-model.)

3.1.2 Piping

All parts of the pipeline are loose and related work is done on site. This work includes welding of supports and pipes, pickling and flushing, and painting. The pipe material is delivered with the primer.

3.2 Prefabricated Pipe Racks

This rack option is mostly used in projects with a tight schedule where quick installation is required. It is assembled off-site before being transported and installed at the power plant location.

3.2.1 Pipe Rack

Pipe racks are assembled at workshops and delivered as a whole steel structure to the site. This rack is made of structural steel S355J2 and weighs around 840 kg. The total amount of weight is around 4000 kg with the pipes, and therefore this must be lifted into its place with a big crane.

In a power plant, there are several racks in the pipe system, so these are preassembled and tested at the workshop to ensure that all pipes and racks are aligned for the best outcome.

Figure 4. Prefabricated big pipe rack. (3D-model.)

Figure 5. Installation and alignment at the workshop. (Wärtsilä 2022.)

3.2.2 Piping

Pipes in this rack are the same as in the standard option, but these are prefabricated with flared flanges. Pipes are fully painted and installed in the racks ready for use.

3.3 Modular Channel Support

The modular channel support is a new alternative solution for the cooling system, which is assembled on-site, and its benefits are bolt on connections and weldless design. This option has been designed for special projects where time is of the essence, where the labour costs of welders are remarkably high, or where welding is avoided.

3.3.1 Rack Model

The rack model is assembled on-site from pre-cut pieces, and the parts are connected to each other with screws. The weigh of one support is around 210 kg, which is 50 kg less compared to Wärtsilä standard secondary support.

The frame does not need to be treated, which is typically required when using a standard rack, and therefore the work steps are reduced in comparison to a standard rack. All the parts used in this option are hot dip galvanized with a 21 µm zinc-magnesium covering, and therefore protective painting is not required. /4/

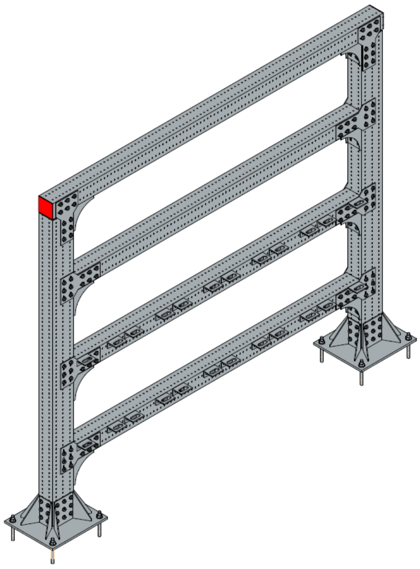


Figure 6. Modular channel rack. (Assembly drawing.)

3.3.2 Piping

The installation of the prefabricated pipes is done on-site. Brackets are fixed with screws, so the installation is quick. Pipes are already painted, so only the paint damages must be repaired, if there are any.

4 METHOD

This chapter discusses the qualitative study methodology, data collection technique, and the benefits of the interviews. Wärtsilä employees were interviewed during the procedure.

4.1 Research Work Method

In qualitative research, the main instrument for gathering and analyzing data is the researcher himself, through whom the real world is filtered into research results. Qualitative research involves open-ended conversations between researcher and participants. The study is conducted in a real context. Qualitative research is often descriptive. The researcher is interested in processes, meanings, and understanding the phenomenon through words, texts, and images. Research methods affect the results obtained. /6/

The thematic subjects of the interview are predetermined, but there is no strict order of submissions. This form of interview allows for a diverse interaction between the interviewer and the interviewed. In a theme interview, the questionnaire primarily serves as the interviewer's memory list, which gives flexibility to the situation. All selected topics will be discussed with the interviewees, but differences in the scope of the topics may vary between interviews. The preparation of a topic interview requires a great deal of familiarity with the subject and careful selection of interviewees in accordance with the research objective. /9/

4.2 Interviews

The purpose of the interviews was to gather viewpoints and development suggestions regarding the prefabricated pipe racks and the entire cooling water pipe system in general.

The supervisor of the thesis recommended people who could provide important information about the pipeline systems of the projects. The qualitative part of the study was conducted by interviewing six employees from different departments of the organization of Wärtsilä. Some of the questions were formed during the interview because all the interviewees' queries related to the projects they had worked on and their opinions of these solutions. Preliminary questions were sent for interviewees, so that they knew what the interview involves. The interviews were conducted remotely, as some of the interviewees were on site on the day of the interview. The language spoken was Finnish in all interviews.

4.3 Benefits of the Interviews

The interviews with the employees were useful from the point of view of the thesis, because they revealed some information that otherwise would not have even thought to be considered. Developable ideas were formed during these interviews and confirmation for the use of prefabrications and pipe connections that speed up the installations was received. The interviews also provided ideas for improving the pipes manufactured on site, and emphasized the importance of the basics, for example the choice of pipe materials.

5 COMPARISON

This chapter reviews the results and the confidentiality of the cost comparison. Tables with percentages from Excel are shown, where the main sources of costs are explained more specifically.

5.1 Confidentiality

The aim of the comparison tool was to get an actual price for each option so it can be used to estimate the costs of the selected support option. All the prices, costs and durations of the installations are gathered from Wärtsilä employees and from subcontractors. The information obtained is considered confidential because it is current, and it is used by Wärtsilä. This is a functional tool that can be used during the project sales phase and strategic purchasing.

5.2 Comparison

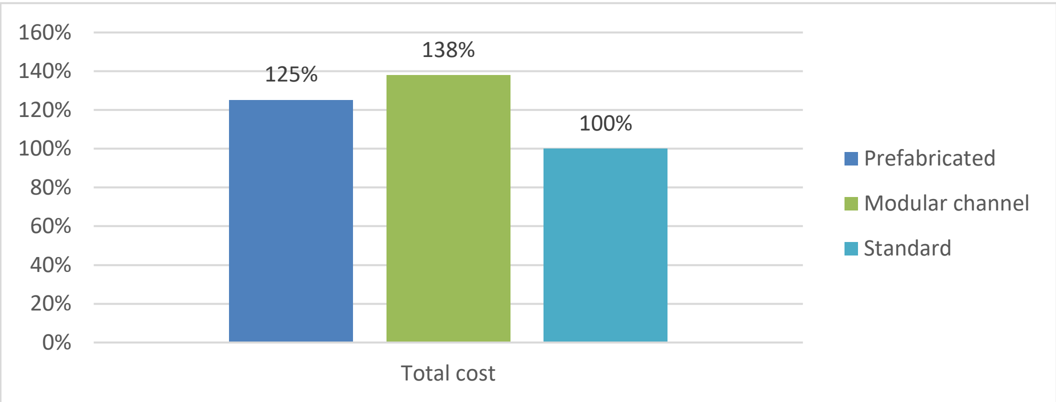
The comparison tool was created for Wärtsilä to show the cost differences between the options, and for this thesis, it is converted to show percentages instead of prices, and therefore confidential data is not shown here. Several sheets are included in the Excel document that Wärtsilä received to show how the calculations were made. The modular channel and prefabricated option costs are compared to the standard option, to show how the costs are divided. This is the final comparison where all the data from the Excel sheets are gathered.

As can be seen in Table 2, the standard option has the lowest overall cost option for this 6xW18V50DF project, but the major thing here is that the difference between them is not as great as had been assumed. It can be seen from the Tables 2 and 3, that the total cost between prefabricated and standard is a quarter higher, and slightly more than a third, compared to the modular channel.

Table 3. Comparison table.

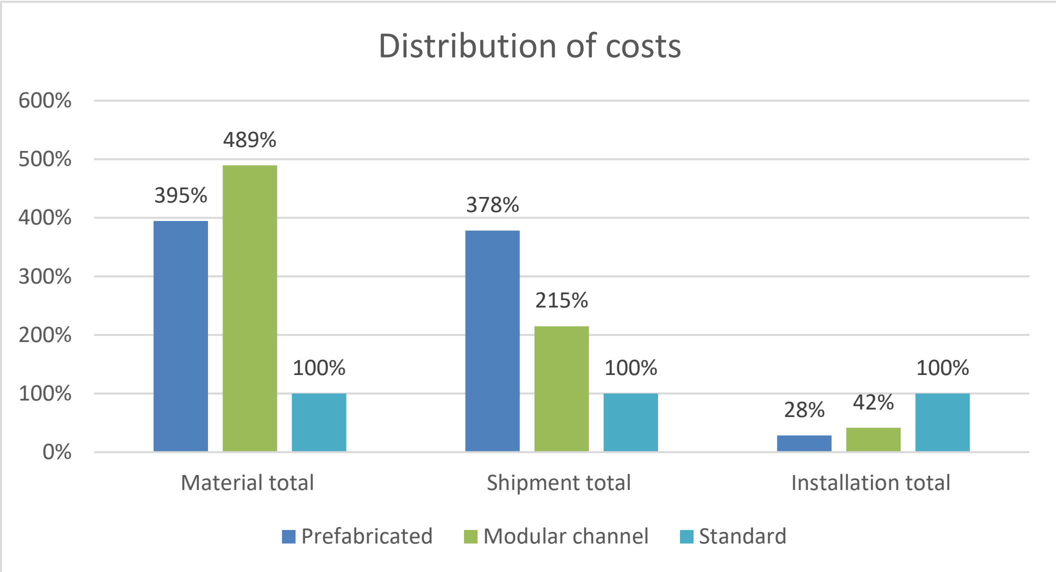
	Prefabricated	Modular channel	Standard
Pipe materials	950%	1024%	100%
Rack materials	149%	253%	100%
Material total	395%	489%	100%
Shipment total	378%	215%	100%
Site installation	17%	42%	100%
Indirect cost	17%	42%	100%
Installation total	28%	42%	100%
Total cost	**125%**	**138%**	**100%**

Table 2. Total cost comparison.



This table 4 shows how the costs are distributed. The material total is almost 5-times higher compared to the standard rack, and if this could be lowered, then the modular channel option could be very competitive. It was known that materials total for the prefabricated, and modular channel is high, but the most important part of the whole comparison is the installation total. The shipping costs have been calculated for 20-foot containers to make the comparison even. The price table also shows prices for a 40-foot container, but it was not needed in this comparison. The shipping costs of the two different projects are compared to provide an estimation of what a cooling water system will cost to ship when it is delivered to the site.

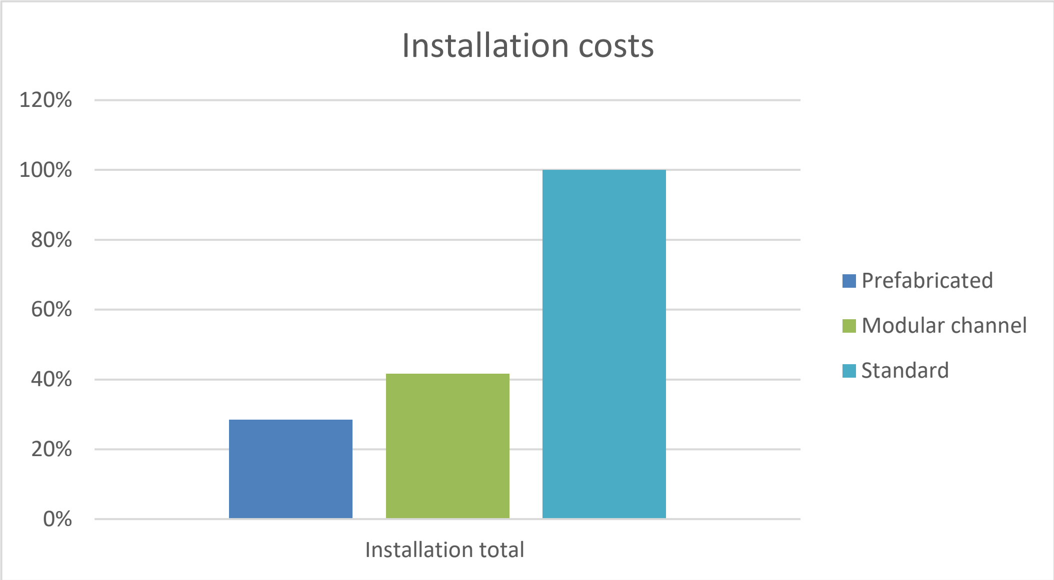
Table 4. Distribution of costs.



Each of the three options has its own delivery costs, which had to be roughly calculated to be able to use them in the Excel comparison tool. The material volume had to be calculated by taking the head dimensions from manufacturing drawings and multiplying them together. This was increased by 30% to make the multiplier more accurate when packaging supplies are included. This method cannot be completely accurate because the sizes of goods vary and it is not possible to completely fill a shipping container, but this was a rough calculation made on purpose.

The installation cost of the prefabricated option is almost four times lower and the modular channel option more than half the price of the standard option. The modular channel option was designed for challenging projects where labour costs are high, or welding is not desired. For a regular project, it is not necessarily the most cost-effective solution, but it is the most environmentally friendly option due to its lower carbon footprint compared to these other options.

Table 5. Installation costs.



5.3 Example of Configuration

The cost comparison testing at the sales stage was not practically possible due to the thesis schedule, but the cooling water system of this ongoing project was redesigned, and its result was compared with the comparison tool. The project that is examined is a 5xW20V34DF power plant located in the Caribbean, whose cooling water system was completely implemented using Wärtsilä standard secondary supports and site welded pipes. This was redesigned to a fully prefabricated system.

The goal is to show in practice how costs and installation times would have changed with the other support options.

The comparison table of this configuration will be for Wärtsilä internal use only.

6 RESULTS

This chapter contains a summary of the features of the different options, the benefits of prefabrication, and development ideas for the future.

6.1 Summary

Although the costs of each option are partially known, they can now be presented concretely with the help of the cost comparison tool. There were differences in the total cost comparison, but as the prefabricated solutions develop, the cost differences will level out. Prefabrications are used in projects where the site conditions and contractors are not known from the previous installations.

6.2 Pros and Cons of Different Solutions

6.2.1 Standard Secondary Support

This option is built on-site which means the design is flexible and simple. These can be customized for a particular location, improving placement and space efficiency and if there is a change in the plant design or layout, these can be easily modified. Site welded supports are a suitable option in terms of materials, and usually this option is used when labour is affordable.

The installation phase of this option is work intensive, because the primary and secondary supports must be cleaned of paint before welding, and only after welding these are painted with the final paint. The final cost of on-site welded pipes and supports can increase significantly if the installation process takes a long time to complete. Time spent also consumes resources and possibly slow down the performance of other tasks. Site welded supports may not always meet the same quality standards as prefabricated, as the construction process is less controlled. The most costs come from painting and welding in this option.

Qualified labour for welding is necessary, as the pipes must be class welded to be approved. There are not always qualified welders available, and the cost of labour per hour can be quite high in some locations. In some cases, Wärtsilä uses additional contractors to guarantee the quality of the work.

The flushing and pickling of welded pipes on site take resources and time, which may be a problem in some projects.

6.2.2 Prefabricated Pipe Racks

Prefabricated pipe racks are manufactured under strict control with high quality standards. The quick and efficient installation of this rack option reduces the possibility of delays and imperfections during the installation phase. When compared to the Wärtsilä standard support installation methods, the prefabricated pipe rack significantly reduces the work tasks and installation time, and the reduced installation times result in lower labour costs.

One of the advantages of this option is the predictable manufacturing costs. These racks can be manufactured in large quantities, which leads to cost saving. To minimize waste and decrease the impact of the project on the environment, racks are also made to precise specifications. When welding, painting, and additional cleaning are not required as site work, the installation phase becomes faster. Prefabricated options require more time to design than site-welded options, so the offshore costs are typically higher compared to each other. Finland's manufacturing cost may also be higher, but when installation is quicker, overall costs are lower.

Shipping costs are the highest compared to the other options, as one 20-foot container can fit one prefabricated rack. For projects where this option is used, these will be shipped in 40-foot containers, as two of these will fit in one 40-foot container. There is a lot of extra space in the container, that can be utilized for other packing goods.

Prefabricated pipe racks are large and heavy, which makes the handling challenging. The installation time is low, but the shipping costs are high due to the number of containers.

6.2.3 Modular Channel Support

Since the modular channel support is a new solution and it has only been implemented in projects experimentally, its pros and cons cannot be identified with precision. Wärtsilä has used similar options in different pipe systems, but not with the cooling pipes.

These modular channel supports do not need to be treated, which is typically a time-consuming process, so the work steps are reduced compared to a standard rack. The corrosion resistance in this option is C3/C4 low, which means that these do not need to be treated, since all the parts are hot dip galvanized with a zinc-magnesium covering. These supports are calculated to withstand high loads, even though its material thickness is only 3mm. This single support is 50 kg lighter than standard option and due to the thin material, it is also simpler to handle. Installers can quickly and effortlessly assemble this option on-site using screws.

Designers have calculated that the material saving compared to the Wärtsilä standard secondary support in a normal-sized project reduces the carbon footprint by 25%, which means a 10t CO_2e savings. This saving is equivalent to one-persons total carbon footprint per year in Finland. Therefore, this is a more environmentally friendly option also in terms of logistical costs. /8/

In the standard option, a lot of time is spent welding the pipe brackets, unlike in the modular channel option, where the brackets are installed only with screws and locking plates, which makes the installation of the pipe primary support simpler and therefore also faster. This is a cost-efficient option for projects where the labour costs of welders are high and for similar projects where welding is to be avoided.

The disadvantage of this modular channel support is the high purchase price, but the final cost can be compensated with the short installation time.

6.3 Other Benefits of Prefabricated Solutions

Materials can be saved when the pipes and supports are manufactured in the workshop, and due to this, prefabricated options produce a lower carbon footprint than standard options, therefore making them more environmentally friendly.

Projects with tight installation schedule and difficulties to find qualified manpower at the site benefit from using the prefabricated piping. Prefabrication makes it possible to shorten the duration of installations from several months to a few weeks only. It is recommended that in EPC delivery projects at least a part of the piping deliverables is prefabricated. Prefabrication saves time as there is remarkably less welding, pickling, flushing, and painting at site. Quality is controlled more precisely as the manufacturing takes place in the workshop environment.

Prefabricated options can be used in a project where the civil part of the contract is taking more time than planned. For example, the soil is limestone which is hard rock, and it must be drilled, or the soil is muddy, and it must be changed to better ground. The process of these takes longer than a stable soil type, and by using prefabricated solutions, it is possible to catch the schedule, and the commissioning of the plant can be done in time and avoiding the penalties of the delay.

When prefabricated solutions are used, quality and functionality is checked at the workshop closely to avoid possible inaccuracies. These prefabricated solutions save time on installations and allows more time for the commissioning.

The custom clearance process is faster with prefabricated options, as the materials are already certified as products.

6.4 Development Ideas

In some projects, it is not possible to prefabricate the cooling system at all, but it could be done if smaller pipes from DN20 to DN65 were bent using a bending machine at the site workshop. Pipe attaching using press fittings is also an alternative solution that can be used more in the future projects. These could greatly reduce the time required to weld the pipes.

Stainless steel pipe could be used more in certain solutions because the painting and treatment process of carbon steel pipes can be higher in the final cost compared to the stainless pipe.

One important thing in terms of continuous development is that when the supports and pipes of the cooling water system can be installed using less time, it gives more time for electrical work and ultimately for the commissioning of the entire power plant. Future cost-effective solutions will be made by recognizing these issues and learning how to reduce costs.

The cost comparison tool could be programmed even further so that it is possible to select, for example, the engine type and quantity, destination country, in which case the tool would automatically suggest the most cost-effective secondary support models, with all the prices attached.

Prefabricated solutions should be applied even further, in which case traditional solutions could be improved or replaced completely. In the future, prefabricated solutions will replace traditional solutions, at least partially.

In the future, environmental friendliness and greenness will be a significant factor already in the sales phase of projects, and therefore it is good to have a solution ready with a known carbon footprint and lower than standard solutions.

7 CONCLUSIONS

The purpose of the thesis was to create a cost comparison tool that would show the actual prices of pipe support materials and installations. The final prices have not been completely known before, and because of that, the most cost-effective solution has not necessarily been used in some projects.

The comparison tool used for 6xW18V50DF project showed, that the single prefabricated rack is 25%, and modular channel is 38% more expensive compared to the standard support option. This confirms that the standard option is intended for projects, where the installation time is not issue.

This thesis and its objectives were completed on time, although the subject of the thesis was broad and required a lot of research. Completing the work included getting to know the subject area, searching for information, interviews, meeting the subcontractor, and creating the Excel tool. The interviews were a great way to get to ask the project engineers questions that are otherwise difficult to find answers to, and this made it possible to understand the whole system even better. Empirical research and experience of installations will eventually show how the cost estimations match with the cost comparison tool. The interest in the company's industry and particularly in the pipe design increased while working on this thesis.

It was challenging to be able to understand all the variables that affect the choice of materials, manufacturing methods, transportation, the operation of the cooling water system, and Wärtsilä's own way of working. The subject had to be researched from the beginning to be able to fully understand it and create a functional comparison tool to Excel.

7.1 Validity

This comparison was made for one power plant type by gathering internally current information, and then tested for other plant type also. Both results were reliable, and Wärtsilä employees were satisfied with it.

The interviews were held with skilled and knowledgeable employees who have worked on the subject for several years. Honest and constructive feedback was collected from the interviewees, which was reviewed with the supervisor of the thesis.

The costs of prefabrication for Wärtsilä's cooling system should be relatively accurate, as there now has been a study of the cost of supports and different pipe jointing methods.

7.2 Final Words

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