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Resource-based estimating model of tunnel construction phases

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Diplomityön tiivistelmä

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Tiivistelmä

Julkisten hankintojen kilpailutus on oikeudenmukaisuussäännön mukainen valintaprosessi, jossa paras tarjous määrää hankkeen toteuttajan. Tämän prosessin myötä tarjouskilpailumenettelyssä määräytyvä kustannustavoite urakoille on spekulatiivinen. Menettelymalli on luonut urakoitsijoille tilanteen, jossa he hinnoittelevat työvaiheita tarjouksessa resurssivahvuuksiensa mukaisesti. He arvioivat rakennusvaiheiden kustannukset tasapainottamalla tehokkaat tuotanto-osat haastavien rakennusvaiheiden kanssa. Tämä luo yksilöllisen kustannusmallin eri urakoitsijoiden välillä. Yksilöllinen hinnoittelumalli on aiheuttanut julkisella sektorilla vaikeuksia laatia ajantasaisia, realistisia kustannusarvioita suurista hankkeista. Arviot kustannusrakenteesta ovat suuresti vaihdelleet ja urakoitsijoiden tarjousten arviointi keskenään on usein haastavaa. Tämän ongelman ratkaisemiseksi Väyläviraston johdolla perustettiin IHKU-Allianssi. Allianssin tehtävänä on luoda avoin kustannuslaskentajärjestelmä, joka tarjoaa avointa ja panospohjaista kustannuslaskentapalvelua suunnittelijoille ja tilaajille. Uusi laskentapalvelu on suunniteltu vastaamaan tilaajien ja suunnittelijoiden nykyisiin ja tulevaisuuden tarpeisiin.

Diplomityön tutkimuksessa tarkastellaan laskentamallin toteutusta, sekä implementoinnin mahdollisuuksia tunnelityövaiheiden nimikkeisiin pääryhmissä 1500 Kallion tiivistys- ja lujitusrakenteet, 1700 Kallioleikkaukset, -kaivannot ja -tunnelit, sekä 4510 Suojaus- ja vaimennusrakenteet. Tutkimuksessa hyödynnettiin rakennuttajien, urakoitsijoiden ja suunnittelijoiden kokemuksia ja tietoa panospohjaisen laskentamallin luomiseen. Laskentamallit luodaan avaamalla yksikköhintaiset rakennusvaiheet niiden tuotanto-osiin ja edelleen panoslajeihin. Kustannusten muodostuminen näkyy panoslajien panoshinnoilla työsaavutuksilla sekä rakennusosien ja tuotanto-osien välisillä kertoimilla.

Tämän diplomityön tulokset osoittavat, että panospohjainen, tuotanto-osiin jaoteltuun hinnoitteluun pohjautuva mallinnus tunnelityövaiheista on haastavaa työmaiden yksilöllisten ominaisuuksien takia. Ilman yksityiskohtaista tietojen syöttämistä työmaakohtaisesti, tuotanto-osien hinnoittelu keskiarvollisesti on joissain tapauksissa liian yleinen luotettavia kustannusarvioita varten. Liian yleinen hinnoittelu keskiarvollisesti ei luo tarvittavan tarkkaa kustannusmallia kohteesta.

Avainsanat Resurssiteoria, tuotanto-osa, nimikkeistö, tuotantopanos, tunnelityövaiheet

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Abstract

The acquisition of contracts from the public sector are tied to a fairness rule. This creates a competitive tendering process for contracts. This has created an information gap between the developing public sector and the contractors. The competitive nature of the process has created a situation for contractors where they emphasise their strengths in resource groupings. They calculate construction phases from a speculative angle balancing between effective production components and challenging phases in construction. This creates an individual cost formation between contractors. Due to this fact, the public sector has had difficulty in the past to create up-to-date, realistic cost estimates of large-scale projects. Estimation of cost structure has varied largely, and estimates compared to offers made by contractors are in parts incomparable. To remedy this problem an alliance-project IHKU was created to model a new cost calculation system and modelling services to provide open cost information to the public sector and designers. The new cost calculation model is designed to meet the needs and challenges by providing up-to-date cost information for infrastructure projects.

The study views the implementation of the estimation model and its effect by focusing on the open, up-to-date cost model of tunnelling nomenclatures 1500, 1700, 4510. This study will utilize experience and information from developers, contractors, and designers to create an open information model of resource-based calculation formats. The estimation models are created by opening unit priced construction phases into their production components (where applicable) and further into their resource-based stakes or batches. The cost formation is visible by the resource unit prices and their production component multipliers.

The results of this master’s thesis show that the implementation of resource-based, production component pricing is challenging for tunnelling phases due to their unique worksite specific nature. The results show that without detailed input of data per worksite, the duplication of production component unit prices will be too general for the estimation model to create the needed transparency of costs.

Keywords Resource-based theory, production components, nomenclatures, stakes and batches, tunnelling phases

Preface

I wish to take this opportunity to thank my advisor Aki Peltola for guidance and support with the construction of the estimation models. I would also like to thank my supervising professor Mikael Rinne for his insight and suggestions.

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Hannu Juola

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List of abbreviations

BIM	Building Information Modelling
EU	European Union
GT	Grouting Time
IHKU	Infrahankkeiden kustannuslaskentajärjestelmä ja -palvelualliansi
KHO	Supreme Administrative Court of Finland
PC	Production Component
RIL	Union of Construction Engineers
WRAP	The Waste and Resource Action Programme
YM	Ministry of the Environment of Finland
YSE	General Terms of a Contract

1 Introduction

Current competitive tendering process has created an information gap between developers in the public sector and the contractors taking part in the bidding process. The competitive nature of the process has created a situation for contractors where they emphasise their strengths in resourcing groupings. They calculate construction phases from a speculative angle balancing between effective production components and challenging phases in construction. This creates an individual cost formation between contractors. Due to this fact, the public sector has had difficulty in the past to create up-to-date, realistic cost estimates of large-scale projects. Estimation of cost structure has varied largely, and estimates compared to offers made by contractors are in parts incomparable. To remedy this problem an alliance-project IHKU was created to model a new cost calculation system and modelling services to provide open cost information to the public sector and designers (IHKU, 2019). The new cost calculation model is designed meet the needs and challenges by providing up-to-date cost information for infrastructure projects, delivering high-quality, functional service for calculating cost estimates.

Transparency of information and calculations; is provided for designers and developers through an open calculation logic. The increase in open information and calculations builds up the reliability of cost information and enables cost calculation continuity and assessment of different options and risks at different stages of a project (IHKU, 2019). This brings more understanding of cost formation to the public sector. The new cost model is based on the standards and nomenclatures guide of Finnish infrastructure construction, more precisely its classification of construction phase content and price information.

The estimation model based on the Finnish nomenclatures takes an approach on the problem through a stake or batch unit standpoint. From a translation point of view, stake or batch units of resources does not cover the intended aim of alliance. The research area of resource-based theory creates the international study aspects which guide the development and understanding of the aspects which create effective the estimation models. Where resource-based theory creates bundles of resources to create effective labour, the same concept where multiple groupings of resources are used for one common goal, are used as the concept base for the estimation model. As an example of this, the calculation model is based on standardized production components, i.e. based on building information infra-nomenclatures. Production components are formed on the basis of building blocks which are bundles of stake or batch units. The model creates estimates through resource consumption. This assumes a duplication possibility of production components. In other words, the cost estimation of the model must have a trait of generalisation that can be applied in majority of projects as a duplicate of the same construction phase in question. This target for transparency is aimed to be applied in the model with the following aspects of information set by the IHKU-alliance (IHKU, 2019).:

- Reliability with timely and high-quality cost information and transparency in cost estimates to support decision making
- Response to new opportunities offered by the flexible operating environment and new technology
- Calculations based on accepted standards and guidelines in the field of infrastructure

- Calculation logic is the same for all project types (standard costing)

The aim of this study is to create a model for the tunnelling nomenclature groups of

- 1500, Rock grouting and reinforcement structures
- 1700, Rock excavation and tunnelling
- 4510, Protective and damping structures

With this implementation, this study will focus on the open, up-to-date cost modelling information of tunnelling nomenclatures. The study will attempt to utilize experience and information from developers, contractors, and designers to create an open information model of stakes through interviews. The unique aspects of rock excavations and tunnelling create challenges in the implementation of the model. Due to this fact, the feedback given by different parties in the interviews create a base for the individual needs of these nomenclature groups.

The implementation of the information in the model takes a look at the duplication possibilities of the tunnelling phases. As the transparency goals of the alliance create a demand for this duplication, the model must represent an accurate estimate of these production components in the phases. Due to this fact, the study takes a critical look on this possibility with the challenges and restrictions that come with it.

The estimation model for these tunnelling phases is depicted as a calculation model which will be the basis for the application. In other words, the model is presented as a calculation graph that depicts the estimation of costs through a calculation of production components. Unit prices are avoided as a depiction of costs in the production components. As unit prices do not open up the cost construction of the production components. The thinking behind the estimation is that transparency comes from the understanding of cost formations. Unit prices do not open the resources needed to create the production components. In other words, if a production component such as blasting has only a unit price, we do not know how that price is formed. When opening the production component into the stakes or batches that create the production component, we understand the formation of costs. By updating these batch unit prices we can continuously keep the estimation model up to date.

As contractors form their costing estimates with different perspectives the formation of costs is individual. Because of this, the pricing structures of contractors was not made available for the use of this study. Due to this the cost structures are made available from public sector projects. In other words, the content of unit prices is not made available by contractors. The prices for this study were made available by the public sector from their projects. The interviews of designers, contractors, cost calculation professionals and developers give feedback on the situation of pricings that effect the transparency of costs in public sector developed projects. Their feedback helped to develop and update the unit priced costing of projects to the resource-based estimating tool that is presented in this study.

2 Literature review

2.1 Resource-based theory

For a cost model to be set on the viewpoints of resource-based theory, the understanding of resource logic must be found. The term ‘resource’ is referred to as a something that an organization, company or entrepreneur draws on when reaching to accomplish a set goal. Suggested by Barney and Hesterley, the four main categories of resources are physical, financial, human and organizational. The efficient use of these main categories allows a company to achieve financial gain and a market advantage (Barney & Hesterly, 2012).

All of this relies on the resource-based logic to be set on two fundamental assumptions. According to Peteraf and Barney, firstly the resources of a company must be drawing from multiple bundles of resources made from the four main categories: even if operating only in one industry. This meaning, that even if the company produces a certain product targeted for a single industry sector, with no significant pressure to continuously develop their product, the resourcing should be broadly diverse nevertheless. This allows for flexibility in times of sudden change. Secondly, the bundles of resources the company draws from, must persist in difference as trading between companies must be assumed difficult from time to time (Peteraf & Barney, 2003). What these two assumptions mean, is for a company to be successful it cannot rely only on one type of resource. They must have multiple resources, which combined together can be used efficiently to create value for the company. As well the resources must be drawn from inside the company as reliance on others brings with it insecurity. Especially in industries such as construction where numerous companies draw from the same pools of resources the advantage comes from skill and efficiency. Resource heterogeneity is an assumption for companies that excel over others. This means that they have an advantage due to a unique resource or skill in their use (Peteraf & Barney, 2003). In construction this mainly applies to the skill of utilizing their resources more efficiently than others. Creating more value from the same type of resource as other when the efficiency is utilized correctly. By this effective and outstanding resources being the heterogenic pool where the company draws from.

When these two assumptions are met a company has sustained competitive advantage (SCA) which by Barney and Clark is “*when a company is creating more economic value than the marginal firm in its industry and when other firms are unable to duplicate the benefits of this strategy*” (Barney & Clarke 2007). This is the central aim of resource-based theory. These are found through the set terms of resources and capabilities. The above-mentioned skills are a company’s capabilities that according to Makadok 2001 are “*an organizationally embedded non-transferable firm-specific resource whose purpose is to improve the productivity of the other resources possessed by the firm*” (Makadok, 2001). The talent of the human resource when applied to the other three main groups of resources.

To understand resource-based theory, the above-mentioned resources and capabilities must not be mixed with dynamic capabilities. Where resources and capabilities are the building blocks that a company creates its day to day operations, dynamic capabilities are what the company draws on to develop itself and stay relevant in its chosen field. In other words, resources and capabilities are what the company is made out of and how the company is run. Its culture of operations. Dynamic capabilities on the other hand are the companies’ ability react and change in circumstances that are out of the company’s normal environment. These are in itself a set of resources that can be used to develop and create new opportunities from initial resources in the companies use (Kozlenkova et al., 2014). Example of dynamic capabilities are product development, knowledge creations and resource allocation routines such as new costing models such as this. The dynamic capabilities of a company must be constructed in a way that they are there to advance a company's foot hold in the industry without taking away from the core strengths in the process. Development must come from inside the company with existing resources without taking away from operations. The development drawn from existing capabilities make it an imperfectly imitable resource, a resource of benefit that is expensive to obtain or develop by competitors (Barney & Hesterly, 2012). These are mainly knowledge-based resources that a company finds as its intellectual property.

Resources in the construction industry are varied in the sense of their heterogeneity and ease of duplication from project to project. Where for example housing projects, especially apartment buildings and their construction are quite simple from the aspect of duplication of processes, tunnelling projects do not have the same type of ability. Apartment buildings can be designed and constructed using elements and combination of repeated structures that do not vary as much from project to project. Variance is made by the vision of design and requirements, homed in by budget and timetable. Cognitive difference in firm specific resources dictate how a project is run by managers, but the outcome is mainly the same. In the same scope of time (Alvarez & Busenitz 2001). Tunnelling projects do not work the same way. The design of a tunnel is unique each time and the operating environment from rock quality to permit restrictions in operating times and safety dictate the outcome of the project and its timetable. Here the cognitive difference of companies plays a larger role. Through integration of resources and the understanding of each companies own strengths, the recognition of opportunity is different (Alvarez & Busenitz 2001).

This recognition of opportunity is the bases of calculation that dictates how a project is calculated. In other words, how the price is made. As excavation has a large set of unknowns taken into account, so is the amount of variables and risks in the budget. Even though resource-based theory suggests that heterogeneity is the key to sustainable advantage relying on your companies' core strength resources might not always work (Alvarez & Busenitz 2001). According to Alvarez and Busenitz this can as easily generate short-term advantage until the effect of the resource is found un-useful. The uncertainties and risks of the excavation bring with it a scenario where a company's resources do not work efficiently. If this is not calculated into to the costs, a tunnelling project can turn from a productive endeavour into a cost consuming project very quickly.

Therefore, the cost calculation by entrepreneurs is made by taking informed risks in some parts of the tunnelling phases and playing safe in others. Balancing the economic risk by creating larger profit where possible and being more conservative when the outcome is not as clear. This is in accordance with the estimations of Alvarez and Busenitz. They state that profits are minimized at the lowest levels of uncertainty. Less the risk, smaller the potential reward at the end. A correct organisation of resources allows for a company to minimise the risks in areas where their skills are the best. Where waste occurred previously, now a capable bundle of resources generates maximum profits. The challenge are the uncertainties and their calculations. Other companies see other parts of the tunnelling phases safer than others. When all companies base their risks from an individual perspective, the risk areas and the profitable ones are unique to each company. This is where durability in resource heterogeneity adds sustained value and creates less risk (Peteraf, 1993).

As the competition in construction industry is fierce and all companies gather maximum benefit from capital goods the assumption of that marginal productivity from them is available to all companies. The price of construction material is approximate the same for all. So, the profits and sustained value for companies is in the valuation of their resources and the balance between risk and reward (Alvares & Busenitz 2001).

"In a resource-based view, discerning appropriate inputs is ultimately a matter of entrepreneurial vision and intuition, the creative act underlying such vision is a subject that so far has not been a central focus of resource-based theory development" (Conner, 1991).

2.2 Resource-efficient construction

In the vast construction sector, tunnelling projects can be considered nowadays resource-efficient and by-product effective when compared to many other construction types in process. According to the statistics given by the European Commission's report on resource efficiency and opportunities in the building sector in 2014 when considering the construction sector as whole,

- *Construction sector generates approximately one third of all waste.*
- *Half of all extracted materials.*
- *Half on all consumed energy.*
- *One third of all water consumption.*

Fighting against this significant amount of consumption, tunnelling projects are slowly growing into an effective example on efficiency and resource awareness in utilization of goods and capabilities. There is an ever-growing pressure to cut down on waste production, energy efficiency and a clear awareness on a full lifecycle way of thinking in all construction projects. Even though majority of all tunnelling projects are unique from one another and the final product is custom built to the needs of the client, around the geological limitations of the site; the design, construction, refurbishment and end life use can be very efficient (Sfakianaki, 2015).

WRAP, a non-for-profit company aimed to the study, promotion and movement towards resource efficient economy stated in 2015 that most resources in construction have operational and embodied impacts such as water, waste, and energy. In other words, the resources used in construction effect the quality and consumption of water waste and energy. This means that the effects of poorly managed use of resources has an effect on not only construction phases but during main life cycle use as well. From design flaws to poor allocation of time to under skilled workforce and financial troubles can lead up to an expensive life cycle of the final product.

Resource-efficiency has moved away from not only worrying about the financial effects of resource allocations to a more holistic approach to efficiency. EU's targeted green deal aspirations make requirements to large construction projects that if not taken into account in planning and the effective use of their resources can affect negatively to the financial gain of the project. WRAP sets as a priority, addition to a sustainable advantage and economical profit, carbon reduction. It their 2015 report, limitations in carbon reduction pose such restrictions on construction that if not taken into account in the whole planning process, it can cut the profit of any project down completely.

Resource-efficiency should take into account (WRAP, 2015a, b)

- *The optimization of durability and lifespan.*
- *Reduction of water and energy during construction.*
- *Enhancement of resources during their use.*
- *Maximation of by-product and re-use content.*
- *Reduction of material and waste.*

As the control in tunnelling phases is not primarily in the means of how a tunnel is excavated, as this is dictated by the needs of the facility and the restriction in geological aspects and permits. This can be achieved by a thorough look into resource use, by-product efficiency and waste reduction.

Largest amounts of gain achievable by tunnelling projects is in the use of excavated rock and the use of excess shotcrete and micro-cement from grouting. Especially in larger development areas and cities where distances of transport for construction material and rock plays a large effect on the pricing, the use of excavated rock should be taken into account when calculating the price of excavation. In a report conducted by the Finnish ministry of Environment on a plan on development of excavation and the use of excavated rock, only the transportation distances of earth work material can be cut down to a fifth when using excavation material locally. Municipalities are taking the carbon emission effects of transport into account and allowing for onsite processing of excavated rock more easily. The option of making underground crushing plants is calculated more frequently. This is an incentive taken seriously as the transportation costs of rock is 50 cent / m3 / km. This quickly grows into an amount that allows for the process on site and the use of excavated rock completely. Another investigated and promoted option is the use of excess shotcrete on site. Instead of expensive transportation and recycling fees, the shotcrete is encouraged to design into the mass of earth structures onsite (YM, 2018).

Supreme Court of Finland has taken interest in the development of local use of construction material and optimization of resources. Last year in their decision of transportation of excess material and waste from excavation sites, they stated that the permit process and environmental aspects of decision making should be viewed from a larger scope than only the main affected area of transportation. They state that the onsite consumption and minimization of waste material and by-products should be a strong argument when permitting the transportation of material. They state that not only the impacts to the environment but the impacts to neighbourhoods and infrastructure are strong motivations to allow local consumption of material. By this the noise levels and minimization of carbon emissions are guiding aspects in the development of guidelines in the future (KHO, 2019).

When the resource efficiency in tunnel phases is calculated from a zero-sum aspect, the main resources affected are organization, human and physical. In other words, the costs and consumption of one resource is away from all of them in the long run. Carbon emission restrictions create a pressure for companies to renew their equipment from gasoline powered to electric powered machines. By doing this they almost accidently upgrade their equipment for more efficient and productive versions (Ding, 2008). Another example of renewal is when the organization of a project is faced with a financial dilemma of minimizing the transportation of waste. Here the new ideas and viewpoints of renewal and minimization of waste is created. Design and implementation of new efficient processes are then created (YM, 2018).

As the economic performance is the key factor that controls construction it is by affecting this factor that efficiency and change of procedures to more effective ones are created. Decisions and new guidelines by the public sector create the working environment for contractors. As all companies wanting to create sustained competitive advantage think of new ways to maximise the efficiency in their operations. New implementations forwarded down to the workforce create ideas and development. As the built environment is increasing but at the same time land is becoming scarce, increasing amount of the built environment is underground. The efficient construction is mainly kept in discussion through sustainable discussion. This is commented more in detail in the chapter on Effects of circular economy to resource-based estimating (Sfakianaki, 2015).

2.3 Challenges and opportunities in resource management

The largest challenges that resource management faces is the rapid change in construction technology. Earthworks and with it tunnelling and excavation phases are guided towards information-oriented planning and delivery of facts. Building Information Modelling (BIM) and modern documentation are promoted not only by service providing companies but by the public sector. The European Union launched in 2017 a handbook to unify the implementation of information technology into the construction sector (EUBIM, 2017). A unified European policy allows for cross the borders international co-operation and larger business endeavours. With it, the precise changes and detail in planning and the relay of information becomes faster, live (Kerosuo, 2017).

Even though the technology and processes to support this is all ready, the capability and structural readiness of entrepreneurs is falling behind in development. A large portion of companies in the field are small or micro-businesses where majority of the company's wealth is tied into the existing hardware. The modifications needed to make the transition is expensive (Kerosuo & Paavola 2016). Additional to the upgrades needed into the machinery, personnel need education and training as well. As the demand of the technology is slowly being introduced and demanded in projects, so is the transition of the company's reaction to the demand. Resource efficiency is tied into learnt efficient practices (Kerosuo et al., 2015). New technology takes many of the companies into unsafe territory where their core speciality is not as strong. For many this demands the re-structuring of their personnel either by recruiting new staff with capabilities to support the company or the education of current staff. If education and training of current staff is chosen, this brings with it a transition phase during which the bidding for modern projects is more difficult or out of reach. In other words, companies must plan for a smaller revenue period (Kerosuo et al., 2015).

With new technology the development of project management, efficient resourcing legislation and common terms must develop as well (Kerosuo et al., 2015). In Finland this is a current challenge that is not moving on the same speed. The general terms of a contract (YSE), a legally binding document, was published in 1998. The terms and the atmosphere of the time 22 years ago does not correspond with digitalization very well. As the document is outdated and this fact is recognized by the construction sector, the terms and conditions of the document are undervalued or opportunistically referred to, when the situation is allowing it (Infra Ry, 2019). In other words, the terms and conditions are referred to when it suits the goals of the party involved. This puts the weighted value of negotiated terms above the YSE document. As a large portion of the negotiated terms and pricing of contracts are unit price based the flexibility of the contractual terms are rigid. The acquisition law of Finland protects the rights of contractors by determining the procedure how public authorities select the contractors of supply goods, services and construction work (Finlex, 2016). Due to this, terms of the contract must be set at the point when bidding commences.

- *Productivity and the quality of public construction increases.*
- *Transparency of modelling.*
- *Growth of export and attraction of intellectual resources through digitalization.* (EUBIM, 2017)

The opportunities in resource management bring with it the benefits that all companies already have in their existing capabilities. As a company's capabilities are comprised of bundles of different resources, they draw on their own strengths and skills. They estimate risks and speculate consumption of goods and demand of work force through the experiences in previous endeavours. As demand grows and the aim to minimize risks controls development, the aim of dynamic capabilities is to expand the field of expertise in the company. In other words, more skills that the company can safe say they poses, easier it is for them to make more accurate, detailed and competitive bids. (Peteraf & Barney 2003)

Technology brings with it the opportunities for in-depth precise estimating of projects. BIM technology applied in machines allows for mass stabilization and excavation to be precise and cost effective (Kerosuo et al, 2015). Material waste is minimal and through up to date design plans, the effective use of manpower can be maximized. As the construction sector is going through challenging times, trying to answer to the growing questions on environmental impacts, economically uncertainty and sociological changes, it is facing large opportunities as well. (EUBIM, 2017)

When facing the fact that that on a large scale one third of all waste and half of consumed energy goes into construction at the moment, this is half the picture. Finland has challenges with climate change, resource efficiency, greater focus on social services requirements, urbanization and migration, aging infrastructure, need promote economic growth and limited financial resources (EUBIM, 2017). This is also the focus on opportunities in the future. Companies that can excel in the development of resource efficient procedures and minimize the effect of waste and consumption their own processes will have a sustained competitive advantage in the future. This calls for open and up to date information to be at the use for development, as well as in the long run the challenge that early gained advantage of some will incentivise others to copy or modify the same building blocks of new success. (Barney & Clarke, 2007)

Resource-based theory suggest that the development of resource management comes in three stages. Firstly, resource-based view. Secondly, knowledge-based application and thirdly, relational view of facts. Resource based view assesses the development of a company's strategic assets. It evaluates the effective and efficient application of the company's resources and determines desired changes for sustained competitive advantage. When the assessment reaches some sort of consensus, it is time for a company to determine how their knowledge-based applications are equipped for this change. As the intellectual property of a company is difficult to imitate their strengths are unique as well. The heterogeneous knowledge and capability of the company determine the success of strategic changes planned. Finally, if the first two steps in the development of resource management are favourable, relational view judges how the advantage is in relation to others in the same field. (Acedo et al, 2006)

This means, that the recognition of opportunities is not enough. If wanting to enhance the efficiency of a company's resources, the presented opportunity must be viewed from three different angles. Firstly, the company must make an honest look at the resources in their use and compare the situation of competence as it stands to the desired outcome through development. Is the level of competence capable to make the strategic changes needed? If the possibility is there, secondly the company must evaluate the potential of their human resources. Can they keep up and manage the needed change in the long run. If so, thirdly they must assess their stance in their competitive field. Can they uphold their gained advantage against competitors? If the effects are to their core resources, the opportunities are then in their grasp. (Acedo et al, 2006)

2.4 Resources in tunnelling phases

Resources in tunnelling phases are directly comparable to the type of tunnelling project which is being performed. The largest influence on the type of resourcing being used is the amount of drifts. As time is the single most effective contractual aspect in a project, the amount of drifts makes the outcome. The fewer the amount of drifts being excavated the more affect there is to the timetable when changes are made (Mazaira & Konicek, 2015). As time is not a resource on its own, but it is a sum of many resources that can affect the outcome of effective time use during a project. In other words, the positive effect of time is achieved by effective use of resources in bundles.

As mentioned in the previous chapters, a large influence on the construction sector is the global development of environmental questions as well as the fast digitalization of technology. These aspects affect all four main types of resourcing. The EU's new Green Deal agenda is implemented to all member states (EU, 2019). As the demands for the cut down of environmental impacts of construction are demanded and changes to all resource segments are made, there is a growing worry on the consistency of decisions (EU, 2019). The investments that companies are making into growth to meet the demands new legislations are large monetarily. So, the indicators from decision making must show a steady and consistent development in the trend towards the set goal. If the way points on this path are ever changing or the goal is not completely clear to all, development costs are larger than needed. This creates a false emphasis in estimating. Creating a larger estimate of total costs when the changes and insecurity of development is calculated in all aspects of projects, instead of a steady assertive development from start to finish. (ILO, 2011)

The use of resources in tunnelling projects is also dictated by the type of contract that is made for the project. There are three most commonly used contractual projects in use in Finland. Total price-contract (kokonaishintaurakka), unit price-contract (yksikköhintaurakka) and target price-contract (tavoitehintaurakka). (Väylävirasto, 2009)

- Total price-contracts bind the contractor to undertake the complete construction work of the project at a fixed total price. In this the main focus is for the content, the scope of the contract to be precise and define the whole construction period. If the plans for the project are not precise or they change during construction, this raises construction costs for the client through additional work costs and alterations. (Väylävirasto, 2009)

- Unit price-contracts bind the contractor to achieve the agreed construction project and be compensated by the client on an in advance agreed upon fixed unit price. Unit prices are measured by quantity units of performance which are easily measurable, separately priced and clearly structural. Unit priced contracts are well suited for tunnelling projects and are nowadays the most commonly used contract model. It is well suited due to the fact that quantitative units can significantly change during the implementation phase of original plans. Unit priced contracts require comprehensive nomenclatures and agreed upon means of quantity measurements. (Väylävirasto, 2009)
- Target price-contracts divide the economic risks and responsibilities equally between the contractor and client. Here the contract is a cost-based invoicing contract where the invoicing is made from total costs of construction work. This includes a consideration fee that consists either on a agreed fixed fee or a target percentage fee of the final goal. If the final price of the project is either above or below the target, the final price is shared by both parties. It is common to add a ceiling price to the target, with which if that is reached and gone over, the exceeding amount is entirely at the contractor's expense. (Väylävirasto, 2009)

The physical resources of a company in the tunnelling and excavation field are tying up most of the company's wealth. Investments to the capability and demands of modern machinery are expensive and are made due to the demand of bidding criteria. Material used in the reinforcement and grouting phases are priced upon the set fluctuations of market pricing. This means that the prices of steel, aggregates, cement, and other materials can affect the end costs of materials during construction. (Väylävirasto, 2009) As most of the contract models have pricing set before hand, this can have a significant effect on the calculated profit margins. The location of the tunnelling project and the permits given dictate a large portion of the physical costs as well. As all machinery and other material used as resources, either owned by the contractor or rentals, have a calculated daily cost estimate. A daily price for tying up the resource to this project. The more the efficient and more hours a day the resource can be used, the more beneficial it is for the contractor. If permits allow tunnelling phases to operate only parts of the day, the operating costs of these resources is higher. (Kozhevnikov, 2018)

Financial resources of the contracting company dictate how well they can withstand risks and how they can part take in different types of contractual models. Depending on the contract model, the inflow of capital during the project varies. The unexpected delays in timetable or changes in plans can affect the target goals of a project or the pace that quantity is counted up during construction. Even though capital is not flowing into the contractors, it is flowing out. The fixed costs of the construction project such as employee fees, sub-contractor invoices and maintenance costs are running daily. (Väylävirasto, 2009) If the financial resources of the company are not equipped to handle uncertainty and do not have a required buffer for changes the consequences can have dire effects on the project and company. (Kozhevnikov, 2018)

Human resources of a company are the most sensitive and intolerant to change and insecurity. As the skills and expertise of construction companies is the core of their business, it is vital for them to be able to hold on to talent. The culture and structure of the company, as well as their rewarding system and human resource capabilities are in high demand. (Kozhevnikov, 2018) As tunnelling phases are not a common line of education and talented workforce are fully employed, employees are aware of their worth as well. A new aspect in human resourcing is the change in working culture. Younger generations do not engage themselves to a certain company in the same way as before. The movement of workforce from company to company is more common and workmen look for more incentives to commit to a company than financial benefits alone. This creates new challenges in a very conservative line of work as construction and tunnelling is. (Infra.Ry, 2017)

Organizational resources of tunnelling projects are dependent on the model of contract that the project is working under. Where the capability of the managerial staff can be considered efficient, largest affects to the resources use are the time constraints or delays during construction. If the organization is not capable or skilled to work under changing conditions, the outcome will affect all aspects and segments of resourcing. (Kozhevnikov, 2018)

2.5 Tunnelling nomenclatures

The current nomenclature system was updated in 2015 from the infrastructure nomenclature of 2009. The updates to the previous version consisted of moderate changes aiming to (INFRA, 2015)

- *Restructure the nomenclature so it better supports the development of information modelling*
- *Updating the missing titles of the previous nomenclature so it better serves the management of costs and quantities*
- *Clarification of unclear content in previous versions*.

The tunnelling nomenclatures were designed for effective project management during various phases of construction, from design to excavation and re-enforcement. The nomenclature system describes tunnelling phases as construction segments and describes the process as quantitative volumes of resources. This helps in the estimation of costing, resource allocation and formation of contracts (Rakennustieto, 2015). Especially in the most common contract type, unit price-contracts the division of resources into sub-categories allows for detailed cost estimation. The nomenclature system for tunnelling phases consists of sub-nomenclatures that follow loosely the same resource categories of resource-based theory. They are divided from a project management viewpoint to the following (INFRA, 2015):

- *Nomenclature of tunnelling phases*
- *Stake or batch nomenclatures*
- *Nomenclature of production*
- *Nomenclature of end products and operations*.

The nomenclature structure provides a simplified model of tunnelling works. They are common enough so the exchange of information between different parties in the project is efficient. Basically, this means that the nomenclature system is an agreed upon structure of tunnelling phases (INFRA, 2015). When discussing different parts of the project, these modelled structures are used when referring to a topic at hand. This allows for all parties involved to discuss the same topic using the same set of terms. This minimizes misunderstanding and keeps the structure of construction the same for all.

Additional to creating a common set of terms with which to view a tunnel phase, the nomenclature creates an agreed upon standard of values with which a single phase of tunnelling will be judged upon. From quantitative standard of production, resourcing and value to a qualitative standard of production. Dividing the tunnelling phase to the least amount of tunnelling works which make up the tunnelling phase. In other words, the nomenclature describes the basic steps on how a tunnelling phase is implemented, how the tunnelling phase is measured in production rate, speed, and a standard unit of invoicing (INFRA, 2015).

As a whole, the 2015 infrastructure nomenclature is set up as a four-digit numbering system. The nomenclature is broken down in a hierarchy following the outline of project management guidelines. As such the nomenclatures follow from phases, to stake or batches, to production and ending in end production or operation units. This means that the four-digit code for a single nomenclature consists of four detailing parts of the nomenclature. For example, 1511 is the nomenclature for grouted rock structure by micro-cement or chemical compound. The breakdown of the nomenclature is (INFRA, 2015):

- 1: Rock mechanics
- 15: Grouted or re-enforced structures in rock mechanics
- 151: Grouted rock structures in rock mechanics
- 1511: Grouted rock structures by micro-cement or chemical compound

Unit is kg or drilling meter. Means of measurement for quantity is consumption of grout or length of drilling.

For cost calculation this basic breakdown of a tunnelling phase is not enough. The nomenclature of a tunnelling phase must be equipped with additional information. A further breakdown identifies the variables affecting the cost structure of the finished product or work phase. The same applies when the basis of invoicing, the agreed upon contract model is target-price contract. As here the final costs are made up as the project advances. Both parties must have a means of identifying which parts of the nomenclature are fixed units where the cost does not change, and which parts of the nomenclature are affected during construction (INFRA, 2015).

The infrastructure nomenclature system 2015 is very detailed in identifying basic titles consisting of different supplies and materials. Due to practicality reasons, as the system does not take opinion on which supplies, materials and operations are important to cost calculation, the system covers all the inputs required for the project. Although some are subject to further subdivision. The stakes or batches in question are grouped into the following subheadings (INFRA, 2015):

- *pay grouping or vocational title sub-nomenclature*
- *equipment sub-nomenclature (transport and transfer equipment and construction machinery)*
- *the sub-nomenclature of construction products (materials, construction equipment and prefabricated components)*.

In tunnelling projects many phases are often carried out by subcontractors. The general terms of a contract state that subcontracts may only contain labour with needed equipment or labour and materials including equipment needed. This makes the identification of subcontracted phases by nomenclatures difficult, especially as the extent of subcontracted performances varies. Therefore, the nomenclature system does not include a subcontracting nomenclature. The production nomenclature largely meets the needs of subcontracting in terms of cost calculation. In this sense the subcontracted phase is taken primarily as a single unit work phase with one identifying unit of measurement (INFRA, 2015).

2.6 Future in resource-based construction

As economic growth in Finland and globally all together is slowing down, it cannot be assumed that construction will keep the same pace as it has had for the past five years. On a positive note, the centres of growth such as the capital city region in Finland does not show the same decline in growth as rest of the country. This keeps the localized growth in these areas going (Työ- ja elinkeinoministeriö, 2019). While construction in these areas is booming, viable areas of good quality land is becoming scarce. Transportation knots slow down the infrastructure of these areas and storage and industry demands are steady as well. As an answer to this problem more area is excavated from underground, or facilities are being built there. A downside to this is, that most of tunnelling projects are economically very large and the decision to commence on such an endeavour is becoming more difficult (Infra, 2019).

As the answer to profitable entrepreneurship in the construction field is profitability and economic growth, this can be achieved two ways. Either by increasing the amount of work that the company takes for itself or by increasing labour productivity. In both cases this demands the efficient use of resources inside the company. Productivity can be found easiest by finding efficient operations, more efficient machines and new areas of venture (Barney et al, 2011). Tunnelling companies as well as the excavation business in whole must start finding new innovative ideas on how to expand their business and develop themselves. As efficiency and the task of improving it demands the growth of resources, it is made under the assumption that the level of capability is dynamic enough in the company. In other words, the skills of the company and the level of quality in it must be high enough. At the end of the day, development needs continuity and continuity of a company needs revenue to succeed (Baker et al, 2005).

The development of resources needs financial backing. As mentioned above, for this companies need an ongoing revenue stream. Majority of tunnelling projects are under the public sector, so the bidding for these projects is under competitive tendering laws of Finland. There is growing critique of this procedure. As the evaluation of the bids is made by dividing the content mainly between price and quality, the decision is made by the content of evaluation criteria. A study by Hansel, a governmental agency that is devoted to the development and legislation of public acquisitions, has found in 2017 that the criteria of quality is mainly poor in decision making. The emphasis on quality is either placed in areas of construction which do not have any effect on the outcome of the project or on equipment and other hardware. In other words, this means that in cases where for example 25% of the bidding is placed on a quality rating of the company, it favours large companies that can buy the needed hardware or have a possibility to lower their bidding price so that the emphasis on quality weighing 25% of the bid is not a relevant factor any more. (Hansel, 2017).

Due to this fact, there is a trend that competitive tendering is 100% based on a pricing viewpoint. Cheapest bid wins. This does not in all cases mean that the quality standard of tunnelling is declining. It does show the trend that development of resources is slowing down as the margins of projects is smaller. Here the estimating tools that are in use for developers, the clients and for contractors is a key for success in the future. When the decision makers in the public sector have a clear picture on how the cost structure of a project should be built, they can discard bidding where the structure of the bid is false or has too many risk variables that can affect the outcome of the project or its quality. This meaning, that when the cost structure is transparent for all parties and the information for cost estimation is detailed enough, only realistic bidding and cost estimation succeeds in bidding (Hansel, 2017).

As the measurable unit for effective use of resources is productivity, this growing trend of price-oriented decision-making effects the production rate of tunnelling. Even though the development of prices by 'lowest bidder wins' culture is kept conservative, the production rate is slowing down. The reason for this is, that the quality standards of end users and clients is higher than previously. As the demand for better quality is improving the overall costs of construction are higher. To keep construction costs on a tolerable, the pace of construction is kept moderate. For the reason that a high pace of production does not necessarily equal the same level of quality. For this, there is a new way of viewing production and how it is measured. A joint document covering the description and results of an investigation to resource management and development of construction, financed by the council of state and the Union of Construction (RIL), determined that a production rate of a project should be viewed as follows (RIL, 2019).

$$Productivity = \frac{amount\ of\ output + quality}{amount\ of\ stakes\ or\ batches + quality} \tag{1}$$

What this implies is, that the productivity of a company is no longer viewed on the sole basis of how much output it is capable of producing with what amount of resources. Productivity is now viewed by the output which meets the standards required produced by the company, made with resources that meet the quality standards expected. This follows directly the new requirements set by EU's Green Deal standards. As the environmental aspects of construction become a strong criterion in all phases the amount of quality in this equation becomes larger. It is no longer about who can produce the most meters of tunnelling in a set time with the lowest costs. Instead it is about, who can make the most tunnelling meters, with the most environment friendly equipment, leaving the smallest impact on nature, able to utilize the most by-products and having the most sustainable human resources available (RIL, 2019).

This creates new opportunities for employees who are seeing that their employer has trouble catering to all the demands of modern construction. As many phases of a tunnelling projects are subcontracted, there are opportunities for entrepreneurially thinking workmen who see opportunities in this new way of evaluating quality. Construction sector is a stiff and conservative field where change and development in values happens slowly. The dynamic capabilities of companies might not be fast enough to react, so opening in niche segments of the market are available (Baker et al, 2005). The future of resource-based construction is development oriented. As quality controls this growth the increase in standards promotes latent productivity and development. As the quality standards of clients cannot be lowered or the increase cannot be slowed down, constructors must produce what the clients require. For this to happen, efficient use of resources and the production process in general must should be developed with following (RIL, 2019):

- *Development of contractual frameworks*

- *Development of design and construction processes*
- *Development of acquisition and logistics management*
- *Development of site operations*
- *Implementation of new digital solutions*

2.7 Effects of circular economy to resource-based estimating

There is a duality in the awareness of circular economy in tunnelling projects and the demands set by society. The new restrictions in carbon emissions and targets of waste consumption are more in the words of the public sector than in the adoption of new implementations in the field (Adams et al, 2017). A large factor in this is the lack of enabling decision making and the incentives that are given towards the construction sector. The target of what society wants as an outcome of the green deal concept is clear to everyone but the contributing factors that enable to reach this target, are unclear to most. A breakdown in the supply chain of tunnelling projects show that there is confusion or little knowledge in the adoption of circular economy concepts by clients and designers. As the tools and instructions on how a project is carried out, comes mainly from these two parties the confusion extends to the contractors as well (Chamberlin et al, 2013).

The challenges mainly are in the incentivisation of procedures. The market mechanisms and the design formats do not promote end-of-life issues. This means that the use of materials used in construction are viewed as waste, rather than components of renewal. Due to this, the recovery chain of waste is viewed from an economical perspective. As the restrictions in environmental questions are promoted only through penalties and guidelines, it is in the interest of the contractor to put effort only into figuring out how to meet the guidelines and avoid penalties. If the incentive would promote development of procedures, this type of negative promotion would not be necessary. This would free resources on both ends to development from supervision (Adams et al, 2017). As the growth in tunnelling projects is concentrated around growth centres there are technical difficulties in processing waste. The recovery routes for waste do not identify by-products as an effective recovery route of waste, as permits for tunnelling do not take this into such an account compared to noise pollution and effects on surrounding neighbourhoods (Geng & Doberstein, 2008). The transition phase from the current methods towards the requirements set by the public sector need a thorough re-establishment of incentives. As the tunnelling construction field is fragmented and lead by commercial benefits, only a clear business case forum can promote the change that is required (Adams et al, 2017).

As the development of circular economy concepts is slowly making its way to tunnelling projects, the emphasis on environmental development is in supply chain management practices. The efforts are in finding suppliers and products that reduce the negative consequences of consumption. Here the emphasis is in the relationship between ecological procedures and economic growth (Nasir et al, 2017). Emphasis being in finding a transformation from linear supply chains into circular ones. This in other words is an aim to meet set environmental targets of construction by making more efficient and circular choices with suppliers. Basically, showing the credentials of green products as the aim for environmentally friendly construction as the phases in tunnelling works are more costly or difficult to transform. This will not be a functioning way promoting one’s environmental aspects for much longer, as the carbon maps of supply chains are much more visible than previously.

The studies in lifecycle emissions have shown that the transport elements of circular supply chains play the largest proportion in their total emissions. What this means is that circular products might not be the most effective choice as it all comes down to the transportation distances. To promote more effective procedures of circular economy in tunnelling projects, the indicators that are taken into account should be multiple. The comparison between linear and circular supply chains are more of a promotional slogan used by contractors. The resulting impact is more debatable (Nasir et al, 2017).

The development of circular economy thinking can be best promoted with new ideas for management. The reinvention of economic models to support sustainable development is a tool that is not efficiently used. The economic models, such as contract types and through them the estimating tools that are used, do not take into consideration the use of by-products as an economic factor (Geissdoerfer et al, 2017). If the efficient use of waste on-site would be considered a direct factor in calculations, this would speed up development. As the study of environmental impacts is studied by environmental analysists rather than economic professionals, the assessment tools do not give answers to how implementation can be effectively made. The principals of circular economy *reduce / reuse / recycle* would benefit tunnelling phases better if they would be viewed more from a *reuse / refurbish / recycle* standpoint (Ghisellini et al, 2017). In other words

- reusing material, energy, and resources
- refurbishing resources and outdated procedures
- recycling and effective use of by-products. (Ghisellini et al, 2017)

The adoption of this framework will provide economic benefits as well as effectively reducing overall impact. The largest problem in implementing this framework, is in the fact that all projects are site specific. The market of recycling, re-using of resources and the effective use of circular supply chains is directly affected by how far from suppliers the site is and how much market presence of competing goods there are on offer. Basically, the economic and political context of circular methods is dependent on the ease of supply. If the transportation of goods, difficulty of permits or the availability of inexpensive linear supply is larger than the benefit of circular models, it will not work efficiently (Ghisellini et al, 2017).

The re-thinking of design is the best way to start implementing new strategies into tunnelling projects. It starts with the idea of redesigning of processes and discussing the reprioritizing of the choices that companies make. Circular economy has been a trending buzzword during the last years and with an overuse of the term it has lost its basic meaning. Due to this, it is up to the choices that companies start making that will define their reputation in the future. The choices can be viewed from a resource-based standpoint and development starts by redesigning the four main categories of resources (Ghisellini et al, 2017).

- Physical resources, by developing digital solutions
- Financial, by creating new business models
- Human, re-thinking conditions of labour and reward
- Organizational, by developing efficient circular design strategies (Ghisellini et al, 2017).

3 Modelling and interviews

3.1 IHKU-Alliance

Projects in the infrastructure sector of construction make up a large portion of public sector funded development in Finland. With competitive tendering as the basis of contracts, the actual content of invoicing has become harder to interpret. Meaning, that the actual bid for the contract has made the parameters for invoicing. How the costs accumulate inside these parameters are not so clear. Due to this the public sector is facing difficulty to create up-to-date, realistic cost estimates of large-scale projects. Estimation of cost structures by public sectors preliminary work have varied largely, and estimates compared to offers made by contractors are in parts incomparable. To remedy this problem an alliance-project IHKU was created to model a new cost calculation system and modelling services to provide open cost information to the public sector and designers. IHKU-alliance is made up of the six largest municipalities in Finland and the centre for infrastructure and logistics (IHKU, 2019). As majority of development projects are conducted in these growth centres so they can provide up to date current information on the requirements for information. The new cost calculation model is designed to meet the needs and challenges by providing up-to-date cost information for infrastructure projects, delivering high-quality, and functional service for calculating cost estimates.

The model is a resource-based estimating tool which calculates stake/batch inputs of resourcing groups to form an estimate on the average pricing of production through previous projects. This provides a sounding tool for designers and developers to evaluate bids submitted by contractors. In other words, the estimating model allows to evaluate the submitted bids and their potential. For example, the model allows to evaluate low bids to realistic pricing. Can the construction be done with that price, or is the contractor taking a risk with the bid, which will cause financial trouble for the project eventually. The increase in open information and calculations builds up the reliability of cost information and enables cost calculation continuity and assessment of different options and risks at different stages of a project. In other words, it helps create a more honest structure of costs, creating a library of cost information that is available to all parties involved. By this the unbalanced terms of contracts and misplaced costs into wrong segments of projects can be avoided more efficiently (IHKU, 2019).

The new cost model is based on the standards and nomenclatures guide of Finnish infrastructure construction, more precisely it's classification of construction phase content and price information. The aim of is to create a guiding model that portraits current and reasonable costs for all users in a project. Results of estimation are created by modelling resource-based calculations on building components according to the Infrastructure-nomenclatures. The nomenclatures building components are basically detailed version of resourcing, estimating cost formation from sub-units. Stake/batch listings create a guideline not only for cost estimation but for a code of conduct to create a quality standard for construction (IHKU, 2019). A guideline of sorts that advises on minimum resourcing that creates desired work phases.

As the nomenclatures are very detailed and the amount of sub-units is large, they are too heavy on their own to make up to calculation model for estimating tools. Due to this fact the nomenclatures are simplified and attempted to transform into a 'only essential information' structure model. By doing this the models becomes user friendly and allows for only crucial costs to be taken into account. If too much information is provided into the estimation model, the desired open and assessable is not found.

IHKU-alliance has structured the aims of the calculation model as the following:

- Reliability with timely and high-quality cost information and transparency in cost estimates to support decision making.
- Response to new opportunities offered by the flexible operating environment and new technology.
- Calculations based on accepted standards and guidelines in the field of infrastructure.
- Calculation logic is the same for all project types (standard costing).

The calculation model is based on standardized project-, and building components, i.e. based on building information infra-nomenclature. Project components are formed on the basis of building blocks. Such blocks are made up of production parts which in turn are made up of stake/batch inputs as they are portrayed in resource-theory. Unit prices for building components may also be used. The pricing of the estimation model units are based on a simple division of content. Unit prices are used where applicable (IHKU, 2019).

- Stake/batch sub-units: physical, financial, human resources, which are translated into labour, machine and material.
- Stake/batch sub-unit prices: physical, financial, human resource-costs, which are translated into labour, machine and material.

3.2 Estimating model

IHKU-Alliance estimating model is designed to create a calculation application that uses the common structure on infrastructure information nomenclatures of 2015 as their basis. The nomenclature itself is too detailed and heavy to work on its own and due to fast development of digitalisation in construction it is starting to be partly outdated. The logic of the IHKU-estimating model is to create a stripped down, functional version of the nomenclature logic. It builds the estimating of resource costing by naming construction phases by nomenclature identification. The construction phases are detailed into necessary production components by their resource types (IHKU, 2019). These are accounted by their standard of costing. Interviews are conducted with contractors, designers, and consultants on the basis of how the current tendering process works and what type of development do they see necessary. This feedback is implemented into the IHKU-estimating model. The process is depicted below in figure 1.

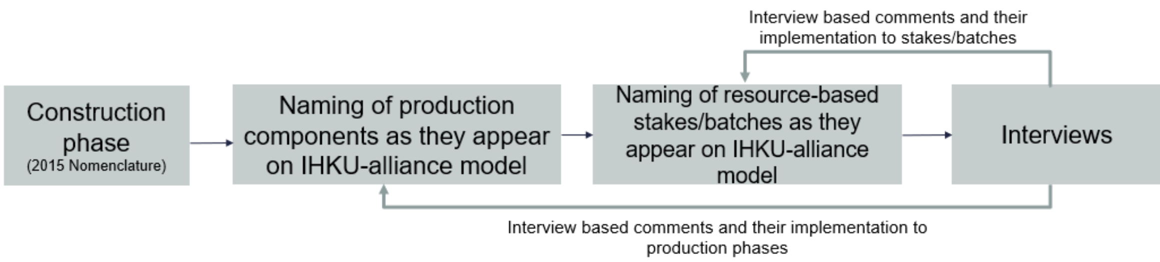

Figure 1. Process of development implemented on the modelling process for the IHKU-estimating model (IHKU, 2019).

The given feedback creates a picture of what information is current and necessary to form a costing estimate of construction phases. These are made from production components that are formed from inputs of resource-based stakes/batches. Initially, unit prices for construction phases may also be used, which will be specified on the basis of inputs of resources. This is common in tunnelling phases as many of the tunnelling phases are measured by their productivity or consumption of materials.

The contents of the nomenclature titles are deconstructed in the model by the structuring viewed in figure 2. Contents of construction phases: production components and further resource-based inputs contained in the production components (IHKU, 2019):

- Inputs (labor, machine and material costs)
- Input prices (labor, machine, material prices)
- Unit prices where applicable

Nomenclature ID number	**Infrastructure 2015, Nomenclature titles**
1500	**Rock grouting and reinforcement structures**
1510	Rock grouting injections
1511	Injected rock structures
1519	Other rock injections
1520	Mechanically reinforced rock structures
1521	Rock bolts
1522	Rock anchors
1523	Mesh structures
1529	Other mechanically reinforced rock structures
1530	Shotcrete structures
1531	Shotcrete surface structures
1532	Shotcrete drains
1539	Other shotcrete structures

	Construction phase
1510	Rock grouting injections

Production component
Long hole

Production component
Grout injection

	Resource-based stake/batch
Long hole	Mining Jumbo
	Workforce

	Resource-based stake/batch
Grout injection	Grouting equipment
	Workforce
	Grouting material

Figure 2. The deconstruction of nomenclature titles and their construction phases to production components and stakes/batches (IHKU, 2019).

As the feedback that arises from the interviews is more detailed than the structure in the estimating model, a conduct guideline is created alongside the estimation model. These advices the user of the application in the finer details of said construction phases being calculated. Lists of different types of material options to additional options of estimation, dependent on type of project are included. Feedback is viewed in this chapter by their nomenclatures and the results in the models and changes by interviews feedback is presented in chapter four.

For the estimating model to work it requires that the construction phases and their production components are duplicable from a project to another. If the duplication of the production components is too general, so are the costs estimates of their stake unit prices. The input of data must able the model to create enough identification of a project that the cost estimate is accurate. In other words, if the resources, their consumption, or efficiency is too general, the cost estimate does not give the desired transparency of costing. The tunnelling phases create a challenge in this sense, as their designs are unique to each project. To ease the modelling, a few various examples of the same production phase are created. They represent the different common variations of the construction phase. By altering the input data of these variations, it is possible to get a more precise estimate as with only one options

3.3 Interviews

Interviews were conducted during February and March of 2020. Invitation were sent to all of the largest contracting and design companies operating in Finland. Additional to them also representatives of developers were interviewed. Majority of them are working as independent consultants. The representatives differ from designers as their task is to advocate the interests of the client. They do not provide design as much, but they control the quality and economic interests of the client. The objective of the interviews was to discuss the current situation in competitive tendering as well as problem areas in bidding and contractual invoicing. The interviews were made in an order so, that contractors were interviewed first. Second designers and third developers' representatives. Discussions were carried out by going through a list of questions which were targeted by addressing competitive tendering as a whole, then 1500 rock grouting and reinforcement structures, 1700 Rock excavation and tunnelling, and finally 4510 Protective and damping structures. The interviewed parties were the following:

- Contractors
    - Kalliorakennus-Yhtiöt Oy
    - Skanska
    - YIT Suomi Oy
    - Destia Oy
- Designers
    - Sitowise
    - Ramboll
    - Sweco
- Developers
    - Minna Alantie, Länsimetro Oy
    - Seppo Janhunen

The questionnaire of the interview was sent in advance to all parties. The questions were designed so that contractors were sent separate questions to designers as the questions were focused more on their independent expertise. The feedback of those interviews is covered in the following sections of chapter 3. Results and effect on the estimating model are viewed in chapter 4.

Questions for contractors were the following:

- Competitive tendering

1. Is the material attached to the competed tenders generally sufficient?

2. If the material is lacking necessary information, is it repeatedly the same?

3. If so, what?

4. What are the biggest challenges currently in calculating bids?

5. Is there any feature in the current bidding model that distorts pricing?

6. If something distorts pricing, what?

- 1500 Rock grouting and reinforcement structures

7. Injection Grouting. Is the current billing basis good? If not, how do you think it should be developed?

8. What do you think is the minimum resourcing for injection?

9. Work safety bolts, is the current billing basis good? If not, how do you think it should be developed? How does the application of bolts vary if they are systematic versus sounding in this context?

10. Permanent reinforcement bolts, is the current billing basis good? If not, how do you think it should be developed? How does the application of bolts vary if they are systematic versus sounding in this context?

11. What do you think is the minimum resourcing for bolts?

12. Shotcrete. Is the current billing basis good? If not, how do you think it should be developed?

13. What do you think is the minimum resourcing for shotcrete?

- 1700 Rock excavation and tunnelling

14. Is the current pricing basis correct? If not, why not?

15. Minimum manning to be taken into account in the calculation:

    - Open excavations
    - Rock channels, pits, and depressions
    - Construction and bridge excavations excavated into the rock
    - Underwater rock cuts and trenches
    - Post-treated rock surfaces
    - Underground rock facilities
    - Holes and wells drilled in the rock

- Protective and damping structures

16. Structure of the pricing criterion in the calculation:

- 4513 Vibration damping structures
- 4519 Other damping structures

Questions for designers and developers were the following:

- Competitive tendering

1. What input data do you have available at the time the cost estimates are prepared; i.e. how does the calculation differ from the contractors' bid calculation?

2. If the material is lacking necessary information, is it repeatedly the same?

3. If so, what?

4. What challenges do you have in estimating the cost of tunnel projects (or those building components) in the design phases?

5. Is there any feature in the current bidding model that distorts pricing?

6. If something distorts pricing, what?

- 1500 Rock grouting and reinforcement structures

7. Injection Grouting. How do you think it should be developed?

8. What do you think is the minimum resourcing for injection grouting?

9. work safety bolts? How do you think it should be developed? How does the application of bolts vary if they are systematic versus sounding in this context?

10. Permanent reinforcement bolts? How do you think it should be developed?

11. What do you think is the minimum resourcing for rock bolts?

12. Shotcrete. How do you think it should be developed?

13. What do you think is the minimum resourcing for shotcrete?

- 1700 Rock excavation and tunnelling

14. Is the current pricing basis correct? If not, why not?

15. Minimum manning to be taken into account in the calculation:

    - Open excavations
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    - Construction and bridge excavations excavated into the rock
    - Underwater rock cuts and trenches
    - Post-treated rock surfaces
    - Underground rock facilities
    - holes and wells drilled in the rock

- Protective and damping structures

16. Structure of the pricing criterion in the calculation:

- 4513 Vibration damping structures
- 4519 Other damping structures

3.4 Competitive tendering

During the conducted interviews, the feedback on the tendered bidding phase followed the same critique from all contractors and designers. Even though they were giving feedback from two different points of view the message was the same. As contractors are the bidding party and designers are contracted by the developer to assign the needed information for tendering, the similarity of feedback gave a picture that the points raised are valid. Firstly, the amount of time given for bidding calculations and covering all the data given was seen as too short in most of the projects (RATU, 2018). There was a suggestion of separating the overall informative segment of the project form the technical part, into two different documents. By doing this the technical data which effects the bidding calculation more, is separate and not hidden in the large amount of 'nice to know' general information of the bidding project. Another time effected issue was the time reserved for extra questions and clarification which most projects and contractors need to make their bid. In most cases this was more or less a week at the end of the bidding period. As the extra questions submitted to the client developer side and through them to the designers were inside a week to the deadline it did not leave enough time for thorough research of the questions. Answers were rushed and, in many cases, just a comment of 'please look at material submitted with tendering request'. Especially as in most cases the reserved time for decisions after the tendering is the same as bidding.

Another problem area for bidding calculations are the reserved quantities list of materials and amounts which are delivered as a part of the bidding contract. This list is an estimated minimum of consumption of products and consumed advancement in production. In other words, with the bidding information there is provided a list of construction materials such as rock bolts, anchors, steel nets etc. As well as consumed advancement quantities, such as amount of shotcrete and excavated cubic meters of rock. The safety factoring of these amounts and tendency of playing safe with estimates makes these reservation quantities large. Due to this fact they have a financial aspect for resourcing. Larger the amounts, smaller the unit prices. This brings a strong speculative aspect to the bidding process. As all of the reserved quantities are larger than intended, it is up to the contractor to estimate which of them can be gambled with pricing that is cheaper than in reality. In other words, contractors will estimate which of the required materials and quantities and amounts are close to the truth and which are over estimated. Pricing the units that they suspect to be realized in full with correct prices and the overestimated ones with cheaper pricing. This creates a risk for the contractor. As they speculate with the consumptions, and if the true consumption is larger than expected this can cause financial problems for the project. In worst cases make the whole endeavour barely profitable or even nonprofitable (RATU, 2018).

As these reserved quantities are larger than expected it creates a problem of timetabling as well. When contractors estimate the overall duration of the project, they base it on the given information from the developer. After this they need to speculate parts of the duration and create an estimate on true duration. This affects the fixed costs of the project and ties resourcing up. If the duration of the project is radically shorter or longer than estimated, it still only effects the contractor. Fixed costs do not have a possibility for profit for the contractor. Even if the duration is shorter than expected. Through general terms of contracts, the developer has an option of cancelling the accumulation of costs to the same timetable as the ending of the project. By this, the fixed costs do not provide help, even if rental costs for example are agreed by the contractor with the original timetable. If timetables are longer than estimated, but in the scope of the general contract, the loss is completely to the contractor. The more detailed content of the bidding information and a shared risk of reserved quantities could better prevent an unbalanced estimation of fixed costs (RATU, 2018). When unit prices can be made closer to the truth, less risk there is with over timetable as well.

3.5 1500, Rock grouting and reinforcement structures

3.5.1 Injection grouting

In the conducted interviews, the topics concerning rock grouting and reinforcement structures made up most of the conversation. Designers and contractors saw that this is the nomenclature group that has the most need for development. The nomenclature group is made up from three main structuring phases of construction. Grouting, rock bolts and shotcrete structures. Injection grouting can be made either as a preliminary or post-excavation phase, rock bolts are made either as a work safety phase or permanent reinforcement structure and shotcrete reinforcements are as well, either a work safety phase or permanent reinforcement (Stille, 2015). What all three of the structuring phases have in common is that they are a pacing phase of work. It can slow down or even prevent the conducting of other construction phases. By doing this, they are crucial parts of tunnelling and effect timetabling. They can make or break targets and are difficult to estimate due to varying quality of rock.

For injection grouting phases the largest discussion came from the newly implemented invoicing criteria that has become the common practice in tunnelling. With the West Metro 1 (Länsimetro 1) project, which was one of the largest single projects in the near history, injection grouting was invoiced only by consumptions. As the most common Stop criteria for grouting is Max pressure or volume, the pumped volume of grout was the easiest and safest unit of measure that could be used as documentation for invoicing. What the invoicing came down to was a matter of trust. Does the client organisation trust the invoicing of contractors? Injection grouting can be made preliminary or post-conducted. As the decision for grouting varied from work site to work site under the West Metro 1 project the manner of how systematic this grouting phase was varied as well.

A team of workmen designated for this task is reserved for operations for the whole duration of tunnelling. The costs of labour would run day to day for contractors, did the team produce any injected volume for invoicing or not. As the injection grouting has initial task such as moving to site of grouting, setting up of equipment, mixing of grout and transportation of material this takes time, and is not calculated into the invoicing. The injection grouting has maintenance tasks as well, which must be conducted after a designated site has been grouted (Stille, 2015). Cleaning of pumps, lines and packer equipment must be done otherwise the equipment will not function properly during the next round of grouting. If grouting is made only from the point of necessity or if systematic grouting is made on a tunnelling site that has only a few faces that can be worked simultaneously, the amount of un-billable hours can create a large amount of total labours costs. As the projects are handed out through competitive tendering, the lost costs of pre- and post-task cannot be calculated into the volume cost of grout. The amount of collateral costs in injection grouting is completely speculative when calculating costs during bidding. If the costs during construction become higher, contractors will designate the extra costs somewhere else, such as fixed costs of operation. This will create a situation where grouting costs are not current, and neither are fixed costs. The contractor is invoicing true amounts of costs but with false labelling and the client is paying true costs but doesn't have a clear understanding on how they are accumulated.

Before West Metro 1, the collateral costs were invoiced, either by a fixed unit cost per mobilisation of grouting team or by hours. The manner of invoicing that changed with the Metro project stayed as the new normal. Perhaps the worry of overbilling in collateral hours created the initial change, but what it mainly created was a situation that the public sector, the client, wanted to avoid in the first place. Now no hours are invoiced, but they are calculated into some other cost. The loss of trust in invoicing created more mistrust and misuse of agreed practices. It is only human for contractors to create demand for volume of grout if that is the only means of income in that phase of construction.

Designers do not see the current normal as the best means of conduct either. Even though, their view is from another angle, the end result is the same. A better and more clear practice for everyone involved. As the competitive tendering creates an unbalanced evaluation of costs, all contractors are looking for the most inexpensive way to perform all phases of construction. This creates web of subcontracting that is built when looking for savings. In some cases, this doesn't promote the best practices in construction. The cheapest option is not always the best. Because of this consumption is not a healthy measure of costs. The intended Stop criteria is misread or misused. Due to this, designers see the analytical GT-method more useful. Grouting Time-method is based upon the relations between grout penetration and grouting time. With this the grouting becomes systematic and the collateral costs are easier to calculate. As the GT-method is dictating the amount of grout injected, it leaves less of the decision to the workmen in the team. This gives more security for the client in the sense of necessity of invoiced consumption, as well as a base of reasoning for contractors. Contractors do not need to justify their invoiced volumes as much, as they are consumed with a pre-set penetration requirement.

GT-Method does require for more thorough evaluation of rock during tunnelling. As the quality of rock is dictating the needed grouting time to reach the targeted penetration, a geologist or geotechnical engineer must be available on-site to make the necessary evaluations and calculations. This does create more costs on its own, but they are transferable into other phases of tunnelling as well. It is quite common that the engineer or geologist making evaluations is not working on one site alone. Usually they have multiple sites that they oversee. This creates a delay in decision making. Not only in grouting-based questions but other as well, such as safety bolting. If an on-site engineer or geologist is available, the real time decision making compensates for the additional cost of labour. Most probably the effect on timetables creates more benefits for both client and contractor. This speaks in favour of splitting the costs between both parties. Creating a possibility for effective use of the GT-method (Hollmen, 2007).

The estimation of costs and the conflict of interests that has been created around injection grouting seems unnecessary. As the premises of creating criteria for invoicing is to prevent unnecessary costs and misuse of trust, creating a set of rules that are unprofitable, fight against this. As the use of resources is a direct line of costs for a contractor, they will always seek ways to receive compensation for all their losses. As the aim of the public sector is to create an equalizing and transparent system of commerce, the basis of invoicing should make compensation without prejudice possible. Competitive tendering was originally built for this purpose, but it is back firing on its original purpose when the trust between parties is missing. Even though the volume-based invoicing of injection grouting is an effective and simple means of calculation and easy to mimic from worksite to worksite, it leaves too much room for speculation and estimation.

3.5.2 Rock bolts

Rock bolts are a vital part of tunnelling works, as they secure safety during excavation and create permanent reinforcement of rock mass. As the function of rock bolts is to conserve inherent strength of the rock mass by attaching loose rocks to solid rock surfaces it creates structures which are self-supporting (Li, 2017). Rock bolts are a pacing phase of tunnelling that has made strong opinions and polarization between contractors and clients due to the terms of invoicing in contracts. They do not give much room for distribution of costs between the parties involved if delays due to bolting are longer than anticipated. When interviews were conducted for this research, the topic of rock bolts in contractual estimation had the strongest show of feelings and opinions.

As rock bolts are made either as a work safety phase or permanent reinforcement structure it creates time-effective parts of excavation, either before scheduled excavation or after. Work safety is a vital aspect of construction that is a strongly emphasised during tunnelling. This makes work safety rock bolting a daily occurrence. Contractors see that economical decisions have affected the practice of how safety bolting is exercised in tunnel work sites. Rock and geological mapping of the planned tunnel are made to cover the whole site area but are educated estimates of the quality of rock (Li, 2017). Because of this fact, the estimation of costs is speculative beforehand. The need for safety bolting is realized only during the excavation as the tunnel advances. Especially in sites where the tunnelling is made with only a few drifts or where environmental permits restrict the work hours during the day, this creates problems. The pacing aspect of safety bolts stops the scheduled advancement of excavation and delays the total timetable of the project.

As mentioned, the outdated aspects of the general terms of contract such as the development of design- and contractual terms after bidding, make negotiations in these circumstances difficult. The reserved quantities list which is usually created for projects has an abundance of rock bolts reserved for this type of work. When the competitive tendering was made, contractors had to make an estimate of consumption which created their opinion on pricing (Li, 2017). All this is made on the information that is provided of the upcoming project. When the speculative amount of work safety bolts realizes to be larger than anticipated, contractors have to perform rock bolt phases on a lower price than originally intended and creating more delay into their timetable than originally planned. An argument against this can be made on the assumption, that the bolts already were reserved in the list of materials. Contractors see that this is an unfair way to create demand for material, as a large proportion of the reserved materials is not used. What this means is, that all materials and measurable quantities are listed with high amounts and safety factors are calculated into all of them. If calculating a bid for the contract with a realistic pricing of all the materials and quantities, the bidding price of the contract would go too high. As mentioned, this will create a dilemma of what to calculate below informed amounts (Li, 2017). Rock bolts are a large expenditure for contractors. Usually this is one of the heavily speculated aspects for bidding. Due to this, it is always a gamble how well you estimate the need for pacing rock bolt works. If the gamble goes wrong and the contractor is forced to make more safety bolting, they carry the risk and cost alone. General terms of the contract are in this case on the side of the client which references on the pre-requisite list of materials reserved.

This creates once again the dilemma for contractors where they are faced with costs that are unavoidable but cannot be invoiced for their true purpose. So, costs are once again designated into fixed costs of the project or other flexible parts of the contract. In a blog during September of 2019, Kari Kauniskangas; the CEO of YIT construction company voiced his opinion on this exact problem. He stated that the unrealistic timetables for projects and the speculative aspect of competitive tendering has created a confrontation between good quality of work and fines for tardiness. He stated that fines for tardiness are calculated into the bidding price for a contract. Basically, contractors already know before commencing a project that they cannot carry it out in the agreed upon timetable. Due to this fact, prices of contracts are higher than intended and the total costs frame of a contract is off balance.

Another costly effect of pacing rock bolts are the question of demand. In the interview's contractors voiced their discontent on the uncertainty of procedure. The demand for work safety bolts is made by sounding of drifts. Contractors wish that the demand should be voiced as a systematic procedure after the results of the onsite geotechnical investigations are made. This means that when proceeding to reinforce loose rock mass with safety bolts, the drift must be executed from start to finish in one phase (Li, 2017). The contractors see that too much follow up due to lack of co-operations and discussion is done to drifts which have already once been reinforced. The repetitive need for work safety bolts into areas which are already once geotechnically investigated and executed, disrupts the timetable numerous times. A reason for this is the unclear chain of command in the sounding procedures. The need for safety bolts is established by many individuals. Representatives from the client, design and contractor are all making their own assessments of situation. Due to the fact that all of these individuals are rarely working on one site alone and rarely making decisions together, the need for rock bolts is numerous. If all of these work phases are pacing the construction, they effect the timetable each time.

Permanent reinforcement was not seen as a problem by contractors. The systematic nature of permanent bolting makes their cost calculations and speculation of consummation more effective. The procedure works and contractors did not see any need for changing the procedures from what they are at the moment. Designers saw that only question that needs to be addressed more in depth is the correlation between work safety bolts and permanent bolts. Clients tend to regard temporal work safety bolts into the amount of permanent reinforcement rock bolts. If this is the case, more detailed instructions must be created on the installation premises of work safety bolts. The effects of the distance of work safety bolts to close by blasting must be studied more in detail and the use of passive or active bolts should be directed with set rules of conduct through these studies. (Li, 2017). Contractors see that there are as many opinions on bolt materials and their functionality as there are supervisors on sites. The preferences of the supervisors can affect the application of bolts with effects to the consumption and costs that differ from what was originally anticipated. Concern of the modelling parameters for bolting phases was discussed as well. As bolts are ordered for delivery to site during construction and the amounts vary from month to month, so does the price of bolts. The price is heavily dependent on the price of steel at the time of purchase, and even though contractors try to foresee drastic changes and order in advance it cannot completely cancel out the variation in pricing.

3.5.3 Shotcrete structures

Shotcrete structures brought the most comments from the designers during interviews. Both designers and contractors did not see the logic of work safety shotcrete and permanent reinforcement shotcrete structures being calculated as two separate structures. This gave in their eyes too much overlapping and addition thickness into the reinforcement structure. Designers saw that the work safety structure can be calculated and taken directly into the permanent reinforcement structure. The worry of blasting causing damage into the work safety layer and thus not being able to be a part of the permanent reinforcement was not seen. The studies of concrete aging unproperly due to vibrations has not been studied enough for it to be excluded from the calculations (Hoek et al, 1993).

Another aspect which was seen odd by designers and contractors was that during West Metro 1 project it became common to use steel fibre shotcrete for work safety layers but the plastic fibres for the second permanent reinforcement layer. From then onwards this had slowly come the new normal which was preferred by clients. Designers did not see the logic behind this as an effective means of conducting reinforcement. With the same effect it could be constructed with the same fibrin and quality, allowing for more systematic use of shotcrete delivery (Hoek et al, 1993). When all loads of shotcrete are of same quality they can be used in all drifts and shotcrete phases. The reason for using both fibres in layering did not become completely clear. The economic effects of this are larger than using the same fibre. Not only is steel fibre more expensive as plastic fibres but the mixing and spraying process must be done separately. The effective use of resources loses effect due to this. What this means is if two or three shotcrete teams are working simultaneously on the worksite, but in different phases of reinforcement the delivered loads of shotcrete can be designated more flexibly between the teams. If one is being delayed but another is not, the delivered shotcrete can be redirected to another team. If using two different types of shotcrete fibrin the delay is affecting the transported loads more directly and may cause pileups at the site.

Contractors agreed with the comments of designers when being presented to them. They reminded as well of the cost-effective aspect of reinforcement. When designing the layering with combining the calculated thicknesses of work safety layers and the permanent reinforcement layer, the work can be made systematically and so that large areas can be sprayed with the same thickness of shotcrete. More difference there is in thickness of shotcrete in smaller areas, the more tedious it is to apply (Hoek et al, 1993). This making it slower and more expensive for the contractor. They agreed that the common consumption of shotcrete is the best means of invoicing. As long as it is logically distributed.

3.6 1700, Rock excavation and tunnelling

The invoicing and cost summary of the excavation and tunnelling work phases did not create much discussion. Both designers and contractors were happy with the model as it is. This can be due to the fact that this is the core of tunnelling phases. The excavation is simplified into a quantity-based cost where the advancement of excavation creates the basis for invoicing. Either by cubic or square meters. Suggestions were raised that in tunnelling works cubic meters as the primary unit of measure works the best. Future development of estimation should be focused on the differentiating of excavation sites by scale, according to contractors.

What this means, is that contractors see the difference of costs become with the requirements set by the challenges of each site. The assigned parameters of demand though construction rating C-B-A-AA have direct effect on pricing. As some larger sites can be operated with multiple drifts simultaneously, they can accumulate invoicing criteria more efficiently than sites where only one or few drifts are being worked at the same time (Vuolio & Halonen, 2012). This means that the accumulation of quantity brings more invoicing in these sites. They do not need as much working capital to operate as the invoicing is larger than on smaller sites. As the fixed costs and resourcing does not grow in the same proportion it makes the financial stability better. Due to this fact, contractors suggested that the invoicing should be tied in relevance to the amount of drifts. A correlation factor that is added by the difficulty of utilizing resources designated to the project. This would incentivise the developers as well, as more systematic means of excavation create more effective and economical means for construction. This in turn keeps the timetable in check and additional costs to a minimum.

3.7 4510, Protective and damping structures

3.7.1 4511, Noise barriers

These structures are unique, and custom fitted into their required positions in tunnelling projects. They are in all cases that the interviews showed, ordered by the developer themselves. They are separate projects on their own and directly calculated as a unit based invoicing work (RIL, 2010).

3.7.2 4512, Noise railings

Where noise barriers are walled structures which absorb or reflect traffic noise, these are mainly used in subway sites in tunnelling projects and near bridges and highways in open excavations. The walled structure is dependent on the area and amount of decibels that are required to be blocked. This makes each barrier a custom construction and invoiced by metric unit (RIL, 2010).

3.7.3 4513, Vibration damping structures

Noise railings are targeted into areas where noise barriers are too large to be constructed or the amount of decibels is small which need to be blocked. These seem to be quite rare in tunnelling sites. If used, they are found in subway tracks dividing junctions or segments of platforms from each other. Metric unit invoicing is used (RIL, 2010).

3.7.4 4519, Other damping structures

Other damping structures are used when sensitive instruments or other structures are near blasting sites. They are invoiced either by kilogram of the structure that requires damping or by square meter of area (RIL, 2010).

4 Results and discussion

4.1 Competitive tendering

An option on fixing the time constraint issues of the tendering period as well as the oversized lists of reserved quantities is to create a more co-operative system to the design and structuring phase of a project. From all three parties involved in the process, developer, designer and contractor; a more involved participation into the preliminary phases of construction was hoped as feedback. What this meant, was that the co-operation during preliminary phases of a project was seen as lacking at the moment. If feedback, ideas and suggestions were made between all parties involved, the transparency of costs would be more easy to create. From this point of view, the tendered bidding does not necessarily have to extend all the way to the finalisation of quantities and pricing. With a more transparent estimating model such as the one in development by IHKU, the cost structuring of construction phases is the same for all parties. With this, the competitive tendering of a project can be made to create a base line for agreed costing. This meaning, that the competitive tendering is to create an understanding on the base line costing of a project. Contractors compete to bid for a preliminary estimate of total costs, or average unit pricing. By a uniform estimating tool, the client can choose an offer closest to their estimate. From here onward, the finalization of costs, not dependent on contract model is made from design information in co-operation. This helps to create a more detailed and truthful cost estimate where resourcing and timetables are up to date and with all information in use (RATU, 2018). The development of the competitive tendering process is visualized below, showing the effects in development.

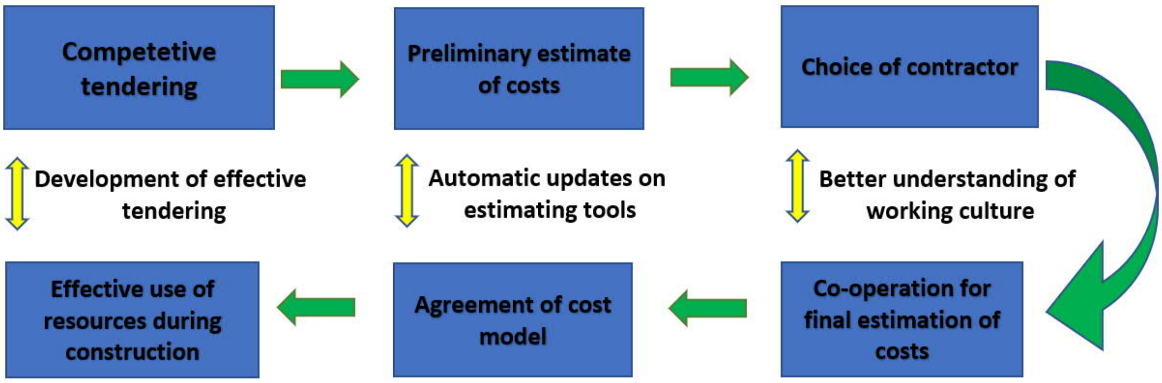

Figure 3. Development of competitive tendering with impact of development.

With this the estimation tools can be developed by project to project. What this means is that by creating experience in joint estimating, the target of creating an open and transparent estimating model will create development and efficiency on its own. The incentive to find effective resourcing is a target that benefits all parties. As many of the issues for contractors are timetable problems where inefficient use of resourcing or overestimated construction phases create costs that cannot be invoiced truly. This can lead to wrongly placed costs that unbalance the project. Effective resourcing cancels out many of these problems.

By taking an active part in the preliminary phases of the project, contractors can give their individual feedback on the construction phases. This creates a dialogue between designers and the contractor on reserved quantities and their effect on the company's individual capabilities. As mentioned previously the strengths and weaknesses in each project are individual with each contractor. They create the costing of the contract by choosing the areas where their resources are most effective, pricing them lower and pricing more challenging parts of the project more costly. If this identification is made with the designers, the construction phases and their methods can be made so that they fit better into the agreed upon base line costing. This creates more room for surprises in the timetable and takes away the financial risk from one party and divides the responsibility more fairly. Visualized in figure 4, the benefits of early on co-operation can bring effective use of resources to contractors, which in return lowers costs. With open information, the costs can be open to both parties as well as the understanding of methods. The largest reason found in the interviews for uneven cost responsibilities is due to the lack of trust in invoicing. If the methods and costing criteria are more unanimously agreed upon, the less of a risk is seen by all involved (RATU, 2018).

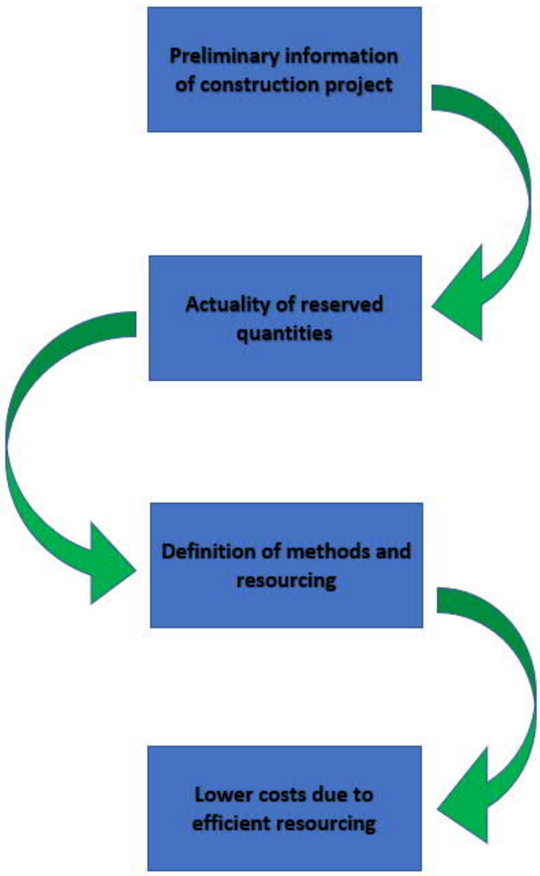

Figure 4. Positive aspects of co-operation during preliminary phases of design.

This method of co-operation does not exclude any of the contract types. The dialogue of costing can develop either unit pricing, pricing of construction phase extras, additional work hourly invoicing to name just a few. This does not depend on projects sharing costs between developers and contractors, it is only an agreed rule of cost estimation customized to the demands of said project and location. For this to work in modern legislation, this development of the general terms of contract (YSE). The dated version does not allow the contract terms and pricing to be agreed after the tendering period by parties involved. This basically means, that the pricing terms of the general scope of the contract must be agreed upon at the point tendering conclusion. It sees that the parties that have made bids but not chosen are placed in a disadvantage at this point if the pricing is developed after choosing a contractor. Legislation sees that if the content of contractual pricing is developed after the bidding phase, the contractors which lost in the bid, could not alter their bidding with the new information presented. The reasoning behind this is that the pricing is made in a competitive state. Here the content of costing is made as a bid, not making its formation transparent. If this can change, into a more open costing model, the disadvantage ceases to exist (RATU, 2018).

4.2 1500, Injection grouting

As grouting injections are one of the crucial phases of tunnelling construction, finding a constructive compromise in how the phases are invoiced is crucial for transparency. Especially as this phase is usually a pacing construction phase. Without a beneficial set of rules for all parties, the costing is not designated correctly during construction. With allowing all costs to be allocated into the production components of grouting the implementation of the estimation model will work better. This allows to create the desired transparency for estimation modelling. The steppingstones in this phase is creating an effective guideline that takes comment on the timetable and invoicing issues. This far the invoicing has been mainly made by the basis of quantitative billing. Not to take away from this, but to add to a working system, the interviews made a uniform suggestion of adding old policies to new ones.

The lost hours of preliminary and maintenance work, which is included into the daily tasks in grouting, need to be included back into the invoiceable production phases of grouting if transparency of costing is wanted. If this is not done, the lost costs will be placed somewhere else. In the interviews a suggested 2 hours of additional labour hours was a common compromise. This should be added to each starting phase of injections. This mainly affects the preliminary injections. Additional to creating an actual basis for estimation model, it incentivises the developer side to put more taught into their systematisation of grouting works. Additionally, the GT-method should be taken more effectively into use (Hollmen, 2007). It allows to make more effective planning of human and physical resources. The time-concept makes it possible to utilize geological mapping in construction phase timetabling more efficiently. When estimating the construction site quality of rock, this makes it possible to evaluate grouting time per drifting meters. In figure 5, shown below, the effects of the improvements suggested in the interviews are visualized at different stages of design and construction. The added amount of information and systematic grouting will eventually create less costs and more efficiency.

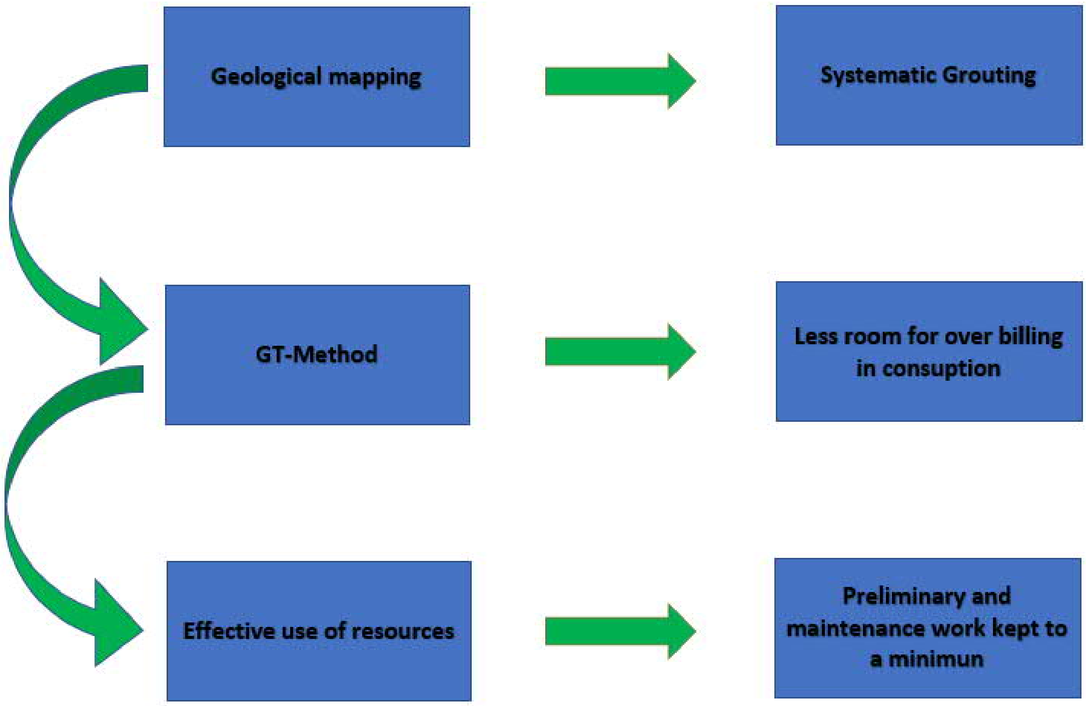

Figure 5. Effects of suggested improvements into grouting invoicing methods.

The estimating models for grouting phases posed some difficulty in finding average quantities or qualities that can be applied in estimating. As the tool is designed to create a model that can be applied into majority of projects, tunnelling phases are very difficult to implement into this concept. Compared to other infrastructure construction phases tunnelling phases are unique. Their construction is dependent on the quality of rock and restriction of space and time, and this can be variable by tens of meters in one project. Additionally, the personnel making the estimations are not necessarily the designers involved in the planning process. Due to this fact, the options in the model must be easy to access and use. In the mindset that the estimating engineer is not a professional in tunnelling construction, but more in the costing estimation.

The modelled estimation of injection grouting is visualized below in an example of construction phase. Here the nomenclature of 1511.1 Grout injections in rock, cement grouting of rock structures, moderate quality rock is in the form of excel data that is passed on to the coding department. The data that they receive is given in the depicted calculation format. Here the productions components are divided into stakes/batches and their resource grouping. These have their pricing units and consumption rates. These units will be calculated by the efficiency of the production component and receive a production component unit price. This will give a stake/batch-oriented unit price that creates the estimation of the construction phase.

1511.1	Grout injection in rock, Cement Grouting of rock structures, moderate quality of rock (Cement grouting 38 kg/dhm)	
Production component	**Stake/Batch**	**Resource**
Drill hole, by Jumbo	Drill Jumbo	Physical
	Workforce	Human
Grout injection	Injection-machine	Physical
	Workforce	Human
	Grout, cement	Material

	Stake pricing €/Unit	**Resource / material consuption**	
80	rental-hour	1	pcs
40	labour cost per hour	2	pcs
50	rental-hour	1	pcs
40	labour cost per hour	2	pcs
0,55	kg	38	dhm

						drilled hole meter (dhm)
	PC-efficiency	**PC-unit price €/unit**	**PC-unit**	**PC-multiplier**		**unit price €/dhm**
30	dhm/h	2,67	dhm	1,00	dhm/dhm	2,67
30	dhm/h	2,67	dhm	1,00	dhm/dhm	2,67
500	kg/h	0,10	kg	37,50	kg/dhm	3,75
500	kg/h	0,16	kg	37,50	kg/dhm	6,00
	dhm	20,63	dhm	1,00	dhm/dhm	20,63
						35,71

Figure 6. Example of a modelled estimation of injection grouting nomenclature 1511.1.

The model is divided into three types of rock quality, labelled in layman terms of good, moderate, and poor rock. The rock quality is estimated by the Q-system categorization. As the users of the estimation model do not themselves know the Q-system, the 9 sectors of quality presented in the Q-system are put into these three layman terms as follows. Poor rock has grouping G,F,E (exceptionally-, extremely- and very Poor rock), Moderate rock has grouping D,C (poor and fair Rock), Good rock has grouping B, A (good, very-, extremely- and exceptionally good rock). The amount of grouting is estimated as an average of the grouping. They are made by the amount of grout consumption per meter of bored long hole. The information made available in the preliminary phase of the project allows to create an estimate of the rock quality and by this the amount of consumed grout. With this the GT-method allows the estimate of invoicing per consumption, and the use of systematic grouting the starting times of the construction phase can be calculated. Even though the quality of machines used for drill holes or injection vary from contractor to contractor, it is estimated that the same amount of time is consumed to drill a certain amount of drill hole meters as it is to inject grout into them. An agreed average by all contractors in the interviews was 30 drill hole meters per hour (Hollmen, 2007). This is with a 3 man and machinery team.

The physical and human stakes of grouting are dependent on the amount of grout consumed per meter of long hole. As this is the unit of measure. The fore mentioned 2 hours of additional labour cost per starting of construction phase cannot be directly added into the cost of unit in measure due to the differences in sites. By the estimated need for systematic grouting at a certain site, this cost is to be added as an extra cost. The long hole boring is a part of the injection grout process, but not a calculated cost measure. It is included in the model and can be affectedly added as a separate cost especially in additional work phases where hourly billing is applied. Examples of the estimating models for 1500 injection grouting are found in attachment 1, 1500 nomenclature. The unit prices are not applicable as presented in the printed model. They are there as an example. The correct prices are placed later to the model when IHKU-alliance receives current pricing from clients.

4.3 1500, Rock bolts

The rock bolts nomenclatures consist of two main production components. The drilled hole and the bolts structure. As the construction phase is dependent on its permanency and type of bolt structure, the estimating model can be most effective with a distinct separation between work safety and permanent bolting. The construction phase is a pacing part of construction, especially with work safety bolts, the transparent effect of this estimating needs for the costs to be able to be placed in correct areas. For this to be possible the work safety bolting should be investigated and planned in co-operation between the client and contractor. The amount of work safety bolting should be agreed upon by both parties. This amount should be included with a fixed pricing in the contract, all safety bolts that go over this amount and the loss of effective work due to pacing factor of the phase should then be carried by both parties. This incentivises to share and utilize all data available to estimate the quality of rock. As well as the scarce amount of preliminary investigations of the area come to both parties' risk. The co-operation during design and construction brings the transparency and effective use of resources as depicted in figure 7 below. This solves the problem of overbilling as co-operation in design creates transparency of costs.

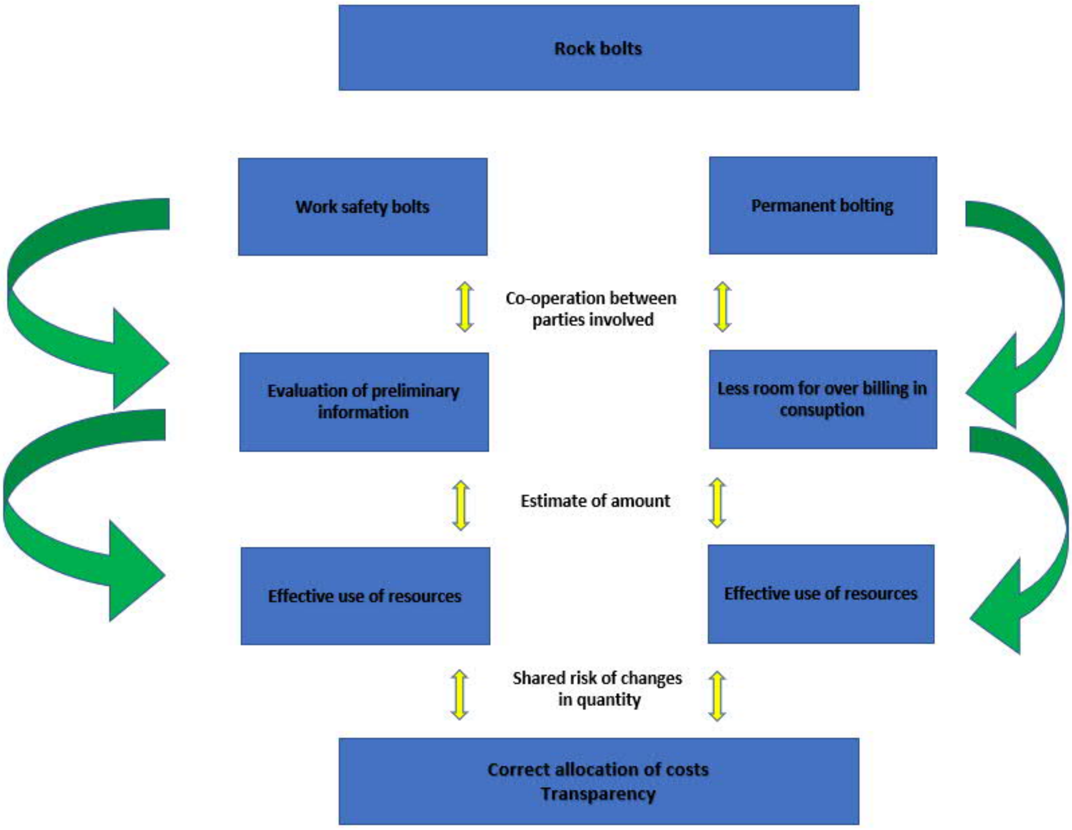

Figure 7. Effects of transparency in Rock bolt nomenclatures.

The estimating model finds the rock bolt nomenclatures best to calculate through the efficiency of drilling and possible grouting of bolts. With this the interviews agreed that the average amount of bolts per hour, not completely dependent on equipment or space for working, is 30 m of bolts per hour. This is calculated with a 3-man team with machinery. As this is dependent on the type of bolt, dimensions of the tunnel and amount of drifts in work simultaneously, much of the estimating must go through designers. Without length of the bolt and the information on conditions for working the estimation will not be accurate. The effects of hourly work are more in play if safety bolts are in question, compared to permanent bolting.

1521	Rock bolts, rebar bolt 3m (example)	
Production component	**Stake/Batch**	**Resource**
Drilled hole, by Jumbo	Drill-Jumbo	Physical
	Workforce	Human
Rock bolt + grout structure	Rebar bolt + equipment	Material
	Grouting machine	Physical
	Lifting machine for workforce	Physical
	Transportation vehicle	Physical
	Workforce	Human
	Grouting material	Material

Stake pricing €/Unit		**Resource / material consuption**	
80	rental-hour	1	pcs
40	labour cost per hour	2	pcs
18	bolt	1	pcs
15	rental-hour	1	pcs
50	rental-hour	1	pcs
50	rental-hour	1	pcs
40	labour cost per hour	2	pcs
0,6	kg	7,50	kg/pcs

						pcs
PC-efficiency		**PC-unit price €/unit**	**PC-unit**	**PC-multiplier**		**unit price €/pcs**
30	dhm/h	2,67	lhm	3,00	dhm/pcs	8,00
30	dhm/h	2,67	lhm	3,00	dhm/pcs	8,00
		18,00	pcs	1,00	pcs/pcs	18,00
60	kg/h	0,25	kg	7,50	kg/pcs	1,88
60	kg/h	0,83	kg	7,50	kg/pcs	6,25
60	kg/h	0,83	kg	7,50	kg/pcs	6,25
60	kg/h	1,33	kg	7,50	kg/pcs	10,00
1	pcs	4,50	pcs	1,00	kg/pcs	4,50
						62,88

Figure 8. Example of a modelled estimation of Rock bolts nomenclature 1521.

The modelled estimation of rock bolts is visualized above in an example of construction phase 1521, figure 8. Here the nomenclature of 1521 Rock bolts, rebar bolt 3m is in the form of excel data that is passed on to the IHKU-Alliance. Examples of the estimating models for 1500 rock bolts are found in attachment 1, 1500 nomenclature. The unit prices are not applicable as presented in the printed model. They are there as an example. The correct prices are placed later to the model when IHKU-alliance receives current pricing from clients.

4.4 1500, Shotcrete structures

A large issue what has kept the work safety layers of shotcrete from being counted into the permanent reinforcement thickness of the shotcrete layering is that the invoicing basis for this has been different for them. In most cases the work safety layers have been invoiced by cubic meter of consumption. The permanent reinforcement structure has been invoiced by the square meter of surface in final thickness. This is mainly for the reason that the final layering is more detailed and has an esthetical aspect that is required additionally to its reinforcement abilities. As both of these are being invoiced the system cannot be fixed so that the same shotcrete is being invoiced twice from the client. Basically this means that if the work safety shotcrete is being invoiced first by the cubic meter of consumption and then it is counted into the thickness of the final reinforcement layer, the cost of the shotcrete will be double for that part of the final structure. The invoicing for this must be calculated so that these two structures even so, that they should be calculated together, are in one unit of calculation for invoicing. For this the most effective is to join both structures into a consumption of shotcrete by cubic meter. The cost for the less defined, crude safety shotcrete areas of reinforcement structures have a a lower cubic meter cost compared to the finely defined upper parts of the shotcrete structure. The final price of the reinforcement structure is dependent on the complete shotcrete design. For one layer to have an effect on total pricing, the application of layers must be systematic. (Hoek et al, 1993).

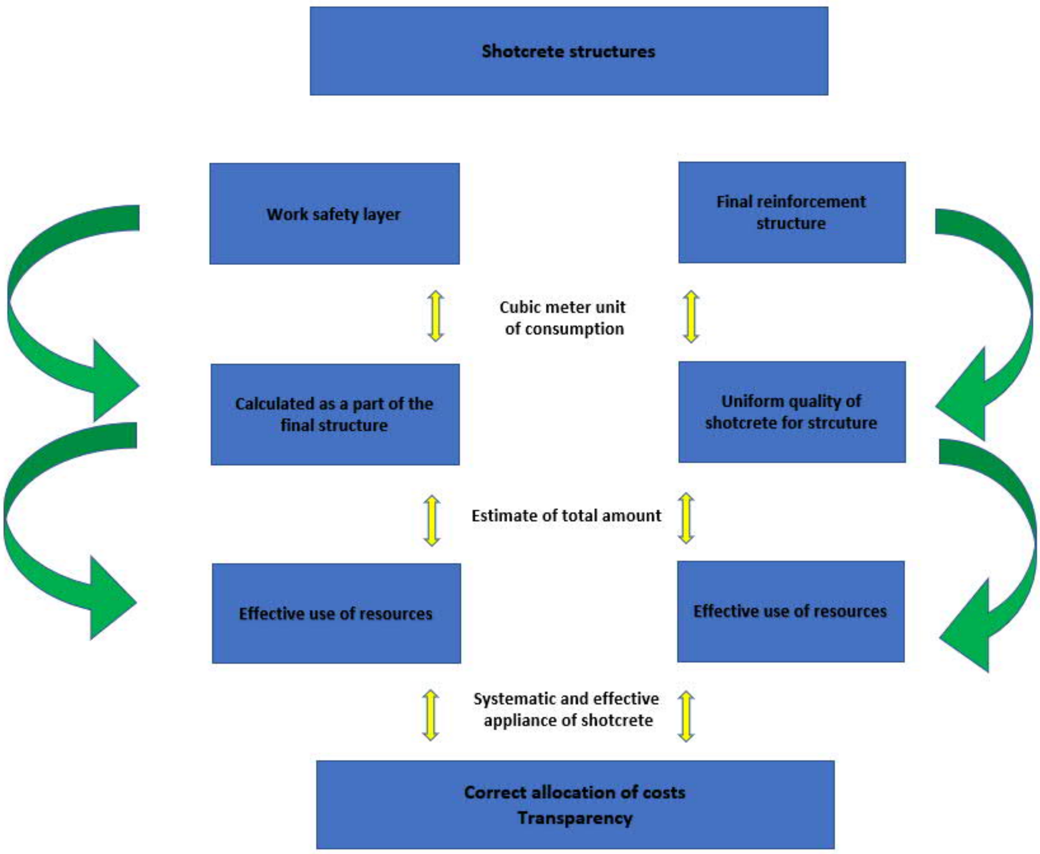

Figure 9. Effects of efficiency in correct allocation of costs in shotcrete structures.

The estimating model for the shotcrete structures was the simplest of the tunnelling phases to finalize. This due to the reason that the production components of this phase are generally straight forward in means of duplicate from site to another. This meaning, that this is one of the phases in tunnelling that works the same way in majority of cases. The estimating model is implemented on the idea that the cost estimations are by the average production efficiencies of said phase of construction. By this, a sprayed layer of shotcrete is duplicable from site to site and the efficiency rates are quite the same.

1531.1	Fiber shotcrete structure, R4 elastic fibre (c30/37 S3 8mm aggregate 5kg/m3 elastic fibre)	
Production component	**Stake/Batch**	**Resource**
Shotcrete structure	Shotcrete robot	Physical
	Workforce	Human
	Shotcrete, incl. Delivery	Material

Stake pricing €/Unit		**Resource / material consuption**	
80	rental-hour	1	pcs
40	labour cost per hour	2	pcs
88	m3	1	m3/m3

PC-efficiency		**PC-unit price €/unit**	**PC-unit**	**PC-multiplier**		m3 actual **unit price €/m3 actual**
6	m3/h	13,33	m3 actual	1,00	m3actual /m3	13,33
6	m3/h	13,33	m3 actual	1,00	m3actual /m3	13,33
		88,00	m3 actual	1,16	m3actual /m3	102,08
						128,75

Figure 10. Example of a modelled estimation of Shotcrete structures, nomenclature 1531.1.

The shotcrete structuring phase is one of the largest labour endeavours in the tunnelling. Due to this the costs of shotcrete make up a large part of the project. It is understandable that the focus on these accumulated is large. The misuse of invoicing comes mainly due to irregularity in systematic use of resources. The less effective hours for labour the more costs there are for the contractor. If the work can be made effectively allowing for areas to be covered either in two parts, safety and final layering, or in one work phase, the cost calculation for competitive tendering is more accurate. Hence, less need for additional costs. In the future, due to the green deal initiative, the use of by-products will become more common. At this point, the pricing of excess shotcrete is included in the cubic pricing of consumption. But in cases where it can be utilized, the pricing of recycling can be deducted from the cubic pricing (Tam, 2008).

The modelled estimation of shotcrete structures is visualized above in an example of construction phase 1531.1, figure 10. Here the nomenclature of 1531.1 fibre shotcrete structure, R4 elastic fibre is in the form of excel data that is passed on to the IHKU-Alliance. Examples of the estimating models for 1500 shotcrete structures are found in attachment 1, 1500 nomenclature. The unit prices are not applicable as presented in the printed model. They are there as an example. The correct prices are placed later to the model when IHKU-alliance receives current pricing from clients.

4.5 1700, Rock excavation and tunnelling

The duplication of rock excavation and tunnelling cost models are very difficult to create for the estimation model. The variables of the construction phase are site specific. It was agreed upon in the interviews that in open excavation 0,2m of drilling hole meters for blasting equal to 1 cubic meter of excavated rock. In tunnelling the same is translated by 0,35 m of drilling meters for blasting equal to 1 cubic meter of excavated rock. This is one of the only mediums in the construction phase which can be calculated with some chance of duplication. Most of the other production components are individual to the site (Vuolio & Halonen, 2012).

As mentioned previously in this study, environmental permits, dimensions of the site and tunnels, operating hours, location of surrounding building and their type, to name a few dictate the efficiency and methods of excavation. The model of estimation requires averageable production components that give an estimation of the costs. Excluding the fore mentioned long hole meter ratio to cubic meter of excavated rock, other mediums are more unique to the site in question (Vuolio & Halonen, 2012). Below are examples of variables that have impacts on pricing in Drilling and blasting as well as Scaling and hauling. These variables in many cases unique to the construction site that is being modelled. They are difficult to create a average duplicable example out of, that can be used from site to site in the model.

- Drilling and blasting
    - The drilling meters are portioned to the blasting area
    - In open excavations the drill hole meters are relative to the blast field, which is relative to the location and permits
    - Tunnel drifts, usually blasted 6m in length, are dependent on their area of face that creates the volume of rock. This dictates the amount of long hole meters to drill.
    - Amount of drifts being worked on simultaneously dictates the efficiency of blasted rock accrual. This creates the amount of labour hours for one drift, which is directly in proportion to its cost.
    - Permits and location with design dictate explosive material. These have different pricing.
    - Ventilation after blasting creates a delay of operations. The amount of drifts in use either minimise or maximise this delay. The longer the delay, less excavated rock is possible on one day. This decreases efficiency.

  - The space for working on a blasting field or tunnel dictate the size of drill-Jumbos that can be used for labour. Their efficiency dictates the amount of long hole meters that can be drilled per hour.

- Scaling and hauling
  - Scaling can be conducted either by machine or manpower. It is the amount of space in the tunnel that dictates which of these can be used. Machine powered scaling is much more effective than man powered scaling, but it requires more space as well.
  - Hauling of excavated rock is made by machines, the capacity of these machines is dependent on the area and space that they have to work in. The capacity dictates time spent clearing area before next blasting cycle.
  - If the excavated rock can be directly hauled away from the tunnel or blasting site and transportation costs are effective. The more mid stops there are during hauling, less effective and more expansive it becomes per cubic meter of rock.
  - If the efficiency of hauling can be secured, and the transportation is systematic, contractors can calculate pricing by cubic meter pricing. Less efficient the more typical is hourly invoicing for hauling. This creates additional costs for contractors.

The interviews and modelling of the 1700 nomenclatures proved to be difficult without knowledge on site per site information. Because of this fact the suggestion of this study is, to allow designers ability to alter all aspects of the model. The model makes certain assumptions of production component efficiency and consumption of resources. These nevertheless might not be accurate enough in all cases, as the variables in tunnelling can be a large part of calculations. Batches, resources, unit prices, product component efficiency and multipliers. Without these, the estimate is too general and will not allow for an applicable result.

The problem of site-defined information is attempted to be corrected by implementing a qualification multiplier as a production component. Each tunnelling construction phase has a choice of several qualification levels. These represent the Ministry of the environments established C-A/B-AA qualification degree of difficulty and a quality of rock grade, adequate-poor-very poor. These two attributes are joined to create a qualification multiplier that represents the closest qualification level. The changes to production components due to a change in difficulty will effect the pricing. This is corrected by adding a multiplier of costs to the end price.

1715	Open rock excavation and mid-way storage	
Production component	**Stake/Batch**	**Resource**
Blasting	Scorpion drill unit	Physical
	Workforce	Human
	Maintenance crew	Human
	Explosive material	Material
	Spare parts	Material
Hauling	Wheel loader	Physical
	Excavator	Physical
Transportation	4-axel truck	Physical

Stake pricing €/Unit		Resource / material	
80	rental-hour	1	dhm
33	labour cost per hour	2	pcs
33	labour cost per hour	1	pcs
9	m3 theoretical	0,35	kg/dhm
4	m3 theoretical	1	m3 theoretical
100	rental-hour	2	pcs
100	rental-hour	1	pcs
8	m3 theoretical	1	m3 theoretical

PC-efficiency		PC-unit price €/unit	PC-unit	PC-multiplier		m3 theoretical unit price €/m3 theoretical
120	dhm/h	0,67	dhm	1,00	dhm/m3 theoretic	0,67
120	dhm/h	0,55	dhm	1,00	dhm/m3 theoretic	0,55
120	dhm/h	0,28	m3 theoretical	1,00	dhm/m3 theoretic	0,28
120	dhm/h	9,00	m3 theoretical	1,00	m3 theoretical/m	9,00
		4,00	m3 theoretical	1,00	m3 theoretical/m	4,00
100	m3 theoretical/h	2,00	m3 theoretical	1,00	m3 theoretical/m	2,00
60	m3 theoretical/h	1,67	m3 theoretical	1,00	m3 theoretical/m	1,67
80	m3 theoretical/h	8,00	m3 theoretical	1,00	m3 theoretical/m	8,00
						26,16

Figure 11. Example of a modelled estimation of Rock excavation, nomenclature 1715.

The modelled estimation of rock excavation is visualized above in an example of construction phase 1715, figure 11. Here the nomenclature of 1715 open rock excavation and mid-way storage is in the form of excel data that is passed on to the IHKU-Alliance. Examples of the estimating models for 1700 rock excavation and tunnelling are found in attachment 2, 1700 nomenclature. The unit prices are not applicable as presented in the printed model. They are there as an example. The correct prices are placed later to the model when IHKU-alliance receives current pricing from clients.

4.6 4510, Protective and damping structures

As mentioned in chapter 3, these structures are unique, and custom fitted into their required positions in tunnelling projects. They are separate projects on their own and directly calculated as a unit based invoicing work (RIL, 2010). The acquired information on costing showed that there are no correlations between pricing in different projects. Because of this fact, these nomenclatures are modelled with unit prices.

4513	Vibration damping structures	
Production component	**Stake/Batch**	**Resource**
Vibration damping structures	Damping structure	Material

Stake pricing €/Unit		**Resource / material consuption**	
0	pcs / kg	0	pcs

PC-efficiency	**PC-unit price €/unit**	**PC-unit**	**PC-multiplier**	structure **unit price €/structure**
	0,00	pcs / kg	1,00	0,00
				0,00

Figure 12. Example of a modelled estimation of Protective and damping structures, nomenclature 4513.

The modelled estimation of protective and damping structures is visualized above in an example of construction phase 4513, figure 12. Here the nomenclature of 4513 Vibration damping structures is in the form of excel data that is passed on to the IHKU-Alliance. The estimating models for 4510 rock excavation and tunnelling are found in attachment 3, 4510 nomenclature. The unit prices are not applicable as presented in the printed model. They are there as an example. The correct prices are placed later to the model when IHKU-alliance receives current pricing from clients.

5 Conclusions

Competitive tendering has created a demand for development in construction. The structure of costing has been under constant development since the public sector has chosen contractors through bidding processes. The estimation model is targeted to create a system that develops itself by updating the pricing of construction phases as they are updated from tendered bidding to another. The model takes the assumption of moderate duplicability of said phases. In other words, the model must be precise enough to give an educated estimate of costing, but common enough to represent a larger sampling of projects. This creates restrictions into the model's flexibility to start. The general attributes of a duplicable model dictate that the estimated costs of projects are as accurate as the construction phase is duplicable. This requires that the same construction phase has generally similar productions components and resource consumptions. The model requires current and updated pricing as well. This is accomplished by time and the frequent use of the model. The more transparency is created by the common use of this estimating model, the more understanding and correct structuring of costs is created. By this the cost become more realistic and common to all parties involved in the bidding processes. The transparency creates awareness which in turn aids the pricing to become more in uniform from contractor to another.

The commonality that came up in all of the interviews, between all of the parties involved, was mistrust of each other in invoicing. This has created a situation where contractors cannot invoice the full extent of their accumulated costs of construction. Developers want to be able to have factual units of measure that they can check against development as a basis of invoicing. This is sensible as on many occasions the project and design develops as the project progresses. When designs develop during construction it creates changes in the use of resourcing as well. With this, the amount of additional, hourly billed work can increase substantially. This can create a situation where invoicing basis are not measurable with units of progress. This has created the current situation where cost formation is of balance due to pressure from competitive tendering and risks of information gaps in design during planning and construction.

If contractors feel that they are not able to create actual calculations of costs to form their competitive bid, they start finding other means of forming billable costs. As well, if a construction phase is not billable by all costs involved in its execution, contractors will start misplacing the undesignated costs. The transparency of an estimation model will correct this flaw. This will only work if the cost estimates are factual enough to create unbiased, correct costs that benefit each side of the contract. If the cost estimate doesn't work or the pricing is not up to date, the problems of current bidding are not erased.

Tunnelling phases are very tricky to implement into this kind of scenario. The estimation requires the fore mentioned duplicability. Tunnelling and excavation phases are very unique to each location and their conditions of execution. When designing an estimation model for such production components the accessibility of information input is the key for current and usable estimation data. If the resources, their consumption volumes and production component multipliers are not able to be fixed by each project and its data, the estimate will be too general. This will form room for speculation in pricing and estimates.

If the basis of measurement is made by the suggestions of the infrastructure 2015 nomenclatures, there is much room for speculation if detailing is not permitted as mentioned previously. The argument can be made, that different possible scenarios can be programmed into the model in advance. By choosing the closest option to the project, the model can be applicable. The problem comes from this nomenclature basis of measurement. For example, if cubic meter is the basis of measurement, the estimation model does not comment entirely on the conditions how the cubic meter was accumulated. The model works to its full effect if the conditions are similar as mentioned for duplication.

The interviews themselves turned out to be a form of discussion on the state of tunnelling phases and their invoicing. A feeling of necessity came out of the discussions. It seemed that a dialogue of the problems in invoicing was necessary and in demand. It appeared that the problems had been discussed within companies but not voiced out as much as was needed. What came up was the proportion of the tunnelling and excavation projects as a view of total budget. Majority of these types of projects are large and the costing of each phase as well. Due to this the focus on their development during construction is intense. Only problem that was pointed out, is that the development of procedures has not been on the same level with other segments of infrastructure construction. In this, tunnelling and excavations play only a small part of the total expenditure in Finland annually. Perhaps, this is the reason why old habits and assumptions have created the imbalance of cost structures.

The estimation model is the most beneficial for the 1500 nomenclatures on reinforcement structures. These are also the tunnelling phases which are the most difficult for this model to be implemented in. As mentioned in the interviews, most of the issues of disagreement between parties is in the way these phases are either calculated for means of quantity for invoicing, or the production components included in the construction phase. Difficulty with this is the said mentioned duplicability for modelling. As the topic of the nomenclature grouping states, these nomenclatures are for phases which establish reinforcement for structures. The need for this reinforcement, comes from necessity during construction and is calculated by the quality of rock in that destination. This is the core of the problem. The unknowns of rock excavation and tunnelling come from the differences in locations of construction and the differences in design. Because of the differences it is difficult to create standardized averages of these nomenclatures. In the basic standard of the model the resource consumptions and multipliers are in the model ready, they cannot be influenced. For many construction phases, these are the unknowns of the production components which need input to create an accurate estimate.

In the case of grouting injections resource consumption is the key for debate during invoicing. As the construction phase is divided into preliminary and post construction injections the consumptions are widely apart from each other. Additionally, the estimation of consumption is difficult without onsite studies and tests. The issue remains as well, of choice for grouting. As long as the choice and extent of grouting is left to contractors and their estimation of necessity, the costs and their accumulation is not in uniform between projects. It is as well left to the estimates made during competitive tendering which creates the necessity for this phase. If the winner of bidding has calculated the need correctly, the grouting can be efficient and cost formation transparent. If they estimate it incorrectly, the cost can be exponentially larger than intended, this creates pressure for finding means of justifying these costs and the need to allocate them into the project costing.

The rock bolts are on the other hand are more design-oriented reinforcement. As the consumption of resources is dependent on the type of bolt and the conditions for labour. These cannot be duplicated and depicted in the model as a numerical factor that is presenting some type of working average for each bolt type. This makes it again necessary for designers to be able to make more of an impact on the models estimate for this phase. As the model itself does not comment on the degree of difficulty in the production components application on site, the effect of resources needs to be evaluated by each case individually. This makes the challenge in the estimation model. The model can become too generic making the estimate too low or high. This can create a false basis for pricing and cause conflicts between parties in invoicing. In the worst case the transparency of the model will lose effect if the pricing estimates are not accurate enough.

For shotcrete structures this modelling is the most straight forward to accomplish. As the production components of this construction phase are not as open for influence of the conditions and parameters of the site. The production components and the resource consumption are similar from site to another. The challenge of the model is to create a transparency that can take into account the different options for invoicing. If the means for invoicing can be mixed between different units of measure in one and same project. If the units of measure are mixed and the production components count the efficiency with same standards, the units do not depict the impact on the costs as they really are. Transparency at this point needs for costing to be made accurate and depict the effects that they have on the accumulation of costs.

Rock excavation and tunnelling nomenclatures are on the basic level possible to duplicate. They are not composed of many production components and the components themselves are close to other infrastructure phases in the nomenclature. Additional to this, there are not many aspects that allow for the duplication to be possible with additional information to be placed into the model. What this means is that the nomenclature group 1700 phases are subjected to a conditionality of worksite individuality. As the tendering process takes a comment of effectiveness in use of resources, the conditions for work play a strong part in this. Drilling and blasting either in tunnels or open areas requires a space-to-excavated rock ratio to be effective. The less open area or working room the site or tunnel allows, the less effective the use of resources is. It is as well subjected to environmental and municipal permits which dictate the methods used and their time restrains during a workday. For example, the use of different explosive materials is restricted in some municipalities. As well as tremors near kindergartens for example. These create a higher cost for resources and effect resource and material consumption. The space restrictions affect the use of physical resources such as machines and this in turn effects the cost of stake pricing.

The duplication can be made, but it needs to have an understanding amongst users that the result is generic. The estimation model creates a cost profile for a most common case for an excavation or tunnelling project. Due to this fact the input that is given for the estimate model is essential for an accurate estimate. If the model only takes into account an averaged stake, resource or consumption, the averages must be available for tendering bids. If they are not, the estimated resources and their costs made by contractors might not be enough in bidding. The averages in this case profit larger contractors compared to smaller companies as they can adjust their resources by the outcome of the bid better.

Even though the estimation models target is to create understanding and transparency of costs in projects. In some cases, there are no measurement units which can be used as averaged production components or its parts. For example, the 4510-nomenclature grouping of protective and damping structures are made custom designed for each destination. The depiction of these construction phases by common production components will not create a cost estimate that can be used. In these types of cases the unit price of a construction phase product is the best way to create an accurate estimate of costing.

The conclusion of this study is that excavation and tunnelling phases including reinforcement structures are not as simple to duplicate as they should. The estimation model works best when the production components of each nomenclature are opened up into resources and their unit prices as well as possible. Due to this fact, the models resourcing should be opened to duplicable production component pricing. The challenge with the tunnelling nomenclatures of 1500, 1700 and 4510 is that these unit prices are project specific. Without taking into account the projects limitations and permit details, the unit pricing will be too general. It will not open the model into the accurate pricing transparency which is needed. The estimation model can only work if the costing estimate is accurate enough to depict a truthful estimate of pricing. If being too generic, the trust in the model will stop and the tendering process will lose its transparency. The model should be opened up to allow for inputs into all segments of its calculation. The model should be created with a target of it being a tool for designers or the information from them to create accuracy. As the model itself is used by calculation engineers who do not have themselves the expertise to estimate the differences between projects, the information received from designers should be inputted into the model as a whole. The accuracy given in preliminary design material is the tool to create the estimate models transparency. It should be used as a whole, not only by duplication of general aspects. For future development of the estimation model IHKU-Alliance should look into the possibilities that are offered in co-operation projects. The influence of joint designs between contractors and developers create more open information and update old estimation models.

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Attachment 1. 1500, Rock grouting and reinforcement structures. 2 pages.
Attachment 2. 1700, Rock excavation and tunnelling. 2 pages.
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Attachment 1. 1500, Rock grouting and reinforcement structures

1511.1	Injektoidut kalliorakenteet, Sementillä injektoidut kalliorakenteet, keskimääräinen kivirakenne (injektointimassaa 38 kg/pom)												pom
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus		TO yksikköhinta €/yks	TO yksikkö	TO-kerroin		Yks.hinta €/pom
Porereiät, jumbolla	Porajumbo	kone	80	kone-h	1	kpl	30	pom/h	2,67	pom	1,00	pom/pom	2,67
	Työntekijä	henkilötyö	40	tth	2	kpl	30	pom/h	2,67	pom	1,00	pom/pom	2,67
Injektointirakenne	Pumppauskalusto	kalusto	50	kone-h	1	kpl	500	kg/h	0,10	kg	37,50	kg/pom	3,75
	Työntekijä	henkilötyö	40	tth	2	kpl	500	kg/h	0,16	kg	37,50	kg/pom	6,00
	Injektointimassa (sementti/microsementti)	materiaali	0,55	kg	38	kg/pom		pom	20,63	pom	1,00	pom/pom	20,63
													35,71

1511.2	Injektoidut kalliorakenteet, Kemiallisesti injektoidut kalliorakenteet												pom
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus		TO yksikköhinta €/yks	TO yksikkö	TO-kerroin		Yks.hinta €/pom
Porareiät, käsin	Käsipora	kalusto	15	kone-h	1	kpl	10	pom/h	1,50	pom	1,00	pom/pom	1,50
	Työntekijä	henkilötyö	40	tth	2	kpl	10	pom/h	8,00	pom	1,00	pom/pom	8,00
Injektointirakenne	Pumppauskalusto	kalusto	50	kone-h	1	kpl	60	kg/h	0,83	kg	15,00	kg/pom	12,50
	Työntekijä	henkilötyö	40	tth	2	kpl	60	kg/h	1,33	kg	15,00	kg/pom	20,00
	Kemiallinen-injektointimassa	materiaali	20	kg	15	kg/pom		pom	300,00	pom	1,00	pom/pom	300,00
													342,00

1521	Kalliopultitukset, harjateräspultti 3m (esimerkki)												kpl
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus		TO yksikköhinta €/yks	TO yksikkö	TO-kerroin		Yks.hinta €/kpl
Porereiät, jumbolla	Porajumbo	kone	80	kone-h	1	kpl	30	pom/h	2,67	pom	3,00	pom/kpl	8,00
	Työntekijä	henkilötyö	40	tth	2	kpl	30	pom/h	2,67	pom	3,00	pom/kpl	8,00
Kalliopultti + Juotosr	harjateräspultti, 3m+muut vaadittavat osat	materiaali	18	pultti	1	kpl			18,00	kpl	1,00	kpl/kpl	18,00
	Juotoskone	kalusto	15	kone-h	1	kpl	60	kg/h	0,25	kg	7,50	kg/kpl	1,88
	Q-kulkija **tai** saksilava	kalusto	50	kone-h	1	kpl	60	kg/h	0,83	kg	7,50	kg/kpl	6,25
	Pakettiauto **tai** kuorma-auto	kone	50	kone-h	1	kpl	60	kg/h	0,83	kg	7,50	kg/kpl	6,25
	Työntekijä	henkilötyö	40	tth	2	kpl	60	kg/h	1,33	kg	7,50	kg/kpl	10,00
	Valmis juotosmassa	Materiaali	0,6	kg	7,50	kg/kpl	1	kpl	4,50	kpl	1,00	kg/kpl	4,50
													62,88

1522	Kallioankkuroinnit, **1m esijännitetty kallioankkuri (esimerkki)**												kpl
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus		TO yksikköhinta €/yks	TO yksikkö	TO-kerroin		Yks.hinta €/kpl
Porereiät, jumbolla	Porajumbo	kone	80	kone-h	1	kpl	30	pom/h	2,67	pom	1,00	pom/kpl	2,67
	Työntekijä	henkilötyö	40	tth	2	kpl	30	pom/h	2,67	pom	1,00		2,67
Kallioankkuri + Juoto	Kallioankkuri +muut vaadittavat osat **esijännitetty ankkuri 1m**	Materiaali	5	kpl	1	kpl			5,00	kpl	1,00	kpl/kpl	5,00
	Juotoskone	kalusto	15	kone-h	1	kpl	60	kg/h	0,25	kg	2,00	kg/kpl	0,50
	Q-kulkija **tai** saksilava	kalusto	50	kone-h	1	kpl	60	kg/h	0,83	kg	2,00	kg/kpl	1,67
	Pakettiauto **tai** kuorma-auto	kone	50	kone-h	1	kpl	60	kg/h	0,83	kg	2,00	kg/kpl	1,67
	Työntekijä	henkilötyö	40	tth	2	kpl	60	kg/h	1,33	kg	2,00	kg/kpl	2,67
	Valmis juotosmassa	Materiaali	0,6	kg	2,00	kg/kpl	1	kpl	1,20	kpl	1,00	kg/kpl	1,20
													18,03

1523	Verkotukset **(ei sisällä kalliopultituksia)**												m2td
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus		TO yksikköhinta €/yks	TO yksikkö	TO-kerroin		Yks.hinta €/m2td
Verkon asennus	Verkko+muut osat	Materiaali	7,5	m2	1,20	m2/m2td			9,00	m2td	1,00	m2/m2td	9,00
	Työntekijä	henkilötyö	40	tth	3	kpl	60	kg/h	2,00	kg	10,00	kg/m2td	20,00
Kalliopultti	Littera 1521 kalliopultitukset												
													29,00

1531.1	Kuituruiskubetonointirakenteet, R4 elastinen kuitu (c30/37 S3 8mm kivellä 5kg/m3 muovikuitua)												m3rtd
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus		TO yksikköhinta €/yks	TO yksikkö	TO-kerroin		Yks.hinta €/m3rtd
Ruiskubetonikerros	Ruiskutusrobotti	kalusto	80	kone-h	1	kpl	6	m3/h	13,33	m3rtd	1,00	m3rtd/m3	13,33
	Työntekijä	henkilötyö	40	tth	2	kpl	6	m3/h	13,33	m3rtd	1,00	m3rtd/m3	13,33
	Betoni, muk.luk toimitus: R4 elastinen kuitu (c30/	Materiaali	88	m3	1	m3/m3			88,00	m3rtd	1,16	m3rtd/m3	102,08
													128,75

1531.1	Kuituruiskubetonointirakenteet, R4 teräskuitu (C30/37 S3 8mm kivellä 50kg/m3 teräskuitua)												m3rtd
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus		TO yksikköhinta €/yks	TO yksikkö	TO-kerroin		Yks.hinta €/m3rtd
Ruiskubetonikerros	Ruiskutusrobotti	kalusto	80	kone-h	1	kpl	6	m3/h	13,33	m3rtd	1,00	m3rtd/m3	13,33
	Työntekijä	henkilötyö	40	tth	2	kpl	6	m3/h	13,33	m3rtd	1,00	m3rtd/m3	13,33
	Betoni, muk.luk toimitus: R4 teräskuitu (C30/37 S	Materiaali	145	m3	1	m3/m3			145,00	m3rtd	1,00	m3rtd/m3	145,00
													171,67

1532	Ruiskubetonoinnin salaojat												mtr
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus		TO yksikköhinta €/yks	TO yksikkö	TO-kerroin		Yks.hinta €/mtr
Salaojan asennus	Q-kulkija tai saksilava	kalusto	50	kone-h	1	kpl	15	mtr/h	3,33	mtr	1,00	mtr/mtr	3,33
	Pakettiauto tai kuorma-auto	kalusto	50	kone-h	1	kpl	15	mtr/h	3,33	mtr	1,00	mtr/mtr	3,33
	Työntekijä	henkilötyö	40	tth	2	kpl	15	mtr/h	5,33	mtr	1,00	mtr/mtr	5,33
	vaahtomuovia (suljetuila soluilla) 60 x 10, 30 kg/m	materiaali	0	m	2	mtr/mtr			0,00	mtr	1,00	mtr/mtr	0,00
	vaahtomuovia (suljetuila soluilla) 50 x 10, 30 kg/m	materiaali	0	m	2	mtr/mtr			0,00	mtr	1,00	mtr/mtr	0,00
	vaahtomuovia (suljetuila soluilla) 500 x 10, 40 kg/	materiaali	0	m	1	mtr/mtr			0,00	mtr	1,00	mtr/mtr	0,00
	kanaverkkoa >500	materiaali	0	m	1	mtr/mtr			0,00	mtr	1,00	mtr/mtr	0,00
	Salaojaputkea d ≥ = 50 mm	materiaali	0	m	1	mtr/mtr			0,00	mtr	1,00	mtr/mtr	0,00
	Rautalankaa sitomiseen ø 4	materiaali	0	m	1	mtr/mtr			0,00	mtr	1,00	mtr/mtr	0,00
	Teräsverkkoa ø 3,4 k 100, leveys väh. 1000 mm	materiaali	0	m	1	mtr/mtr			0,00	mtr	1,00	mtr/mtr	0,00
	kiinnitysrakenne	materiaali	0	m	1	mtr/mtr			0,00	mtr	1,00	mtr/mtr	0,00
													12,00

Attachment 2. 1700, Rock excavation and tunnelling

1711	Kallioavoleikkaus, erittelemätön tietyömaa ympäristö											m3ktr
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus		TO yksikköhinta €/yks	TO yksikkö	TO-kerroin	Yks.hinta €/m3ktr
Louhinta	Scorpion	Kone	80	kone-h	1	pom	120	pom/h	0,67	pom	1,00 pom/m3ktr	0,67
	Työntekijä	Henkilötyö	33	tth	2	kpl	120	pom/h	0,55	pom	1,00 pom/m3ktr	0,55
	Remontti	Henkilötyö	33	tth	1	kpl	120	pom/h	0,28	m3ktr	1,00 pom/m3ktr	0,28
	ANFO + nallit ym.	Materiaali	9	m3ktr	0,35	kg/pom	120	pom/h	9,00	m3ktr	1,00 m3ktr/m3ktr	9,00
	Varaosat	Materiaali	4	m3ktr	1	m3ktr			4,00	m3ktr	1,00 m3ktr/m3ktr	4,00
Lastaus	KUP 210	Kone	100	kone-h	1	kpl	100	m3ktr/h	1,00	m3ktr	1,00 m3ktr/ktr3ktr	1,00
	KKHt 45	Kone	100	kone-h	1	kpl	60	m3ktr/h	1,67	m3ktr	1,00 m3ktr/ktr3ktr	1,67
Kuljetus	KA 4-akselinen	kone	69	kone-h	4	kpl	100	m3ktr/h	2,76	m3ktr	1,00 m3ktr/ktr3ktr	2,76
												19,92

1713	Kallioavoleikkaus ja läjitys tietyömaa ympäristö											m3ktr
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus		TO yksikköhinta €/yks	TO yksikkö	TO-kerroin	Yks.hinta €/m3ktr
Louhinta	Scorpion	Kone	80	kone-h	1	pom	120	pom/h	0,67	pom	1,00 pom/m3ktr	0,67
	Työntekijä	Henkilötyö	33	tth	2	kpl	120	pom/h	0,55	pom	1,00 pom/m3ktr	0,55
	Remontti	Henkilötyö	33	tth	1	kpl	120	pom/h	0,28	m3ktr	1,00 pom/m3ktr	0,28
	ANFO + nallit ym.	Materiaali	9	m3ktr	0,35	kg/pom	120	pom/h	9,00	m3ktr	1,00 m3ktr/m3ktr	9,00
	Varaosat	Materiaali	4	m3ktr	1	m3ktr			4,00	m3ktr	1,00 m3ktr/m3ktr	4,00
Lastaus	KUP 210	Kone	100	kone-h	1	kpl	100	m3ktr/h	1,00	m3ktr	1,00 m3ktr/ktr3ktr	1,00
	KKHt 45	Kone	100	kone-h	1	kpl	60	m3ktr/h	1,67	m3ktr	1,00 m3ktr/ktr3ktr	1,67
Kuljetus	KA 4-akselinen	kone	8	m3ktr	1	m3ktr	80	m3ktr/h	8,00	m3ktr	1,00 m3ktr/ktr3ktr	8,00
												25,16

1717	Irtilouhittu rakenne											m3ktr
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus		TO yksikköhinta €/yks	TO yksikkö	TO-kerroin	Yks.hinta €/m3ktr
Louhinta	Scorpion	Kone	80	kone-h	1	pom	120	pom/h	0,67	pom	1,00 pom/m3ktr	0,67
	Työntekijä	Henkilötyö	33	tth	2	kpl	120	pom/h	0,55	pom	1,00 pom/m3ktr	0,55
	Remontti	Henkilötyö	33	tth	1	kpl	120	pom/h	0,28	m3ktr	1,00 pom/m3ktr	0,28
	ANFO + nallit ym.	Materiaali	9	m3ktr	0,35	kg/pom	120	pom/h	9,00	m3ktr	1,00 m3ktr/m3ktr	9,00
	Varaosat	Materiaali	4	m3ktr	1	m3ktr			4,00	m3ktr	1,00 m3ktr/m3ktr	4,00
												14,49

1731	Rakennuskaivannot kalliossa tietyömaa ympäristö											m3ktr
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus		TO yksikköhinta €/yks	TO yksikkö	TO-kerroin	Yks.hinta €/m3ktr
Louhinta	Scorpion	Kone	80	kone-h	1	pom	120	pom/h	0,67	pom	1,00 pom/m3ktr	0,67
	Työntekijä	Henkilötyö	33	tth	2	kpl	120	pom/h	0,55	pom	1,00 pom/m3ktr	0,55
	Remontti	Henkilötyö	33	tth	1	kpl	120	pom/h	0,28	m3ktr	1,00 pom/m3ktr	0,28
	ANFO + nallit ym.	Materiaali	9	m3ktr	0,35	kg/pom	120	pom/h	9,00	m3ktr	1,00 m3ktr/m3ktr	9,00
	Varaosat	Materiaali	4	m3ktr	1	m3ktr			4,00	m3ktr	1,00 m3ktr/m3ktr	4,00
Lastaus	KUP 210	Kone	100	kone-h	1	kpl	100	m3ktr/h	1,00	m3ktr	1,00 m3ktr/m3ktr	1,00
	KKHt 45	Kone	100	kone-h	1	kpl	60	m3ktr/h	1,67	m3ktr	1,00 m3ktr/m3ktr	1,67
Kuljetus	KA 4-akselinen	kone	8	m3ktr	1	m3ktr	80	m3ktr/h	8,00	m3ktr	1,00 m3ktr/ktr3ktr	8,00
												25,16

1732	Siltakaivannot kalliossa tietyömaa ympäristö											m3ktr
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus		TO yksikköhinta €/yks	TO yksikkö	TO-kerroin	Yks.hinta €/m3ktr
Louhinta	Scorpion	Kone	80	kone-h	1	pom	120	pom/h	0,67	pom	1,00 pom/m3ktr	0,67
	Työntekijä	Henkilötyö	33	tth	2	kpl	120	pom/h	0,55	pom	1,00 pom/m3ktr	0,55
	Remontti	Henkilötyö	33	tth	1	kpl	120	pom/h	0,28	m3ktr	1,00 pom/m3ktr	0,28
	ANFO + nallit ym.	Materiaali	9	m3ktr	0,35	kg/pom	120	pom/h	9,00	m3ktr	1,00 m3ktr/m3ktr	9,00
	Varaosat	Materiaali	4	m3ktr	1	m3ktr			4,00	m3ktr	1,00 m3ktr/m3ktr	4,00
Lastaus	KUP 210	Kone	100	kone-h	1	kpl	100	m3ktr/h	1,00	m3ktr	1,00 m3ktr/m3ktr	1,00
	KKHt 45	Kone	100	kone-h	1	kpl	60	m3ktr/h	1,67	m3ktr	1,00 m3ktr/m3ktr	1,67
Kuljetus	KA 4-akselinen	kone	8	m3ktr	1	m3ktr	80	m3ktr/h	8,00	m3ktr	1,00 m3ktr/ktr3ktr	8,00
												25,16

1741	Vedenalaiset kallioleikkaukset ja -kaivannot, erittelemätön											m3ktr
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus		TO yksikköhinta €/yks	TO yksikkö	TO-kerroin	Yks.hinta €/m3ktr
Louhinta	Porakalusto	Kone	128	kone-h	1	pom	36	pom/h	3,56	pom	1,00 pom/m3ktr	3,56
	Työntekijä	Henkilötyö	52,8	tth	2	kpl	36	pom/h	2,93	pom	1,00 pom/m3ktr	2,93
	Remontti	Henkilötyö	33	tth	1	kpl	36	pom/h	0,92	m3ktr	1,00 pom/m3ktr	0,92
	Räjähdeaine ym.	Materiaali	14,4	m3ktr	0,35	kg/pom	36	pom/h	14,40	m3ktr	1,00 m3ktr/m3ktr	14,40
	Varaosat	Materiaali	4	m3ktr	1	m3ktr			4,00	m3ktr	1,00 m3ktr/m3ktr	4,00
Lastaus	KUP 210	Kone	100	kone-h	1	kpl	70	m3ktr/h	1,43	m3ktr	1,00 m3ktr/m3ktr	1,43
	KKHt 45	Kone	100	kone-h	1	kpl	42	m3ktr/h	2,38	m3ktr	1,00 m3ktr/m3ktr	2,38
Kuljetus	KA 4-akselinen	kone	8	m3ktr	1	m3ktr	70	m3ktr/h	8,00	m3ktr	1,00 m3ktr/ktr3ktr	8,00
												37,62

1751.2	Kiviaineksella tasattu louhittu kalliopinta											m3ktr
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus		TO yksikköhinta €/yks	TO yksikkö	TO-kerroin	Yks.hinta €/m3ktr
Kiviainespinta	kiviainespinta	Materiaali	0	m3tr	0	kpl			0,00	m3tr	1,00 m3tr/m2tr	0,00
												0,00

1761.1	Kalliotunnelit, 1-perä												m3ktr
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus		TO yksikköhinta €/yks	TO yksikkö	TO-kerroin		Yks.hinta €/m3ktr
Louhinta	jumbo	Kone	80	kone-h	1	kpl	200	pom/h	0,40	pom	1,00	pom/m3ktr	0,40
	Mittamies	Henkilötyö	45	tth	1	kpl	200	pom/h	0,23	pom	1,00	pom/m3ktr	0,23
	Työntekijä	Henkilötyö	33	tth	2	kpl	200	pom/h	0,33	pom	1,00	pom/m3ktr	0,33
	Remontti	Henkilötyö	33	tth	1	kpl	200	pom/h	0,17	pom	1,00	pom/m3ktr	0,17
	emulsio + nallit	Materiaali	11	m3ktr	0,35	kg/pom	200	pom/h	11,00	m3ktr	1,00	m3ktr/m3ktr	11,00
	tunnelivarustelu	Materiaali	1,5	m3ktr					1,50	m3ktr	1,00	m3ktr/m3ktr	1,50
	Panostusalusta	kone	2	m3ktr					2,00	m3ktr	1,00	m3ktr/m3ktr	2,00
	Varaosat	Materiaali	4	m3ktr	1	m3ktr			4,00	m3ktr	1,00	m3ktr/m3ktr	4,00
	Rusnauskalusto	Kone	100	kone-h	1	kpl			0,26	m3ktr	1,00	m3ktr/m3ktr	0,26
Lastaus	KUP 210	Kone	100	kone-h	1	kpl	100	m3ktr/h	1,00	m3ktr	1,00	m3ktr/m3ktr	1,00
	KKHt 45	Kone	100	kone-h	1	kpl	60	m3ktr/h	1,67	m3ktr	1,00	m3ktr/m3ktr	1,67
Kuljetus	KA 4-akselinen	kone	8	m3ktr	1	m3ktr	80	m3ktr/h	8,00	m3ktr	1,00	m3ktr/m3ktr	8,00
Vaativuuskerroin	C, kohtuullinen	kerroin	0	kerroin	1	kerroin			30,54	eur			0,00
	C, huono	kerroin	0,04	kerroin	0	kerroin			30,54	eur			0,00
	C, erit.huono	kerroin	0,12	kerroin	0	kerroin			30,54	eur			0,00
	A/B, kohtuullinen	kerroin	0,03	kerroin	0	kerroin			30,54	eur			0,00
	A/B, huono	kerroin	0,07	kerroin	0	kerroin			30,54	eur			0,00
	A/B, erit.huono	kerroin	0,15	kerroin	0	kerroin			30,54	eur			0,00
	AA, kohtuullinen	kerroin	0,05	kerroin	0	kerroin			30,54	eur			0,00
	AA, huono	kerroin	0,11	kerroin	0	kerroin			30,54	eur			0,00
	AA, erit.huono	kerroin	0,22	kerroin	0	kerroin			30,54	eur			0,00
													30,54

1761.2	Ajotunnelit												m3ktr
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus		TO yksikköhinta €/yks	TO yksikkö	TO-kerroin		Yks.hinta €/m3ktr
Louhinta	jumbo	Kone	80	kone-h	1	kpl	200	pom/h	0,40	pom	1,00	pom/m3ktr	0,40
	Mittamies	Henkilötyö	45	tth	1	kpl	200	pom/h	0,23	pom	1,00	pom/m3ktr	0,23
	Työntekijä	Henkilötyö	33	tth	2	kpl	200	pom/h	0,33	pom	1,00	pom/m3ktr	0,33
	Remontti	Henkilötyö	33	tth	1	kpl	200	pom/h	0,17	pom	1,00	pom/m3ktr	0,17
	emulsio + nallit	Materiaali	11	m3ktr	0,35	kg/pom	200	pom/h	11,00	m3ktr	1,00	m3ktr/m3ktr	11,00
	tunnelivarustelu	Materiaali	1,5	m3ktr					1,50	m3ktr	1,00	m3ktr/m3ktr	1,50
	Panostusalusta	kone	2	m3ktr					2,00	m3ktr	1,00	m3ktr/m3ktr	2,00
	Varaosat	Materiaali	4	m3ktr	1	m3ktr			4,00	m3ktr	1,00	m3ktr/m3ktr	4,00
	Rusnauskalusto	Kone	100	kone-h	1	kpl			0,26	m3ktr	1,00	m3ktr/m3ktr	0,26
Lastaus	KUP 210	Kone	100	kone-h	1	kpl	100	m3ktr/h	1,00	m3ktr	1,00	m3ktr/m3ktr	1,00
	KKHt 45	Kone	100	kone-h	1	kpl	60	m3ktr/h	1,67	m3ktr	1,00	m3ktr/m3ktr	1,67
Kuljetus	KA 4-akselinen	kone	8	m3ktr	1	m3ktr	80	m3ktr/h	8,00	m3ktr	1,00	m3ktr/m3ktr	8,00
Vaativuuskerroin	C, kohtuullinen	kerroin	0	kerroin	0	kerroin			30,54	eur			0,00
	C, huono	kerroin	0,04	kerroin	1	kerroin			30,54	eur			1,22
	C, erit.huono	kerroin	0,12	kerroin	0	kerroin			30,54	eur			0,00
	A/B, kohtuullinen	kerroin	0,03	kerroin	0	kerroin			30,54	eur			0,00
	A/B, huono	kerroin	0,07	kerroin	0	kerroin			30,54	eur			0,00
	A/B, erit.huono	kerroin	0,15	kerroin	0	kerroin			30,54	eur			0,00
	AA, kohtuullinen	kerroin	0,05	kerroin	0	kerroin			30,54	eur			0,00
	AA, huono	kerroin	0,11	kerroin	0	kerroin			30,54	eur			0,00
	AA, erit.huono	kerroin	0,22	kerroin	0	kerroin			30,54	eur			0,00
													31,76

1761.4	Kuilut												m3ktr
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus		TO yksikköhinta €/yks	TO yksikkö	TO-kerroin		Yks.hinta €/m3ktr
Louhinta	jumbo	Kone	80	kone-h	1	kpl	200	pom/h	0,40	pom	1,00	pom/m3ktr	0,40
	Mittamies	Henkilötyö	45	tth	1	kpl	200	pom/h	0,23	pom	1,00	pom/m3ktr	0,23
	Työntekijä	Henkilötyö	33	tth	2	kpl	200	pom/h	0,33	pom	1,00	pom/m3ktr	0,33
	Remontti	Henkilötyö	33	tth	1	kpl	200	pom/h	0,17	pom	1,00	pom/m3ktr	0,17
	emulsio + nallit	Materiaali	11	m3ktr	0,35	kg/pom	200	pom/h	11,00	m3ktr	1,00	m3ktr/m3ktr	11,00
	tunnelivarustelu	Materiaali	1,5	m3ktr					1,50	m3ktr	1,00	m3ktr/m3ktr	1,50
	Panostusalusta	kone	2	m3ktr					2,00	m3ktr	1,00	m3ktr/m3ktr	2,00
	Varaosat	Materiaali	4	m3ktr	1	m3ktr			4,00	m3ktr	1,00	m3ktr/m3ktr	4,00
	Rusnauskalusto	Kone	100	kone-h	1	kpl			0,26	m3ktr	1,00	m3ktr/m3ktr	0,26
Lastaus	KUP 210	Kone	100	kone-h	1	kpl	100	m3ktr/h	1,00	m3ktr	1,00	m3ktr/m3ktr	1,00
	KKHt 45	Kone	100	kone-h	1	kpl	60	m3ktr/h	1,67	m3ktr	1,00	m3ktr/m3ktr	1,67
Kuljetus	KA 4-akselinen	kone	8	m3ktr	1	m3ktr	80	m3ktr/h	8,00	m3ktr	1,00	m3ktr/m3ktr	8,00
Vaativuuskerroin	C, kohtuullinen	kerroin	0	kerroin	0	kerroin			30,54	eur			0,00
	C, huono	kerroin	0,04	kerroin	1	kerroin			30,54	eur			1,22
	C, erit.huono	kerroin	0,12	kerroin	0	kerroin			30,54	eur			0,00
	A/B, kohtuullinen	kerroin	0,03	kerroin	0	kerroin			30,54	eur			0,00
	A/B, huono	kerroin	0,07	kerroin	0	kerroin			30,54	eur			0,00
	A/B, erit.huono	kerroin	0,15	kerroin	0	kerroin			30,54	eur			0,00
	AA, kohtuullinen	kerroin	0,05	kerroin	0	kerroin			30,54	eur			0,00
	AA, huono	kerroin	0,11	kerroin	0	kerroin			30,54	eur			0,00
	AA, erit.huono	kerroin	0,22	kerroin	0	kerroin			30,54	eur			0,00
													31,76

Attachment 3. 4510, Protective and damping structures

4511	Meluseinät									rakenne
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus	TO yksikköhinta €/rakenne	TO yksikkö	TO-kerroin	Yks.hinta €/rakenne
Meluseinät	Seinärakenne	Materiaal	0	mtr	0	kpl		0,00	mtr	1,00	0,00
											0,00

4512	Melukaiteet										rakenne
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus	TO yksikköhinta €/rakenne	TO yksikkö	TO-kerroin	Yks.hinta €/rakenne
Melukaide	Kaiderakenne	Materiaal	0	mtr	0	kpl		0,00	mtr	1,00	0,00
											0,00

4513	Tärinänvaimennusrakenteet										rakenne
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus	TO yksikköhinta €/rakenne	TO yksikkö	TO-kerroin	Yks.hinta €/rakenne
Tärinänvaimennusrak	Vaimennusrakenne	Materiaal	0	kpl / kg	0	kpl		0,00	kpl / kg	1,00	0,00
											0,00

4519	Muut vaimentavat rakenteet										rakenne
Tuotanto-osa	Panos	Panoslaji	Panoshinta €/yks		Resurssi / materiaalimenekki		TO:n työsaavutus	TO yksikköhinta €/rakenne	TO yksikkö	TO-kerroin	Yks.hinta €/rakenne
Vaimentava rakenne	Vaimennusrakenne	Materiaal	0	kpl / kg	0	kpl		0,00	kpl / kg	1,00	0,00
											0,00