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**The search for an effective way to deliver Finnish granite for the restoration of historical heritage sites:  
*a review on the business potential of the stone industry***

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History and future of natural stones in architecture (NaStA) –  
bridge between South-Eastern Finland and Russia

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# Introduction

From landscapes to living spaces, we are surrounded by the beauty of natural stone. The world has been built with natural stone. Stone architecture lasts for hundreds of years and within stone architecture history is stored for centuries. Many famous 19<sup>th</sup> century buildings in St. Petersburg, were built mainly with Finnish natural stone. The historical centre of St. Petersburg is on the list of UNESCO World Heritage Sites, which proves its outstanding architectural value. The cultural appearance of this city has been preserved and includes not only buildings, bridges, monuments but also special ornaments and finer architectural details. Granite culture lives on for hundreds of years.

In St. Petersburg, the urban stone heritage shows signs of damage and much has been refurbished in recent years. Old stones have been replaced with newer stone that was available, however the stone differs from the original and this causes visual damage to the building and its surroundings. The conservation of architectural monuments requires us use the original natural stone in the restoration process. As such, the state of original quarries, mining stone industry, and stone industry in Finland are the focus of this review.

The review investigates and discusses the question of what new business models could contribute to developing supply chains and logistics processes in the Finnish stone industry. The empiric results draw on expert interviews, literature, open source material and a case study. The material for this review is based on the work conducted within the EU-project “**History and future of natural stones in architecture (NaStA) – bridge between South-East Finland and Russia**”. The activities of the project supports both the stone industry and geology, production and traditions of cross border market chains. The project was co-funded by the European Union.

## 1 The history of natural stone quarrying in Finland

Granite is a common material used in the construction of Helsinki, St. Petersburg, and other northern cities. Its widespread use is associated with the development of deposits of various types of granite on the shores of the Gulf of Finland.

The granite quarrying industry in Finland is not a recently developed activity as is the case in many other countries. The history of Finnish stone industry is often associated with the history of Saint Petersburg. The importance of using stone in construction and architecture took a huge step forward when in 1703, Tsar Peter the Great moved the Russian capital from Moscow to St. Petersburg, located on the estuary of the Neva River. Constructing the city required large amounts of building materials.

The growth of St. Petersburg over the last 300 years made this city the largest site for stone construction in Europe for a long period of time. This is unusual in some respects as it is located on swampy terrain on the river linking Lake Ladoga to the Gulf of Finland.

At the time of construction, streets, lanes, and paths were made of wood. Then the Tsar ordered that all those entering St. Petersburg, were to be charged with a stone tax. This meant they had to bring head-sized stones when they entered the city. These stones were used to build streets and roads. Founded in 1703, the Peter and Paul Fortress was originally made of wood and earth, but it was transformed into stone fortress in 1730–1740.

In 1763, Catherine the Great ordered that the infrastructure of the city must be built of stone. The most renowned international architects and experts were summoned for realization of this ambitious project. From modest beginnings, the centre of St. Petersburg grew over the next 300 years to attain its current form. Many of its large buildings, monuments, and pavements have been built from Finnish red granite,

which have endured well to modern times. Natural stone like marble, sandstone and limestone have been widely used for building interiors as well as for decorative purposes. By 1795, the new capital already had about a thousand new stone houses with granite stone foundations.

Since the first half of the XVIII century, Finnish granite has been used as the main stone decorative material in the construction of St. Petersburg. The earliest places where granite was mined were the famous quarries in Pyterlahti, located in Virolahti, not far from the modern border between Finland and Russia. Supplies of building stone to St. Petersburg from those quarries took place from the eighteenth to the beginning of the twentieth centuries. Pyterlahti granite became the subject of sale, which marked the start of the development of the mining industry in Finland. This only occurred at the end of the 19<sup>th</sup> century. Red rapakivi granite has become a kind of stone symbol of the city. The Peter and Paul Fortress, bridges and embankments are lined with it, the Alexander Column is carved from it, the columns of St. Isaac's Cathedral are made of rapakivi as are the pedestals of many monuments. The streets of St. Petersburg and the embankments of the Nevajoki and its canals have also been paved with stones from local quarries.

It was fortunate that in the search for suitable building stones, some of the nearest locations in southeastern Finland proved to have an abundance of red granites with ideal properties, both aesthetically and technically. This good fortune enabled quarrying of the largest and tallest columns anywhere. The favorable jointing and mechanical strength enables the extraction of exceptionally large blocks of rock. This is attested to by natural processes in which retreating glaciers have revealed large numbers of huge erratic boulders.

There were also quarries on several islands such as Virluodo, Vanhankylänmaa, Kunnettoma and Reiseri. In the stone quarries of Haapasaari saaristo, the boulders were wedged out of the rock, the quarrying proceeded from the vertical wall, from the breastwork, in a stepwise manner. (Kajatkari T., 1987).

In stone quarries, the boulders were loosened without explosives. If bottom cracks made by nature were missing from the rock or there were too few of them, we had to shoot it with small stakes, a black gun or carry out a wedge. According to earliest practices, straight furrows about 10-15 cm deep were cut into the rock and thick iron wedges were driven in. The frozen water in the crevices of the rock contributed to the cracking process. Later, a row of holes was drilled along the natural crack direction of the rock. Suitable iron wedges were placed in the holes, which were gradually tightened to cut the blocks of stone.

The granite in the quarries of Virolahti was intact and when polished, very beautiful. Therefore, the chief architect of St. Petersburg chose this red stone for 112 carved columns in St. Isaac's Church. The 48 portals on the lower floor are made from Pyterlahti granite. There were 24 smaller columns in the dome and 32 smaller columns in the bell towers. Eight small pillars were installed at the edges of the windows. St. Isaac's Church was designed by the French architect Auguste de Montferrand, who recorded the construction stages in drawings and texts. He describes in detail how the men quarried the billets for the columns from the granite rock. The tools used in this process in the 19<sup>th</sup> century were gunpowder, drills, wedges, mallets and levers. In the 18<sup>th</sup> century however, the stone boulders were removed without drilling and only a wedge groove with a hacksaw, specifically V-shaped wedge groove, were used. Two track bars were then placed, and wedges were driven between them.



Figure 1 St. Isaac's Cathedral, complete with the beauty of its red granite pillars is a great tourist attraction in Saint Petersburg for hundreds of years already.

The construction of St. Isaac's Church took 40 years and started in 1818. The cut of the columns for St. Isaac's Cathedral began in the summer of 1819 and continued into the 1830s. The church was completed in the center of St. Petersburg in 1858.

In 1829, Auguste de Montferrand offered a spectacular monument to be erected in Palace Square in memory of Alexander I. In the 19<sup>th</sup> century, during the reign of Tsar Nicholas I, August de Montferrand played a central role in the construction of Saint Petersburg. He had extensive knowledge in the field of assessing the quality of natural stone, mining and transportation as well as in the fields of architectural design and construction. The most noticeable features of the Montferran period are huge granite columns.

Emperor Nikolai I approved and confirmed Montferrand's monument plans in the fall of 1829. August de Montferrand discovered the necessary monolith in the Pyterlahti quarry, where columns for St. Isaac's Cathedral had already been mined. It was a piece of rock, without cracks, up to 30 meters long and up to 7 meters thick. Quarrying work began at the end of June in 1830 and continued through the winter, until the fall of 1831.

The stone was transported by barge to St. Petersburg where the stones were rolled from the ship to shore and then to a large shed, where they were shaped and polished into columns. In St. Petersburg's Palace square, the column was raised on its base with the help of a log frame and pulleys on August 30 1832. The scaffolding of the monument was dismantled during the winter of 1832–33.

On August 30 1834, as per the great architect Auguste Montferrand wishes, in the very center of Palace Square, a column of pink rapakivi granite with a statue on its top 47.5 meters high was installed. This was a monument to Alexander I, the winner of the war of 1812-1814 against Napoleon. The monument consists of a 2.8m pedestal and a column rod 25.6m tall. The monument is the longest monolith, cut from one-piece stone pillar, in the world.

Finland's foreign trade in 1860 -1917 was represented in the research of Finnish history professor Yrjö Kaukiainen in their work "Punaiset Pilarit".

1860–1864	110–290
1870–1874	220–270
1880–1882	250–340
1890–1894	310–740
1900–1904	1030–2340
1910–1914	2200–4020

Figure 2 Stone in Finland's foreign trade during the period 1860-1917. These data show the export of stones to Russia, minimum and maximum values in thousands of marks. (Kaukiainen Y, 2016).

According to the information on Finnish Foreign Trade, in the half century between 1860 and 1917, the export of granite and street stone increased tenfold.

All the red granite delivered to St. Petersburg was retrieved from an old stone quarry located in Hevonniemi, Pyterlahti village of Virolahti, near the eastern border, on the shore of the Gulf of Finland, by the sea. The source of the pillars and red stone was not forgotten. At the historical stone quarry "Granite Quarry Pyterlahti", you can see that the history of quarrying in Finland has become a place of attraction for tourists!

Today, these rock masses are an open-air mining and industrial museum, where red granite for many building projects, particularly during the 18<sup>th</sup> century, were extracted. Many quarry slopes and wreck stones with traces of wedging have been found in Virolahti as well. At this historic quarrying site in Virolahti, locals and tourists visit to see history firsthand. The site was recently renovated during the Covid-19 pandemic. The quarry museum in Pyterlahti explains the mining techniques of the time and explores the history of the quarry and at the same time reflects an appreciation of the important contribution made by the stone industry.

The foundation of the natural stone industry in Finland was connected to Finnish natural stone deposits and their location close to St. Petersburg. Further, Finnish granite was used for the construction of the Kazan Cathedral (1801–1811), and red Finnish granite became famous through its use in the construction of the St. Isaac Cathedral (1818–1858) and the Alexander column (1832–1838) and monuments, embankments and other famous architectural attractions in the region (Härmä P, 2020).

### 1.1 Transport and Logistic Solutions

It is interesting to delve deeper into the logistical decisions and matters concerning the transportation of gigantic columns in the middle of the 19<sup>th</sup> century. After separating the granite monolith from the rock, it was roughly hewn in the quarry for transportation. Stone quarried in Virolahti often weighed as much as 600 tons and had to be delivered to its destination in St. Petersburg.

Transporting large and very heavy stone blocks to St. Petersburg posed enormous challenges. In fact, the only possible mode of transport was waterborne transport. Thus, the waterway proximity and the construction of loading docks at sheltered sites contributed to the export efforts of stone from South-Eastern Finland.

The roughly hewn stone pole was rolled to the shore for shipping and then was transported to St. Petersburg by a special vessel towed by two steamers. For the delivery of the monolith, a special barge was ordered from the merchant Gromov's shipyard, where ship engineer K. A. Glazyrin designed and built a 45m long and 12 wide boat-barge named "Saint Nicholas", with a carrying capacity of up to 1100 tons. A wooden pier was also specifically built to carry out the loading operations of unusual cargo (Figure 3).



Loading this monolith of about 670 tons onto a barge was an extremely difficult operation, which needed to take the logistical requirements for transporting weighty blocks of stone into account. It took 15 days to move the column from the place of its extraction to the loading dock. There were difficulties

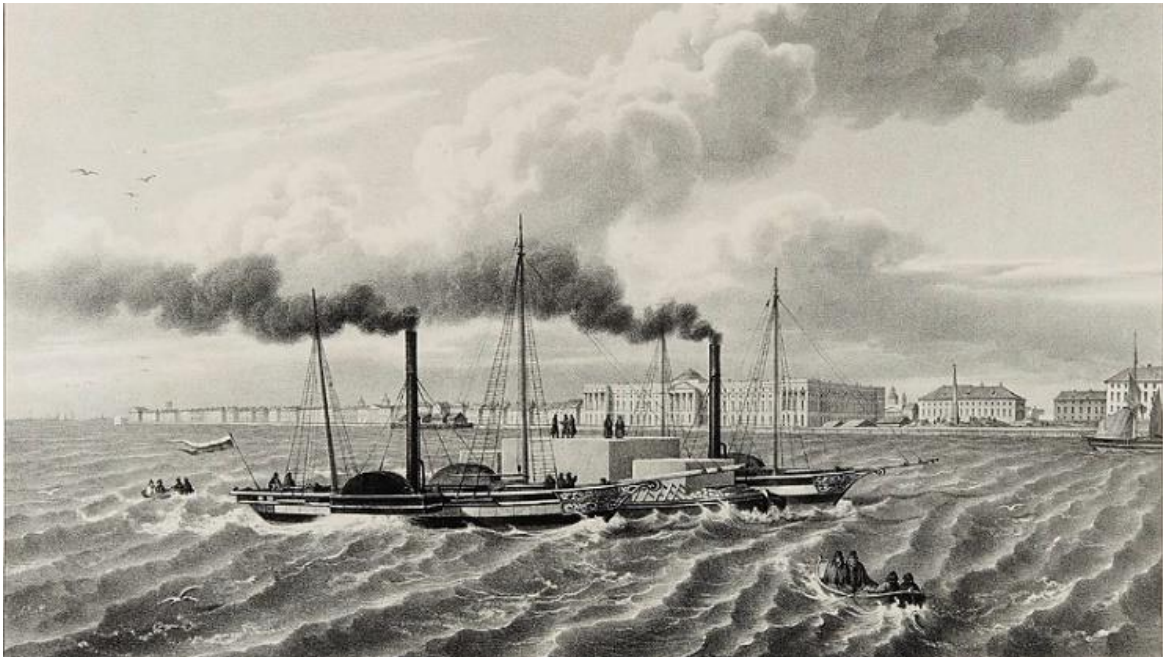


Figure 3 Architect A. Montferrand's drawing. The granite cargo of Alexander's column arrives by ship in St. Petersburg. Museum Agency.

during the loading of such a huge piece of granite in Pyterlahti. First, the barge tilted and the pole fell into the sea after the support bars broke. Fortunately, the water was not so deep and the ship did not capsize. This meant that the problem could be handled promptly. The two large stones of the monolith's foundation were also transported with it. The delivery and unloading of the monument took considerable time and effort.

1250 six-meter-long piles were sunk into the foundation. Standing on its own weight, the column was raised on August 30 1832, with the help of a rack and rope system designed by engineer Agustín de Betancourt. Three thousand people participated in the erection, which lasted an hour and 45 minutes.

It is estimated that more than 2.5 million tons of granite have been quarried and exported from the Virolahti area to St. Petersburg; equivalent to the 220 shiploads of cargo. This operation required a tremendous amount of planning and effort and involved hiring a large workforce skilled in stone processing. Much of this occurred prior to the advent of mechanized quarrying and transport. Thus, in demanding conditions, without modern cranes and machines, it was possible to quarry and transport stone about 200 years ago.

The result of all these forces is the granite appearance of Saint Petersburg in its architecture, monuments and embankments. This appearance is valued by tourists, specialists and city residents as well.

### **1.2 Natural stone industry later development and the architecture grow 1917-1970**

In 1885, Tsar Alexander III (1845–1894) established a Finnish geological service that is today part of the Ministry of Labour and Economy. Through a series of research, events and publications it works to develop the stone industry and increase the sales of Finnish natural stone. This service is now known as Geological Survey of Finland and it is a leading European competence center on the assessment and sustainable use of geological resources.

Until the end of the 19<sup>th</sup> century this first exploitation of the Finnish natural stone deposits was mostly accomplished by simple means and without the use of machines. Thus, it does not entail the development of an industry. Later when the first private companies started to invest in modern stone saws and grinders and granite quarries at various locations along the coast, the foremen were sent to other countries for education, such as Scotland. (Härmä P., 2020).

In Finland, the application of natural stone in architecture occurred faster than any other Nordic country. In 1893, the geologist Jakob Johannes Sederholm took over the Geological Service and mapped the Finland's granite deposits. Later in 1900, he established the company Finska Stenindustri (Finnish Stone Industry), which rapidly grew into the country's largest natural stone producer. One of the shareholders in Finska was the famous architect, Lars Sonck. He made such buildings as Tampere Cathedral, Kallio church and the Telephone Association building in Helsinki. As a building stone, granite has been used in stone foundations, colonnades of buildings, emphasizing their solidity, and street structures.

The first large company in the stone industry was the Joint-Stock Company "Granite" that was founded in Finland and later Moscow, Riga, and Warsaw. Also, there was Joint-Stock Company of the Finnish Stone Industry (Suomen Kiviteollisuus Osakeyhtiö), East Finland Joint-Stock Granite Company and some other firms engaged in granite quarrying and processing at the time. Suomen Kiviteollisuus Oy company was founded in 1900 and still exists today. They worked mostly with red rapakivi granite at the beginning of the 20<sup>th</sup> century.

Before the First World War Suomen Kiviteollisuus Oy supplied a lot of building stone, especially to St. Petersburg and Helsinki. The company's significant building stone sites of that period are the Johannes church in Tampere or Tampere Cathedral, National Museum of Finland in Helsinki, Polytechnic Association building, Wuorio building, Finnish National Theatre, the mortgage association's building (now occupied by Ministry of Transport and Communications), Telephone Association house, Otava's building, Kallio church in Helsinki, Finnish cities fire station in Turku, insurance company Salamandra's building in St. Petersburg.

Kovakivi Oy of Tampere, for example, celebrated its 100<sup>th</sup> anniversary in 2014. Another well-known Finnish granite miner is Palin Granite Oy, a family business that was founded in 1921. It successfully quarrying and exporting a good amount of granite product to global markets. Ylämaa Granite started their operations in 1958 and is committed to Finnish granite.

According to the Geologic Survey of Finland's research, there were more than 70 quarries in total, operating during a period spanning from 1763 to 1917 (Härmä P, 2019).

At the turn of the century, building stone and street paving stones were needed for construction both in Finland and abroad. At the beginning of the 19<sup>th</sup> century, high-quality rapakivi was transported to Tallinn and Narva for the construction of fortresses. In the past, granite has been exported from Finland to Russia and the USA, among locations. There were tens of thousands of palaces and smaller houses in St. Petersburg at the beginning of the 20<sup>th</sup> century that were built with granite. Coastal walls and bridges along the Neva River and canals were also built with Finnish granite. There was a great demand for Finnish granite at the beginning of the 20<sup>th</sup> century that helped the stone industry take a central role in the economy of Finland.

The Virolahti and Vyborg Bay areas had already become very busy stone quarrying and processing centres by the first half of the 18<sup>th</sup> century. This also involved shipbuilding as it was needed to transport stone, as well as sawmilling, renting land for quarries, and the development of freight and catering services. The professional skills have developed over decades, and nowadays the stone industry uses a wide range of modern techniques in mining and product processing.



## 2. An International project at Xamk builds bridges

In 2019, the **EU project NaStA** started, and it that is implemented within the framework of the Cross-Border Cooperation program CBC 2014-2020.

The joint project between Russia and Finland arose as a continuation of the shared history and close ties between Russian and Finnish geologists. The partners of South-Eastern Finland University of Applied Sciences (Xamk) in the NaStA-project are Lappeenranta University of Technology (LUT) and St. Petersburg State University of Economics, State Company Mineral / SC MineraL, Ltd Geostrom with Geological Survey of Finland as a lead partner.



The idea of this 3-year project, which ran from 1 October 2019 until 31 July 2022, is to support the stone industry and geological interaction, production, applications, and traditions of cross-border market chains. The programme area is characterized by valuable historical buildings and constructions built of stone extracted and produced in the programme area.

For example, Helsinki has many interesting architectural monuments, architectural ensembles, cathedrals, and churches made of granite, such as Helsinki Cathedral, the University of Helsinki, the Helsinki University Library, and the Government Palace. There are a lot of good examples of granite beauty and durability. Finnish stone made many pieces of architectural heritage which decorate many different cities all over the globe: St. Petersburg, Vyborg, Moscow, Narva, Tallinn, to name but a few.

Figure 4. Rapakivi rock in national Repovesi park

The project's full name is "**History and future of natural stones in architecture – bridge between South-East Finland and Russia**". Partners from the Russian and the Finnish side started the joint activity in working groups. The project was divided into 5 activity groups and the basic aims were:

- Evaluation of the demand for original natural stone in buildings and constructions collecting a catalogue of natural stones used in buildings and needs for restoration in cooperation with authorities;
- Evaluation of availability of original stone from old quarries and from alternative stone deposits. Based on the results of fieldwork and laboratory measurement conclusions of possibilities to re-exploit historic quarries or the need to use alternative sources for restoration works will be drawn;
- Evaluation of indicators that characterize the historical stone type as a "fingerprint" to connect the traditional stones to the original quarries. Methods to produce the appearance of the exposed historical natural stones for newly produced stones in case of restoration;
- Assessment of new business opportunities with stakeholders of the project in the project area to begin and facilitate cross-border business relations with Finnish and Russian actors. Providing a description of the logistic supply chain from the quarry to restoration construction.

Xamk is responsible for activity 4 "Business potential for enterprises and technical and economic feasibility assessment". The activities of Xamk focus on gathering material to complete an assessment of new business opportunities in cooperation with the project stakeholders. Logistics operators in South-Eastern

Finland and Russia will be involved from the start to facilitate cross-border business relations between Finnish and Russian operators. There was also an idea to describe the logistics supply chain from quarry to restoration structures.

In the NaStA-project, Xamk planned to expand and strengthen the operating environment for SMEs by increasing knowledge about the use of natural stones and related business opportunities in the fields of cultural and historical heritage. Granite was seen as the most important natural stone in this work. Despite the fact, that granite is a durable rock, it is subject to destruction, especially in architecture after hundreds of years. Granite destruction ones from the influence of industrial emissions, exhaust fumes, and atmospheric pollution, as well as vandalism and natural ageing.

Currently, there is certainly a demand for restoration works that preserve the original characteristics of natural stones. The planning activity should reveal the demand and provide the diversity of business solutions for the benefit of the stone industries in both countries.

The main measures of the project include studies on the restoration needs for original natural stone resources in buildings and construction, as well as the availability of suitable materials for restoration. This goal is supported by our partners' research and classifying the types of stone used in historic buildings.

In Xamk, we have two main tasks to do. The first of them, 4.1. contains an evaluation of key stakeholders, including stone producers, suppliers, authorities, and logistic operators located in the project's operating area. The project area includes Kymenlaakso, South Karelia, and Uusimaa in Finland and Saint Petersburg in Russia. The project activities create:

- 1) a framework for logistic cluster and natural stone commercial activities;
- 2) a description of the logistic supply chain;
- 3) a video of the "Story of stone".

After this, we would make a review to submit, analyze, and assess all gathered information and material. While planning the activity, it seemed possible to compare the stone extraction process in Finland and in Russia to exchange knowledge and competence.

The next task in work 4.2 was describing the natural stone cross-border logistic supply chain from quarry to final use. This activity is accomplished by comprehensive examination and clarification of the natural stone logistic supply chain. The collected data is described and distributed transparently and the logistic chain and history of using traditional stones will be also visualized by making a video.

The materials were obtained with the help of open literature and discussions with experts. In addition to expert discussions, representatives of companies in the natural stone industry were interviewed as well as authorities to gain a full picture of the state of the industry. Based on these materials, it could be possible to develop the study into possible forms of cooperation or working business models.

Finnish granite is available for the needs of historical renovation, as it provides authentic materials from the same or nearby quarries. It would be reasonable to develop and strengthen cooperation between Finland and Russia with respect to the stone industry. Commercial cooperation ensures the availability of stone raw materials as well as the restoration of historical heritage sites. The demand for stone production could lead to some new forms of business cooperation, benefiting both Russian and Finnish history, tourism, and the economy.

### 3. Stone industry in Finland

The mineral market is a well-developed business and in all countries the use of natural stone is observed. More than 70% of the total consumption of stone products is used by the construction industry. There are large reserves of natural stone in the world, but the distribution of their deposits is uneven. The main stone producers and suppliers of products to the international market, which account for more than two thirds of world production according to data from 2015 are China, Italy, India, Iran, Brazil, and Ukraine. While the main markets for natural stone were the countries of Western Europe, the USA, and Japan. The Nordic countries have an interesting range of natural stone deposits, some of which are well known in international markets.

Finland is one of the largest exporters of granite worldwide. In Finland, the export of stone industry products play an important role in the economy. According to the Finnish Natural Stone Association, there are currently 200 companies in Finland that mine and process granite. Today, there are 50-60 operating granite quarries in Finland. As a producer of natural stone, Finland is among the 15 largest countries and among the 10 leading exporters of granite. (Kiviniitty 2020).

The main types of natural stone mined in Finland are granite, marble, slate and steatite. The absolute leaders in mining in this list are granite and soapstone. Large quantities of granite are mined from 20-30 locations in large blocks for the export market. Due to the large production size, these stones are well suited for a variety of projects that require significant quantities of uniform quality material. (Härmä P. 2021). In fact, the development of the stone industry could be in the form of raw material pieces of different sizes and processed products. Regarding the stone industry, Finnish stone manufactures offers a large range of monuments, tables, paving stones and polished slabs the customers inside the country and outside. In the last few years, the interest of world market is mostly focused on raw material from Finland. The finished product which goes on sale can be in the form of large blocks, flat slabs, decorative stones, gravel (crushed from larger pieces or even in form of stone dust).

Due to the good quality of rapakivi granite, its beautiful color, and the fact that stone in Northern countries is robust, the natural stone demand outside the country is mainly focused on big granite blocks, which could be transformed in different forms later. Based on the statistics from Finnish Customs, granite blocks accounted for 97% of stone export in 2019 (Figure 5).

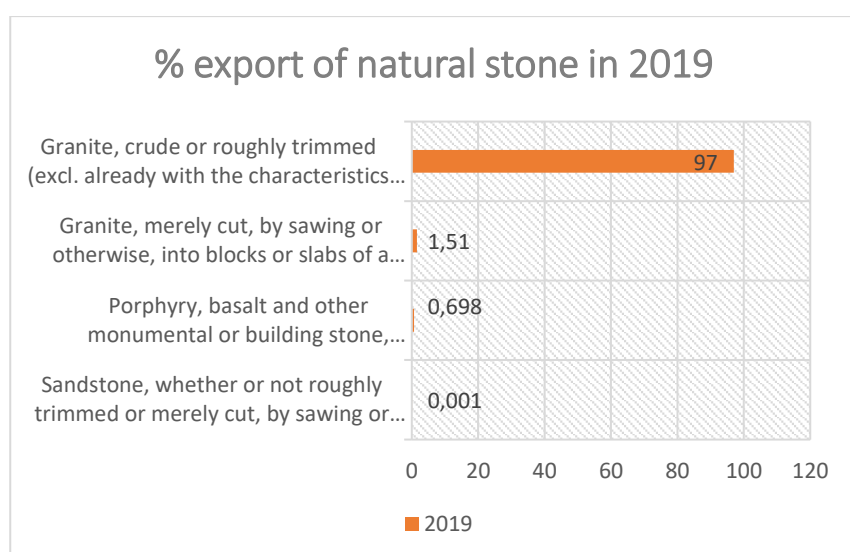


Figure 5. Export structure of natural stone from Finland in 2019, represented by the following main commodity groups (Customs statistics).

The block is a product of a granite quarry for which there are strict quality requirements in terms of integrity, appearance, and size.

A granite block is a large piece of stone extracted from the granite deposit. In a mining process, stone producers aim to produce rectangular-shaped stone blocks that meet quality criteria. A specific feature of the blocks is their large mass to their volume. Figure 6 shows the drill marks of the granite block



Figure 6. Granite block with special marks and personal ID number. This number carries information about the stone color and weight, among other things.

Granite blocks are the basis for subsequent cutting and processing. They are used for the production of complex granite products: from simple curbstones and tiles to complex structures.

The Finnish stone industry provides a wide range of rough granite blocks in different shapes, sizes, and quantity demanded by international buyers. Some blocks can be 10 tons, some 25 tons, ranging from 0.5m<sup>3</sup> to 5.0m<sup>3</sup>. Some stone sizes can be, for example, 310x140x205, some of them smaller. In the Finnish stone producers' opinion, blocks are the optimal form for the transportation of granite to the customer with great potential for being cut into slabs or crushed for smaller parts. A block is easy to fix on a transport floor, easy to keep safe during transportation, and easy to make it into the desired form later. It can be monument or tiles, polished, crashed or just cut.

The extraction of natural stone in Finland has increased in the years before 2008. In recent years, approximately 40% of all mined stone was exported to Russia, the countries of North-Eastern Europe and other states. Granite is mined in large volumes at several sites within the same deposit. Mining is carried out mainly in the form of rough blocks for export deliveries.



### 3.1 Rapakivi is a well-known granite

The Finnish natural stone industry is traditionally represented by soapstone, granite, schist, marble, and some over stones. Finland is well-known for granite production and export of Finnish granite creates world famous, durable, and unique architecture.

The best-known type of granite in Finland is rapakivi. Almost 70% of all granite produced in Finland is rapakivi granite. The main production area is the Wiborg rapakivi granite batholith in south-eastern Finland. The batholith is a source of mostly brown and red coarse-grained granites with the characteristic texture of large round K-feldspar crystals. (Härmä P.2020).

Due to its beautiful, uniform color and structure, as well as its durability, it is very popular and used e.g., as building blocks. In some areas, the rock surface is strongly weathered, forming a gravel like surface which was called rapakivi by the local people. Similar granites were later discovered in several other areas, e.g., Sweden, the Baltic countries, Russia, Ukraine, North and South America, Africa, and Australia. (Selonen O, Geotechnical report),



Figure 7. Red rapakivi granite in Hamina.

According to GTK science information, rapakivi granite is the most important raw material for granitic natural stone in Finland, as almost 70% of all granite produced in Finland consists of rapakivi granite. (Härmä P, 2020). The main production area is the large Wiborg rapakivi granite batholith, which extends over an area of 18,000 square kilometres in south-eastern Finland. The largest rapakivi area in Finland includes the entire Kymenlaakso region up to South Karelia, continuing from there to the Russian side to the vicinity of Vyborg. This batholith is a source of brown and red granite with the characteristic texture of large round feldspar crystals. There is also a green rapakivi granite variant. Today, the Wiborg batholith is the main production area for granitic natural stone in Finland.

The prevailing rock type in the area is brownish rapakivi granite with commercial name “Baltic Brown”. “Carmen Red” is a more desirable reddish coloured granite mostly located close to the village of Pyterlahti, within the Virolahti area. There is also Eagle or Kotka red rapakivi, which is located close to Kotka. Green rapakivi can be found closer to Lappeenranta, in the Ylämaa area.

The textural appearance of rapakivi granite is highly distinctive. A typical feature of rapakivi granite is the distinct surface with an abundance of beautiful feldspar crystal ovoids, typically 1-4cm in diameter and usually mantled by a thin layer of coloured plagioclase mineral.

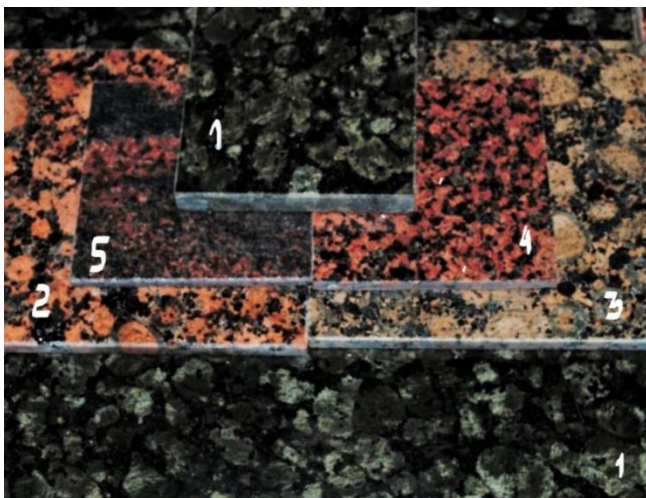


Figure 8. Famous types of Finnish granite with distinctive textures: 1 - Baltic Green, 2- Carmen Red, 3 – Baltic Brown, 4 – Eagle Red, 5 – Aurora. Picture Kiviniitty A.

There is a large range of countries, that values all the special features of Finnish rapakivi granite. They are the USA, Canada, Taiwan, China and many others.

Finnish granite is resistant to both climate change and environmental pollution. These granite grades are in the highest demand.

### 3.2 Modern industrial quarrying

#### NATURAL STONE QUARRIES 2022

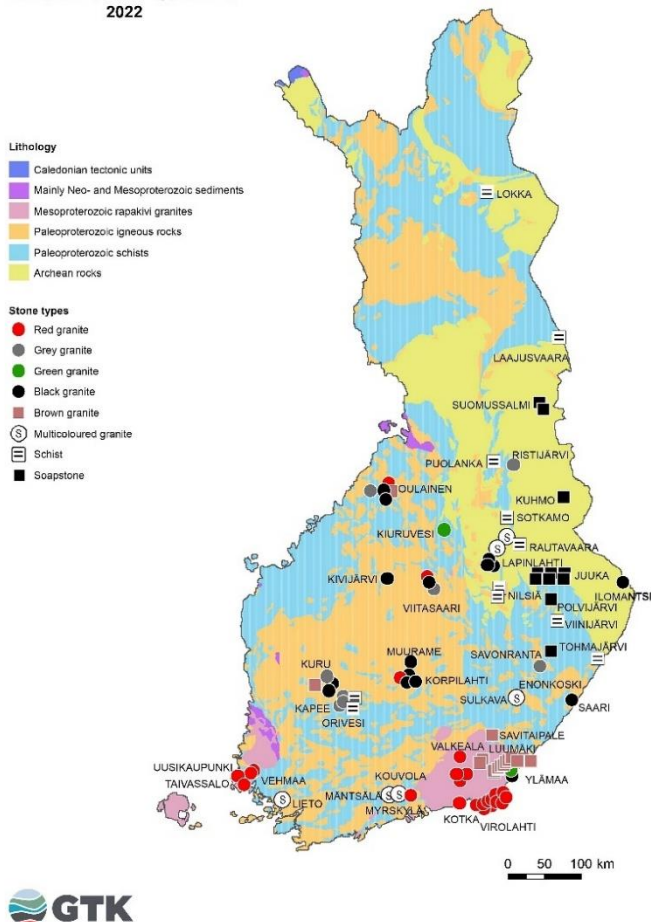


Figure 9. Natural stone quarries GTK, 2022

There are several rapakivi areas in southern Finland, but the largest of them is the Wiborg rapakivi area, which stretches from eastern Uusimaa all the way to Russia. This massive 18,000 km<sup>3</sup> rock batholith consisting of several lava rock types formed inside it. (Valkama M. 2016). Most of the currently active quarries are located in South Karelia, close to the Russian border and Virolahti. In the map, we can see the Wiborg batholith in the south-east, with areas of red, brown and green types of rapakivi quarrying.

Modern industrial quarrying has a long history. From the beginning of the 1900s up to the 1970s, granite was quarried in the Wiborg batholith in localized areas for both domestic markets and for export. The modern industrial scale quarrying of granite in the Wiborg batholith started in the 1970s. (Härmä P, 2020).

Currently, the main granite types in the Wiborg batholith, produced in the eastern and south-eastern parts of the batholith are rapakivi granites. The current production has mainly red tone for granites with commercial names “Carmen Red”, “Eagle Red”, and “Karelia Red”, also “Balmoral Red”. The brown granite variety and green rapakivi Finnish stone produced are named “Baltic Brown” and “Baltic Green”.

**Carmen Red** There are three quarries of Suomen Kiviteollisuus Oy company: Pyterlahti, Lypsyniemi and Joukaisten quarry in Virolahti. Palin Granit Oy has a quarry in Virolahti, Vilkkilä and Granicon Oy has one also there.

**Karelia Red** Finnish companies Interrock Oy, Palin Granit Oy, LT Granit Oy work in two quarries in Virolahti and one in Kouvola.

**Eagle Red** Two quarries of Palin Granite and one of Suomen Kiviteollisuus Oy – Finska Stenindustri Ab are located in Kotka.

**Baltic Brown** Palin Granite has permission for 3 Ylämaa quarries and one quarry in Luumäki. LT Granit Oy has two places in Ylämaa to harvest granite. Suomen Kiviteollisuus Oy Parkkola's quarry, Interrock Oy has one and Granicon Oy has a quarry in Ylämaa.

**Baltic Green** There are two quarries with green rapakivi: LT Granit Oy and Palin Granit Oy, both in Ylämaa.

According to the Geological Survey of Finland GTK, there are about 30 active granite quarries in the south-east of Finland. Industrial quarrying of granite started in 1971 with the production of brown rapakivi granite in the Ylämaa area in the eastern parts of the Wiborg batholith. Later, active quarrying operations spread further south in the Virolahti and Kotka areas, extracting red granite.

So, the main important quarrying sites in the Wiborg batholith and one of the main locations for production in the world are Ylämaa, Kotka, Virolahti, Anjalankoski, and Savitaipale. Today, industrial quarrying on the Wiborg batholith has grown to be the main location for the production of Finnish granite.



Figure 10. Quarrying process in Ylämaa. Kuva Kiviniitty A. 2021

In 2019, new deposits of red granite were found in Finland. The Geological Survey GTK has mapped the rocky areas of Southeastern Finland and continues to search within the framework of the Nasta project. In



the Nasta project, the availability of original stone from old quarries and alternative bedrock is also evaluated, and conclusions are made about the possibilities of utilizing historical quarries. South-eastern Finland is home to most of the rapakivi granite quarries, some of which have been operating for 100 years already. The columns of St. Isaac's Cathedral in St. Petersburg were quarried from the red rapakivi granite of Pyterlahti about 200 years ago. Both historical and other quarries in south-eastern Finland are in the common Vypurg rapakivi massive and are concentrated near the Russian-Finnish border.

### **3.3 Aspects of import and export of Finnish stone industry**

Exports play an important role in the natural stone industry of Finland. The granite quarries are well placed to increase exports of red granite to Russia. Cross-border cooperation and the use of local materials minimizes transport emissions.

At the end of the 20<sup>th</sup> and the beginning of the 21<sup>st</sup> centuries, the production and processing of stone in Finland was intensively developed. Mining and processing of natural stone in Finland, combined with good market demand, has led to an accelerated growth in Finnish granite exports. The interest in natural stone building material helped in exploring batholiths to discover good supplies of granites suitable for construction.

As a producer of natural stone, in 2019, Finland was among the 15 largest countries and 10 leading exporters of granite stone production.

Since 2000, natural stone production in Finland has gradually increased. Based on the statistics from Finnish Customs, Finnish granite was in high demand in Italy, Spain, Germany and Asia in recent years. During the same period, there was a gradual increase in export (Figure 11). In the last decade, the stone industry trend is growing export to China. Although stone is exported to China, it is at the same time the world's largest stone producing country. In fact, China exports granite to many construction projects in Finland, so Finland as a stone producing country is facing a tough situation.

In 2007, the annual turnover of the stone industry was almost 200 million Euro, half of it was granite products. The value of export counts 40% of the turnover. The number of actively operating companies was about 200. They employed 2000 persons in Finland. (Loudes N. 2007).

There was a sudden decline in granite export in 2008–2009, which experts attribute to the global financial crisis. Subsequent growth in natural stone exports peaked at 431,242 tons. In the last 20 years, the highest export figures for natural stone were in 2011, since then the export of granite has shrunk. In recent years Finnish granite exports have been declining. The total export value of natural stone decreased in the last 5 years due to tough competition with imported natural stone.

At the same time, as we can see from the table with the data from Finnish customs, there was a increase in natural stone imports and by 2019 import achieved the highest value of 77,181 tons. Finnish stone producers and also Finnish society noticed this fact. The open source data mention the arrival of imported stone, for instance; 2015 in Seinäjoki, 2016 – in Kouvola, 2017 - in Turku, the large Metro construction project in Helsinki and others. It was noticed that municipalities and decision makers chose imported natural stone for city construction goals for one main reason: the price of imported stone is more affordable than local stone.

EU procurement law demands that the price of the offer into account first in land construction or renovation sites for municipalities. Therefore, stone industry entrepreneurs, representatives and industry specialists also confirm an intensification of competition with Asian producers.

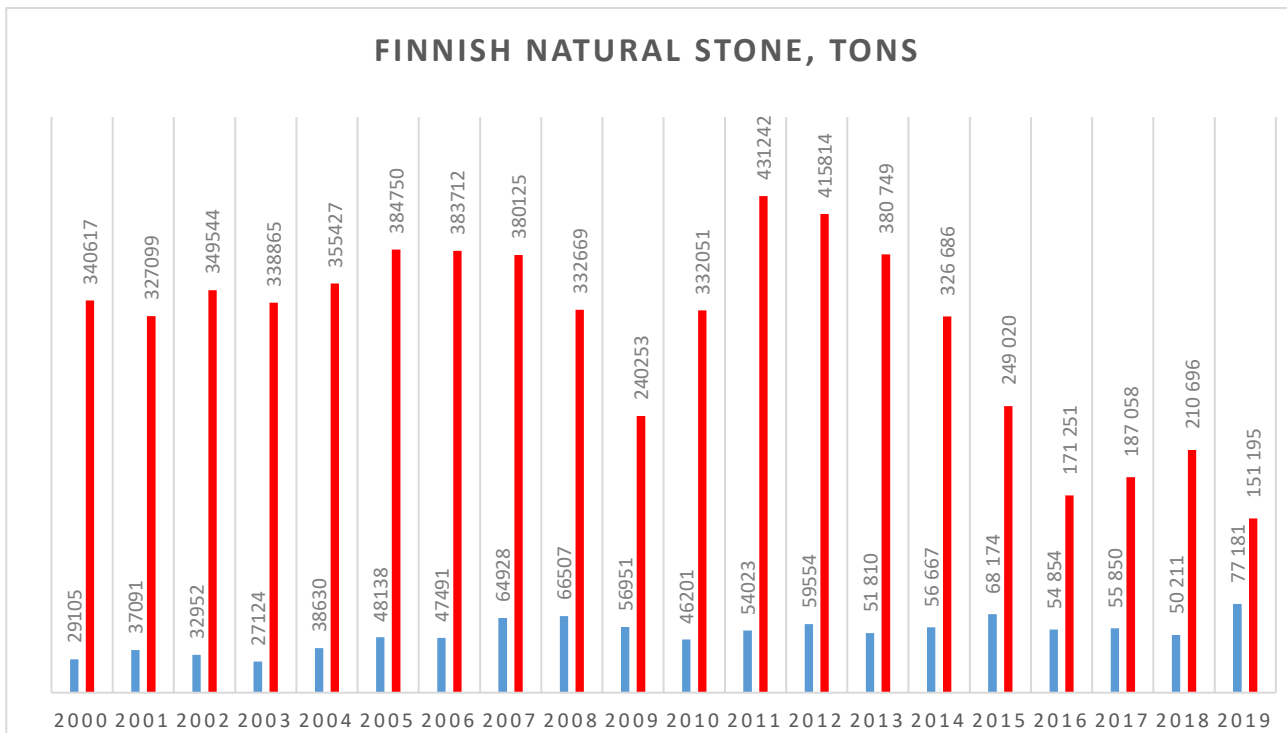


Figure 11 Natural stone trade in 2019, Kivi Ry

The Nasta-project area in south-eastern Finland has excellent global connections. The rapakivi granite producing area is well equipped with transport networks. HaminaKotka port is Finland's largest general port and is an important freight transport center in Europe and the Baltic Sea region. The navigable waterways nearby are a large advantage. The port of HaminaKotka is located at the junction of the eastern Baltic Sea and is the core port of the Trans-European Transport Network (TEN-T) along the Scandinavian-Baltic Sea core corridor.

Inland water traffic consists of lakes, river and Saimaa canal traffic and international traffic for many. Cargo often starts from Lappeenranta's port Mustola, which is the most important cargo port in the Saimaa area. Ylämaa's quarries are located at a distance of about 10km from Mustola, which is very close.

The basis of Southern Finland's transport system is the road and rail networks that connect cities, ports, airports and customers to each other and to other transport centers. The international border crossing point exclusively for rail traffic is Vainikkala, right in the vicinity of many quarries. Kouvola is Finland's largest railway hub and rail delivery suits the transportation of granite block well, if the distance is more than 500km or if the delivery is a large amount of blocks.

In Finland, road E18 plays a key role in this transport system as it serves urban areas, industrial areas, and connects them to border crossings, all ports, and railways on the south coast. Almost all of Finland's and Russia's export cargo in recent years was road freight transport. The road network enables stone blocks to travel to Russia by truck. The Kymenlaakso region in Finland is often called an international hub of logistics and logistics-related business & knowhow in the Baltic Sea region

What does the stone block supply chain look like? First of all, stone block that is extracted from the bedrock, is loaded into trucks in the quarry with help of wooden pallets with chains (Figure 12). Modern quarry work deals with the lifecycle phases of a natural stone quarry, quarry operation, landscaping, and after-use.



Figure 12 Fixing granite cargo to the truck. 2021

From the quarry, huge blocks of raw stone are examined, named, sorted, and stored in warehouses or loaded onto powerful trucks. Later they are sent to nearby factories for processing or often are sent to the port for container loading. Large blocks from warehouse, upon request, are sent by road for further delivery to customers by rail, to the port for loading into containers and shipping by water. Special manipulators are folded into wagons and securely fastened so as not to be damaged during transportation. The stone is not covered, but often additional fastenings are used with bars or wooden fixing materials.

Granite blocks from Finland have wide possibilities, but mainly use land routes close to the destination and container transport by sea for long distances.

Each mode of transport choice for the stones is appropriate according to the terms of delivery and distance. Transporting granite from Finland to Russia is the most popular and logistically sensible form of transport by road. Rough stone blocks are transported by road over distances of up to 500km. Usually these are flatbed trucks. The road network and the proximity of the border enable stone blocks to travel to Russia by truck. The versatility of transport links in this region is not yet fully used in the natural stone supply chain from the quarry to Russia. This is due to the relatively short distances between the two points and the ease of transportation, since only one loading and unloading session is needed compared to, for example, a combination of a truck and a train.

According to Finnish customs data, the total export of granite to Russia is about 2,000 tons per year. The average load for a truck is 20–23 tons. In other words, about 100 truckloads of granite are transported to Russia each year. This same trend continued from 2015 to 2020.

When the truck arrives at the customs inspection station at the border, it can be checked for radiation. Most types of granite have a radiation level between 0.02 and 0.05 microsieverts/hour. Natural stone in

Finland corresponds to the normal value ranges of terrestrial radiation. When the truck physically arrives at the terminal, the driver delivers the documents to Russian customs in electronic form. In general, within a day, the customs clearance process is completed, and the stone block is delivered to the customer.

Trucks are not only used for the Russian delivery of granite, but also to European countries, such as the Baltic countries or Poland. The granite goes by road directly to customer from the quarry.

Sea shipping can partly include road transportation from the quarry to the port (Figure 13). As the blocks are natural material, they do not have special fixing points that can be used to secure the load during transport. For the safe fixing of stone on the bed of a container or transport, special requirements are imposed on the transportation of blocks. Export and import restrictions, special conditions and



requirements for wooden packaging material are done according to the local customs rules.

The so-called ISPM 15 standard's handling and marking requirements for wooden packaging material are meant to prevent wood-destroying elements, e.g., pine anthrax transmission from one country to another.

The port of HaminaKotka loads granite blocks into containers, provides fixing norms and load containers to the vessels to deliver to European and Asian clients. Containers are used for delivery to China, India and other Asian countries. The transport company delivers stone blocks from the quarry to the port, then the blocks are packed into containers. The stone container leaves the port in a smaller feeders to Antwerp and Bremenhaven to be reloaded to an ocean vessel, if necessary. South-eastern Finland's stone producers use logistics services on all routes in the port of HaminaKotka, with assistance of 3PL company.

Figure 13. Truck on route to the port of HaminaKotka from the quarry in 2022.

Supply chain leaders and stone producers operate in a competitive environment and are increasingly working with the third-party logistic company 3PL to stay ahead of the competition. There are several reliable stone industry logistics companies in the port of HaminaKotka that have been working with granite cargo for many years.

### 3.4 A Cluster of Companies in the Stone Industry

The main actors of Finnish stone industry are stone producers. In the 1970s, there was an intensive development of Finnish natural stone quarrying and processing rapakivi. In the area of Ylämaa the companies Lehdon Kiviliike Oy, companies Baltic Granit Oy, Louhinta Tielinen Ky, and Finska Stenindustri Ab operate. Later quarrying operations started closer to Kotka and Virolahti.

Nowadays, the production of rapakivi granite is still concentrated in south-eastern Finland and represented by such companies as Ylämaa group, Suomen Kiviteollisuus, Palin Granite, Granicon Oy, Interrock Oy and TG Granite Oy. The natural stone industry is a very SME-dominated industry. The majority of the companies

are small family businesses. For example, Suomen Kiviteollisuus Oy celebrated its 100<sup>th</sup> anniversary in 2014 and Palin Granit was founded in 1921.

**Suomen Kiviteollisuus Oy** has a long history and it was founded more than 100 years ago. It has special role in the stone industry cluster because red rapakivi granite, used in the architecture of St. Petersburg was produced from their quarries in Virolahti. Additionally, they produce green stone from quarries in Ylämaa and Hujakkala.

**LT Granit Oy** is a company within the **Ylämaa Group**. Their activities started in 1958 and now they are a family of five companies with a wide range of working directions: from landscape projects, production, to Environmental Stoneworks service, manufacturing and construction projects. It is one of the leading stone companies in Finland. Their production of stone blocks is located in Ylämaa.

**Palin Granit Oy** produces stone in Virolahti, Vilkkilä, Luumäki and Ylämaa. The Palin Granit company was founded in 1921 and initially engaged in the manufacture of monuments before diversifying to construction but is now focused on mining. The largest quarry, owned by Palin Granit, produces between 15 and 20,000 m<sup>3</sup> of brown rapakivi material per year. The company is run by the third generation of the original family, and the fourth generation is getting ready to join it.



FIGURE 14. Loading of the block to a truck in the Palin granite quarry

**Granicon Oy** has 2 mining sites in Ylämaa and in Virolahti. Since 2000, the Finnish company **Granicon** has been a member of the Hellenic Granite Company Group. Granicon exploits granite deposits and has three active quarries in the regions of Ylämaa, Virolahti, and Luumaki. The annual production exceeds 20,000 m<sup>3</sup> of granite. The company aims to further increase the production via new investments in equipment and cutting-edge technology in order to meet increasing demand. Granicon quarries the famous granites Carmen Red and Baltic Brown.

Also among Finnish green granite producers are such companies as Euro Granit, red granite producers TG Granite and Kymen Granite Oy with its own truck park.

**Kymen Granite Oy** is a Finnish company specialising in the production of coarse-structured granite. Although stone production started in the 1980s, the company was established later in 1992. Kymen Granite has two quarries in southern Finland. From these quarries many different granite products and blocks are delivered to domestic and international markets. The landscaping stone production is a large part of all operations, environmental stone production, and also crushing.

**Veljekset Turpeinen Ky** is a family business in the construction industry that has been operating in the Kotka area since 1953. In addition to the owners, the company employs more than 30 land construction professionals with modern machinery. The number of involved companies is quite large.

Currently there are about 10 stone producing companies engaged in granite mining. These stone quarry entrepreneurs collaborate with different groups of transport companies and logistic companies. They contact clients from Finland and abroad. The logistic company takes care of documents for delivery, customs clearance, and process of loading in the port. The system of cooperation can be seen in Application 2.

List of stone industry involved companies is presented below:

Quarring companies

- Ylämaa Group
- Palin Granite
- Suomen Kiviteollisuus Oy
- Granicon Oy
- TG granite Oy

Carriers:

- Jokimiehen Kuljetus OY
- Kuljetusliike Aho ja Huutinen Oy
- Husun Metsäkuljetus Oy

Construction

- Veljekset Turpeinen Oy
- Lujatalo Oy

Port operators, logistic companies

- Greencarrier Oy
- DSV Road Oy
- Teamlog Oy

Infrastructure companies

- Sweko
- YIT
- NCC
- SRV

Customs

HaminaKotka port authorities

The list of companies is obviously larger because stone (and the industry supporting it) has large range of applications. To the list, there could be added municipalities or cities, architectural firms, landscape gardening companies, interior design or building companies or stone shops. The subcontractor and customers can be small local businesses, or even cities in nearby areas, factory communities, municipalities.

Cluster of connected companies are presented in a form table below (figure 15) which names companies that have more active cooperation activities in the stone business.

Cluster of stone industry companies in South-East Finland					
Quarrying and manufacturing	Transport Companies	Construction and infra companies	Port operators, logistic companies	Authorities	Additional
<ul style="list-style-type: none"> <li>•Ylämaa Group</li> <li>•Palin Granite Oy</li> <li>•Suomen Kiviteollisuus Oy</li> <li>•Granicon Oy</li> <li>•TG Granite</li> <li>•Euro granit</li> </ul>	<ul style="list-style-type: none"> <li>•Jokimiehen kuljetus OY</li> <li>•Kuljetusliike Aho ja Huutinen Oy</li> <li>•Husun Metsäkuljetus Oy</li> <li>•Kymen Granite Oy</li> </ul>	<ul style="list-style-type: none"> <li>•Turpeinen Veljekset Ky</li> <li>•Lujatalo Oy</li> <li>•Sweko</li> <li>•YIT</li> <li>•NCC</li> <li>•SRV</li> </ul>	<ul style="list-style-type: none"> <li>•Greencarrier Oy</li> <li>•DSV Road Oy</li> <li>•Teamlog Oy</li> </ul>	<ul style="list-style-type: none"> <li>•the Customs</li> <li>•Ministry of Employment and the Economy and Geologic Survey of Finland GTK</li> <li>•Ministry of the Environment</li> </ul>	<ul style="list-style-type: none"> <li>•Koneurakointi Stefcon oy</li> <li>•Suomen Kuljetus ja Logistiikka SKAL ry :n.</li> <li>•Kuljetus Graniitti Oy.</li> <li>•JJP-Graniitti Oy</li> </ul>

Figure 15. Cluster of stone industry companies



Russian stone industry cluster was studied in connection with the Finnish granite supply chain, it differs from Finnish one. After the crossing the border the connections of involved companies become more hidden; it was called a “commercial secret” in one phone interview with a Russian stone industry customer. Typically, a stone producer has certain client from Russia, who orders product and also, they can be the company representative or product distributor in Russia. Being named in a document as a receiver, Russian client takes care of the customs documentation, transporting and dealing with customs, paying necessary taxes and so on. They play a leading role in the connections and contacts abroad. It can be seen in Application 2 of this work.

### 3.5 Recent problems facing the stone industry

The world stone industry faces serious competition with the import of natural stone from Asia. For many Finnish stone producers this competition led to a reduction of business activity and lost profits. But it is not only Finnish granite that has been affected. The Russian stone industry has also been reduced and import of Asian stone was gradually growing in the period 2010-2014 to Russia. There is a strong demand for the reconstruction of granite monuments and historical architecture in Russian Federation, but some original stones have already replaced by other stone of differing appearance. In the photo below, you can see how the Moika-river stone shows different colors from the different granite pieces used in construction and restoration.



Figure 16. Mistakes in reconstruction of river lining in historical centre of St Petersburg 2021.

Another negative factor was the global financial crisis in 2008 that played negative role in the decrease of granite export. Further in 2014, the EU sanctions and Russian counter-sanctions impacted the stone industry partly. This does not include granite for restoration purposes. In case of St. Petersburg, the historical center is a UNESCO World Heritage site. UNESCO has emphasized that St. Petersburg has

outstanding historical universal value. The city has preserved its historic beauty of granite architecture. However, this is not without problems. Unfortunately, Professor A.G. Bulakh observed that the unique pattern and color of granite is replaced during restoration work by completely different types of granite from other deposits despite the fact, that the original quarry and stone source is nearby. This leads to distortion, and sometimes to the loss of the overall impression of the restored objects (Bulakh, 2017).

With help of cooperation within the project, the Finnish stone industry can provide historical objects of St-Petersburg the original building material and planning optimal routes for suitable price. In the first months of the project, we devoted significant resources to the planning the joint work and build networks to be able to hold meetings on certain issues with the right people.

The global transport chain that functioned well before 2019 was impacted by the Covid-19 pandemic in spring 2020. Global transport collapsed and a transport crisis began. Even though Finnish ports were not congested, Finnish companies were hit by bad delays. Container circulation has slowed down significantly. Furthermore since 2020, the price of cargo and transportation from China has risen significantly.

The Covid-19 pandemic has particularly affected sea transport. The representatives of the logistics companies of HaminaKotka port noticed that the costs have increased 6-7 times compared to previous years. Many researchers in the stone industry observed that logistics has become an unexpected serious problem for the stone industry. Delays in deliveries lead to delays in payments to suppliers which significantly strain the working capital of many companies. The lack of stable freight prices and uncertain delivery times make it risky to implement projects with binding commitments. The 2020-2021 Covid-19 pandemic did not affect local transport as much as sea transport.

The sanctions introduced by the EU against Russia led to a change in standard routes and traffic schedules along the Baltic Sea, as Saint Petersburg remained outside permitted ports. Many interesting innovations remain under question. Compared to the period before Covid-19, freight prices during 2020-2021 were unclear and fluctuated so much, that calculating optimal offers was difficult and it was hard to maintain profitable operations with these high rates. For stone firms, perspective planning gave way to daily searches of best transportation offers and prices.

At the same time, a common issue of stone industry is leftover stone material. Issues of responsible stone production have become particularly important in recent years. The use of materials left over from mining operations in quarries requires a solution. There are possible alternatives as aggregate for large construction sites and as armor stone for breakwaters. Projects involving the use of the remaining material could be successfully implemented with the help of regional logistics services and transportation capabilities, despite the overall global situation.

There was an idea within the project to provide calculations and analyze current business models with some optimistic ideas and innovations in this uncertain time. But in February 2022, this was no longer possible as cooperation was interrupted.

The effects of the war in Ukraine seriously threaten the entire economic development of Finland. Now we have to adapt to changes in logistics in inland and sea transport. Business ideas for the inland water route is no longer relevant, when the utilization rate of the Saimaa canal is almost zero. This has caused changes in the vitality of the Southern Karelia region and development needs as large changes have taken place in logistics flows.

Higher education and research cooperation with Russia has been frozen since March 4<sup>th</sup> 2022. According to *the recommendation by Ministry of Education and Culture*, ongoing RDI projects can continue without partners from Russia.

The aim of the project was to promote the natural stone market and trade across and beyond the border between Finland and Russia, to support and develop the operating environment of natural stone companies, and to create a business model for the use of natural stone in Russia's historically and architecturally valuable renovation sites. Due to the changed world situation, the development of the natural stone business to the Russian architecture that was originally aimed at in the project is no longer planned. Currently, it is impossible to build a **bridge between South-East Finland and Russia** for reasons beyond our control. However, the stone industry development is a key interest and ideas of new models of cooperation are being actively developed. In many ways, we are living in a time of uncertainty and we have many global concerns.

#### **4. Ideas for Stone Producers to Facilitate Cross-border Business Relations.**

The global Covid-19 pandemic brought about significant changes in global trade, especially in logistics. For many, work was transformed to distance work and borders were closed. During this situation, people learned new tools, like Zoom or Teams. Distance collaboration saved a great deal of time, previously used for traveling or commuting. Teams (and similar tools) made the digitalization of our work smooth and brought us closer together. Some stone industry sales specialists created digital product repositories with great pictures available. In 2020, some sales specialists searched with the clients online for the desired block of choice with new Internet and business capabilities.

The pressures of the current global economy are forcing supply chain functions to play a more active role in reducing costs, improving customer experience, and creating value across the organization. The relationship between logistics companies and shippers returned to basics and focused back on the customer and survivability. This was enabled by the use of regular data and analytics.

On the other hand, pandemic impacted countries differently. Chinese stone producers facing transport obstacles meant that they were less represented in the main natural stone markets. Currently, competition with Asian granite is not so meaningful in the granite industry. In 2020, the only method of transportation without reduced delivery volumes was truck transportation. Freight price raised, but volumes kept at the same level. Twice a week, trucks crossed the Finnish-Russian border to provide Russian clients with Finnish granite.

***Favorable Services Package.*** One of the working ideas for stone industry could be delivery of granite blocks not by one or two blocks, but a larger number with a discount. Blocks of granite can be sent from quarries by road, but rail and water transport are available, too. With the diversity of transport modes it is natural to calculate several options with a discount on wholesale purchase. For instance, if a block of granite about 3m<sup>2</sup> costs 300€ plus transport costs, then 6 blocks by rail could cost 1200€ plus transport cost. Water transportation is also available, then 20 blocks by boat with bulk loading could be 5300€, in containers about 5700€. Here are the prices are arbitrary, but the package order is interesting for stone producers in order to facilitate the company sales and are financially beneficial for the customer.

The area's provision of transport links is not yet fully used in the natural stone supply chain from the quarry to Russia. The issues of responsible stone production have become particularly important in recent years. The use of materials left over from mining operations in quarries requires a solution. There are possible alternatives, such as aggregate for large construction sites and as armor stone for breakwaters. Projects involving the use of the remaining material could be successfully implemented soon with the help of the logistics services and transportation capabilities of the area.

It can be package delivery for restoration of historical buildings.

Despite the large governmental investment in Finnish inland waterway in September 2021, recent events led to the reduction of inland transportation and this option would not be useful. But Red Granite is available from Finland to secure the needs of stone materials for the (re)construction of St. Petersburg and the surrounding areas. The beautiful red rapakivi granite from Virolahti, situated on the Gulf of Finland, has all the advantages of being easy to quarry, process and transport. Indeed, it would be interesting to promote the idea to load stone blocks directly from the quarries onto ships and transported along the Gulf of Finland to St. Petersburg. This idea supposes some temporary pier construction.

**Rail delivery to the Baltic countries.** The natural stone industry produces a high-quality product but during the process of production 70-90% of unused side stone is created. This could be stone material with color or form defects and is considered waste. However, Finnish stone is a pure natural raw building material, the usage benefits emphasize sustainable development and a low carbon footprint. Side stone is suitable for use in many areas, both as basic products and as special products, especially in environmental construction. Advanced technology can be seen in stone structures. Large blocks and boulders can be broken into smaller pieces with impact hammers and thus utilise stones with crushers or hydraulic presses. Crushed stone can be used in earth and water construction, for example in embankments and roadbeds. There are many possibilities for the productisation of side stone, and collaborations with different companies from abroad can promote the realization of granite utilization.

As noted by Vitala Markko in a logistic study on export statistics (Vitala M, 2020), the cost of exporting crushed granite is relatively modest compared to the whole block, because it is processed by crushing and sorting it does not increase the value. In conversations with the Estonian Minister of Finance Margarita Golovko and some Baltic construction companies representatives, they stated that there is a certain demand for Finnish stone, but this is not yet true for Baltic and European markets. At least in terms of price, it is worth exporting it further afield. Perhaps the crushing of side stones could be a viable option.

Finnish-Russian rail connections have significantly reduced in 2022, but are not fully stopped. There is border traffic under certain strict terms. The rail transport infrastructure and service in Kymenlaakso's Kouvola is highly developed. In 2019, the project on the construction of a modern rail terminal was started. With the help of the rail and road terminal Kouvola RRT creates a framework for entrepreneurs and new operators to grow their business in the field of logistics. This terminal could enhance the search for new business possibility for stone industry.

**Utilisation of side stones in port construction of Estonia, Denmark, Sweden.** The process of stone extraction is focused on stone blocks of perfect colour and quality characteristics. After evaluation, the specialist picks the correct one. The quantity of good blocks is more than all the other blocks. Blocks for sale get their personal code, including details about the specific stone characteristics. Broken, unusable stone is moved to the sides of quarries, and are called side stone or leftover stones. Over many years, side stones are gathered in the same places and a granite row of large stone quantities appeared (Figure 16).





Figure 16. A mountain of side stone in granite quarry. 2021

These rows of valued side stone could be successfully utilized in different areas of natural stone production and city construction projects. Side stones in granite production are used in water and environmental construction in different structures or after mechanical processing in rock aggregates in road construction or as a raw material for concrete. Efficient utilization of the waste rocks requires understanding the factors affecting their environmental acceptability in conjunction with the technical properties of the rocks. (Heikkinen P, Aatos S, Nikkarinen M, Taipale R, 2019).

In Finland, granite blocks are widely used in port construction because it is ecological and the most durable construction material ever. For instance, the Port of HaminaKotka used granite not only in the terminal, but also in the construction of freight transfer facilities. The wide usage range for stones include breakwater/jetty construction, docks, dredging, locks and lock gates, underwater trenching, shore protection, wharves and marinas.

It seems wise to offer Estonian ports the same wide range of possible construction options, because the Estonian geology has no similar construction material as granite in Finland. There is no industrial quarrying neither in Sweden nor in Denmark. The ports in these Northern countries need durable material, that suits land and sea construction, and is ecological.

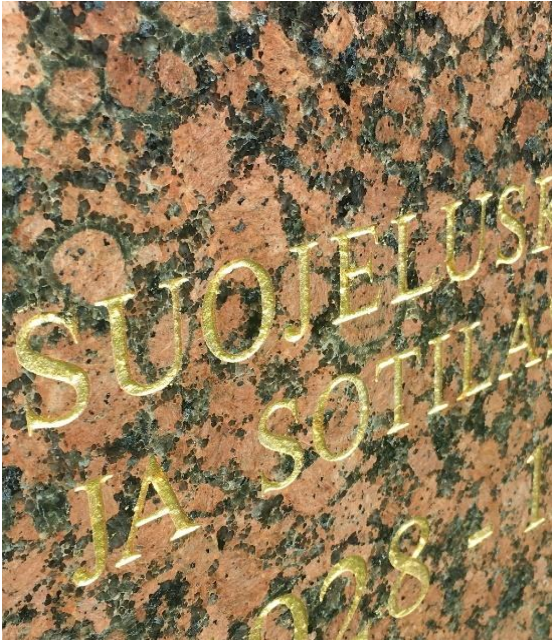


Figure 17. Beauty of red rapakivi granite in city monument in Hamina

We contacted the Estonian port administrations in written form, providing links to the visual project materials and contacts. Here is the list of ports that could be interested in use of granite:

- Heltermaa
- Kopli-Port Of Tallinn
- Kuivastu
- Kunda
- Muuga-Port Of Tallinn
- Paldiski-Port Of Tallinn
- Pyarnu
- Narva-Joensuu port
- Narva port

The stone is part of the street appearance in many countries. From them, you can observe the traditions of construction and the work-technical solutions of the time of construction. Finnish granite could be used for the reconstruction of historical buildings. There is a large programme of reconstruction in Estonian special Committee ICOMOS, which takes care of cultural heritage through the research and restoration of historic buildings. Interestingly, after discussion with the representative Tiina Hallimae, revealed they are only planning to renovate wooden buildings this year.

#### 4.1 Reuse of Stones & Ecological Aspects Granite

Natural stone is mined from nature, bedrock, it is an ecological natural raw material. The impact of the environment is often not considered. According to a recent life cycle assessment, stone products made from Finnish natural stone have a low carbon footprint. In the natural stone industry, it is hoped that domestic stone will be preferred in public procurement due to its smaller carbon footprint. The stone market provides granite production mostly for the needs of the building and construction industries. As construction work accounts for about a third of the world's greenhouse gas emissions, responsible construction companies should seek to obtain local quality stone. As most natural stone emissions come from transport, it is easy to reduce them by reducing transport distances. Cross-border cooperation and use of local materials would minimize emissions from the production and transportation of Finnish stone by as much as 80% compared to products imported from Asia. (Kivi Ry, 2019).

One of the biggest lessons learned by stone producers from the 2008 recession and challenges in recent years was that their business must be adaptable. Some changed their target market; others changed the foundation of their business. In case of challenging times, companies should search for more working models, if some of possible models did not work or were inefficient. Stone can be a material for restoration, providing authentic material and it can be material for new architecture items, externally granite usually is used for facing buildings and inside houses granite is often used to decorates kitchens, bathrooms and stairs. Further, for cemetery monuments there is no better material.

The industry has significant work to do in the further processing of products, the processing of service products, marketing, and perhaps new innovations. We see opportunities especially for by-products of



stone quarries. A side stone created during the mining process should be used for new products and new business. City construction is a great application for granite.

Finnish stone is an ecological and completely recyclable natural product. The recycling potential of stone has been well demonstrated in the so-called "capital of the parks" – Kotka. During the last 40 years, Kotka has transformed into a garden city and is now known as the park capital of Finland. Gardens and parks are all extensively decorated with stones. Stone is a very natural medium for landscaping and complements the natural beauty of plants, trees, and flowers while at the same time ensuring that the parks are durable.

Sapokka is a beautiful park in the middle of Kotka, which is popular among locals and visitors. The main elements of this park, situated by the sea are water and stone. Water can be found in small ponds and in the waterfall. Stone is represented mostly by reused granite parts of paper-mills and waste blocks from local quarries. At the top of the water park, we find another stone park guarded by "Stone Eagles". Here you can see more than twenty stone figures made of domestic granites displaying different colours and patterns. At the same time, they demonstrate the range of possibilities for stone processing and the beauty of Finnish stone. Sapokka receives the most awards out of all Finnish parks. Reusing old stones is a specific theme for this park. Everywhere you can see example of stones that have found new uses. Paving stones that people once walked on through the city can now be admired here as retaining walls. Old stone blocks that have been used as housing foundation have been reused as stairways, benches, and walls

The front gate of Kotka's Sapokka water garden is made of granite pillars. These are reused two old rolls that were used in paper machines. The stone in parks is reused to improve people's comfort.



Figures 18 & 19. Examples of granite recycling in Kotka park. Reused old stone rollers, spare parts from former paper machines serve as a recreation area.



Awarding parks of Kotka with a green flag proved the quality of design and implementation, as it is well-known quality certification. The Katarina park has been given a green flag and it is a wonderful recreational zone, with a stone labyrinth, beautiful and durable granite stones, and several stone sculpture. The park is



located by the seashore with beautiful sea views and small tree and water areas. It has been built with help of natural stone to make it look like it was formed by nature. The green flag requires regular, once every two years, satisfying the criteria of the award.

The stones of Katarina Park have their own history behind them. The water from the wooden houses on Kirkkokatu drained into the rocky street drain. In modern times, hundreds of stone parts were obtained from old buildings and yards on Kotkansaari and are reused in construction of the Katarina Park.

Stone plays a special role in the improvement of general appearance of the city. Granite products are both durable and noble; it is difficult to find a more reliable and beautiful material for decorating streets, parks, and gardens.

Side stone from the stone industry or old granite blocks are reused as embankments and steps. Natural stone can be easily reused and recycled for new applications and projects. Whether for entire buildings, floors, walls and landscape tiles, blocks or decorative accents, stone offers a wide range of options for designing a second life. Granite in architecture only gets stronger over time, it worked and looks beautiful for many centuries. Now, when the circular economy is a megatrend in our everyday life, it would be a good time to take control of the use of our own natural resources and value our own wealth. Domesticity should definitely be one of the valid purchase criteria, in which case the money invested by the government stays in Finland to boost the country's economy and thus create growth.

### **Conclusion**

In the second half of the 19<sup>th</sup> century, new methods for quarrying and processing natural stone were developed. In Finland, technological progress goes hand-in-hand with systematic geological development and the exploitation of natural stone deposits. New constructions demonstrate the positive result of interaction between geological exploration, the architectural and commercial development, and technical inventions.

Methods for quarrying and the transportation of stones at Pyterlahti scarcely differ from those used elsewhere and throughout history, some features have little changed over thousands of years. A true masterpiece of granite architecture and the polished surface remains almost perfect and unchanged after even 200 years. Granite patination gives the stone surface even more beauty and the colours remain bright for centuries.

The granite architectural monuments of history highlight the aesthetic success in past installations and provide insight for future creative opportunities for the consumer. We clearly see the durability and sustainability of natural stone, which exemplify that utilizing natural stone in projects can benefit both the user, residents of built areas, and nature.

The quarries in Kymenlaakso and Southern Karelian provinces of south-eastern Finland are ideally placed from a transport logistics perspective, due to the modern harbour facilities at the port of HaminaKotka and the national border crossing points at Nuijamaa and Vaalimaa that have the greatest volume of road freight transport between Finland and Russia. There is huge potential for increasing the volumes of granite for transport, due to the combination of favorable location and existing demand.

Nowadays, environmental friendliness is one of the main procurement criteria. Stone inspires clients to imagine, design and create eternal beauty. Global stone architecture is worthy of restoration. Stone can be renewed, recycled, and reused. Granite is the most durable, sustainable, and versatile material for any build, design, or remodel project, for both residential and commercial use.

The consequences of the global Covid-19 pandemic did not significantly affect Finnish stone production, but on a general level freight costs have increased significantly. The pandemic has affected granite shipping volumes in a negative way. The changes in international trade and the resulting problems in container traffic have increased container export freight from Finland to Asia. As a result, significantly fewer containers loaded with granite are exported through HaminaKotka port than before the pandemic.

All over the world, companies must adapt their operations to difficult situations.

The original idea of the Nasta-project to support the cooperation avenues of stone between neighbouring countries, such as for the restoration of historical architecture is no longer possible to fulfil. Restoring historic sites is now only possible in the Baltic or other countries than Russia. Instead of authentic material promotion, we promote the use of granite materials in modern construction in the surrounding area. In addition to this, there are some other new business ideas that have appeared which could support the technical and economic feasibility of existing enterprises.

Incorporating recycled stone may take some extra time at the outset of a project and close coordination throughout design and construction. However, the results are worth it. Not only are you saving a valuable part of history, but you are also letting the stone continue to tell its story and bring no harm to our lives.

In many ways, the world is now living in a time of uncertainty, and we have many global concerns. Within the frames of the project, we have achieved the goal to highlight important themes of ecology and the circular economy in the stone industry as prominently as possible. We hope we have also stimulated discussion around them. Xamk succeeded in compiling a snapshot of the situation in South-Eastern Finland and its effects on logistics chains, where water transport has played a significant role for companies and industry as an environmentally friendly and efficient form of transport.

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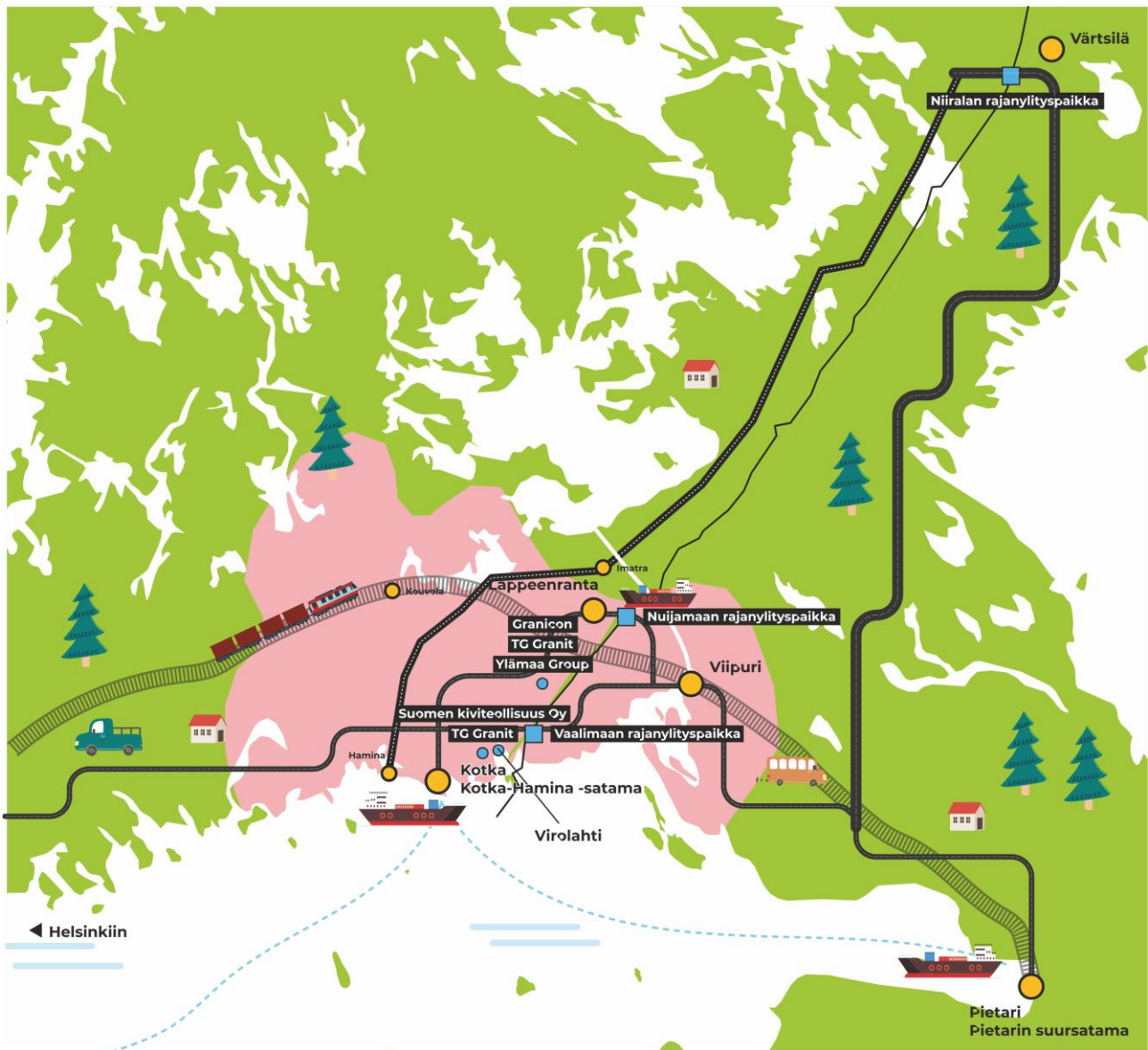
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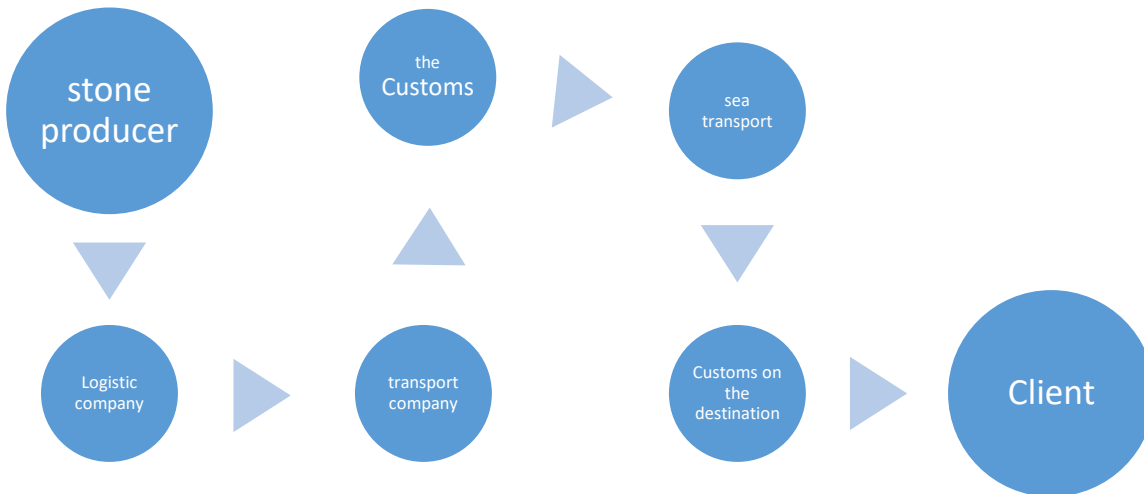
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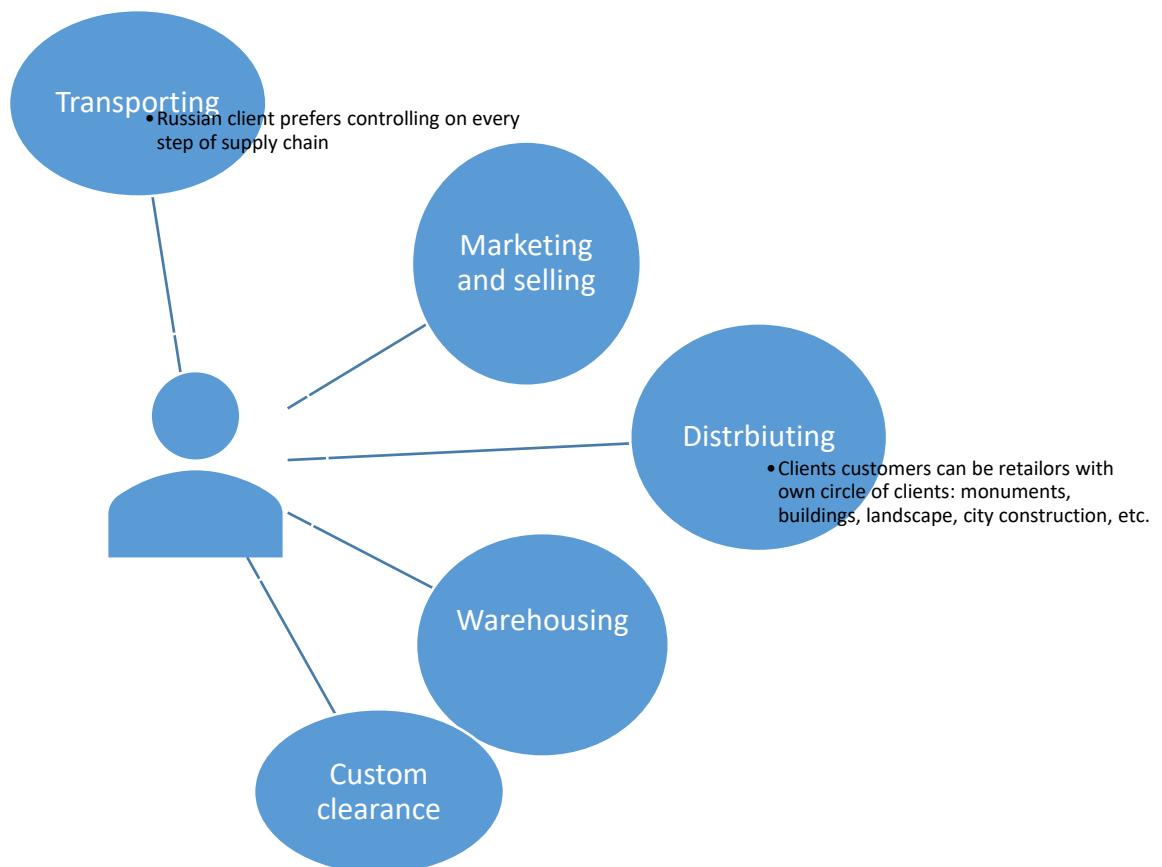
# Application 1 Transport system and logistic supply chains of stone industry in Finland



## Application 2 Structure of relationships and cooperation within the stone industry



### Finnish supply chain



### Russian supply chain

### **Application 3 Examples of rapakivi granite use**

#### **1 EAGLE RED/ KOTKA RED**

1. PG Legacy Tower, Rochester, New York, the USA
2. Core Pacific, Taipei, Taiwan
3. Pontiac Building, Chicago, the USA
4. Shanghai World Plaza, Shanghai, China
5. Kyoudou Building, Nishinshinbashi, Tokyo, Japan
6. Kantou Namako, Funabashi, Tokyo, Japan
7. Artist Construction Building, Taipei, Taiwan
8. Federal Building, Boston, the USA
9. Kuochdoch Building, Tokyo, Japan
10. Yu Su Building, Taipei, Taiwan

#### **2 KARELIA RED/CARMEN RED Virolahti**

1. Touhou Seimei BLDG, Seoul, Korea
2. First Interstate Bank of California, San Diego, California, USA
3. Lurgi-Hause, Frankfurt-am-Main, Germany
4. Saarbrücken, Saarbrücken
5. Aker Brygge, Oslo, Norway
6. Water Side Tower, Norfolk, Virginia, USA
7. Phoenix Plaza, Phoenix, Arizona, USA
8. Travellers Express Tower, St. Louis Park, MN, USA
9. Arco Tower, Los Angeles, USA
10. Central Daily Newspaper Building, Seoul, Korea
11. Korea Trade Centre, Seoul, Korea
12. Malayan Credit House, Singapore
13. Wilshire Court Plaza, Los Angeles, USA
14. Neues Lurgi Haus, Frankfurt, Germany
15. Landesarbeitsamt Saarbrücken, Saarbrücken, Germany
16. Bank of California, San Diego, USA

#### **3 BALTIC BROWN, Ylämaa**

1. PG EY:n headquarter, Helsinki
2. Elefant, Aboa Vetus & Ars Nova, Turku
3. Mihailov's palace, Pietari
4. Shiscidou Building, Ginza, Tokyo, Japan
5. Daikan Seimei Hoken, Seoul, Korea
6. Yorkshire Bank, Leeds, England
7. Bleichstrasse, Frankfurt-am-Main, Germany
8. DBS Land Building, Singapore

#### **4 BALTIC GREEN, Ylämaa**

1. Varma headquarter, Helsinki
2. UPM:n main office, Helsinki