Accessibility assessment and improvement of road networks in Hernesaari, Helsinki

SEN124A	Alexander Groen 5246075
Project-group 3	Friso Voorn 6328164
09-04-2025	Jesse Labe 4959337

Introduction

Urban transport networks consist of nodes, such as crossroads, terminals, and major facilities. These nodes are connected by links, for example, routes and roads, enabling the movement of people and goods. The accessibility and efficiency of this network are crucial for the economic and social functioning of cities (Rodrigue et al., 2016). Accessibility refers to the extent to which residents have access to essential destinations such as employment, services, and facilities. High accessibility promotes economic efficiency by improving the flow of people and goods, leading to increased productivity and economic growth (Rode et al., 2017).

Urban accessibility is connected to urban form and transport infrastructure. Cities with good accessibility usually have more compact and well-connected urban structures, which reduces the need for long-distance travel, resulting in lower transportation costs and improved mobility for residents. However, when accessibility is reduced, due to inadequate infrastructure or disruptions, vulnerable groups may be excluded from these essential services. Therefore, it is not only important that urban networks are efficient but also robust and resilient enough to provide access for all, even in times of crisis (Rode et al., 2017).

Urban transport systems are vulnerable to disruptions, such as natural disasters, congestion and accidents. These disruptions can extensively disrupt road networks, increasing the time it takes to get to essential facilities. This impacts the residents, and above all the vulnerable groups, struggle to reach vital places such as hospitals or shelters (Schuster et al., 2024). Therefore it is necessary to not only research the network under normal circumstances but als during disruptions. This sheds light on how networks perform under pressure and identifies which improvements need to be made to enhance the resilience and accessibility of the system.

This paper focuses on Hernesaari, Helsinki. While the area is planned to be a dense urban structure prioritizing walking, cycling, and rail transit, with many daily services designed to be accessible by public transport, it is currently still primarily structured around car traffic. Therefore, despite the future-oriented vision, the existing road network for vehicles remains a critical part of mobility in the area. This makes it a relevant subject for analyzing the accessibility and resilience of the driving road network under both normal and disrupted conditions (Hernesaari City of Helsinki, 2025).

This paper is structured as follows: First, an accessibility analysis under business-as-usual conditions is presented, where the network, chosen metrics, and findings are described. The second section discusses the disruption scenario, assumptions, and results of the analysis. In the third section, improvements are proposed and evaluated to demonstrate their effectiveness. Finally, the report concludes with a discussion of the findings and strategic recommendations.

Accessibility Analysis in Business As-Usual Conditions

To analyze the network of Hernesaari a simplified model of the neighborhood was made, with only driving roads. This model, which can be seen in figure 1, has 30 nodes and 54 edges. Furthermore population data (HSY, n.d.) can be seen in the figure 2.

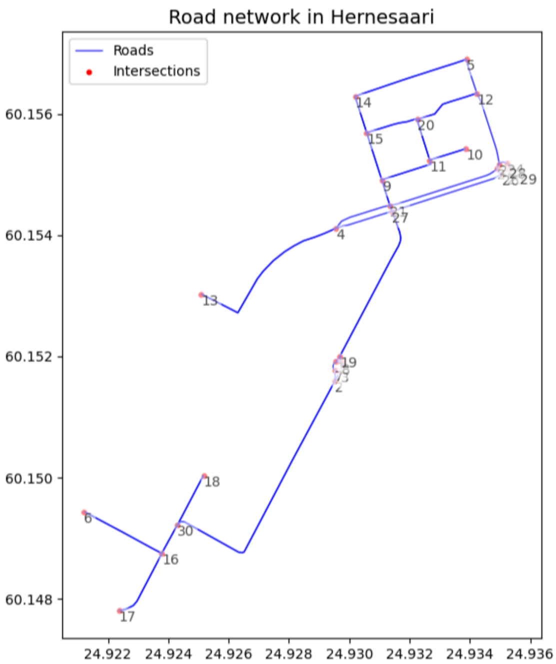

Figure 1: Simplified road network of Hernesaari *Figure 2: population data Hernesaari. Transparent squares represent population (HSY, n.d.).*

Looking at figure 2 it can be seen that only two areas contain residential areas, which are shown by the squares within the red dotted line. First of all the top right residential area, shown by three squares. In addition a smaller residential area is shown on the middle left by one square. In the area's in the bottom of Hernesaari no residential areas are visible. Even though no population is shown in the figure there are companies and a cruise ship terminal. Furthermore as stated in the introduction there are plans to build more residential areas in the bottom half of Hernesaari (Hernesaari City Of Helsinki, 2025). Therefore we assume that for all nodes it is important to be accessible.

In case of emergencies the accessibility of hospitals is very important to be able to help potential victims of disruptions or other people in need. In Hernesaari itself there are no hospitals as can be observed in the figure 3.

Figure 3: Hospitals near Hernesaari (Google Maps, n.d.)

Figure 3 shows that the closest hospital is the Eira hospital and medical centre. Meaning in emergency the nodes connecting Hernesaari to the rest of Helsinki should be accessible from anywhere within Hernesaari to be able to give quick medical help. Zooming in on the upper right residential areas shows the connections exiting and entering the neighbourhood. This can be seen in *figure 4*.

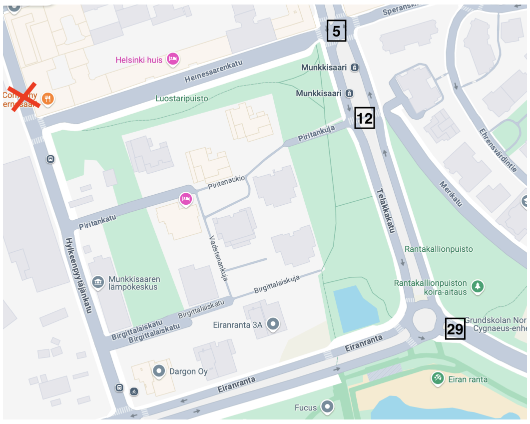

Figure 4: Residential area in Hernesaari (Google Maps, n.d.)

Figure 4 shows that to enter or exit Hernesaari two modelled nodes can be used to exit the neighbourhood: 5 and 29. Figure 4 also shows node 12, which as seen in the figure has no connection exiting the neighborhood.

Furthermore figure 4 shows another road on the top left and above node 5. These roads were not implemented in the simplified version of the road network and therefore will not be used in this analysis.

In conclusion, in an emergency the path to nodes 5 and 29 is very important. The accessibility of these nodes will be first of all analyzed using the betweenness centrality.

The betweenness centrality quantifies the importance of nodes in the shortest paths within a network. In this case it means that if a node has a high betweenness centrality it is on a lot of shortest paths to the hospital and therefore important. The betweenness centrality of the nodes can be seen in figure 5.

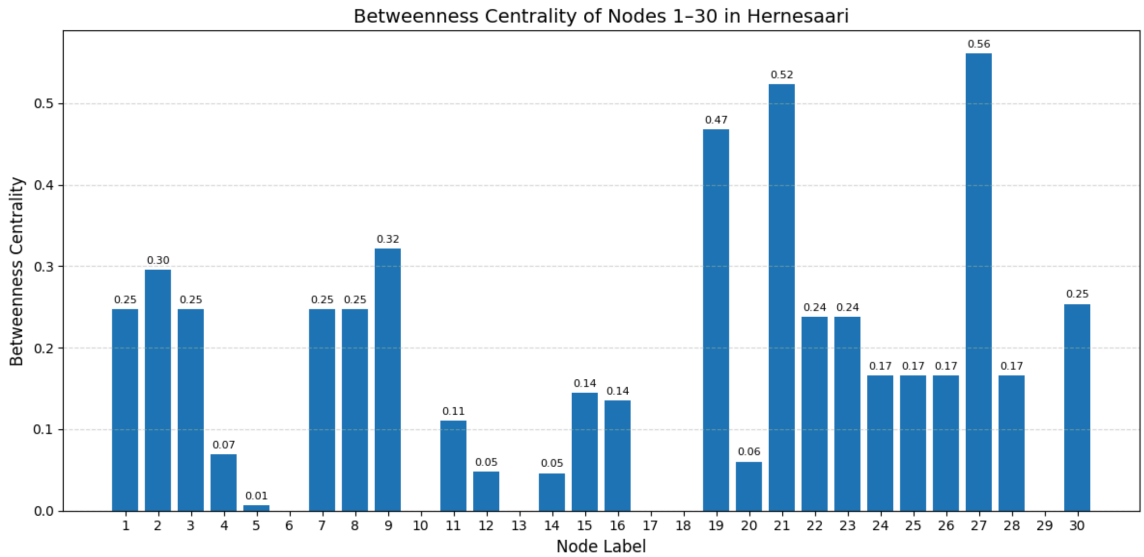

Figure 5: Betweenness centrality of 30 nodes in Hernesaari.

Figure 5 shows that nodes 19, 21 and 27 have the highest betweenness centrality, with 0.47, 0.52 and 0.56 respectively. Therefore these nodes are the most important to the network and will have a high probability of significant impact in case of disruption.

Second, the average shortest path for each node to node 5 and 29 will be calculated to analyze which areas have the longest routes to the hospital and therefore could be the most vulnerable to disruptions. The average shortest paths of the nodes can be seen in figure 6.

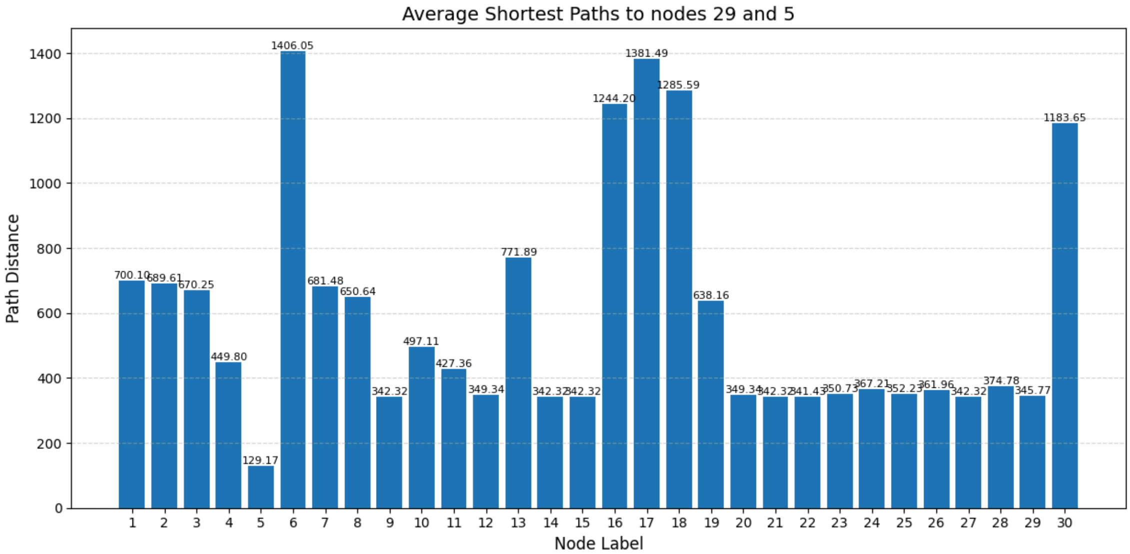

Figure 6: Average shortest paths to nodes 29 and 5 of every node. Path distance is in meters.

Figure 6 shows that nodes 6, 16, 17, 18, and 30 are the nodes with the longest average paths to nodes 5 and 29. With node 6 being the least accessible node with an average shortest path of 1406.05 meters. Therefore these nodes are most likely the nodes most impacted by a disruption.

Disruption Scenario and Impact Analysis

In this section, a realistic disruption scenario is introduced to analyze how the accessibility of the transportation network in Hernesaari changes compared to business-as-usual conditions.

Disruption Scenario: Flooding in Hernesaari

Hernesaari, Helsinki is part of the Uusimaa River basin and has been identified as one of the areas with the highest flood risk. The coastal areas are increasingly affected by heavy rainfall and melting snow. These factors cause water levels to rise significantly, especially when combined with storms, resulting in flooding. This is particularly the case in low-lying coastal areas such as Hernesaari. Floods can cause substantial damage to buildings and roads. For example, in 2005, sea levels rose as much as 1.5 meters above normal, with flood waters spreading to Helsinki's market square and other locations (Vesi.fi, Suomen ympäristökeskus, 2025). Therefore, for our analysis, this disruption can be considered a realistic scenario that needs to be taken into account when planning and analyzing the transportation network in Hanasaari.

In the proposed disruption scenario, a severe flooding event occurs along the main road with the roundabout located on the eastern waterside of the network. The flooded area is indicated in figure 7. As a result of the flooding, the road becomes completely unusable, leading to a full road closure and the removal of connectivity between key nodes in the network. The nodes that have been removed from the network are 1, 2, 3, 7, 8, and 19, which are located around the roundabout. This results in a new network structure after the disruption, as shown in figure 8. This is a significant problem, as node 19 was directly connected to node 27. Furthermore, the connection between node 2 and node 30 has also been lost. Because of this, nodes 6, 16, 17, 18, and 30 are no longer reachable from the northern part of the network.

Figure 7: Disruption scenario, flooding

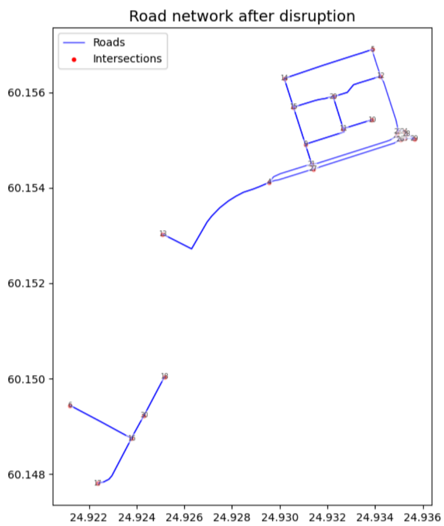

Figure 8: Network post-disruption

This is alarming, since there is a terminal located in the southern part of Hernesaari, where cruise ships arrive. In addition, several workplaces are located in this area, increasing the number of people who may be present during a disruption. Moreover, future urban development plans for Hernesaari include the construction of new residential buildings and workplaces, which will increase population density and thus the potential number of people affected in the case of an emergency (Hernesaari City Of Helsinki, 2025).

This disruption has significant implications. As mentioned earlier, hospital accessibility is very important to help potential victims or other people in need. Especially during flooding, people may need medical attention, and it is essential to ensure a good connection between the affected area and the hospital, especially if the hospital is located outside Hernesaari.

Analysis of accessibility impact

To assess the impact of the flooding scenario, the changes in accessibility of Hernesaari under normal conditions and during the disruption scenario are compared. This analysis is based on the same graph metrics used in the analysis of the normal situation: betweenness centrality and average shortest path.

Betweenness centrality analysis

In the business-as-usual scenario of betweenness centrality (figure 5), nodes 19 (0.47), 21 (0.52), and 27 (0.56) had the highest betweenness centrality scores. These nodes function as essential connectors within the network and carry a high probability of significant impact in case of disruption. After the flooding scenario, nodes 1, 2, 3, 4, and 19 were removed, resulting in a change in the network structure. The post-disruption betweenness centrality graph is shown in figure 9.

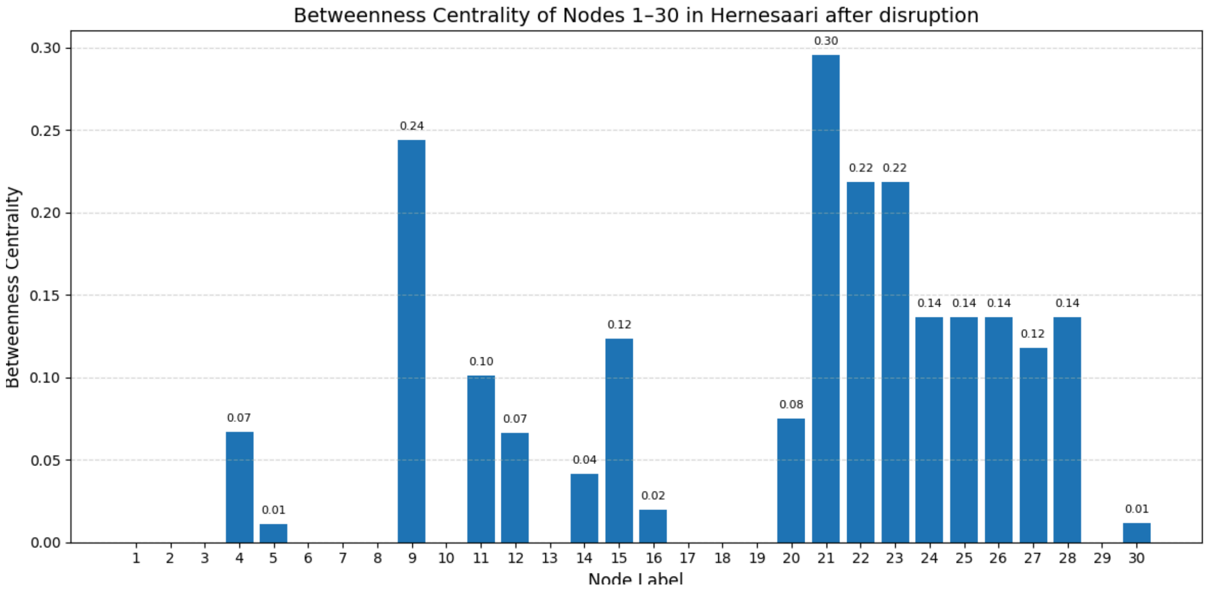

Figure 9: Betweenness centrality in Hernesaari after disruption

Significant changes have emerged in the post-disruption betweenness centrality graph. As expected, nodes 1, 2, 3, 4, 7, 8, and 19 now show a betweenness centrality value of 0, as they have been completely disconnected from the network due to the flood. Similarly, the now isolated southern nodes 6, 16, 17, 18, and 30 all exhibit values close to 0, with the most dramatic decrease occurring at node 30, which dropped from 0.25 to 0.01.

Under normal conditions, node 27 was the most important node in the network, with a betweenness centrality value of 0.56. However, after the disruption, this value has significantly decreased to 0.12.

This decline is explained by the loss of the crucial connection between node 19 and node 27, meaning node 27 no longer serves as the key link between the southern and northern parts of the network.

As a result, node 21 has become the most critical node after the flooding, with a betweenness centrality of 0.30. This indicates that node 21 now accommodates a much larger proportion of the shortest paths within the fragmented network. Additionally, nodes 9 (0.24), 22 (0.22), and 23 (0.22) have gained in importance, playing a central role in maintaining the remaining connectivity within the northern part of the network. The resulting network fragmentation has significantly reduced the overall accessibility.

Average shortest path analysis

In the business-as-usual scenario of average shortest path (figure 6), nodes 6, 16, 17, 18, and 30 had the highest average path length to nodes 29 and 5. Node 29 and 5 are essential, because this is where the exit of the neighborhood is and thus the route to the nearest hospital. The after flooding scenario effect on the average shortest path is shown in figure 10.

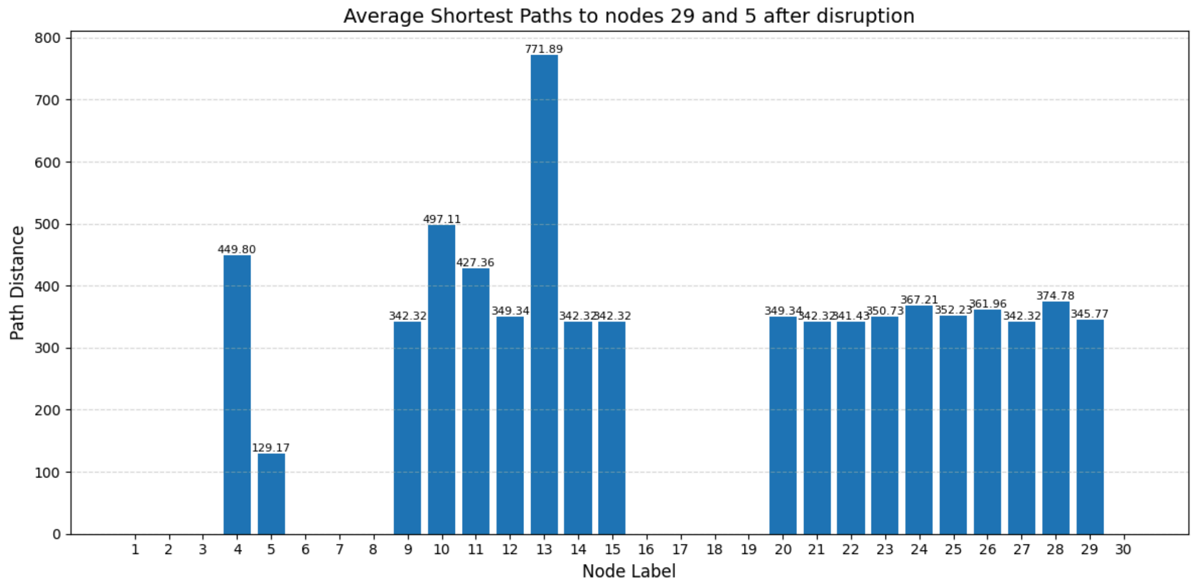

Figure 10: Average shortest paths to nodes 29 and 5 after disruption

After the disruption, the flood completely isolated the distant southern nodes 6, 16, 17, 18, and 30 cutting off all paths to the northern part of Hernassi, as the connecting nodes 1, 2, 3, 7, 8, and 19 were removed from the network. This is clearly visible in Figure 10, where these nodes now show no value in the graph, confirming their disconnection. Now the highest average path length to nodes 29 and 5 is node 13. This isolation of several southern nodes results in a significant deterioration of overall network accessibility, severely hindering quick and safe access to essential services such as hospitals.

This analysis shows the vulnerability of Hernesaari's transportation network to disruptions and highlights the need for resilient infrastructure planning to ensure critical accessibility. .

Proposed Improvements

In order to improve mobility and account for the risk of the disruption discussed in the disruption analysis, an additional road connection can be added to the network to connect node 13 and node 18. The new road network is seen below.

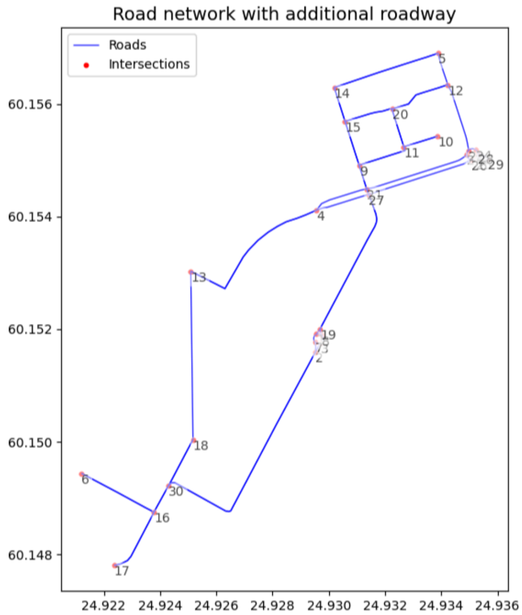

Figure 11: Hernesaari improved road network with additional roadway.

This improvement was proposed to solve the issue with the network that was discovered in part 2, namely that the bottom segment of the network (nodes 6,16,17,18,30) would be unable to exit the network via 5 or 29, which imparts potential risk to those present at those nodes in the network. In order to account for this, the additional connection was made to provide a redundant path back into the city, separated from the current path. In addition, this roadway allows for improved connectivity in the general case, as the extreme nodes of 6 and 17 are now more able to utilize the network. As can be seen in the betweenness centrality graph in figure 12, nodes 4 and 13 benefit the most in this metric as they are no longer on the extremes of the network. For the majority of the network in the nominal case, the impact on this metric is minimal, but outsized gains are provided in the disaster case.

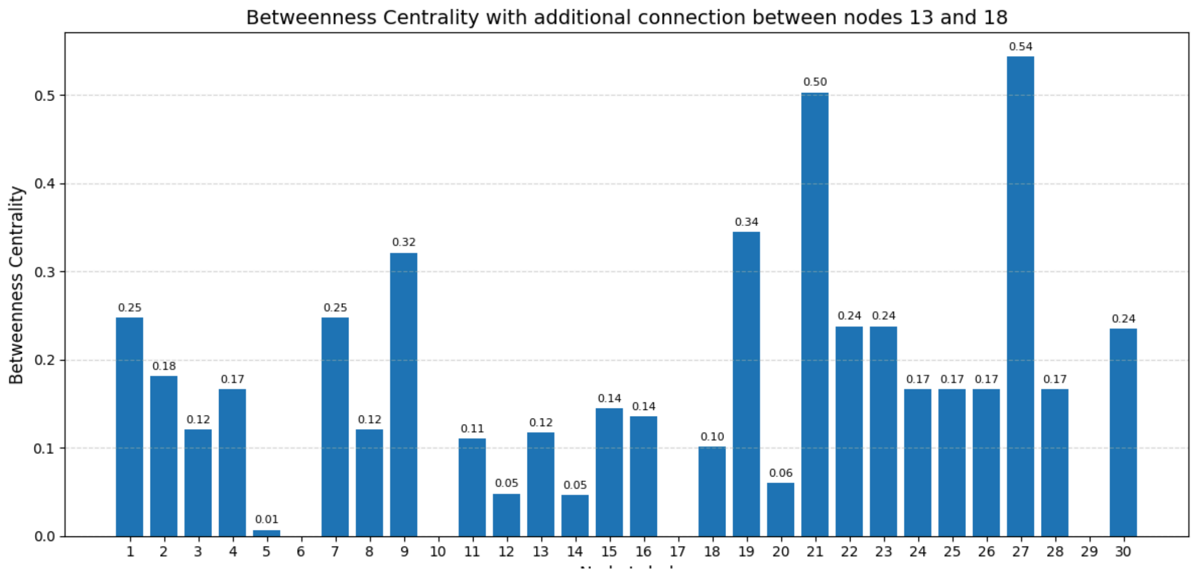

Figure 12: Betweenness centrality of nodes with additional connection

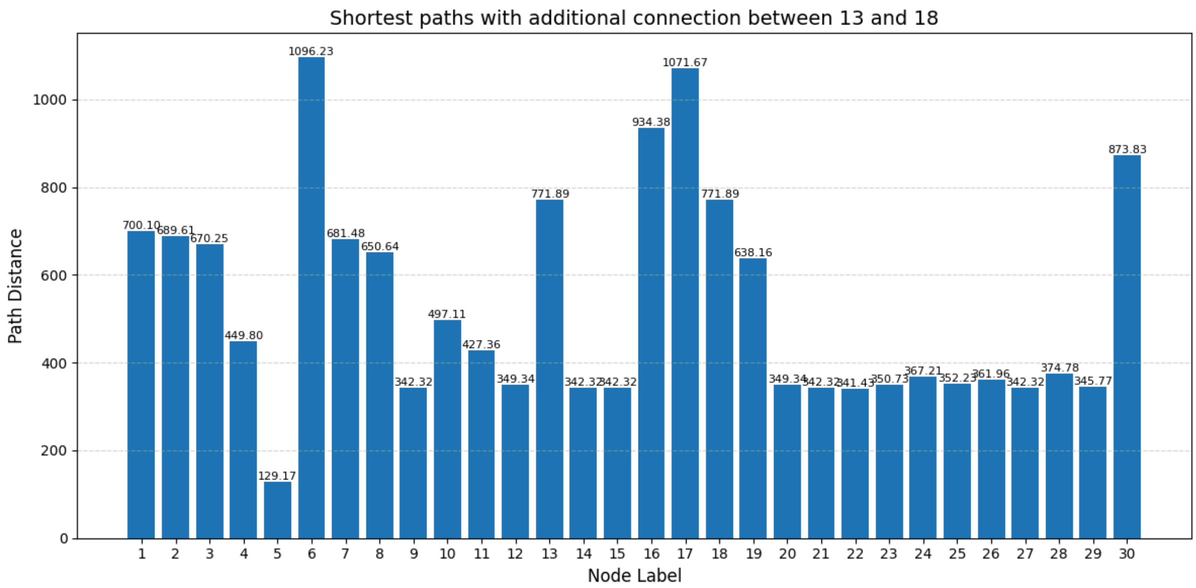

Figure 13: Average shortest paths to nodes 29 and 5 of every node with additional connection. Path distance is in meters.

As can be seen with the shortest path chart in figure 13, a number of paths have been improved especially in the southern terminal area; however, the main impact will be in mitigation of the flooding disruption case. Provided below in figure 14 is the flooded network after the addition of this additional road connection, along with corresponding betweenness centrality and shortest path charts. Through these charts it can be seen that even with the disruption, all remaining nodes are able to exit the network at 29 and at 5, which massively improves accessibility in the disaster case. As the remaining nodes exist above the breakage, the shortest paths are unaffected for that segment. Betweenness centrality is also improved, as seen in figure 15, both through the connection of node 13 to node 18 as discussed in the nominal case as can be seen in figure 16, but also in the reconnection of the southern terminal.

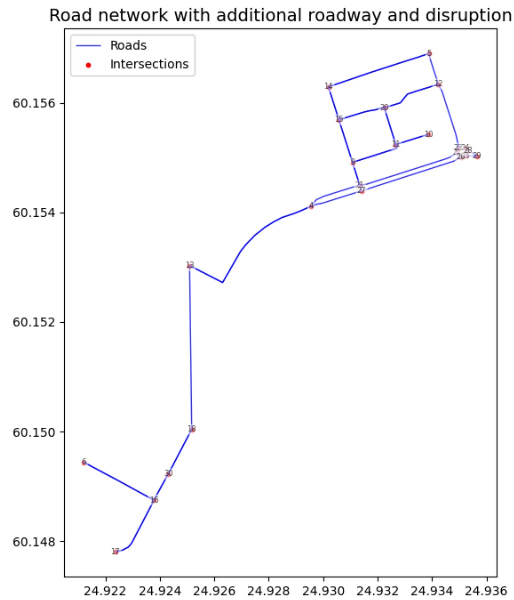

Figure 14: Network with both disruption and additional edge

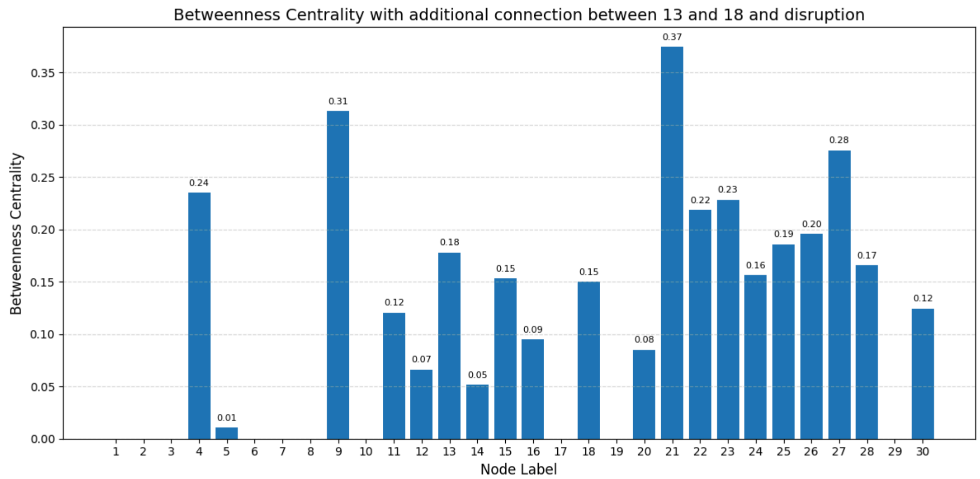

Figure 15: Average betweenness centrality of nodes with both disruption and additional edge

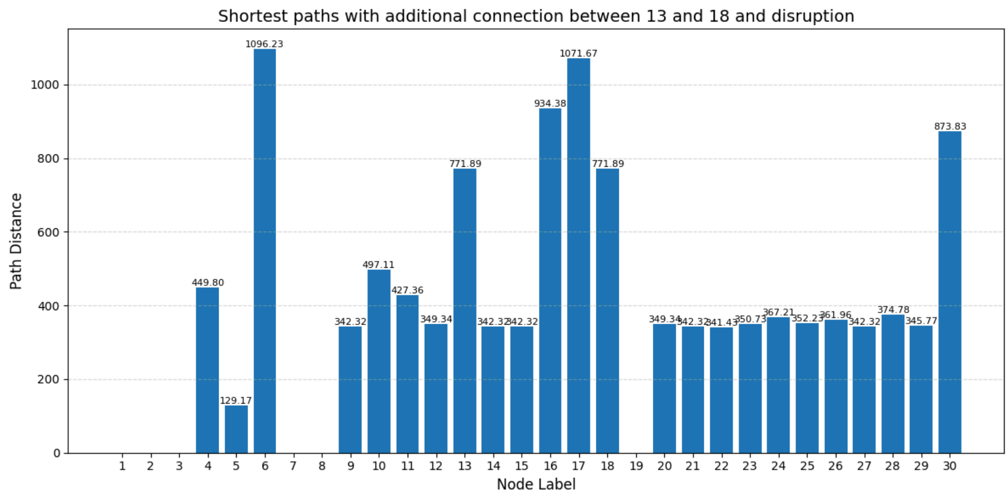

Figure 16: Average shortest paths to nodes 29 and 5 of every node with disruption and additional edge. Path distance is in meters.

This data is even more apparent when considering all 4 cases together, as can be seen below in figures 17 and 18. Nodes such as 6,17,18 and 30 which were not able to pathfind to the exit nodes in the disaster case are able to be pathed in the adjusted disaster case, while the adjustment makes small improvements to both betweenness centrality and shortest paths in both cases. As such, this improvement is highly effective at improving the accessibility of the network.

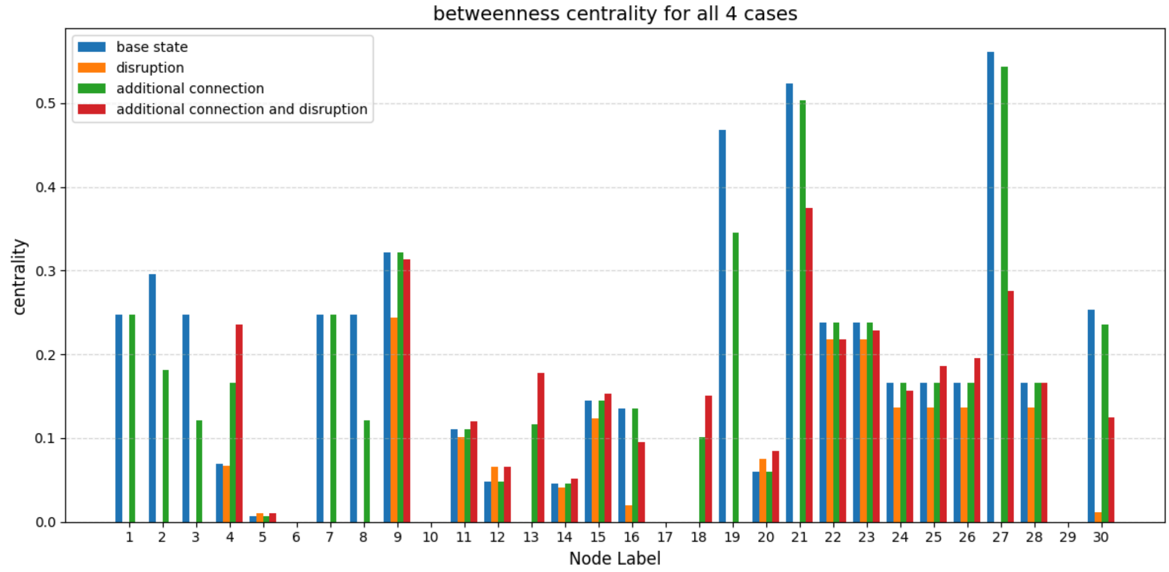

Figure 17: Betweenness centrality of all 4 cases.

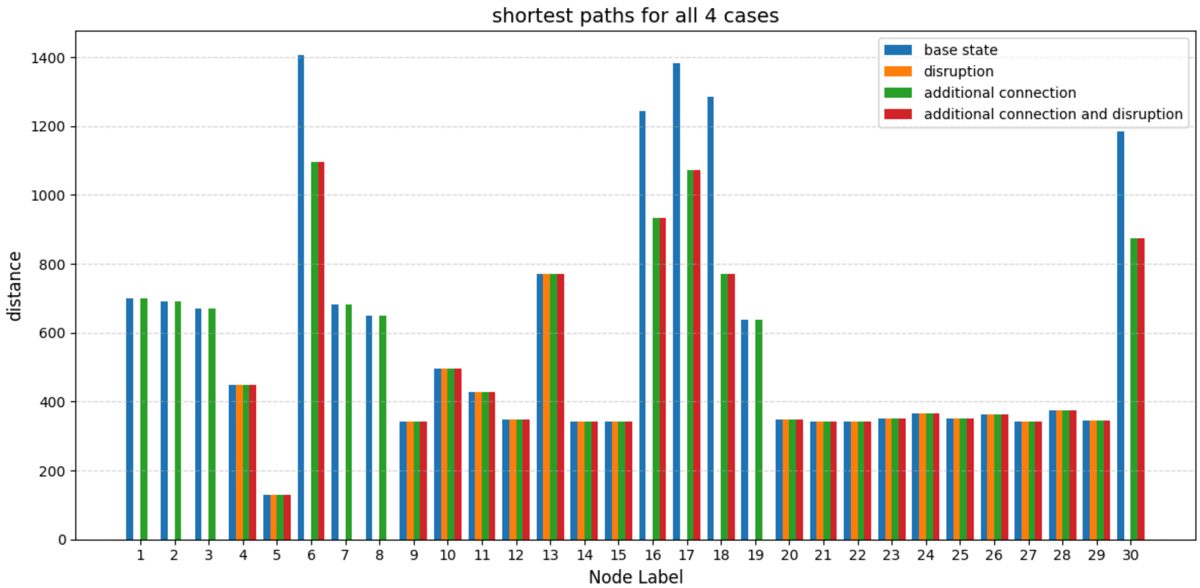

Figure 18: Average shortest paths to nodes 29 and 5 of every node for all cases. Path distance is in meters.

Discussion & Recommendations

The assessment of Hernesaari's road network concluded that the network has a weakness in the accessibility from north to south. This became an apartment in the disruption scenario where several southern nodes were denied access to the rest of the neighborhood and thus to hospitals. An improvement was designed where an extra road is built between the most southern part and a more northern part. This improvement showed that accessibility was improved in normal conditions, but especially in conditions with a disruption. Making the network more robust against disruptions and thus better at providing help to people in case of emergencies.
This assessment however does have some limitations. First of all the analysis was done using a simplified model of Hernesaari, where only driving roads exist. Other modes of transport were not considered. Future research should therefore focus on all types of transport.
Furthermore the throughput of roads was not researched. Meaning in case of disruptions where evacuation is needed possible road capacity issues might occur. This should be researched further to truly assess the accessibility.

Lastly the recommendation for the city planners of Hernesaari, planning the expansion of the Hernesaari residential areas, is to improve connectivity between the southern and northern areas before developing the south as it is vulnerable in case of disruptions.

References

Boeing, G. (2024). Modeling and Analyzing Urban Networks and Amenities with OSMnx. Working paper. https://geoffboeing.com/publications/osmnx-paper/

Google Maps. (n.d.). Hernesaari. Retrieved April 7, 2025, from https://www.google.com/maps

Google Maps. (n.d.). Hospitals near Hernesaari. Retrieved April 7, 2025, from https://www.google.com/maps

HSY. (n.d.). HSY Karttapalvelu. https://kartta.hsy.fi/

Hernesaari | City of Helsinki. (2025, 11 maart). City Of Helsinki. https://www.hel.fi/en/urban-environment-and-traffic/urban-planning-and-construction/plans-and-building-projects/hernesaari

Rode, P., Floater, G., Thomopoulos, N., Docherty, J., Schwinger, P., Mahendra, A., & Fang, W. (2017). Accessibility in Cities: Transport and Urban Form. In Lecture notes in mobility (pp. 239–273). https://doi.org/10.1007/978-3-319-51602-8_15

Rodrigue, J., Comtois, C., & Slack, B. (2016). The Geography of Transport Systems. In Routledge eBooks. https://doi.org/10.4324/9781315618159

Schuster, H., Polleres, A., & Wachs, J. (2024). Stress-testing road networks and access to medical care. Transportation Research Part A Policy And Practice, 181, 104017. https://doi.org/10.1016/j.tra.2024.104017

Vesi.fi, Suomen ympäristökeskus. (2025, 7 januari). Tulvariskien aluesivut Uusimaa | Vesi.fi. Vesi.fi. https://www.vesi.fi/tulvariskien-aluesivut-uusimaa/