Sustainability Assessment of Smart Mobility Projects in Finland: a Comparative Analysis

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Sustainability Assessment of Smart Mobility Projects in Finland: A Comparative Analysis

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Abstract

The transport sector in Europe contributes to 25.8% of EU greenhouse emissions, and in Finland, it accounted for 24.9% of CO2 emissions in 2019. The Finnish Government aims to achieve carbon neutrality by 2035. This research examines the sustainability of Finnish smart mobility projects by assessing their alignment with the three dimensions of sustainability: environmental, economic, and social. A total of 33 projects were reviewed, considering their funding sources (EU or national) and project locations (South or North). An extensive sustainability indicator framework was applied, comparing 50 indicators across the projects. The results indicate a predominant focus on climate change, economic efficiency, and accessibility, while dimensions such as habitat protection, health, welfare, and affordability receive less attention. This emphasis on climate change can be attributed to ambitious policies and media influence. However, the underrepresentation of certain dimensions raises concerns about the balance of sustainability. Gender equity also emerged as an overlooked indicator, aligning with the gender equity report of Statistics Finland. To address this imbalance, future research should expand the dataset, develop a balanced indicator framework, and adopt a more structured approach to innovation projects on mobility.

Keywords: smart mobility, sustainability, climate change, QCA, indicators

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1. Introduction

1.1. Background

Climate change and global warming are causing a serious threat to nature, and it can be seen all over the world through heavy floods, extreme weather and shifting seasons, etc. The transport and mobility sector makes a high contribution to global emissions contributing to adversities. Therefore, governments across the world are trying to transform the transport and mobility system to minimize and cut down emissions. According to the European Environment Agency report Eurostat, (2019), the transport sector accounts for 25.8% of the total European Union (EU) greenhouse emissions.

The United Nations (UN) 2030 Agenda suggests addressing all three dimensions of sustainability- environmental, economic, and social- that need to be balanced and integrated Poveda, (2016), ESCAP and Scientific, (2015) United Nations, (2016), UN, (2015). Thus, it is necessary to consider all dimensions of sustainability rather than focusing on a single dimension. The UN has set a list of 17 Sustainable Development Goals (SDGs) to achieve overall sustainable development. These SDGs are measured through different indicators Hák et al., (2016), and it varies between different countries due to differences in their targets to implement the UN 2030 agenda. EU aims to have a minimum of 30 million emission-free vehicles by 2030 and all road vehicles with zero emissions by 2050 in its sustainable and smart mobility strategy report by EUROPEAN COMMISSION, (2020).

Eurostat, (2019)reports that the transport sector accounted for 24.9% of the CO2 emissions in Finland. The Finnish Government (2019) has set the target of achieving carbon zero by 2035, emphasizing the significance of environmental aspects of sustainability in transportation as well. Although Finland is ranked first by the UN Sustainable Development Reports, it is evident, however, that there are still challenges remaining in different areas including social equity, climate action, achieving sustainable cities and public transport satisfaction, etc. Sachs et al., (2021), Prime Minister's Office Finland, (2020), Sachs et al., (2022). It has been observed that the environmental impacts of smart mobility have dominated both the scientific literature and government action by Leviäkangas and Ahonen, (2021). The social aspects have been overshadowed by the environmental aspect of sustainability, likely because of focusing on ambitious climate policy. A study by Leviäkangas and Ahonen, (2021) on smart mobility showed that inclusive mobility and integrated sustainability are addressed in European-level projects, while in the national-level projects and policy discussions the projects in Finland are more centered on the environmental aspects of sustainability. Also, there seems to be more support for rural mobility at the national level in Finland and yet rural mobility services seem not to be functioning as effectively as in Denmark, Germany, Netherlands, Belgium, and Austria Mounce et al., (2020).

1.2. Aims and research questions

This research aims to identify how different dimensions of sustainability are addressed in smart mobility projects. The purpose is to understand how smart mobility innovation and research projects are profiled and which of the sustainability dimensions seem to gain the most attention and which seem to be given a lower priority. The priorities of the sustainability dimension in the projects are assumed to reflect the transport policy priorities, respectively. The research questions which will be addressed in this study are as follows:

- *Are the smart mobility projects in Finland addressing sustainability in a balanced and integrated manner as opposed to focusing on a single dimension?*

The first question follows from UN Agenda 2030, which says that "achieving sustainable development in its three dimensions economic, social, and environmental in a balanced and integrated manner" UN, (2015), Purvis et al., (2019). In this report, SDG 11, sub-target 11.2, which underlines "access to safe, affordable, accessible and sustainable transport systems for all, with special attention to the needs of those in vulnerable situations, women, children, people with disabilities, and older person" UN, (2015), United Nations, (2016). According to the Prime Minister's Office, (2020), remote (rural) areas are still facing public transport and accessibility issues. This review report also highlights the need for sustainable and diverse traffic fuel reform to promote the use of electricity and biogas as energy sources for mobility. The Gender Equality survey observes that the presence of females is very low in the transportation industry compared with other industries as mentioned by Ng and Acker, (2020). Statistics Finland, (2021) mentioned that fear of being the victim of violence is also a concern for women to use public transport at night. Therefore, there is a need to adopt a more gender-inclusive policy in future mobility projects by promoting balanced sustainability. These aforementioned examples are all sustainability issues, *per se*.

- *Do European-funded and nationally-funded development, research, innovation smart, and sustainable mobility projects differ in terms of addressing the three main dimensions of sustainability?*

There are mainly two types of funding sources for smart mobility research, innovation, and development projects: either the projects are funded by the EU, or they are nationally and regionally funded projects. The second research question aims to analyze if funding sources affect the addressing of sustainability dimensions.

- *Do the projects in densely populated areas of the country differ from those in sparsely populated parts?*

According to the Finnish Environmental Centre Report 2018 and Helminen et al., (2020), 72.3% of the population live in densely populated regions (i.e., urban). A majority of densely populated regions are in the southern part of Finland; therefore, we use the term South ("Southern Finland") for densely populated regions while North ("Northern Finland") for the rest of the regions (sparsely populated). The motivation behind this research question is to clarify if projects carried out in different parts of the country have a different view on sustainability priorities, especially thinking of the division between rural and urban Finland. In this study, the classification of South and North is based on the report of Statistics Finland, (2022) and urban-rural classification from the Finnish Environment Institute, (2014).

2. Framework development

A framework was needed to analyze and evaluate smart mobility projects to answer the questions of sustainability. First, a detailed literature review of smart mobility and sustainable transport was made to define the sustainability indicators used in the previous research projects including UN SDGs. Toth-Szabo and Várhelyi, (2012). developed an indicator framework to measure the transport sustainability of Swedish cities. Their framework covers emissions, efficiency, liveability, safety, resource use, and accessibility within the domain of economic, environmental, and social sustainability. Another framework to evaluate the transport sustainability in a megalopolis was proposed by Wang, (2014) which consisted of seventeen indicators covering the mobility, social, economic, and environmental dimension. Shiau and Liu, (2013) and Shiau et al., (2015) proposed an indicator system to evaluate and measure transport sustainability at the county/ local level (focused on Taipei City) with a total of twenty-one indicators categorized into environmental, economic, societal, and energy aspects. Litman, (2017) with Victoria Transport Policy Institute developed an extensive list of indicators to assess and measure the key transport sustainability goals including economic, social, environmental, and good governance and planning. Karjalainen and Juhola, (2021) worked on a systematic literature review of urban transportation sustainability assessments by reviewing 99 peer-reviewed articles and classified forty-seven indicators into twenty-four thematic groups. Most of the previous research covers the main three dimensions of sustainability (environmental, economic, and social). However, some of them used technology and energy as separate classification groups.

In AURORAL (2022) project focused on smart rural communities in the domain of smart mobility, health, tourism, energy, farming, etc. Key performance indicators (KPIs) were developed to measure the objectives of twenty-six different use cases After the extensive literature, the authors developed a framework with a list of key performance indicators to evaluate and analyze smart mobility pilots in AURORAL.

Table 1 includes the list of 50 indicators (modified from the authors' previous version (Ahonen et al. 2022) Valtteri Ahonen et al., (2022)) in the left column and the references that suggest those indicators in the right column. A review of different sustainable transport indicators was made to find out how sustainability (including SDGs) was addressed in the evaluated projects.

After a detailed list of indicators was extracted from the literature, the authors made a synthesis using appropriate definitions for selected thematic groups and indicators. Keeping in mind the scope of this study (smart mobility projects in Finland), the authors developed a sustainability indicator framework as shown in Figure 1 (modified from the author's previous version Valtteri Ahonen et al., (2022)). The indicators are grouped into ten different thematic groups following multiple iterative evaluations and brainstorming rounds. The grouping was hence a result of the research team's consensus-building process. The obtained ten thematic groups are categorized around social, economic, and environmental dimensions.

Table 1 List of indicators suggested by the references

Indicators	References that suggest the indicator
Access to public transport	Santos and Ribeiro, (2013);Jeon et al., (2013) ;Karjalainen and Juhola, (2021)
Accessibility	Buenk et al., (2019);Jeon et al., (2013);Toth-Szabo and Várhelyi, (2012);Litman, (2017); Karjalainen and Juhola, (2021)
Accidents & Fatalities	Santos and Ribeiro, (2013);UNECE, (2011);Buenk et al., (2019);Jeon et al., (2013);Bueno et al., (2015);Dobranskyte-Niskota et al., (2007);Wang, (2014);Nicolas et al., (2003); Litman, (2017); Karjalainen and Juhola, (2021)
Air pollution	Santos and Ribeiro, (2013);Haghshenas and Vaziri, (2012);Buenk et al., (2019);Bueno et al., (2015);Dobranskyte-Niskota et al., (2007);Litman, (2017); Karjalainen and Juhola, (2021)
Availability of pick-up places (micro-mobility)	Martí Riera et al., (2022)
Biodiversity	Bueno et al., (2015),Dobranskyte-Niskota et al., (2007);Litman, (2017); Karjalainen and Juhola, (2021)
CO2 emissions	Santos and Ribeiro, (2013);Jeon et al., (2013);Bueno et al., (2015);Dobranskyte-Niskota et al., (2007);Karjalainen and Juhola, (2021)
Congestion	Santos and Ribeiro, (2013);Dobranskyte-Niskota et al., (2007);Litman, (2017); Karjalainen and Juhola, (2021)
Connectivity of transport	Buenk et al., (2019); Karjalainen and Juhola, (2021)
Crime prevention	Buenk et al., (2019);Litman, (2017)
Economic sustainability and resilience	Buenk et al., (2019);Bueno et al., (2015); Martí Riera et al., (2022); Karjalainen and Juhola, (2021)
Employment	Jeon et al., (2013);Bueno et al., (2015);Dobranskyte-Niskota et al., (2007)
Energy efficiency	Santos and Ribeiro, (2013);Haghshenas and Vaziri, (2012);UNECE, (2011);Buenk et al., (2019); Karjalainen and Juhola, (2021) ;Bueno et al., (2015);Dobranskyte-Niskota et al., (2007);Nicolas et al., (2003);Litman, (2017)
Equity between citizens and groups	Santos and Ribeiro, (2013);Haghshenas and Vaziri, (2012);Buenk et al., (2019);Jeon et al., (2013); Karjalainen and Juhola, (2021)
Financial feasibility of transport services	Buenk et al., (2019); Karjalainen and Juhola, (2021)
Fitness and public health	Santos and Ribeiro, (2013);Bueno et al., (2015)
Fuel efficiency	Buenk et al., (2019);Jeon et al., (2013);Dobranskyte-Niskota et al., (2007);Toth-Szabo and Várhelyi, (2012);Litman, (2017); Karjalainen and Juhola, (2021)
Gender equity	Santos and Ribeiro, (2013); Karjalainen and Juhola, (2021)
Household expenditure on transport	Santos and Ribeiro, (2013);UNECE, (2011);Dobranskyte-Niskota et al., (2007);Nicolas et al., (2003);Litman, (2017); Karjalainen and Juhola, (2021)
Households reached by services	Santos and Ribeiro, (2013);UNECE, (2011);Dobranskyte-Niskota et al., (2007);Nicolas et al., (2003);Litman, (2017); Karjalainen and Juhola, (2021)
Inclusivity	Buenk et al., (2019)
Infrastructure cost & quality	UNECE, (2011);Bueno et al., (2015); Karjalainen and Juhola, (2021)
Land use	Santos and Ribeiro, (2013);Buenk et al., (2019);Litman, (2017); Karjalainen and Juhola, (2021)
Light pollution	Buenk et al., (2019)
Microplastics	Martí Riera et al., (2022); Karjalainen and Juhola, (2021)
Modal Split	Buenk et al., (2019);Dobranskyte-Niskota et al., (2007);Nicolas et al., (2003); Karjalainen and Juhola, (2021)

New services	Martí Riera et al., (2022)
Noise pollution	Santos and Ribeiro, (2013);Haghshenas and Vaziri, (2012);UNECE, (2011),Buenk et al., (2019);Jeon et al., (2013);Bueno et al., (2015);Wang, (2014);Nicolas et al., (2003); Litman, (2017); Karjalainen and Juhola, (2021)
Occupancy/load ratio	Karjalainen and Juhola, (2021);Dobranskyte-Niskota et al., (2007)
Operator cost	Karjalainen and Juhola, (2021);Bueno et al., (2015)
Other GHG emissions	Buenk et al., (2019); Karjalainen and Juhola, (2021)
Ozone emissions[1]	Jeon et al., (2013); Karjalainen and Juhola, (2021)
Particulate emissions	Nicolas et al., (2003); Karjalainen and Juhola, (2021)
Public expenditure	Santos and Ribeiro, (2013); Karjalainen and Juhola, (2021);Dobranskyte-Niskota et al., (2007);Wang, (2014);Nicolas et al., (2003)
Public/private investment in transport	UNECE, (2011);Buenk et al., (2019);Dobranskyte-Niskota et al., (2007);Wang, (2014);Nicolas et al., (2003); Karjalainen and Juhola, (2021)
Quality of life and wellbeing	Martí Riera et al., (2022)
Renewable energy	Haghshenas and Vaziri, (2012);Dobranskyte-Niskota et al., (2007); Karjalainen and Juhola, (2021)
Satisfaction of organizations involved	Santos and Ribeiro, (2013);Haghshenas and Vaziri, (2012);Buenk et al., (2019); Martí Riera et al., (2022)
Security against natural and man-made hazards	Haghshenas and Vaziri, (2012); Karjalainen and Juhola, (2021)
Service usability and satisfaction	Santos and Ribeiro, (2013);Haghshenas and Vaziri, (2012);Buenk et al., (2019)
SME/New businesses	Martí Riera et al., (2022)
Subsidies	Santos and Ribeiro, (2013);Dobranskyte-Niskota et al., (2007);Nicolas et al., (2003)
Transport for disabled	Haghshenas and Vaziri, (2012);Dobranskyte-Niskota et al., (2007); Karjalainen and Juhola, (2021)
Transport options	Santos and Ribeiro, (2013);Litman, (2017); Karjalainen and Juhola, (2021)
Transport reliability	Buenk et al., (2019); Martí Riera et al., (2022); Karjalainen and Juhola, (2021)
Travel time/speed/distance	Buenk et al., (2019); Karjalainen and Juhola, (2021);Jeon et al., (2013);Bueno et al., (2015);Nicolas et al., (2003)
User cost	Haghshenas and Vaziri, (2012);Dobranskyte-Niskota et al., (2007);Nicolas et al., (2003); Karjalainen and Juhola, (2021)
Users connected to digital services	Martí Riera et al., (2022); Karjalainen and Juhola, (2021)
Water pollution	Buenk et al., (2019);Dobranskyte-Niskota et al., (2007);Litman, (2017)
Work productivity	Martí Riera et al., (2022)

The thematic group for the social sustainability dimension consists of equity (Eq), safety & security (S), accessibility (Ac), and health (H), while the thematic group for the environmental dimension includes climate change (C), resource use (RU), and habitat protection (HP). The thematic group of economic dimension covers welfare (W), affordability (Af), and efficiency (Ef). The definition of each thematic group is as follows:

- *(C) Climate change means the project is aiming to minimize CO2 emissions and/or reduce other GHG emissions.*
- *(RU) Resource use means the projects aim to the reduction of natural resources, i.e., land use and non-renewable resources.*
- *(HP) Habitat protection means aiming to protect the natural environment and biodiversity (including human beings) by reducing transport pollution such as air, noise, water pollution, and NOx emissions that account for*

[1] Ozone emissions are NOx gases that lead to ground-level ozone.

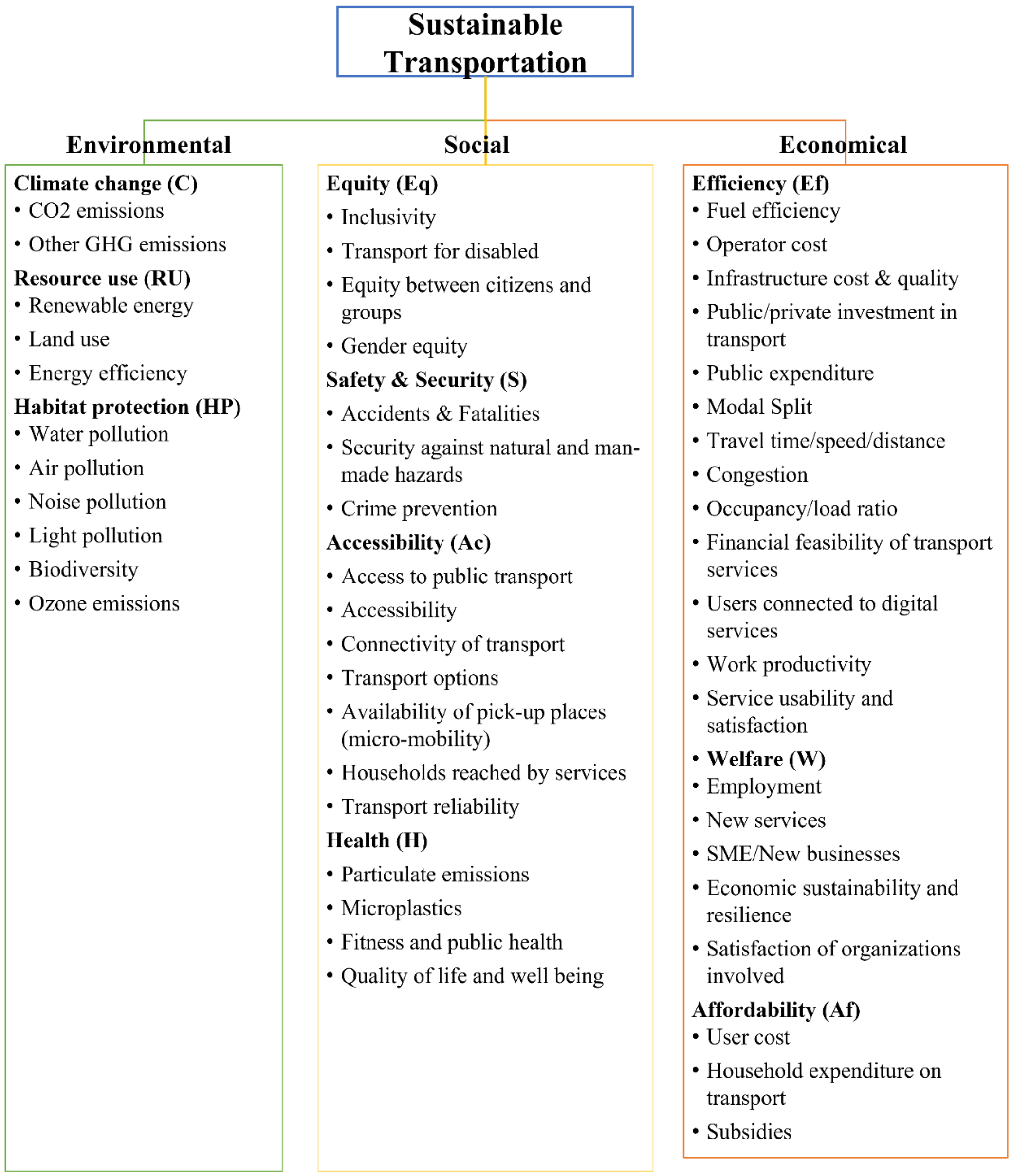


Figure 1 Sustainability Indicator framework for smart mobility projects (sustainable transportation)

ozone formation.

- *(E) Equity means the project aims to develop a fair distribution of transport services among different groups including gender groups and special persons. (S) Safety & Security means enhancing traffic safety against accidents as well as crimes against public transport users and resilience towards natural and manmade hazards.*
- *(Ac) Accessibility means increasing the easy access to mobility options for the public by increasing the connectivity and on-demand pickup points of public transport.*

- *(H) Health means the mobility services are designed to minimize health risks by the transport system including particulate emissions and provide options to improve public health and fitness through healthier options including cycling routes and services etc.*
- *(Ef) Efficiency means improving the efficiency of the transport system without increasing the financial costs with new solutions, minimizing congestion and travel time, and investing in advanced technology to improve the overall efficiency of the transport system.*
- *(W) Welfare means that the project aims to create new employment and bring new services through the transport system.*
- *(Af) Affordability means the transport services are affordable to the users through minimizing user costs or subsidies to encourage the use of public transport.*

3. Research data & analysis

This section discusses the details of data and its collection methods and steps involved. After that, the methods used for analysis and comparison are explained.

3.1. Research data

The data used in this research consists of publicly available smart mobility project documents. The projects were carried out in Finland between 2016 and 2022. Most of the data were found on the Regional Councils' websites and open data sources. Supplement data about the projects was also collected from the project partner websites. The evaluation was done on the aims and goals of the project documents, and it did not include the reported results or claimed impacts. Some of the projects were ongoing or their results (final reports) were not available at the time of data collection. Similarly, in some projects, the publicly available data sources only include web pages and news. However, there were some completed projects, and their final report was available, and in such cases, evaluation of aims and goals was done in the introduction of the final reports. Due to the limited resources and access to the mobility projects data, this study is limited to 60 identified projects/pilots' materials. The collection of research data and the content analysis are defined by the following steps:

Data collection and review

The first step was the data search and collection. The data was collected through open data sources and regional council websites in Finland where most of the data were available. The remaining data were obtained from project partners' websites involved in the identified projects. The acquired data comprised materials from a total of 60 identified projects.

Data review

The second step included reviewing and extracting relevant data from the reports and documents acquired in step 1. The aims, and goals of the projects were reviewed to discover which aspects and dimensions of sustainability were specifically addressed. The evaluation focused on the aims and objectives of the research and innovation pursued in the projects rather than the impacts of the projects.

Data minimization

After reviewing and analyzing the aims and objectives of 60 projects, some of the project documentation was not consistent with the requirements of the study hence they were excluded. Usually this was done when project documentation was ambiguous, unconvincing, or simply incomplete or missing some relevant parts. After that, 33 projects were accepted for this research. Most of the projects were related to passenger transport, while a few of them covered also transport of goods and logistics.

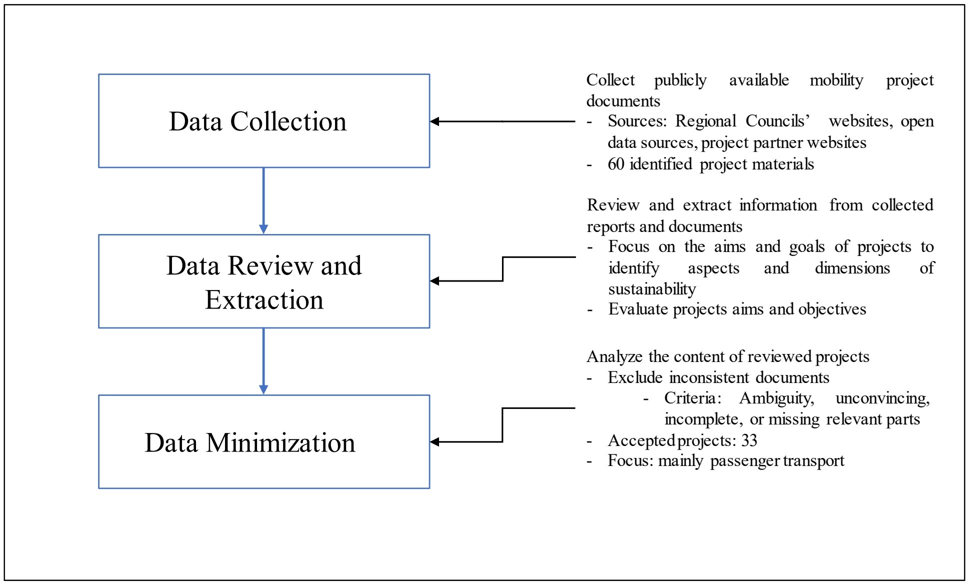


Figure 2 Main steps in research data collection and reduction

3.2. Data analysis

The research material of 33 projects was evaluated using the framework in Fig. 1. The stated sustainability objectives were compared against the indicator framework. Each project was evaluated independently against the fifty indicators and depending on whether the indicator was addressed in the goal setting of the project, a value of either 0 (indicators not addressed) or 1 (indicators addressed) was given. Then, a data matrix (truth table) was assembled After the evaluation, the projects were compared as follows:

- *EU funded vs. National funded (NF) projects*

The purpose of the comparison is to answer Research Question 2: Do the EU-funded, and NF smart mobility projects differ in terms of addressing the different indicators and aspects of sustainability?

- Projects *in densely populated regions (South) vs. other regions (North) in Finland*

This comparison helps to answer the third question which is: Do the smart mobility projects in densely populated areas of the country differ from those in sparsely populated parts?

The frequency of indicators and thematic groups of all four categories EU, NF, South, and North were calculated and compared with each other in the first step. The frequency was calculated by summing up the number of projects addressing the indicators (i.e., CO2 emissions) in each category (i.e., EU) and then dividing it by the total no number of projects in that category (i.e., EU). The frequency shows that the ratio of the projects in each category (i.e., EU) addressed that indicator (i.e., CO2 emissions). Similarly, the frequencies were calculated for all categories. After that, the overall frequency of individual indicators of the total projects was calculated to see which sustainability indicators were dominant in all projects, and similarly, the overall frequency of each thematic group of all projects was calculated to see which thematic groups were highly addressed. This will help to answer the first question to see that is there a balanced approach is the projects or not.

Qualitative comparative analysis (QCA) was also applied to analyze, examine, and interpret the results of the projects. Ragin, (1987) introduced QCA to address the social research questions. Later, several other researchers including Rihoux and Ragin, (2012) used QCA as an analytical technique and research approach to answer social issues and behaviors (qualitative approach). One of the reasons QCA is used widely and attracted researchers [Rihoux and Ragin, (2012); Rihoux and Lobe, (2012)] is the ability to predict outcome models with smaller cases (population). QCA helps the researcher in a meaningful interpretation of the sequence of conditions presented by the cases. The FsQCA tool uses the Quine-McCluskey algorithm as mentioned in Ragin et al., (2017) to minimize the prime implicants to simplify the recipes and outcome model. Consistency of the model is one of the main criteria to refine and accept models that predict the possible outcomes against the causal conditions.

QCA was tested with the proposed framework having 10 thematic groups using the fsQCA tool. For that, initially, a truth table (0 or 1) was developed for all projects against 50 indicators. After that, the frequency is calculated within each thematic group to find out how much the frequency/ratio of indicators in each thematic group is covered. The fuzzy set ruth table was calculated for all projects against the thematic groups (causal conditions). The data of fuzzy set truth tables ranges between 0 and 1 therefore the data do not need further calibration. It was found that there was a total of 9 indicators with zero frequency among all projects. Therefore, they were removed from the QCA analysis for simplicity however they were included in the dendrogram figures in the result section. The final truth table was analyzed under four outcome categories EU, NF, North, and South.

4. Results

This section discusses the results based on the analysis of sustainability indicators and thematic groups across four categories: EU, NF, South, and North. Dendrogram graphs were generated for each category, illustrating the frequency of projects addressing specific sustainability indicators on x-axis. The comparisons were made between EU and NF projects, as well as between South and North projects, utilizing the dendrograms. Additionally, indicators addressed in all projects were assessed, along with the examination of thematic groups using the dendrograms. The analysis further delves into a comparison of EU and NF projects in densely populated regions (south) and a comparison between South and North projects from a national funding perspective. The comparison of projects in the north and south from an EU funding perspective was omitted due to the limited number of EU-funded projects in comparison to NF. Additionally, the scarcity of projects located in the north led us to avoid further categorizing them based on EU and national funding sources. Subsequently, the QCA analysis results are presented and discussed, focusing on the ten thematic groups and comparing EU, NF, North, and South.

4.1. Comparing Sustainability indicators

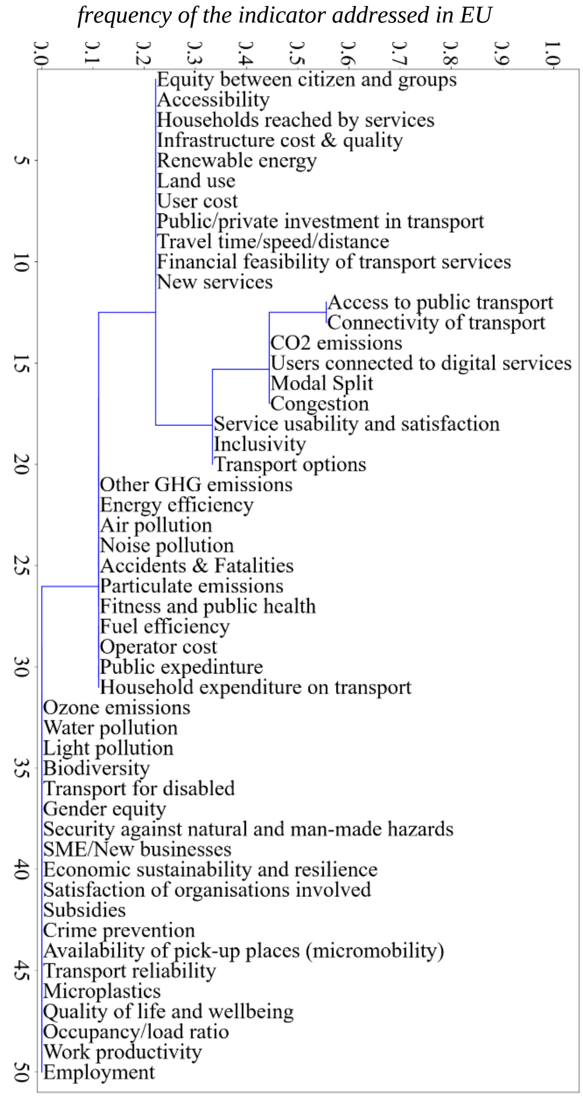
4.1.1. EU vs NF projects

Figure 3 shows the frequency of indicators of EU-funded projects. Access to public transport, connectivity of transport while, CO2 emissions, service usability, and satisfaction, transport options, inclusivity, modal split, congestion, and users connected to digital services are indicators with a relatively high frequency. Air pollution, noise pollution, household expenditure on transport, fitness, and public health, other GHG emissions, fuel efficiency, particulate emissions, accidents & fatalities, public expenditure, operator cost, and energy efficiency are indicators having a minor presence. A total of 19 indicators including ozone emissions, water pollution, biodiversity, transport for the disabled, gender equity, etc. are not aimed to address by any of the EU projects.

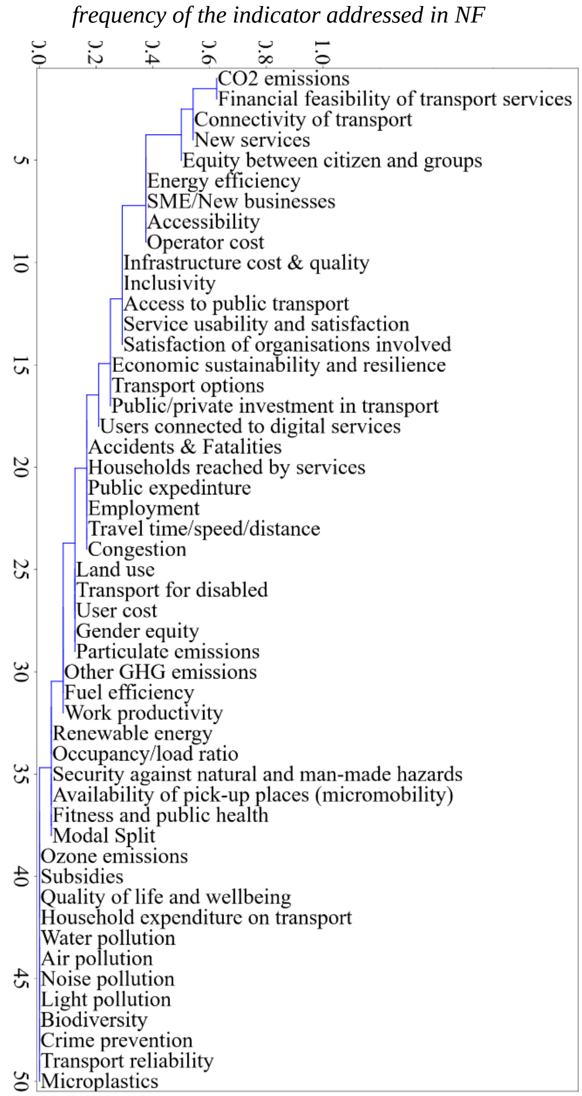
Figure 4 shows the frequency of the indicators of NF projects on the x-axis and a list of indicators on the y-axis. It can be observed that CO2 emissions, financial feasibility, connectivity, and equity among citizens are the indicators with maximum presence while land use, transport of disabled, user cost, gender equity, congestion, other GHG gases, fuel efficiency, and modal split are the indicators with minor presence. A total of 12 indicators including ozone emissions, quality of life and wellbeing, household expenses on transport, water, air, noise pollution, biodiversity, and crime prevention are not aimed at any of the NF projects.

4.1.2. South vs North projects

Figure 5 presents the frequency of sustainability indicators of projects in densely populated regions (South) of Finland. It is clear from the figure that CO2 and Connectivity of transport are the two indicators with the highest frequency. Access to public transport, new services, financial feasibility, inclusivity, equity between citizens, Accessibility, and infrastructure cost are the indicators with a considerable presence (frequency). However, other GHG



[2]Figure 3 Frequencies of sustainability indicators addressed in EU projects



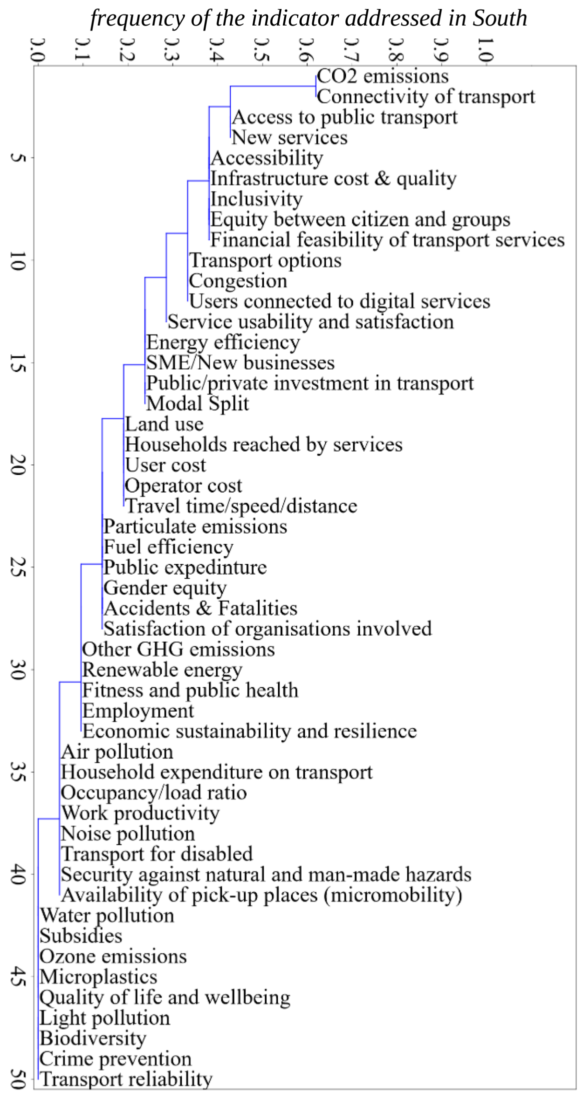
[3]Figure 4 Frequencies of sustainability indicators addressed in NF projects

emissions, renewable energy, transport for the disabled, air pollution, noise pollution, water pollution, ozone emissions, microplastics, biodiversity, and transport reliability are the indicators with minimum consideration (frequency) among the projects in densely populated regions.

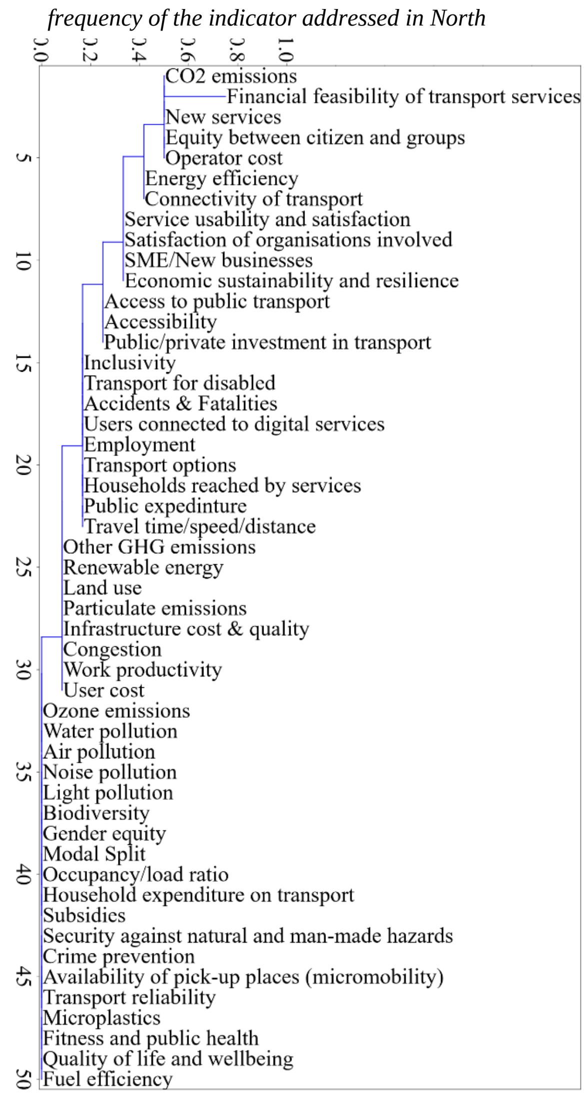
Figure 6 shows the frequency of indicators in the North category. The financial feasibility of transport, CO2 emissions, new services, equity between citizens, operator cost, energy efficiency, and connectivity of transport are the indicators with relatively high consideration. However, the indicators include GHG emissions, particulate emissions, renewable energy, land use, user cost, infrastructure cost & quality, congestion, and work productivity are having relatively low frequencies. It can be seen from Figure 6 that 19 indicators including ozone emissions, water pollution, air pollution, noise pollution, biodiversity, crime prevention, quality of life, and well-being, micro-mobility,

[2] x axis: frequency of indicators (EU); y-axis: List of indicators

[3] x-axis: frequency of indicators (NF); y-axis: List of indicators



[4]Figure 5 Frequencies of sustainability indicators addressed in South projects



[5]Figure 6 Frequencies of sustainability indicators addressed in North projects

gender equity, household expenditure on transport, fuel efficiency, and modal split were not considered (zero frequency) by any of the projects (North) in their goal setting.

4.1.3. EU vs NF projects in densely populated regions (south)

Figure 7 provides an overview of indicators covered by 21 mobility projects in the densely populated region (South). Out of these projects, 12 received NF, while 9 were EU. It can be seen from the figure that, the nationally funded projects prioritized CO2 emissions, Connectivity of transport, New services, Equity between citizens and

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[4] x-axis: frequency of indicators (South); y-axis: List of indicators

[5] x-axis: frequency of indicators (North); y-axis: List of indicators

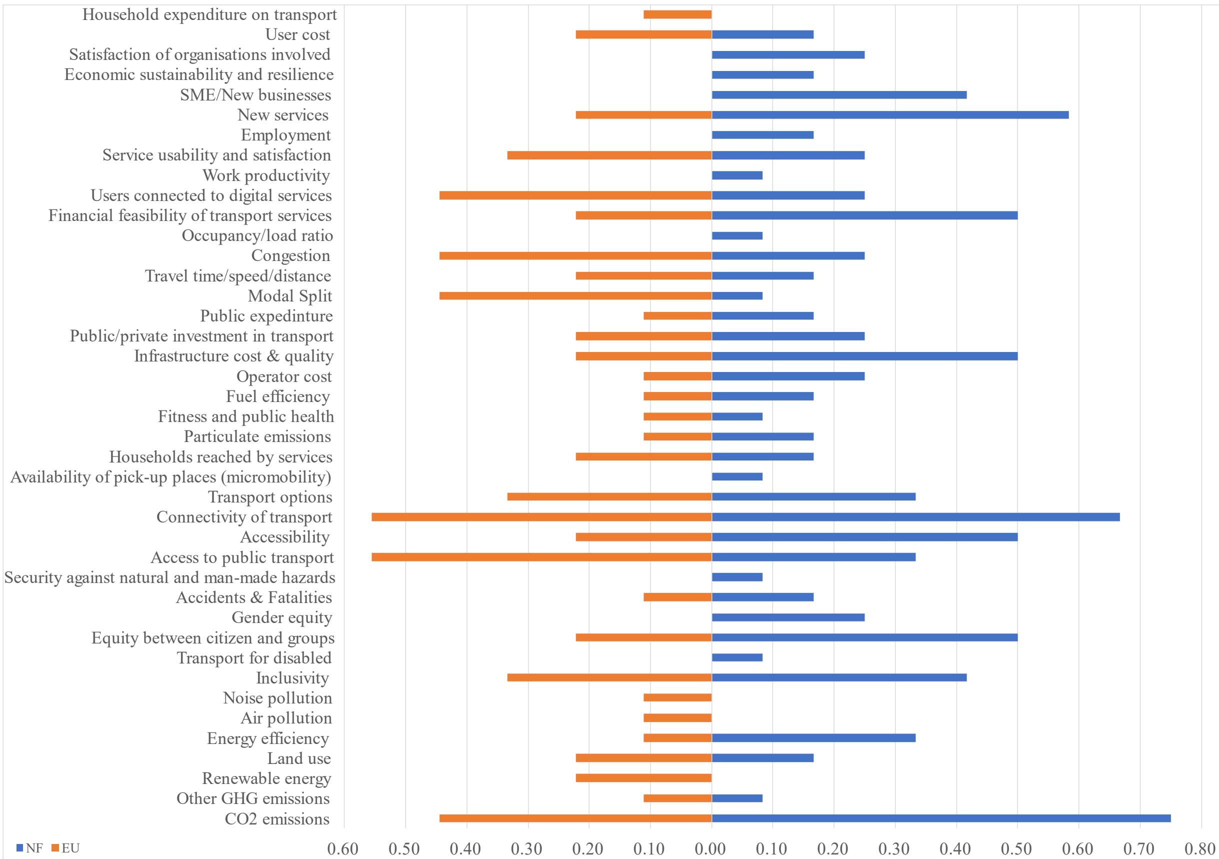


Figure 7 Frequencies of sustainability indicators in EU and NF projects in densely populated regions

groups, Accessibility, Inclusivity, and SME/New businesses. On the other hand, the EU-funded projects focused more on Connectivity of transport, Access to public transport, CO2 emissions, Congestion, Users connected to digital services, Modal Split, Inclusivity, Transport options, and Service usability and satisfaction.

Notable differences between the two funding categories include the emphasis on Access to public transport, Modal Split, renewable energy, Air pollution, Noise pollution, and Household expenditure on transport in the EU-funded projects, while the nationally funded projects placed greater importance on CO2 emissions, New services, Equity between citizen and groups, Accessibility, Infrastructure cost & quality, Financial feasibility of transport services, Employment, Economic sustainability, and resilience, Transport for the disabled, Security against natural and man-made hazards, Availability of pick-up places (micro-mobility), Occupancy/load ratio, and Work productivity. Additionally, economic sustainability and resilience were more frequently addressed in the nationally funded projects, reflecting their focus on the economic aspects of mobility initiatives.

4.1.4. South vs North Project: National funding perspective

Figure 8 shows the overview of the indicators covered by 24 mobility projects that received national funding, out of a total of 33 projects. These projects were categorized as South and North regions. Among the 11 projects in the South category, the indicators with the highest representation are CO2 emissions, Connectivity of transport, New services, Equity between citizens and groups, Accessibility, Infrastructure cost & quality, and Financial feasibility of transport services. On the other hand, the 13 projects in the North category emphasized indicators such as the Financial feasibility of transport services, CO2 emissions, New services, Equity between citizens and groups, Operator cost, Connectivity of transport, and Energy efficiency.

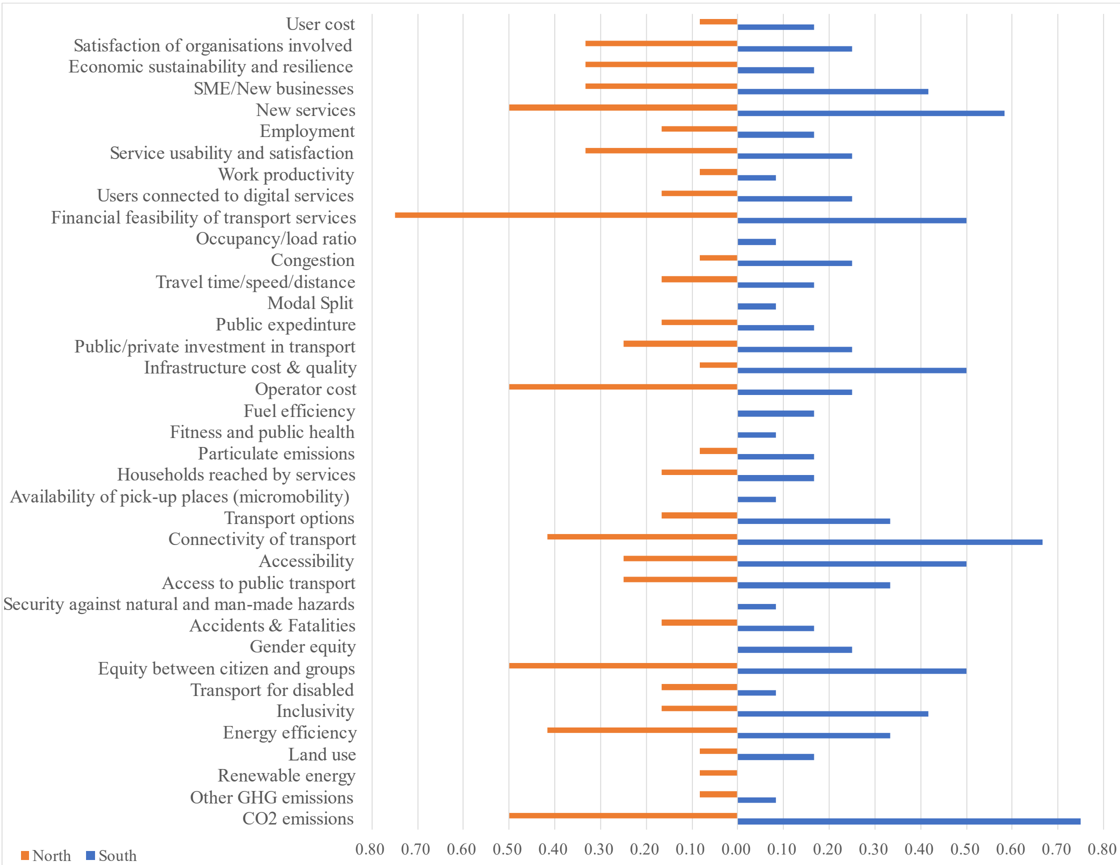


Figure 8 Frequencies of sustainability indicators in North and South projects with National funding

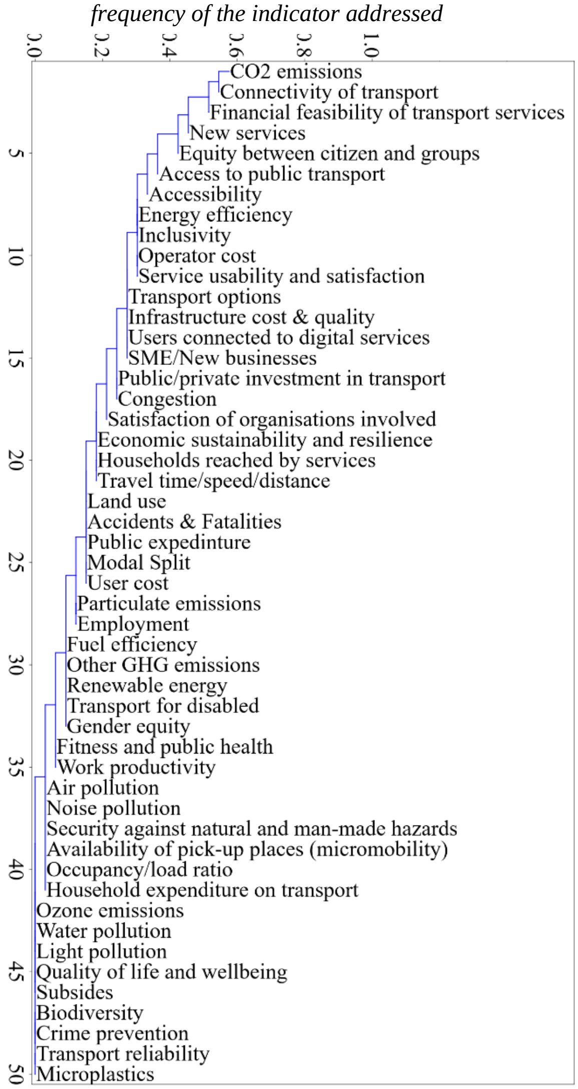
Notable differences between the two categories include a stronger focus on CO2 emissions, Connectivity of transport, Infrastructure cost & quality, Congestion, Gender equity, Fuel efficiency, Availability of pick-up places (micro-mobility), Fitness and public health, and Modal Splitin the South, reflecting the need for efficient, accessible and sustainable transportation options in densely populated areas. In contrast, the North showed a greater emphasis on the financial feasibility of transport services, Operator cost, Economic sustainability and resilience, Transport for the disabled, and Renewable energy possibly driven by cost-effectiveness and sustainability considerations in less populated regions. Additionally, energy efficiency received relatively higher attention in the North, indicating a focus on optimizing energy usage. In terms of inclusivity and accessibility, the South category demonstrated a stronger emphasis, reflecting the need to accommodate diverse user groups in densely populated regions.

4.1.5. Assessing the sustainability indicators addressed in all projects

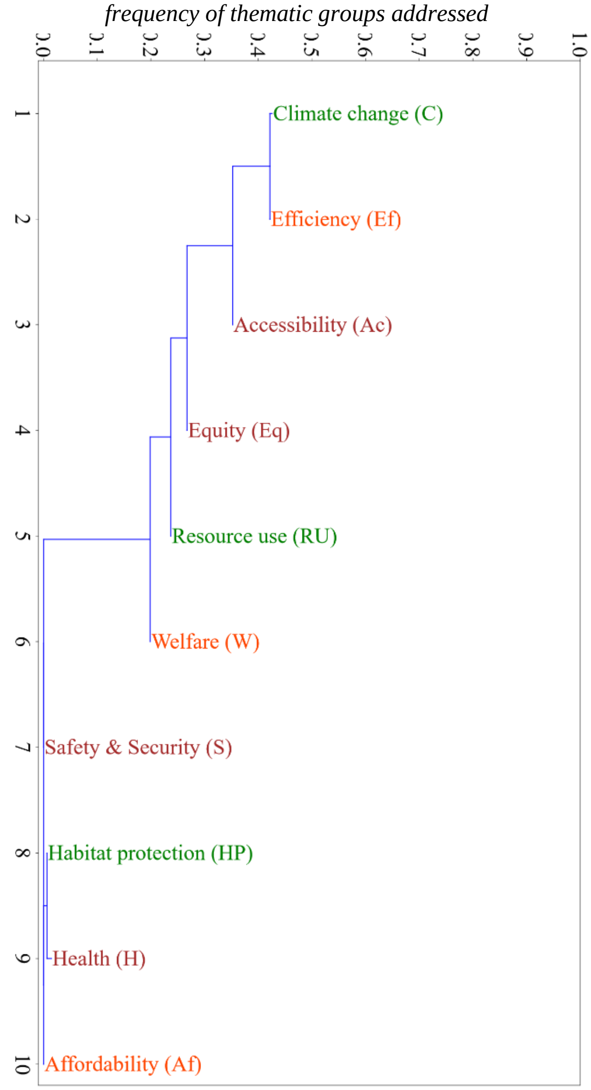
The frequency of sustainability indicators in the whole 33 projects is presented in Figure 9. Overall, CO2 emissions, connectivity of transport, financial feasibility of transport services, new services, equity between citizens and groups, access to public transport, and accessibility are the indicators having a relatively high frequency in the projects. However, other GHG emissions, employment, transport for the disabled, gender equity, fuel efficiency, air, noise, and water pollution, ozone emissions, well-being, and biodiversity are the indicators with minimum presence (frequency) in the smart mobility projects.

4.1.6. Assessing the thematic groups addressed in all projects

Figure 10 presents the frequency of 10 thematic groups (comprising the 50 indicators) of all 33 smart mobility projects. The thematic groups under three aspects of sustainability are differentiated with different colors. Thematic groups in environmental sustainability are mentioned in green color, and brown color represents the thematic groups



[6]Figure 9 Overall frequency of sustainability indicators addressed in all projects



[7]Figure 10 Overall frequency of thematic groups addressed in all projects

in social sustainability while the thematic groups in economic sustainability are presented in orange color. It can be observed that among the three thematic groups in environmental sustainability, climate change has the relatively highest presence, habitat protection has minimum presence while the frequency of resource use is almost average of the two. Similarly, efficiency has the highest presence among economic sustainability while affordability has a minimum frequency. The frequency of welfare is approximately the average of efficiency and affordability.

6 x-axis: frequency of indicators (Overall); y-axis: List of indicators
7 x-axis: frequency of thematic groups (Overall); y-axis: List of thematic groups

Accessibility and equity are the thematic groups in social sustainability with the highest frequency while safety & security, and health have a minimum presence among the projects.

4.2. QCA Analysis Results

Table 2. presents the results of the QCA analysis with four different project categories (EU, NF, North, and South). Each column consists of a single category. The outcome model is mentioned in the first row of Table 2 and each model consists of ten casual conditions (thematic groups). The model consists of multiple formulas known as recipes to predict the outcome.

The first model represents the projects with EU funding, it contains 5 recipes, and the overall consistency of this model is 0.72. It is clear from the recipes that, Accessibility (Ac), and Climate change (C), are more dominant while resource use (RU), efficiency (Ef), and affordability (Af) have a considerable contribution to the outcome. It can be

Table 2 Outcome models of QCA (EU, NF, North, South)

EU = f (C, RU, HP, Eq, S, Ac, H, Ef, W, Af)	NF = f (C, RU, HP, Eq, S, Ac, H, Ef, W, Af)	North = f (C, RU, HP, Eq, S, Ac, H, Ef, W, Af)	South = f (C, RU, HP, Eq, S, Ac, H, Ef, W, Af)
C*~RU*~HP*~Eq*~S*~Ac*H*~Ef*~W*~Af	~C*~RU*~HP*~Eq*S*~Ac*~H*~Ef*~W	~C*~RU*~HP*~Eq*S*~Ac*~H*~Ef*~W*~Af	C*~RU*~HP*~Eq*~S*~Ac*H*~Ef*~W*~Af
C*RU*~HP*~Eq*~S*Ac*~H*~Ef*~W*~Af	~C*~RU*~HP*Eq*~S*Ac*~H*~W*~Af	~C*~RU*~HP*Eq*~S*Ac*~H*~Ef*~W*~Af	~C*~RU*~HP*~Eq*S*~Ac*~H*~Ef*~W*Af
~C*~RU*~HP*Eq*~S*Ac*~H*~Ef*~W*Af	~C*~RU*~HP*Eq*~S*Ac*~H*~Ef*~Af	C*~RU*~HP*~Eq*~S*~Ac*H*~Ef*W*~Af	~C*RU*~HP*~Eq*~S*Ac*~H*~Ef*~W*~Af
C*~RU*~HP*~Eq*~S*Ac*~H*Ef*~W*Af	C*~RU*~HP*~S*~Ac*~H*~Ef*W*~Af	~C*~RU*~HP*~Eq*S*~Ac*~H*Ef*W*~Af	C*~RU*~HP*~Eq*S* ~Ac*~H*Ef*~W*~Af
~C*RU*HP*~Eq*S* Ac*~H*Ef*~W*~Af	C*~RU*~HP*~Eq*~S*~Ac*~Ef*W*~Af	-	C*~RU*~HP*~Eq*~S*~Ac*H*Ef*~W*~Af
-	C*~RU*~HP*~Eq*~S*~Ac*~H*~Ef*W	-	~C*~RU*~HP*Eq*~S*Ac*~H*~Ef*~W*Af
-	C*~RU*~HP*~Eq*~S*~H*Ef*W*~Af	-	C*~RU*~HP*~Eq*~S*Ac*~H*Ef*~W*Af
-	C*~RU*~HP*~Eq*S* ~Ac*~H*Ef*~W*~Af	-	C*RU*HP*~Eq*S*Ac*~H*Ef*~W*~Af
-	C*~RU*~HP*~Eq*~S*~Ac*H*Ef*~W*~Af	-	C*RU*~HP*Eq*~S* Ac*H*Ef*~W*~Af
-	~C*~RU*~HP*~Eq*S*~Ac*~H*Ef*W*~Af	-	-
-	C*RU*~HP*Eq*~S* Ac*H*Ef*~W*~Af	-	-
consistency: 0.72	consistency: 0.95	consistency: 0.75	consistency: 0.95

observed that Equity (Eq), health (H), and welfare (W) have the minimum contribution to the outcome model. The second model with the outcome of NF consists of 11 recipes and the overall consistency of the outcome model is 0.95. Climate change (C), efficiency (Ef), and welfare (W) are the three factors (thematic groups) having maximum presence in the outcome recipes while accessibility (Ac), equity (Eq), and safety (S) have a considerable presence. Affordability (Af) and habitat protection (HP) are the factors that have a negligible contribution to the outcome. The third model comprises 4 recipes of the outcome model North (low population density regions) and the overall consistency of the model is 0.75. In this model, welfare (W), and safety (S) are the factors with the maximum contribution to the outcome however, climate change (C), accessibility (Ac), and Equity (Eq) are the factors with some considerable contribution to the outcome. The factors including resource use (RU), affordability (Af), and habitat protection (HP) have minimum impact on the outcome.

Finally, the fourth model with the South outcome model (densely populated regions) has 9 recipes and overall consistency of 0.95. Climate change (C), accessibility (Ac), and efficiency (Ef) are the three factors with high contributions to the outcome while, safety (S), health (H), equity (Eq), resource use (RU), and affordability (Af) are the factors with considerable impact on the outcome. The factors with the least impact on the outcome are habitat protection (HP), and welfare (W). Overall, the consistency of NF and South is 0.95 while the EU and North models are 0.72 and 0.75, respectively. The reason is that the category EU and North cover approximately 1/3 of the projects while approximately 2/3rd of the projects is in the NF and South category.

5. Discussion

A comparison of Fig. 3 and Fig. 4 shows that CO2 emissions, financial feasibility accessibility, operator cost satisfaction of the organization involved, economic sustainability and resilience, SME/New business, employment, energy efficiency, gender equity, and transport for the disabled, are the indicators which are dominant in NF projects than EU projects. Similarly, access to public transport, user connected to digital services, congestion, modal split, transport options, household reach by services, user cost, land use, renewable energy, fuel efficiency, fitness, and public health, household expenses on transport, air, and noise pollution are the indicators dominant in EU projects than NF projects. Particulate emissions, accidents & fatalities, public expenditure, public/private investment in transport, Inclusivity, service usability and satisfaction, and connectivity of transport are more are less treated equally in both EU and NF projects. Ozone emissions, water pollution, light pollution, biodiversity, crime prevention, transport reliability, microplastics, quality of life and wellbeing, and subsidies are the indicators that are not addressed in a single project in both EU and NF projects.

The comparison of Figure 5 and Figure 6 between projects in densely populated regions and sparsely populated regions of Finland shows the sustainability indicators, CO2 emissions, access to public transport, accessibility, connectivity of transport, transport options, users connected to digital services, infrastructure cost & quality, inclusivity, modal split, land use, fitness, and public health, and user cost are dominant in densely populated as compared to sparse regions. However, transport for the disabled, employment, economic sustainability, and resilience, satisfaction of organizations involved, energy efficiency, connectivity of transport, operator cost, equity between citizens and groups, and financial feasibility of transport services are more dominant in projects in sparsely populated regions as compared to densely populated regions. It is interesting to observe that like EU and NF projects, ozone emissions, water pollution, light pollution, biodiversity, crime prevention, transport reliability, microplastics, quality of life and well-being, and subsidies are the indicators not aimed to be addressed in both North and South regions projects.

Table 3 Summary of results (EU, NF, North, South)

Categories	Method	Dominant thematic groups	Significant thematic groups	Recessive thematic groups
EU	Dendrogram	C, Ac, Ef	RU, Eq, Af	HP, H, S, W
	QCA	C, Ac	RU, Af, Ef	HP, H, S, W, Eq
NF	Dendrogram	C, Ac, Ef, W	RU, Eq, S	HP, H, Af
	QCA	C, Ef, W	Ac, Eq, S	HP, H, Af, RU
North	Dendrogram	Ef, W	C, Ac, Eq, S	HP, H, Af, RU
	QCA	W, S	C, Ac, Ef, Eq, H	HP, Af, RU
South	Dendrogram	C, Ac, Ef, Eq	RU, Af, W	HP, H, S
	QCA	C, Ac, Ef	RU, Af, Eq, S, H	HP, W

The results of Figure 7 compare mobility projects in densely populated regions based on their funding sources. The findings reveal that NF emphasizes indicators like CO2 emissions, new services, equity, accessibility, SME/new businesses, and infrastructure cost & quality, while EU-funded projects prioritize connectivity of transport, access to public transport, CO_2 emissions, congestion, digital services, and modal split. Figure 8 further analyzes the indicators addressed in the South and North regions for projects receiving NF. The South region emphasizes infrastructure, congestion, gender equity, fuel efficiency, pick-up places, fitness and public health, and modal split, reflecting the need for efficient and sustainable transportation in densely populated areas. However, the North region prioritizes the financial feasibility of transport services, operator cost, economic sustainability, transport for the disabled, and renewable energy, which align with cost-effectiveness and sustainability concerns in less populated regions. The findings underscore the need for tailored approaches in mobility projects, considering specific challenges and requirements in densely populated regions based on different funding sources.

The summary of results of four categories (EU, NF, North, South) along with ten thematic groups is presented in Table 3. There are two sub-categories in each EU, NF, North, and South based on the methods used for comparison. The first method "dendrogram" is the comparison of sustainability groups and indicators as shown in Figures 3-6 while the second method is QCA (from Table 2), the summary of the result is presented in Table 3. The then thematic groups are classified into dominant, significant, and recessive based on their presence in each category. Both methods "dendrogram & QCA" are producing more are less similar results for all four categories with some minor differences.

6. Conclusions

Comparing the difference between the EU-funded (EU) and nationally funded (NF) projects, climate change seems to dominate the project scene, Also, efficiency and connectivity and in general the economic aspects are very much present. This partly reflects the national strategies and policies where Finland has set a carbon neutrality target for the year 2035. However, on the other side, the 'usual suspect' of pursuing economic efficiency seems to be still present. Little factual difference can be found between EU and NF projects, and the authors conclude that much of the project goal setting is defined by political rhetoric and media-directed topics, as well as by the issues considered to be publicly correct and acceptable. This has led to the underrepresentation of some other relevant and important issues such as habitat protection, biodiversity, and people's health and well-being. The same result was observed in Leviäkangas, (2021) when the goal setting of a Finnish transport agency was analyzed. Therefore, the conclusion is that both EU and NF projects do have a certain emphasis on their goal setting. Consequently, one can question the balance of sustainability dimensions.

When comparing North and South projects, the sparsely populated areas' projects seem to have a slightly different balance from the rest, but also there the habitat protection and health are having a quite marginal role. This is somewhat surprising if not even worrying thinking of the cruciality of habitat protection issues such as biodiversity and plastic waste (noting that car tires produce a significant amount of plastic waste). The South projects follow by and large the goal-setting profile of NF and EU projects.

The comparison of mobility projects in densely populated regions based on their funding sources highlights that NF projects are more focused on key areas like CO_2 emissions, new services, equity, accessibility, SME/new businesses, and infrastructure cost & quality. On the other hand, EU-funded projects prioritize connectivity, CO_2 emissions, congestion, digital services, and modal split. The analysis of the nationally funded South and North regions reveals that the South region emphasizes the need for efficient and sustainable transportation and the North region prioritizes the financial considerations and cost-effectiveness in less populated regions.

In sum, climate change and economic efficiency were dominating the goal setting of smart mobility projects, be the projects funded by the EU or national funders. Gender equity was one of the indicators that is unrepresented in all projects, and it is also confirmed by the gender equity report of Statistics Finland, (2021). The report shows that transport is one of the fields with the minimum presence of women compared with other professionals. Similarly, other GHG and ozone emissions were very much underrepresented. Habitat protection, health, and affordability are also areas that need more attention in future projects if more balanced sustainability is sought in smart mobility research and innovation projects.

As to limitations, this study was limited to publicly available project material and resources. Some of the initially listed projects were ongoing and their reports were not available. Some of the identified projects had limited access to their data or due to the time limitation, it was not possible to include those projects in this study. Yet the studied sample of the projects can be considered representative, including more than 50% of the identified 60 projects.

The need for future research comprises multiple directions. The data set, for the first, can be updated and extended to have even better coverage. Such analysis would help the funders to create more balanced research portfolios and address also the neglected dimensions of sustainability. Second, even the planning of research portfolios should start from a more balanced point. If all projects address climate change, as important as it is, there is a risk that important dimensions are lost and that projects become repetitive and overlapping. Therefore, the indicator framework could be a way to check that project portfolios and research strategies are balanced. Third, a more structured approach should be applied to direct nationally funded projects. EU-funded research is often enough applicable to national contexts, and there is a risk of resource waste when identical themes and goals are addressed in nationally funded projects. This calls for a review of the national innovation strategy as a whole. National funders should not fund ‘mini-EU clones.

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Authors contribution

The authors confirm their contribution to the paper as follows: study conception and design: Shahid Hussain, Valtteri Ahonen, Pekka Leviäkangas; data reduction and truth table: Valtteri Ahonen; Data analysis and interpretation of results: Shahid Hussain, Pekka Leviäkangas; manuscript preparation: Shahid Hussain; supervision and revision: Pekka Leviäkangas. All authors reviewed the results and approved the final version of the manuscript.

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Appendix A. Project data description and details

Appendix 1 List of projects and their details

ID	Pilot/projects	South/ North	Municipalities/ Region	Main Funder	Funding amount (approx.) M[8]
1	Kutsutaksipalvelu maaseutukunnissa	North	Ruokolahti, Rautjärvi, Parikala	Business Finland	[9]NA

8 M: million Euros

[9] NA: Funding data was not available or confidential

2	Alueellisen Liikkumisen Palveluidan Integroitu Operointi (ALPIO)	Both	Porvoo, Loviisa, Mikkeli, Ylöjärven Kuru, Sastamalan Vammala	Sitra	0.52
3	Open Arctic Maas	North	Ylläs	Sitra	0.04
4	KeLiPa	North	Muonio	ERDF	0.27
5	FitMe!	Both	Parainen, Kuusamo	Business Finland	0.75
6	Vihreät matkaketjut	South	Nauvo	ERDF	0.35
7	Kyytiin	Norh	Kaustinen	Maaseutupolitiikan kehittämisvarat	NA
8	Kyytiin2	North	Perho	ERDF	0.39
9	Päästökauppasovellus CitiCAP	South	Lahti	Urban Innovative Actions	3.79
10	LVM Alueellisen junaliikenteen pilotit	Both	Kouvola, Tampere, Seinäjoki	Ministry of Transport and Communications	NA
11	Pöytyän ja Auran asiointiliikenteen paikannuspalvelukokeilu	South	Pöytyä, Aura	Centre of Economic Development, Transport and the Environment	0.04
12	HAPPILY	South	Porvoo, Askola, Loviisa	ERDF	0.20
13	Peput penkkiin -kimppa-autokokeilu	South	Espoo	N/A	NA
14	SHOTL-kutsuliikennekokeilu (Oulu)	North	Oulu	Oulu public transport	NA
15	GREENSAM	South	Turku	Interreg Baltic Sea Region	0.42
16	Civitas Eccentric	South	Turku	Horizon 2020	3.28
17	NääsMaaS-harrastuskyytipalvelu	South	Tampere	City of Tampere, Ministry of the Environment	0.04
18	6Aika: Perille asti	South	Helsinki, Vantaa	ERDF	1.85
19	RIDE2RAIL	South	Helsinki	Horizon 2020	0.28
20	URBANITE	South	Helsinki	Horizon 2020	0.3
21	MUV	South	Helsinki	Horizon 2020	0.36
22	SMASH	South	Helsinki	Climate-KIC	NA
23	FinEst SmartMobility	South	Helsinki	Interreg Central Baltic	0.67
24	6Aika: Vähähiilinen liikkuminen liikennehubeissa	South	Tampere, Espoo	ERDF	1.92
25	6Aika: SOHJOA	South	Helsinki, Espoo, Vantaa, Tampere	ERDF	0.50
26	Sohjoa Last Mile	South	Helsinki	Interreg Baltic Sea Region	0.24
27	Sohjoa Baltic	South	Helsinki	Interreg Baltic Sea Region	1.17
28	FABULOS	South	Helsinki	Horizon 2020	2.07
29	Kirjaston kuljetuspalvelujen joukkoistaminen (CoreOrient)	North	Jyväskylä	Sitra	NA
30	VASTE - Service Platform for Low-	North	Kokkola	ERDF	0.60

	carbon Logistics				
31	Local Food - Developing rural logistic's resources, business and behaviour (LIKIRUOKA)	North	Central Ostrobothnia, Lapland	ERDF	0.21
32	Smart Countryside mobility	South	Uusimaa	ERDF	0.65
33	Kohti Kestäviä Hankintoja	North	Kemijärvi	ERDF	0.79