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Are smart mobility pilots in Finland fostering sustainability? – An assessment

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Abstract

This research assesses how smart mobility projects in Finland contribute to sustainability aims. Aims of the projects are reviewed applying a sustainability framework with ten subcategories based on literature. A truth table is generated to assess how the different aspects of sustainability are addressed. The observed differences between projects in addressing sustainability are analyzed in terms of funding sources and between projects conducted in urban and rural areas. The results based on qualitative comparative analysis (QCA) show that environmental, social, and economical dimensions are generally addressed in a balanced manner in smart mobility projects, although some of the subcategories are addressed only in a few projects.

Keywords: sustainability; smart mobility; pilot project; rural; QCA;

1. Introduction

1.1. Background

United Nations Agenda 2030 (United Nations, 2015) is declaring that all three dimensions of sustainability – economic, social, and environmental – need to be achieved in a balanced and integrated manner. A list of 17 Sustainable Development Goals (SDG's) (United Nations, 2016) has been set to achieve and foster sustainable development. These goals are further extended to indicators that can be measured and evaluated in regular intervals. The SDG Index (Jeffrey et al., 2021) is based on these indicators and varies a lot between countries, meaning that the implementation of Agenda 2030 varies correspondingly. Even though Finland ranks first in the SDG Index, issues still exist. For example, relational poverty is a significant issue with other forms of poverty such as transport poverty. In Smart Mobility, the environmental dimension of sustainability has long dominated the scientific literature (Puig et al., 2021). Especially the social aspect of sustainability is still a fuzzy concept and lags behind environmental sustainability (EMPL, 2020). An analysis of the policies and research trends in Smart Mobility conducted by Leviäkangas and

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Ahonen (Leviäkangas & Ahonen, 2021) showed that although the topics in social sustainability – such as inclusive mobility – are addressed at the European Union level, the policy discussion at the national level is still centered around environmental sustainability. The Finnish Government (2019) has set an objective of achieving carbon neutrality by 2035, which is emphasising the significance of environmental aspects of sustainability in transportation.

1.2. Research questions

The first research question of this paper considers if mobility pilots in Finland are addressing sustainability in a balanced and integrated manner as stated in United Nations Agenda 2030 (United Nations, 2015). United Nations SDG target 11.2 in the agenda is to "provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons" (United Nations, 2016). Although the Prime Minister's Office (2020) reports that target 11.2 is implemented well in Finland, issues exist in the affordability and accessibility of the transport system. Tiikkaja et al. (2018) state that if access to the public transport system is limited, then car ownership is practically a must (forced car ownership) which in some cases increases mobility costs to the extent that one can drift to transport poverty. Especially in rural areas access to public transport is poor (e.g. Rinta-Piirto & Weiste, 2019), and owning a vehicle is often required to commute to work and carry out daily business. This puts people living in rural areas in an unequal position compared to people living in urban areas. Also, differences between genders exist in mobility, especially in the usage of public transport and active modes as women are more likely to commute by foot, bus, or another more affordable option than a car (Finnish National Survey, 2016; Ramboll, 2021). Combined with the fact that there are only a few cities in Finland that can match the individual's daily mobility needs with public transport or smart mobility solutions, in sparsely populated areas a private car may be the only means of transport. This means that women are at risk of having poorer access to transportation than men.

The second research question is whether there are differences in addressing the dimensions of sustainability in projects that have funding from European Union actions and projects that are funded by national/regional funding sources. European Union funds projects mostly via European Regional Development Fund (ERDF) and European Social Fund (ESF) (Structural Funds in Finland, 2022), Interreg (Interreg Central Baltic, 2022; Interreg Baltic Sea Region, 2022), and Framework programs (European Parliament, 2017). However, ERDF and ESF are in this paper considered regional funding sources because the funds are distributed by regional councils, and ELY centers (regional subsidiaries of state functions) based on the priorities defined by the structural funds programme (Structural Funds in Finland, 2022). National funding sources have specific priorities for the funding they are distributing. For example, SITRA foundation has been promoting sustainable well-being in Finland, whereas Business Finland has been fostering digitalization, new technologies, and innovations. (Tekes, 2016; SITRA, 2016)The funding is applied on a basis of priorities of the funding sources that are at all levels centered on exploiting low-carbon technologies to reduce CO2 emissions, exploiting digitalization, and supporting the SMEs to support the local and national economy. Social aspects of sustainability are visible mainly in themes related to employment opportunities and labor markets. However, there are horizontal goals to promote solutions to societal issues that can be seen in the objectives of the projects researched, mostly in the projects considering equity.

The third research question is whether there are differences in addressing the dimensions of sustainability in projects that are located in urban and rural areas.

2. A framework for analyzing the cases

To be able to evaluate the assessment of sustainability in smart mobility pilots, an evaluation framework was needed. Firstly, a review of different sustainability indicator frameworks in transport was made to find out how could sustainability be evaluated in projects including United Nations SDGs. Secondly, based on the reviewed material, the indicators (40 total) were divided into 10 subcategories as illustrated in Fig. 1. The case project material was reviewed and the aims of the projects were extracted and preliminarily evaluated to test the framework. This evaluation does not take a stand on what are the impacts of the projects on the sustainability of the transport system, but on what are these projects trying to research.

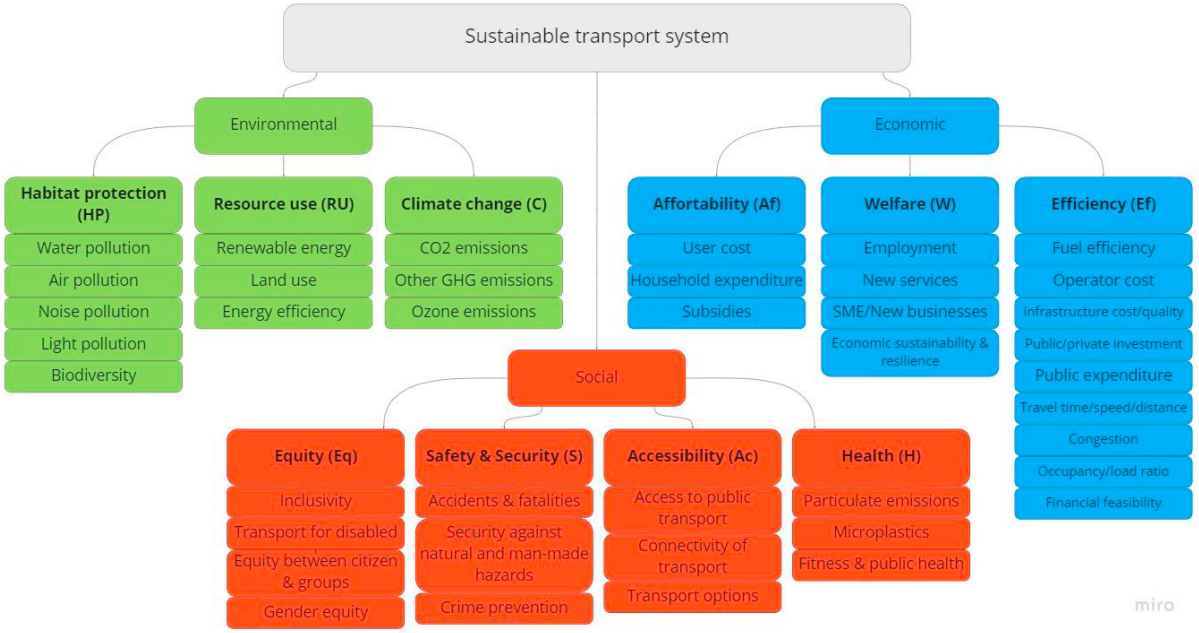

Fig. 1. A framework for analysing the pilot cases.

The derived subcategories for environmental dimensions were climate change (*C*), resource use (*RU*), and habitat protection (*HP*). For the social dimension the subcategories comprised equity (*Eq*), safety & security (*S*), health (*H*), and accessibility (*Ac*), and for the economical dimension efficiency (*Ef*), welfare (*W*), and affordability (Af). These categories were defined based on several sources: Santos & Ribeiro (2013), Haghenas & Vaziri (2012), Karjalainen & Juhola (2021), Bueno et al. (2015), Dobranskyte-Niskota et al. (2009), Toth-Szabo (2012), Nicolas et al. (2003), Litman (2021), and Bachok et al. (2015). The applied framework is a synthesis of these works.

The following interpretations were applied to these ten subcategories:

- (*C*) Addressing climate change means that the project is aiming to decrease emissions accelerating climate change and/or reduce other long-term adverse effects such as ozone depletion.
- (*RU*) Resource use means aiming to decrease the use of natural resources, especially non-renewable resources. In addition, changing the land use to more environmentally sustainable for example by replacing road infrastructure with plant life.
- (*HP*) Habitat protection subcategory means aiming to reduce transport effects on habitat, biodiversity, or nature that are not related to climate change such as pollution to air and water as well as light and noise pollution.
- (*E*) Equity means that project aims to develop equity and inclusivity between societies and groups such as genders, people with vulnerabilities, and people living in rural areas.
- (*S*) Safety & Security subcategory means increasing traffic safety and the comprehensive security of the transport system. This can also mean increasing people's security against crime and natural and man-made hazards.
- (*Ac*) Accessibility means increasing the accessibility of different mobility options and accessibility to public and private services by developing new transport options and connectivity in transport system.
- (*H*) Health means decreasing health risks caused by the transport system such as particulate emissions and microplastics. It also considers healthier mobility choices by increasing fitness and public health.
- (*Ef*) Efficiency means that project aims to increase the efficiency of the transport system by reducing costs with new solutions, investing in new technology and transport systems, reducing congestion, reducing travel time, and increasing the occupancy of transport services.

- (*W*) Welfare means that project aims to increase community welfare by increasing employment and available transport services, supporting local SME's and entrepreneurs, and fostering communities' liveability.
- (*Af*) The affordability subcategory aims to create transport services that are affordable for users.

3. Data and methods

3.1 Research data

The research material consisted of publicly available documents of the pilot projects concerning smart mobility from 2016 to this day. The project data collection was initiated using the regional councils' websites and open data where most of the projects were found. The research material was then supplemented by searching data from the websites of other parties involved in the identified projects. From this material, only the goals and aims of the projects were evaluated, i.e. neither the reported results nor observed or claimed impacts. Many of the projects were either ongoing at the time of data collection or had not provided any final report with results. In some projects, only web pages and news were publicly available for collecting information, and in these cases, if deemed to be of adequate quality and reliability, they were used to evaluate the goals and aims of the projects. Finally, some finished projects had only the final report available in which case the introduction of the final report was used to evaluate the goals and aims.

From over 60 identified projects/pilots, 33 were accepted to be used as research data. The projects were funded by European Union (Framework projects and Interregs), nationally (typically Business Finland, ministries, etc.), and regionally (Structural Funds). Some of the projects consisted of multiple pilot sites scattered around Finland. Most of the pilots were related to passenger transport, but there were also a few related to logistics.

3.2 Data analysis

The research material was reviewed with a framework (defined in chapter 2) by two separate sets of evaluators. Every pilot was reviewed separately, and every subcategory of the sustainability was given a value 0 or 1, depending on that was the subcategory addressed in the pilot's objectives or not. As a result, two truth tables were produced which were then cross-checked to find differences in opinion between the evaluators. The found conflicts were reviewed again to produce one truth table that all evaluators agreed on.

After the evaluation, pilots getting funding from European Union's Interreg or Horizon programs were compared to pilots that get funding nationally and regionally. In addition, the relationship between pilots in urban and rural areas was studied to find out if there is a difference in addressing the sustainability between projects conducted in rural areas and urban areas. As a clarification, the dataset was divided on a basis of rurality and funding source, to get two subsets of data that are then compared.

Firstly, frequencies of subcategories present in the different subsets were calculated and then compared to study the possible differences in addressing the subcategories. This was done by summing up the number of pilots addressing the subcategory in the subset and then dividing it by the number of pilots in the subset. As a result, a value between 0 and 1 is obtained that represents how frequently a subcategory has been addressed in the subset. Secondly, qualitative comparative analysis (QCA) was used to examine, analyze and interpret the pilot's data. QCA was initially introduced in 1987 and later was modified in a different version by Charles Ragin to address the social research questions (Ragin, 1987). Researchers have been using QCA both as an analytical technique as well as a research approach to answer the questions and interest in QCA have been increased among the scientific community in which QCA is widely being used to answer social issues and behaviors (Roig-Tierno et al., 2017; Rihoux, 2009; Olya, 2018; Legewie, 2013). The capability of QCA to identify consistent and sufficient models for predicting behavioral outcomes in a smaller population makes it more interesting for researchers (Ragin, 1987; Rihoux, B., 2008). The main purpose of QCA analysis is to support the researcher in a meaningful interpretation of the sequence of conditions displayed by the cases. One of the main assumptions of QCA is that social phenomena involve "complex causality" (Mahoney & Goertz, 2006; Wagemann, 2010; Schneider, 2012). Consistency and coverage are two main criteria for refining and selecting causal models that explain the possible outcome of cases. (Rihoux, B., 2008; Ragin, C. C. 2008).

In this study, the proposed framework model (Figure 1) was tested with the fsQCA tool, and the results were then interpreted according to the principle of complexity theory (Rihoux, B., 2008; Ragin, C. C. 2008). There was a total of 33 accepted pilots, 10 causal conditions, and four subsets. These subsets are differed by the outcomes that include the EU funding, National funding, and urban & rural application of pilots. Configuration modeling was performed using fsQCA software (Rihoux, B., 2008; & Ragin, C. C. 2008), which involves three steps. First, the data needs to be calibrated (if required) into crisp values from the fuzzy values. However, the data was already in crisp values (either 0 or 1), so calibrating was not required. Secondly, a truth table algorithm was generated that presented a list of causal conditions describing the possibility of outcome conditions for different combinations of conditions. Lastly, consistent and sufficient causal conditions from the truth table were selected for analysis (Rihoux, B., 2008; Ragin, C. C. 2008; Olya, 2018). The fsQCA approach is based on Boolean algebra, which uses consistency and coverage as two criteria for selecting sufficient and consistent causal models (recipes) leading to the outcome condition (e.g., EU funding). FsQCA uses the Quine-McCluskey minimization algorithm for prime implicants to simplify the outcome solutions or recipes (Ragin, 2008).

4. Results

Fig. 2. (a) and (b) illustrate the differences in frequencies of subcategories addressed in the subset based on the funding source (a) and the rurality of the project (b). In addition, frequencies of the whole set can be concluded from the figures as the whole set is represented in the figures, just divided into two subsets. The closer to the diagonal the frequencies position in the figure, the less difference there is between the subsets. As can be seen in Fig. 2. (a) and (b) illustrations, both subsets are quite similar.

However, some observations can be made. The equity (*Eq*) subcategory seems to be addressed more in projects conducted in rural areas (observe Fig. 2b *Eq* being the most distant from diagonal) and accessibility (*Ac*) is addressed more in urban projects and projects funded by the EU (Fig. 2a, *Ac* having most distance from the diagonal). The resource use (*RU*) and climate change (*C*) subcategories seem to divide the subsets also. In urban areas, climate change is addressed more than in rural areas whereas resource use was addressed more in rural areas than in urban areas. Resource use is also more frequently addressed in national projects than in EU projects. In addition, accessibility is more frequently addressed in EU projects than in national projects which is similar in the urban and rural projects. Generally, the subsets have a similar pattern which is partly because none of the rural projects are Interreg or framework projects, but they are all ERDF projects or other national projects.

Table 1. Causal models for predicting outcomes (NF, EU, Urban, Rural)

NF = f (C, RU, HP, Eq, S, Ac, H, Ef, Af, W)	EU = f (C, RU, HP, Eq, S, Ac, H, Ef, Af, W)	Urban = f (C, RU, HP, Eq, S, Ac, H, Ef, Af, W)	Rural = f (C, RU, HP, Eq, S, Ac, H, Ef, Af, W)
~C*Eq*Ac*W	C*Eq*Ac*Ef*Af*~W	~C*Ac*Ef*~W	Eq*~Ac*Ef
C*~Ac*Ef*W	C*Eq*Ac*~H*Ef*Af	C*HP*S*Ef	~C*Eq*Ac*W
~HP*S*Ef*W	C*RU*~Eq*Ac*Ef*W	~RU*~Eq*~S*~Ac*W	~C*Ac*Ef*W
~C*Ac*Ef*W	C*Eq*Ac*H*Ef*~Af*W	C*~Eq*Ac*Ef*W	~HP*S*~H*Ef*W
~HP*Eq*~H*Ef*~Af	C*RU*HP*S*Ac*Ef*W	C*~RU*Ac*Ef*W	C*RU*~Ac*Ef*W
C*Ac*Ef*~Af*~W	C*Eq*~S*Ac*Ef*Af	C*~RU*Eq*Ac*Ef*Af	RU*~HP*Eq*Ef*W
C*HP*S*~Ac*Ef	-	-	RU*~HP*Eq*S*Ac*W
~HP*Eq*Ac*~H*~Af*W	-	-	-
RU*~HP*Eq*S*Ac*W	-	-	-
coverage: 0.91, consistency: 1	coverage: 0. 78, consistency: 1	coverage: 0.79, consistency: 1	coverage: 0.93, consistency: 0.81

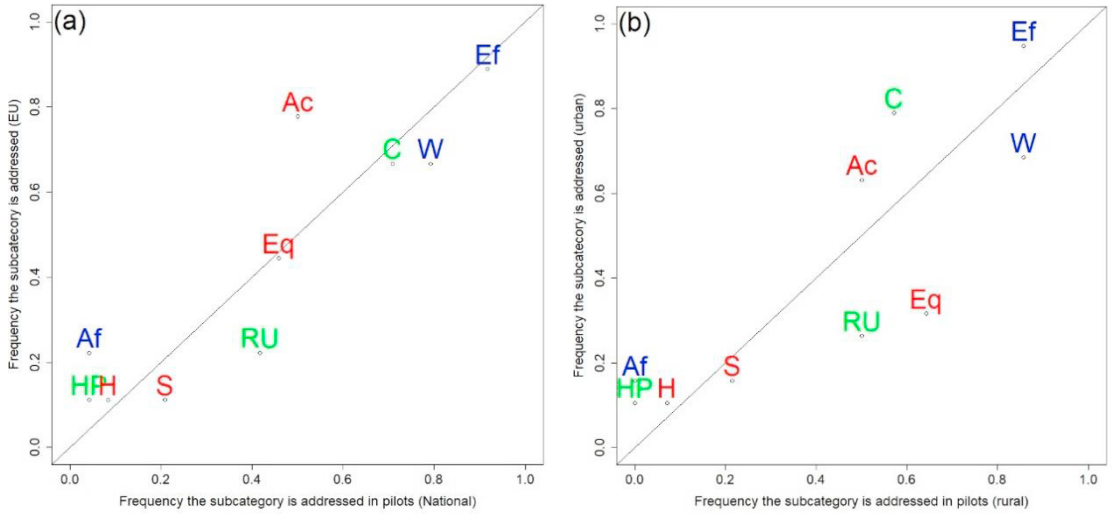

Fig. 2. (a) Frequencies subcategories are addressed in the projects based on the funding source; (b) Frequencies subcategories are addressed in the projects based on the rurality of the project.

Table 1. consists of the results of fsQCA with four different subsets. Each column represents a single case with a national (*NF*), EU funding (*EU*), urban and rural respectively from left to right. Each model consists of ten conditions as represented in Fig 1. Each model consists of multiple recipes for predicting a given outcome. In contrast to the symmetrical method which can be represented by a single recipe (outcome model), fsQCA produces multiple recipes to simulate outcome conditions.

The first model with national funding as an outcome condition consists of nine recipes with an overall consistency of 1 and coverage of 0.91. It is observed that *Ac*, *Ef* & *W* are highly dominant among other conditions while the presence of *C*, *Eq* & *S* is considerably contributing to getting the national funding. However, *RU*, *HP*, *H* & *Af* are least considered among the pilots who are receiving national funding. Secondly, the model with EU funding as an outcome comprises six recipes with an overall consistency of 1 and coverage of 0.78. In this model it is noticed that *C*, *Ac* & *Ef* are relatively important factors while *Eq*, *Af* & *W* are having considerable contributions and *RU*, *HP*, *S* & *H* are having minimum contributions for pilots in getting the EU funding. The third outcome model (urban) contains six recipes with an overall consistency of 1 and coverage of 0.79. It is noted that the factors *C*, *Ac*, *Ef*, & *W* are considered highly important while *RU*, *HP*, *Eq*, *S*, *H* & *Af* are relatively less considered for pilots in an urban environment. Finally, the last model with the rural outcome condition (rural) includes seven recipes with having overall coverage of 0.93 and consistency of 0.81. It is noticed from the recipes that *Eq*, *Ac*, *Ef* & *W* are highly contributing factors, while *C*, *RU* & *S* are less often contributing factors in rural-based sustainability pilots.

5. Conclusion

Efficiency (*Ef*) is highly addressed in the pilot projects and although it is a broad subcategory, it implies that in the analyzed projects one of the key aims is usually related to reducing costs and developing more efficient solutions that are financially viable. Welfare (*W*) is also frequently addressed in the Finnish pilot projects which are probably due to the EU and national level strategies supporting SMEs and local and national economies and promoting new technologies to develop new solutions and services. Surprisingly, climate change (*C*) is not the most frequently addressed subcategory, and other environmental dimensions, habitat protection (*HP*) and resource use (*RU*) have also very few projects addressing them. This does not mean that the projects are not considering environmental aspects of sustainability but more likely are concentrating on social or economic dimensions and keeping the environmental aspect as a self-evident basis of the project. Nevertheless, there may be an implicit message that while on the policy

level climate is getting most of the attention, the operational research and innovation projects still carry the 'imperative of economics'.

Accessibility (*Ac*) is the most frequent social aspect of sustainability and equity (*Eq*) has considered also quite frequently. During the review of the pilot material, it was noted that only a few projects were addressing the urban-rural divide in transport. In these projects, this was seen as an issue of equality between people living in urban and rural areas. Safety & Security (*S*) is addressed only by a few pilots, similar to observations by Leviäkangas and Ahonen (Leviäkangas & Ahonen, 2021). Safety seems no anymore to be an issue discussed, but the focus has changed first to technology orientation and then to sustainability orientation. Individual health (*H*) is not addressed too well either even though many of the projects are developing solutions that have positive health impacts such as cleaner transport and micro-mobility by walking and bicycling. Affordability (*Af*) is likewise addressed in few projects only.

The results of the QCA show that in EU and nationally funded pilots both *Ef* and *Ac* are highly addressed while *C* is more frequently addressed in EU funded pilots compared to national funding. Also, *W* & *S* is more often addressed in nationally funded pilots and lastly, *Eq* is addressed almost equally in both EU and nationally funded pilots. In the subset of urban versus rural pilots, *W* and *Ef* are highly considered in both, however, *C* and *Ac* are slightly more addressed in urban-based pilots and *RU* and *Eq* are factors that are slightly more frequently addressed in rural-based pilots. However, these differences are not decisive. Overall, *C* and *RU* are the major factors considered in environmental sustainability while *Eq* and *Ac* in social sustainability and *Ef* and *W* are the dominant factors in economic sustainability being addressed in all pilots.

In sum, the initial research questions may be answered as follows:

1. *Are mobility pilots in Finland addressing sustainability in a balanced and integrated manner?* The conclusion is that NO, not entirely. There are subcategories of sustainability indicators that are not too well represented in innovation, pilot and demonstration projects. These include affordability, health, habitat protection and safety and security that are not that well addressed. There seems to be an aligning in pilot projects that fairly coherently follow the 'usual suspects' on the politicial agendas, namely efficiency and climate change.
2. *Are there differences in addressing the dimensions of sustainability in projects that have funding from European Union actions and projects that are funded by national/regional funding sources?* The conclusion is that NO - at least no significant differences can not be found. There are only marginal differences between nationally funded and EU funded pilots. The question remains, then, that if all funding sources address the same issues, is there a risk of some kind of bias, or imbalance?
3. *Are there differences in addressing the dimensions of sustainability in projects that are located in urban and rural areas?* The conclusion is that NO, not to a notable extent. Hence the same critical question as presented above can be asked: are the problems of rural and urban contexts really that similar?

Author contribution and acknowledgments

Mr. Ahonen authored most of the paper. Mr. Hussain authored the section concerning QCA analysis and contributed to the development of the framework. Other authors wrote minor parts of the paper and contributed to finalizing the paper. Mrs. Merisalo and Mr. Pekkala reviewed the pilot projects in Finland and collected the relevant project data for this study. The data were supplemented by Mr. Ahonen with a review of publicly available documents regarding the objectives of the projects. The data was analyzed by Mr. Ahonen, Mrs. Merisalo, and Prof. Leviäkangas. This research has been supported by the European Union H2020 program. AURORAL project. Grant agreement ID: 101016854. (Auroral, 2022)

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