IADIS International Journal on Computer Science and Information Systems
Vol. 15, No. 2, pp. 107-122
ISSN: 1646-3692

KEY PERFORMANCE INDICATORS IN DESIGN FOR SUSTAINABLE RURAL TRANSPORT

Amela Karahasanović[1], Alma Leora Culén[2], Jan Håvard Skjetne[1] and Geir Hasle[1]
[1]*SINTEF Digital, Norway*
[2]*Department of Informatics, University of Oslo, Norway*

ABSTRACT

Rural areas are less attractive and sustainable for people and businesses alike, partially due to inadequate transport services. In this paper, we address transport-related challenges in rural Norway. The focal aspect of our approach is to define a set of values for the design and mechanisms of transitioning towards more sustainable rural transport making a real-life difference for people living in rural areas. We connect UN sustainability goals and transition design to discuss how these can be operationalized and used throughout the design process seeking to innovate rural transport. Reflecting on how to find the initial 'leverage points' to scaffold the transition to more sustainable transport systems, we explore the possibility of introducing relevant Key Performance Indicators early on in the design process. We report on our experiences and findings regarding the use Key Performance Indicators in different phases of a design-led innovation process.

KEYWORDS

Sustainable HCI, Transition Design, Leverage Points, Key Performance Indicators, Transportation Systems

1. INTRODUCTION

It has been almost two decades since the field of Human-Computer Interaction (HCI) tried to reconcile its inherent dichotomies between research and design by focusing on designing for values, that is, "HCI must be objectively systematic and reliable in the pursuit of subjective value. Traditional disciplines have delivered truth. The goal of HCI is to deliver value" (Cockton, 2004). Although the HCI community has been working toward establishing its sustainability agenda for more than a decade, during the era of fast social, environmental, and technological changes, views forwarding incremental reductions (e.g., in energy consumption, individual changes in behavior patterns) are no longer enough (Bendor, 2018; Fredericks et al., 2019; Light, 2019; Light et al., 2017). The community is now focusing on larger, at scale, systemic solutions toward sustainable development (Fredericks et al., 2019; Knowles et al., 2018; Silberman and Interpreter, 2013). We position the work presented in this paper within this discussion, in which we focus on the mitigation of challenges that rural communities experience with the transport sector.

Good transport systems can contribute to the sustainable development of rural areas and provide people with novel opportunities, such as the freedom to settle where they want and increase wellbeing ("Ta heile Noreg i bruk - Meld. St. 13," 2013). The rapid development of Intelligent Transport Systems, sharing economies and Mobility-as-a-Service (MaaS) concepts (Alliance, 2017), presents a novel set of potentially better solutions within the sector. In particular, the development of MaaS concepts for rural areas is acutely needed ("Developing rural services," 2017). These concepts are considered enablers of combining transport services from different providers through a unique service platform in which transport needs can be custom tailored. At present, MaaS proposals do not cover a spectrum of needs; for example, transport-induced CO_2 emissions are not covered (Alliance, 2017). According to the World Bank, CO_2 emissions are one of the major contributors to climate change, with transport being responsible for more than 20% of the global CO_2 emissions (www.data.worldbank.org/indicator). Furthermore, some services had to be stopped because of high costs despite their high popularity (Skollerud, 2014). The coronavirus pandemic in 2020 unexpectedly allowed the world to directly witness the impact of traffic and industry emissions on air quality (Watts and Kommenda, 2020).

The challenge is to offer an efficient transport system that provides good transport services to everyone and, at the same time, keeps financial and environmental costs low. This is especially difficult to achieve in sparsely populated rural areas, where the distances are considerable and transport resources are limited. Transport systems, being critical centralized infrastructures (Tomlinson et al., 2015), need to move toward decentralization (ibid.), but such transformations cannot be done hastily. They involve multiple stakeholders, sometimes with conflicting interests, require an interdisciplinary approach, and need to continually adapt to changes in regulations, mobility patterns, and technology. Thus, finding an adequate approach to tackle this challenge is crucial and requires a more systemic approach.

Recently, transition design (TD) has been proposed as an approach to lead transitions toward more sustainable futures and is suitable for addressing wicked problems, such as climate change, over-consumption, pollution, and poverty (Escobar, 2018; Irwin, 2018; Tonkinwise, 2015). It is based on a sustainable, multi-perspective (cross-disciplinary), value-based, long-term, forward-looking design and contributes to a better understanding of societal transitions (Zolfagharian et al., 2019). As such, TD aligns well with our problem of looking into appropriate solutions for rural transport systems. We build on the premises of TD and, in particular, on leverage points that may help initiate and carry out sustainability transitions (Abson et al., 2017).

In this paper, which is an extension of the work presented in (Karahasanovic et al., 2020), we introduce and discuss sustainable transport Key Performance Indicators (KPIs) as a tool focusing on leverage points, such as CO_2 emissions, to address sustainability in TD processes. Concerned with real-life solutions and visible improvements in rural transport services, we focused on how KPIs could align with both sustainability goals and the TD framework. The motivation to explore KPIs is based on our need to identify and consider performance measures already in the design process and use them as building blocks in a larger innovation project aiming to develop a MaaS solution especially tailored for rural areas in Norway.

In what follows, we first discuss existing frameworks that point toward sustainable futures. We then describe the Sustainable Transport KPIs and report our first practical experiences with a prototype for finding alternative transport routes that help reduce CO_2 emissions.

2. TOWARD SUSTAINABLE FUTURES

To establish an understanding of the broader context of this research and to bridge the high-level visions and goals related to sustainability and the development of specific solutions, we first describe national and international efforts to define sustainable futures in general and sustainable transport in particular. We then discuss design that enables sustainable futures.

2.1 Sustainable Goals and Models

Long-term visions for desirable global futures, co-created by the United Nations (UN), were articulated through the UN Sustainable Development Goals (SDGs) ("Sustainable Development Knowledge Platform," 2015). For this work, SDG 9 (*Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation*) is of particular relevance, as it addresses the importance of efficient transport systems and services as the key drivers of economic development. The document (ibid.) defines specific targets related to each goal (e.g., develop quality, reliable, sustainable, and resilient infrastructures, with a focus on affordable and equitable access for all, promote inclusive and sustainable industrialization, increase the access of small-scale industrial and other enterprises), as well as specific indicators that might help reach these targets (e.g., finding out what proportion of the rural population lives within 2 km of an all-season road, number of passengers and freight volumes by mode of transport). The SDGs are not mutually independent. Working with transport systems also relates to other goals, such as SDG 13 (*The Climate Action*), SDG 11 (*Sustainable Cities and Communities*), and SDG 12 (*Responsible Consumption*).

The Doughnut, Kate Raworth's iconic model of an economy that respects both social needs and the ecological boundaries of the planet, is another way of framing sustainable development (Raworth, 2017, 2012). The doughnut represents a developmental space that is safe and just for all, respecting a social well-being boundary that no one should fall below, and an ecological ceiling of planetary pressure that we should not go beyond.

Building on these and on UN and Norwegian policy documents, such as the UN's policy document on sustainable transport ("Mobilizing Sustainable Transport for Development," 2016) and the Norwegian Transport Plan 2018–2029 (Samferdselsdepartementet, 2017), a list of specific transport-related goals is suggested (Samferdselsdepartementet, 2017). These goals highlight the need for reliable available transport that is accessible to all, reduces travel time, and has an adequate capacity for passengers and goods, and aim to double the global rate of improvement in energy efficiency ("Mobilizing Sustainable Transport for Development," 2016).

2.2 Sustainable Transport

Sustainable transport must meet mobility needs and, simultaneously, preserve and improve health, the environment, the economy and social justice (Deakin, 2001). Research on sustainable transport embrace research on electrical and fuel cell vehicles, intermodal transport systems and mobility-sharing services (i.e., car sharing and bike sharing (Geels et al., 2018). It also examines passengers' information needs (Papangelis et al., 2016) and user roles and involvement in the transition to sustainable mobility systems (Sopjani et al., 2019).

Several sustainable transportation indicators have been proposed to aid transport planners and decision makers (Gudmundsson, 2004) by measuring a transport system's performance and economic, social, and environmental impacts. Some indicators relate directly to transport, such as CO_2 emissions per passenger mile, while others measure more general social factors, such as the number of hospital beds. A comprehensive list of indicators of transport sustainability by Rassafi and Vaziri (2005) includes four categories: social, environmental, economic, and transport (air, road, rail, and sea). The transport indicators describe the properties of the transport system, such as number of passengers, number of passenger cars in use, and length of the road network. Social, environmental, and economic indicators include those that may be influenced by the transport system, such as commercial energy use, arable land, and interest rates, that are not directly influenced by transport systems (Rassafi and Vaziri, 2005). The indicators for passenger transport sustainability proposed by Shiau and Peng add novel environmental indicators, such as traffic noise and energy density as well as more detailed passenger-related economic measures, such as average travel time and cost (Shiau and Peng, 2012).

A comprehensive list of indicators of sustainable transport has been proposed by the European project Sustainable Mobility, Policy Measures and Assessment (Hardy, 2011). It includes economic outcome indicators (such as the gross added value and benefit of transport), environmental outcome indicators (such as exposure to transport noise and generation of non-recyclable waste), and social outcome indicators (such as car independence and pedestrian friendliness) (Hardy, 2011).

Indicators for sustainable rural transport include transit policy indicators (such as intermodal travel with transfer fares and the percentage of transit vehicles equipped with bike racks) (Patrick and Roseland, 2005), environmental indicators (such as direct intrusion ecology), economic indicators (such as accessibility), and social indicators (such as security and safety) (Fathoni et al., 2017).

The above-described sustainable transport indicators differ in their scope, level of detail, and specificity. Some have argued that there is no uniform approach to sustainable transport indicators and that they can serve diverse users with various priorities (Gudmundsson, 2004). Particularly, designs for rural areas must address hyper-local needs (Hardy, 2019), and the list of indicators must be adapted to the specific needs of a rural area.

2.3 Design for Sustainable Futures

The TD community strives to link the more abstract principles of sustainable development to concrete, designed outcomes. This approach foregrounds the following main areas of research and design activity (Irwin, 2018) that support transitions to sustainability: (1) finding and using the appropriate theories of change that support socio-technological transformation; (2) understanding and developing visions for transition; (3) working with the mindset and posture, including values, that are appropriate for transition (e.g., precautionary, explorative, reflexive, critical, participatory, local, and situated); and (4) discovering and using new ways to design that lead to impactful, large-scale solutions that contribute to a more sustainable future (Knowles et al., 2018). In contrast to traditional HCI design approaches (including the more systemic ones, such as service design, experience design, and sustainable design), which tend to frame problems within relatively limited spatiotemporal contexts and identify a limited number of stakeholders and potential conflicts of interests, TD calls for a more holistic approach that considers the development of ecological and environmental literacy, takes a long-term perspective, and rethinks potential solutions beyond financial and commercial interests. Within this approach, design depends on a deep understanding of the dynamic of change within complex social and natural systems (Irwin, 2015). Furthermore, a new design or solution is considered to be a single step in a transition toward a long-term goal (ibid.), thus explicitly promoting continuity in design to meet changing needs in complex situations. TD suggests the following phases (Irwin, 2018).

- Re-framing the present and future. In this phase, the stakeholder groups collaborate to visually map the problem space in as much detail as possible and from multiple points of view, to map stakeholder concerns and relationships that are often contradictory, and to cocreate compelling visions of a future that will resolve problems, address fears and concerns, and fulfill hopes and desires.
- Designing interventions. This phase aspires to explore diverse intervention points through multiple interventions at multiple scales and over multiple time horizons (van Selm and Mulder, 2019).
- Monitoring and observing. In this phase, observations and reflections are conducted over time to understand how a system responds to the changes introduced by interventions.

The role of design in TD has been further elaborated by Boehnert, Lockton, and Mulder as follows: "designing for transitions involves designing how transitions are conceived, enacted, governed and managed" (Boehnert et al., 2018). However, Van Selm and Mulder note the lack of case studies with real users to test the TD framework, associated processes, and tools (van Selm and Mulder, 2019). Furthermore, a lack of actionable components has been identified (Ceschin and Gaziulusoy, 2016) as well as a lack of methods for the *waiting and observing* phase before the next intervention can take place (van Selm and Mulder, 2019).

Recently, a Norwegian guide for the development of sustainable, productive, and resilient cities and local communities has been introduced to support local and regional authorities, community groups, researchers, entrepreneurs, and other stakeholders (DOGA, 2019). It describes the basic principles of sustainable development, prioritizing the climate and environment and promoting inclusion and co-creation in design processes. The guide suggests the following phases to move from these principles to smart, sustainable cities and communities: understanding, creating, experimenting, learning, and building. At present, the guide offers only key questions related to each of these phases; measures, tools, and best practices are to be added as the guide evolves.

TD calls for the integration of available design methods from diverse fields to meet the complexity of the tasks at hand. This often involves tools for working with sustainable business models. One such tool is the business model canvas, which has been proposed for quickly sketching business models of services and products (Osterwalder and Pigneur, 2010) and is among the tools used at the implementation stage of service design (Stickdorn and Schneider, 2012). The building blocks of this model are directly connected to key service design tools, such as customer journey maps, personas, prototypes, and service blueprints (Stickdorn et al., 2018). A modification has been proposed for the business model canvas for nonprofit organizations (Graves, 2011). Both the original and modified models include a value proposition as a description of a value (monetary or non-monetary, quantitative or qualitative) that is delivered to customers and key partners.

In summary, many design and research activities aim to lay out alternative paths toward a sustainable future. At the moment, however, few approaches can demonstrate good results in practice.

Our aim is to understand and fill that gap when working to make rural transport more sustainable. We chose the actionable components (KPIs) in collaboration with real users, which may enable designed outcomes with good performance measures in real life.

3. KPIs FOR SUSTAINABLE TRANSPORT DESIGN

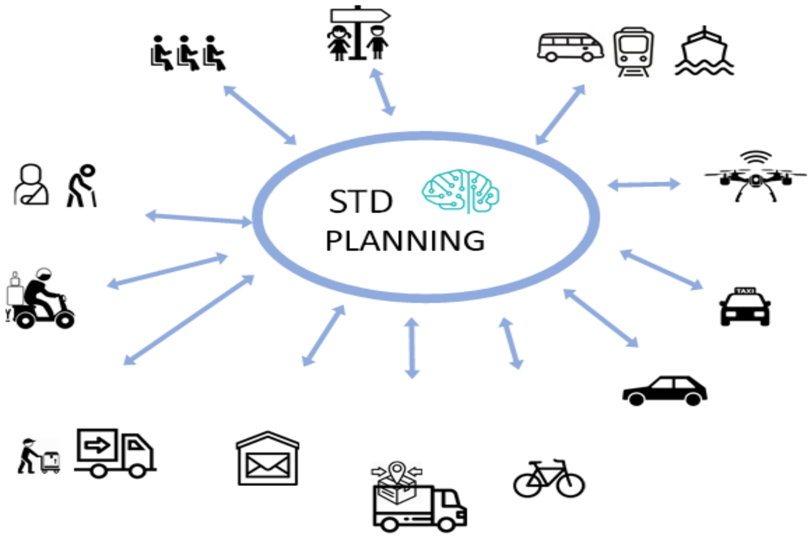

Figure 1. The overall project idea. The Smart Transport in Districts (STD) tool plans and dynamically coordinates the transport of people and goods

The project herein described aims to develop tools and services for MaaS that are specifically tailored to sparsely populated rural areas. The main idea is to create a holistic system for transport planning that dynamically coordinates the transport of people and goods to make the most of transport resources. New services and tools for planning will include carpooling, car sharing, transport on demand, and using mini-buses and taxis to optimize transport. The project was driven by the overall goal to "develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all," which reflects UN Sustainable Target 9.1 ("Transforming our world: the 2030 Agenda for

Sustainable Development," 2015). However, the indicator associated with this target—passenger and freight volumes—is not sufficiently comprehensive. For example, the abovementioned Norwegian set of national goals (Samferdselsdepartementet, 2017) include shorter travel times and sustainable transport systems for all in addition to an adequate capacity for passengers and goods. Although more specific, the Norwegian set of national goals also does not capture the full complexity of transport in rural areas.

KPIs are commonly used to measure the performance of an organization or an activity (Fitz-Gibbon, 1990). They may be quantitative, such as the number of new customers in marketing, or qualitative, such as employee satisfaction in human resource management. The sustainable transport indicators from transport research (described in Section 2.2) offer a broad spectrum of indicators for planning and monitoring large transport systems. Expanding on this idea, we used KPIs to operationalize our design for transitions. We developed sustainable transport KPIs as an instrument to be used throughout the whole lifecycle of the project to scaffold continued focus on sustainability. Within the TD framework, these KPIs offer leverage points that help promote changes through design until a desired outcome is achieved.

4. THE CASE: TD FOR SUSTAINABLE RURAL TRANSPORT

In this section, we describe our research context, followed by the data collection and analysis used in the first phase of the TD process, for reshaping the present and future.

4.1 Research Context

This work was done in the context of a research and innovation project aiming to improve public transport services in rural areas. The project's consortium includes a county's transport section, a county's hospital, its municipality administration; a company providing digital services to public transport in Norway; and a research institute. The project aims to create a holistic system for transport planning that dynamically coordinates the transport of people and goods to make the most of transport resources.

The county where the project is situated, Innlandet County in Norway covers a large but very sparsely populated area with population density of 7.1 inhabitants per km2. Two-thirds of the county 's inhabitants live outside the four largest cities. Both the geography and climate are challenging, featuring high mountains, very cold winters, and warm summers. In addition to the county's inhabitants who need transport to work, school, hospital, and various activities, an increasing number of tourists visit the county and its national parks.

4.2 Data Collection and Analysis

As already stated, transition design supports multiple design perspectives, focusing on careful, systemic mapping of the design context and on holistic, long-term, dynamic solutions. In the design processes of particular interventions and in the prototypes used in them, it allows for the integration of diverse approaches. The development of our design outcomes, including the KPIs and design interventions, followed a traditional Scandinavian end-user design and evaluation approach (Svanæs and Gulliksen, 2008). This project's end-user groups included mobility service users, county employees working with transport planning, general practitioners and hospital staff ordering transport for patients, and municipal decision-makers.

Table 1. The role of KPIs in distinct TD phases and activities

TD phase	Activity	KPIs' role
Re-framing the present and future	Project idea development—a workshop with two domain experts and meetings between project partners	Development of the initial list of KPIs and project impact estimates
	Project start—two workshops with eight experts in total	Development of the KPI list and the radar diagram to be used in the project
	Mapping the problem, stake-holders' concerns, relations between them, visions for the future—a workshop with six domain experts	KPIs used to initiate and structure discussions
Designing interventions	Understanding the problems and concerns at various system levels—interviews with 13 participants	KPIs used to elicit insights from diverse stakeholders
	Prototyping solutions—four distinct prototypes were made and evaluated at three workshops with 15 domain experts in total	KPIs used as a design element and discussions about monitoring the system

The KPIs and design interventions presented here were developed in several iterations. Table 1 gives an overview of KPI development and uses through the first two TD phases. We include the project idea's development in the first phase as we believe that the early use of KPIs is beneficial in developing the idea and choosing the 'right' project to work on. The third phase—monitoring and observing—is not included as our project is still in its first half (month 16 of 36). During the design of interventions, however (particularly in the last two workshops), the discussion of KPIs partly considered their use to monitor the system's performance. One should note that the TD phases are not strictly divided or linear.

The workshops lasted two hours. The first workshops and meetings were organized as physical meetings in which discussions used whiteboards and included various ideation techniques, such as brainwriting and brainwalking. Due to the outbreak of COVID-19, the last three workshops were organized online as Teams meetings. The workshops were moderated by one of the researchers. The collected material (notes, Post-its, pictures, and drawings) was analyzed using content analysis. All but three interviews were conducted in face-to-face meetings. The interviews were conducted in Norwegian, transcribed by an independent consultant, and then coded and analyzed by two researchers using open coding schema.

5. SUSTAINABLE TRANSPORT KPIs IN TRANSITION DESIGN

The idea for the project evolved through a dialog between the problem owner (the county municipality's transport section) and the researchers in several meetings and workshops, resulting in a joint research proposal to design MaaS for rural transport. In this initial phase of the work, a list of KPIs was created, starting with the above-described UN and national goals and input from experts in transport planning and HCI. The list was then expanded with additional indicators using a radar chart (see Figure 2) in two workshops to assess the importance of the KPIs on a scale from 1 (not important) to 3 (very important). The participants of the first workshop were three experts in transport planning and two HCI experts, whereas the participants in the second workshop were two experts in transport planning and one HCI expert. All the participants had long experience (over 20 years) in their fields, and one was female.

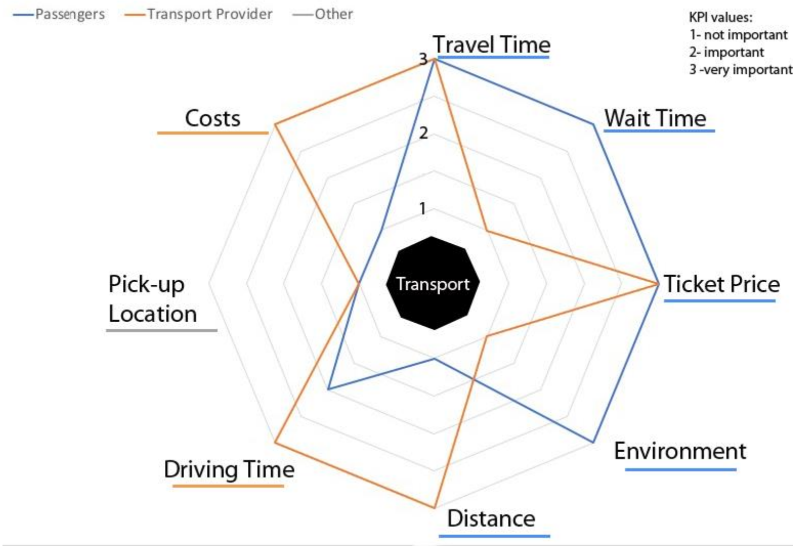

Figure 2. The radar chart was used to elicit the most relevant KPIs for passengers and transport providers

The KPIs found to be most relevant for this project were costs (for passengers, transport providers, and the municipalities), travel and waiting times for passengers, distance, use of resources, reduced use of private cars (measured in kilometers), increased income from ticket sales, impact on the environment, the last mile (distance to the pick-up point), and drivers' workload. The radar chart was designed to show a passenger's perspective (e.g., pick-up at home, travel time, waiting time, ticket price, environment) and a transport provider's perspective (e.g., drivers' workloads, operating costs), but it also had an open category (allowing both providers and passengers to add new indicators).

In what follows, we describe how sustainable transport KPIs were used in a transition design, and we give examples of the insights gained from their use.

5.1 Relating KPIs to Present Concerns and Future Visions

In the next phase, the project stakeholders engaged in a workshop to map the current problems, create a map of stakeholder concerns, and the relationship between them and the visions for transition (Irwin, 2018). The participants, six domain experts (three female and three male), were either had responsible for traffic planning or working with planning on a daily basis. The KPIs that emerged as the most significant from this work included passenger and freight volume, monetary and environmental costs, use of transport resources, travel time, and waiting time. These were further developed through workshops that discussed concerns related to public transport in the rural county participating in the project.

For example, the discussion on the use of resources revealed that there are many small entrepreneurs with vans and minibuses that constitute available resources as their use is not currently optimized. These small entrepreneurs were then included in the list of project stakeholders who should participate in user studies in later phases of the project.

Furthermore, discussions on passenger/freight volumes and costs revealed the importance of these topics for many stakeholders in rural areas. The core issue is that, in lightly populated areas, passenger/freight volumes are low in a range of transport types. One way of keeping costs at an acceptable level is to allow the combining of different transportation types in future solutions. The need to include a broad range of stakeholders in the TD process surfaced again here. Working actively to expand the list of project stakeholders with new ones who might benefit from joining the project was defined as an important project goal.

In the discussion on travel/waiting time, the issue of motivating citizens to change their transportation habits was raised. One stakeholder framed this issue as follows: “We transport people from the place where they don’t want to start their travel to the place where they don’t want to end it at a time that is not convenient to them. People simply want to go from A to B when they want, and there is already a perfect solution. It is called a private car. The question is how to compete with it. How do we motivate people to use public transport?” Exploring how to encourage people to engage in more environmentally friendly behaviors became one of the larger project goals.

The sustainable transport KPIs enabled us to be more specific when envisioning the future and helped us structure our discussion about the project’s expectations and tangible, measurable goals. One of the examples we used was a calculation of the expected benefits from considering two KPIs: environmental cost and passenger volume. We calculated the expected benefits to the environment (reduced CO2 emissions and fuel consumption) and the increased income for transport service providers. The calculations showed that, if two persons took public transportation from Folldal to Alvdal/Tynset (two small Norwegian municipalities) instead of their private cars for 250 days per year, the reduction in driving distance would be approximately 200 km per day, reducing CO2 emissions by approximately 6 kg and fuel consumption by approximately 3,000 L yearly, and the public transportation ticket fares would amount to approximately €5,000 yearly in benefits for the public transport provider.

In summary, working explicitly with KPIs at the very start of the project strengthened the research agenda and set a range of practical goals for the project. When working with sustainable transport KPIs, doing concrete exercises and providing examples illustrated the extent of potential changes.

5.2 Designing Interventions

The next phase of the process involved *"looking up and down system levels in space, and backward and forward in time*" (Irwin, 2018) and implied understanding how the problems and concerns are amplified or mitigated at different system levels and seen from different time perspectives. We started this phase by collecting users' insights and identifying how the current situation amplified the set of problems. Interviews with project stakeholders were used for the latter. The interviewees had a broad understanding of the needs and problems related to public transport in the rural area we observed. We recruited 13 participants (six females and seven males) from the public sector. Four of them were decision makers in leading municipality positions, and nine were employees working with transport daily, both at the strategic and tactical levels. We conducted 11 individual interviews and one interview with two persons at the same time. Three interviews were conducted over the phone, whereas the remaining ones were done in face-to-face meetings. During the interviews, the participants were asked to envision the public transport of their dreams and then critically reflect on it (i.e., find obstacles to using it). They were also asked to reflect on what is important for them when they use public transport or want to send goods. They were shown the radar chart and asked to explain what is important for them and why. We asked them first to answer these questions as citizens of the county (passengers) and then to answer the same questions from the perspective of their work position. After discussing the KPIs we presented, we asked them if they could think of their own indicators.

The participants first talked about their own experiences when using public transport and what would be needed to motivate them to take a bus or train instead of their own car. We found that the way in which they weighted different KPIs depended on the situation (that is, there was no single answer). For example, when asked about the importance of ticket prices and travel time, one participant said, *"I take the bus to work and for leisure activities. When I have children with me, I take the bus rarely. It has to do with costs. When you have three kids with you, then you drive yourself. It is cheaper. And this is, this is a challenge. It has to do with costs and not to mention time."*

The participants added several new indicators, such as the quality of the driver's service, the quality of real-time information, and the quality of waiting places, and argued for their importance when designing new services. The quality of the driver's service was explained as follows: *"I wrote a 'good driver,' and, by this, I mean more than his driving style. I mean a driver who is pleasant to meet on the bus, a driver who is professional and provides good service. It is these three [indicators] that are very important."*

Discussing environmental KPIs, the participants often considered the problem from a broader perspective. KPIs helped them understand situations that contributed to current environmental problems. Two participants explained how the environmental impact of transport is related not only to the planning of transport services but also to the planning of development. One participant said, *"It is also about how we plan municipality development, where to place the kindergarten in relation to residential areas."* Another participant said, *"We would like to be involved much earlier in the development of new residential areas and roads. When they build an area without a space for the bus to turn, it is too late."* Furthermore, discussing environment KPIs helped identify the importance of collaboration among different stakeholders. One participant explained how their planning of school bus services depended on school plans: *"It does not help to plan being in front of school A at 8:15 a.m. and in front of school B at 8:30 a.m. if school B starts at 8 a.m. We have to negotiate with them or drive one bus to school A and another to school B, which is bad for the environment."*

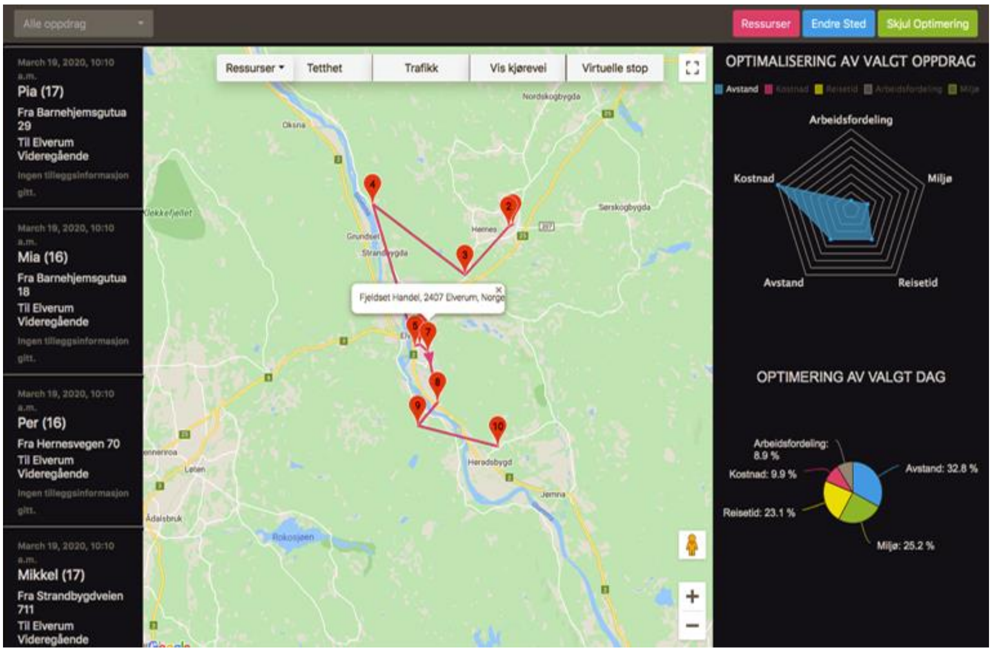

Figure 2. Front-end prototype of a transport planning tool (in Norwegian). The radar chart and the pie chart on the right have five KPIs: drivers' workload, the environment, travel time, distance to the pick-up point, and costs. Incoming orders are listed on the left side of the screen. The map for the proposed route is shown at the center

Insights gained helped us define design goals and engage in prototyping different solutions. For example, the goal to *"motivate the increased use of public transport"* led to some design ideas and suggested solutions. One of the proposed solutions explicitly used sustainable transport KPIs. Figure 2 shows the front-end prototype for a transport planning tool. The envisioned functionality aims to enable operators to work with transport planning and explore the effects of different transport solutions on KPIs. The radar chart in the upper right-hand side allows the operator to prioritize different sustainable transport KPIs for a journey. A user (a passenger, a customer ordering the transport of goods, or an employee at the transport center) can choose priorities for a particular trip using the radar chart; for example, low costs are prioritized over the distance to the pick-up point, travel time, and impact on the environment. An optimization tool that is a part of the system we are developing proposes an optimized solution (a travel route shown at the center of Figure 2) according to the chosen criteria. The pie chart in the lower right corner of the screen summarizes the journeys during a selected day according to KPIs.

The presentation of KPIs as a design element was further developed in the subsequent prototypes, and it initiated several discussions about the role and possible use of KPIs in the prototype we are developing. The first group of suggestions was related to KPIs' centrality in prototyping and the need to reflect this in design. The prototypes were intended to clearly present the selected KPIs visually as well as their priorities and changes through various phases. Furthermore, the system will learn about passengers' preferences regarding KPIs. The second group of suggestions was related to the need to design a new KPI-driven process, which should specify the interactions around KPIs between the passengers, the optimization algorithms, and the operators responsible for transport planning. As the planning system learns about the passengers' preferences and behavior over time, the transport services offered to the county's inhabitants will adapt accordingly. This must be clearly communicated to the passengers to clarify how the future process of ordering and planning transport will look and how the responsibility for selecting sustainable decisions is distributed among transport service users, the system, and the operators.

In summary, the TD approach, with its pragmatic choice of methods, tools, and techniques, can be used to create design interventions, including prototypes of more sustainable solutions, featuring KPIs as a way to evaluate choices.

6. CONCLUSIONS AND FUTURE WORK

We bring the idea of KPIs from business management into TD. Our first experience showed that sustainable transport KPIs were useful in mapping the problem, mapping stakeholder concerns, envisioning the future, obtaining user insights, identifying the current situations that contribute to the problem, and designing interventions. They enabled us to remain focused on sustainability and to sustain common themes through the projects. The insights gained from various phases of the project allowed us to work toward sustainable solutions. KPIs and the associated radar charts worked very well to initiate and structure the discussion in workshops and interviews. They worked well for both individual and group interviews and for both online and face-to-face interviews. However, it was easier to follow up on participants' opinions with additional questions during face-to-face interviews. The indicators also made the analysis of the collected data straightforward as the data collection (e.g., workshops and interviews) was already structured around KPIs and KPIs were used to generate the coding schema (e.g., content analysis of the related projects). This work adds KPIs as an instrument to operationalize design for transitions, meeting the need for actionable components and methods (Ceschin and Gaziulusoy, 2016) (van Selm and Mulder, 2019).

Although KPIs showed their usefulness, more studies are needed to elaborate when and how they can be used successfully. We applied KPIs on a project in the transport sector, and we believe that the same approach may be useful in other domains. As this is ongoing work, we have not yet applied sustainable transport KPIs to evaluate the effect of the interventions introduced by the project. Nevertheless, we believe that sustainable transport KPIs can be beneficial in measuring the short- and long-term effects of TD projects, providing leverage points that ease the transformation of the current situation to a sustainable one. Future work includes further development of this instrument to gain a better understanding of its role in real-life transitions toward sustainable rural transport.

ACKNOWLEDGEMENTS

The project 'Smart Transport in Rural Areas' is funded by the Research Council of Norway, the Transport 2025 program (grant nr. 296639). We thank the project partners Innlandstrafikk, Folldal Municipality, EnTur and Hospital Innlandet for their contribution to this work. Especially, we thank Lasse Jordbru for his insight into challenges of rural traffic and to Ophelia Prillard for prototype implementation.

REFERENCES

Abson, D.J., Fischer, J., Leventon, J., Newig, J., Schomerus, T., Vilsmaier, U., von Wehrden, H., Abernethy, P., Ives, C.D., Jager, N.W., Lang, D. J. (2017). Leverage points for sustainability transformation. Ambio 46, 30–39. https://doi.org/10.1007/s13280-016-0800-y

Alliance, M. (2017). White Paper: Guidelines & Recommendations to create the foundations for a thriving MaaS Ecosystem. Bruss. MaaS Alliance AISBL.

Bendor, R. (2018). Sustainability, hope, and designerly action in the anthropocene. interactions 25, 82–84.

Boehnert, J., Lockton, D., Mulder, I. (2018). Editorial: Designing for transitions. IN: Storni, C. et al, in: Proceedings of the Design Research Society. cc The Authors. Published by the Design Research Society, pp. 892–895.

Ceschin, F., Gaziulusoy, I. (2016). Evolution of design for sustainability: From product design to design for system innovations and transitions. Des. Stud. 47, 118–163.

Cockton, G. (2004). Value-centred HCI, in: Proceedings of the Third Nordic Conference on Human-Computer Interaction, NordiCHI '04. Association for Computing Machinery, Tampere, Finland, pp. 149–160. https://doi.org/10.1145/1028014.1028038

Deakin, E. (2001). Sustainable development and sustainable transportation: strategies for economic prosperity, environmental quality, and equity.

Developing rural services: European Mobility as a Service Roadmap 2025 (2017). Int. VERKEHRSWESEN. URL https://www.internationales-verkehrswesen.de/maas-roadmap-2025/ (accessed 5.3.20).

DOGA (2019). Roadmap for smart and sustainable cities and communities in Norway.

Escobar, A., (2018). Designs for the Pluriverse: Radical Interdependence, Autonomy, and the Making of Worlds. Duke University Press Books, Durham.

Fathoni, M., Pradono, P., Syabri, I., Shanty, Y.R. (2017). Analysis to assess potential rivers for cargo transport in Indonesia. Transp. Res. Procedia 25, 4544–4559.

Fitz-Gibbon, C.T. (1990). Performance indicators. Multilingual Matters.

Fredericks, J., Parker, C., Caldwell, G.A., Foth, M., Davis, H., Tomitsch, M. (2019). Designing Smart for Sustainable Communities: Reflecting on the Role of HCI for Addressing the Sustainable Development Goals, in: Proceedings of the 31st Australian Conference on Human-Computer-Interaction. pp. 12–15.

Geels, F.W., Schwanen, T., Sorrell, S., Jenkins, K., Sovacool, B.K. (2018). Reducing energy demand through low carbon innovation: A sociotechnical transitions perspective and thirteen research debates. Energy Res. Soc. Sci. 40, 23–35. https://doi.org/10.1016/j.erss.2017.11.003

Graves, T. (2011). Using Business Model Canvas for non-profits – Tom Graves / Tetradian. URL http://weblog.tetradian.com/2011/07/16/bmcanvas-for-nonprofits/ (accessed 9.20.20).

Gudmundsson, H. (2004). Sustainable Transport and Performance Indicators. Issues Environ. Sci. Technol. 35–63.

Hardy, D.K. (2011). Sustainability 101: a primer for ITE members. ITE J.-Inst. Transp. Eng. 81, 28–34.

Hardy, J. (2019). How the Design of Social Technology Fails Rural America, in: Companion Publication of the 2019 on Designing Interactive Systems Conference 2019 Companion, DIS '19 Companion. Association for Computing Machinery, New York, NY, USA, pp. 189–193. https://doi.org/10.1145/3301019.3323906

Irwin, T. (2018). The Emerging Transition Design Approach, in: DRS 2018. Presented at the Catalyst, pp. 968–989.

Irwin, T. (2015). Transition design: A proposal for a new area of design practice, study, and research. Des. Cult. 7, 229–246.

Karahasanovic, A., Culén, A.L., Skjetne, J.H., Hasle, G. (2020). Designing for transitions in rural transport, in: ICT, Society and Human Beings 2020; Connected Smart Cities 2020; Web Based Communities and Social Media 2020. Presented at the ICT, Society and Human Beings 2020, IADIS Press, pp. 57–64.

Knowles, B., Bates, O., Maria Håkansson (2018). This Changes Sustainable HCI, in: Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems. pp. 1–12.

Light, A. (2019). Design and Social Innovation at the Margins: Finding and Making Cultures of Plurality. Des. Cult. 11, 13–35. https://doi.org/10.1080/17547075.2019.1567985

Light, A., Powell, A., Shklovski, I. (2017). Design for existential crisis in the anthropocene age, in: Proceedings of the 8th International Conference on Communities and Technologies. pp. 270–279.

Mobilizing Sustainable Transport for Development [WWW Document] (2016). UN DESA VOICE. URL https://www.un.org/development/desa/undesavoice/more-from-undesa/2016/11/29738.html (accessed 5.3.20).

Osterwalder, A., Pigneur, Y. (2010). Business model generation: a handbook for visionaries, game changers, and challengers. John Wiley & Sons.

Papangelis, K., Velaga, N.R., Ashmore, F., Sripada, S., Nelson, J.D., Beecroft, M. (2016). Exploring the rural passenger experience, information needs and decision making during public transport disruption. Res. Transp. Bus. Manag., Innovations in Technologies for Sustainable Transport 18, 57–69. https://doi.org/10.1016/j.rtbm.2016.01.002

Patrick, R., Roseland, M. (2005). Developing sustainability indicators to improve community access to public transit in rural residential areas. J. Rural Community Dev. 1, 1–17.

Rassafi, A.A., Vaziri, M. (2005). Sustainable transport indicators: definition and integration. Int. J. Environ. Sci. Technol. 2, 83–96.

Raworth, K. (2017). Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist. Chelsea Green Publishing, White River Junction, Vermont.

Raworth, K. (2012). A safe and just space for humanity: can we live within the doughnut. Oxfam Policy Pract. Clim. Change Resil. 8, 1–26.

Samferdselsdepartementet (2017). Meld. St. 33 (2016–2017) [WWW Document]. Regjeringen.no. URL https://www.regjeringen.no/no/dokumenter/meld.-st.-33-20162017/id2546287/ (accessed 5.3.20).

Shiau, T.-A., Peng, Q.-K. (2012). Mode-based transport sustainability: a comparative study of Taipei and Kaohsiung Cities. J. Sustain. Dev. 5, 68.

Silberman, M.S., Interpreter, F. (2013). Sustainability and structural change: the role of HCI.

Skollerud, K.H. (2014). "Halv på hel" i Tolga. Brukererfaringer og evalueringer (No. 1343/2014).

Sopjani, L., Stier, J.J., Ritzén, S., Hesselgren, M., Georén, P. (2019). Involving users and user roles in the transition to sustainable mobility systems: The case of light electric vehicle sharing in Sweden. Transp. Res. Part Transp. Environ., The roles of users in low-carbon transport innovations: Electrified, automated, and shared mobility 71, 207–221. https://doi.org/10.1016/j.trd.2018.12.011

Stickdorn, M., Hormess, M.E., Lawrence, A., Schneider, J. (2018). This Is Service Design Doing: Applying Service Design Thinking in the Real World, 1st Edition. ed. O'Reilly Media, Sebastapol, CA.

Stickdorn, M., Schneider, J. (2012). This is Service Design Thinking: Basics, Tools, Cases, 1st Edition. ed. Wiley, Hoboken, New Jersey.

Sustainable Development Knowledge Platform [WWW Document] (2015). URL https://sustainabledevelopment.un.org/index.html (accessed 10.17.18).

Svanæs, D., Gulliksen, J. (2008). Understanding the context of design: towards tactical user centered design, in: Proceedings of the 5th Nordic Conference on Human-Computer Interaction: Building Bridges, NordiCHI '08. Association for Computing Machinery, New York, NY, USA, pp. 353–362. https://doi.org/10.1145/1463160.1463199

Ta heile Noreg i bruk - Meld. St. 13 [WWW Document] (2013). Regjeringa.no. URL https://www.regjeringen.no/nn/dokumenter/meld-st-13-20122013/id715615/ (accessed 7.8.20).

Tomlinson, B., Nardi, B., Patterson, D.J., Raturi, A., Richardson, D., Saphores, J.-D., Stokols, D. (2015). Toward Alternative Decentralized Infrastructures, in: Proceedings of the 2015 Annual Symposium on Computing for Development, DEV '15. Association for Computing Machinery, London, United Kingdom, pp. 33–40. https://doi.org/10.1145/2830629.2830648

Tonkinwise, C. (2015). Design for Transitions–from and to what? Des. Philos. Pap. 13, 85–92.

Transforming our world: the 2030 Agenda for Sustainable Development [WWW Document] (2015). URL https://sustainabledevelopment.un.org/post2015/transformingourworld (accessed 7.8.20).

van Selm, M., Mulder, I.J. (2019). On transforming transition design: from promise to practice, in: Academy for Design Innovation Management Conference 2019.

Watts, J., Kommenda, N. (2020). The Pandemic Has Led to a Huge, Global Drop in Air Pollution. Wired.

Zolfagharian, M., Walrave, B., Raven, R., Romme, A.G.L. (2019). Studying transitions: Past, present, and future. Res. Policy 48, 103788. https://doi.org/10.1016/j.respol.2019.04.012