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Combining the qualitative and quantitative with the Q_2 scenario technique — The case of transport and climate

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ABSTRACT

Two recent trends in scenario making are the starting point of this study: the combination of qualitative and quantitative materials, and inclusion of many kinds of experts. We propose a new scenario technique Q_2 that answers to these calls, and describe it step-by-step. Q_2 scenarios consist of Delphi, cluster analysis of numerical material, qualitative content analysis of interviews, and a futures table. Most of the required tools and methods are well documented and commonly used, but their combination is original, particularly the explorative and disaggregative way both types of material are analysed and compressed into a futures table and further developed into scenarios. We demonstrate the methodology through a case: the growing Finnish transport sector that faces severe pressure to cut CO_2 emissions. Finnish experts were asked about their views of the future up to 2050, using an interactive and user-friendly questionnaire, and interviews. An expertise matrix was formed in order to achieve a comprehensive coverage in terms of key expertise, education, organisation, age, and gender. By widening the concept of expertise, it is possible to get a large variety of viewpoints. The resulting scenarios reveal that reaching the CO_2 targets will require a palette of technical, infrastructural, and behavioural changes.

1. Introduction

In order to understand and plan for the uncertainties of future development, policy makers and scientists often use scenarios. They help in envisioning and understanding alternative future developments, particularly in complex systems. There are many different applications of scenarios, each with its benefits and drawbacks: forward-looking vs. backward-looking, normative vs. descriptive, qualitative vs. quantitative and formal vs. heuristic to mention but a few [1–4]. Some significant recent trends have been the combination of qualitative and quantitative materials, as well as an inclusion of many kinds of experts in scenario building [5,6]. Reflecting and contributing to these trends, we will describe in this paper a new scenario technique called *Q_2 scenarios* and demonstrate its use through a case of transport climate policy in Finland. We will also elaborate on the use of an expertise matrix and an innovative and user-friendly questionnaire for Delphi studies.

The Q_2 technique produces forward-looking and heuristic scenarios that combine qualitative and quantitative Delphi materials gathered from experts by interviews and questionnaires. The basic idea of the Q_2 scenarios is to identify themes and variables that can have different future states which are extracted from both qualitative and quantitative materials, and then to group these states to coherent scenarios using a futures table.

The Q_2 scenario method was developed through the practical application described in this paper, in order to produce expert-based scenarios about the Finnish transport sector. We drew from our earlier collaboration and experiences of combining different types of materials in scenario construction in seven Delphi studies (see [6]), and have now systematised the technique.

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The idea was to benefit from the iteration process of Delphi, the possibility to discover expected or desired changes in the relations of key variables, and to explore the drivers of change beyond what is usually covered in mathematical modelling exercises. We asked Finnish experts about their views of the probable and preferred future development up to 2050, covering a range of transport-related issues, and concentrating on climate issues. The views were condensed into seven scenarios.

This paper will start by discussing some recent trends in scenario literature (Section 2). In Section 3, we will provide an overview of the Q_2 technique. The Finnish transport sector is described in brief in Section 4 to set the background of the scenario case. We will then present the methodology of the Q_2 scenario variant in more detail, demonstrating the practices through the case (Sections 5 and 6). The scenarios are described and discussed in Sections 7 and 8 to illustrate how the results may be presented. Finally, we will critically evaluate the applicability, merits and challenges of the Q_2 scenario method (Section 9).

2. Trends in scenario literature

We first position Q_2 in the scenario literature on a broader scale (Section 2.1) and then review scenario methods that combine qualitative and quantitative data (Section 2.2), demonstrating why and how the new method differs from the earlier ones.

2.1. Layers of scenario literature

An impressive amount of scenario work has been carried out during the past half century [4,5]. The Scirus search engine found 111,000 journal articles with the keywords “scenario AND method AND future” in November 2011. Due to the vast amount and growth of scenario literature, one has to be cautious in making claims of the qualitative development of the field. However, based on identifying the characteristics in the literature, there seem to be at least eight emerging literature layers (a…h) in three thresholds of complexity of the authors' approach. The layers appear to be overlapping rather than consecutive as a single publication may deal with several layers.

Basic scenario work is the simplest approach in terms of complexity. It deals with a) making definitions of a scenario to have initial conceptual tools for a scenario study e.g. [7–9]; b) developing scenario methods for data gathering and analysis e.g. [10–12]; and c) making actual scenario studies to systematically explore alternative futures e.g. [13–15].

Reflection of scenarios represents a higher level of complexity, and can be seen in the literature d) as typologies of scenarios (and more generally, alternative futures) in order to understand the differences between methods e.g. [16–20]; and e) as traditional reviews and textbooks of the scenario literature to understand particular aspects of scenarios e.g. [7,21].

Meta-analysis of reflections of scenarios is the third level of complexity in the scenario literature. It consists of f) typologies of earlier scenario typologies to map the plurality in the scenario field e.g. [3,22]; g) reviews of previous reviews to define the state-of-the-art e.g. [23,24]; and h) bibliometric or data mining studies on scenarios e.g. [5] or more generally futures work, where scenarios have risen as a specific issue e.g. [4], in order to explore the diversity and to identify temporal trends in the field.

Despite this diversity and complexity, it is obvious that actual construction of scenarios, and developing various techniques for the task, remain at the heart of the scenario literature. Our paper mainly contributes to the layers b) and c), although the description of the eight layers above represents a layer g) type of approach.

2.2. Combining qualitative and quantitative materials in scenarios

One way to describe scenario methods is to place them on a field, where the vertical dimension characterises the methods on a continuum from qualitative to quantitative and the horizontal axis on a continuum from formal to heuristic approaches (Fig. 1) see [6,25,26]. Deterministic mathematical modelling is almost completely quantitative and formal (“almost” because the choice of

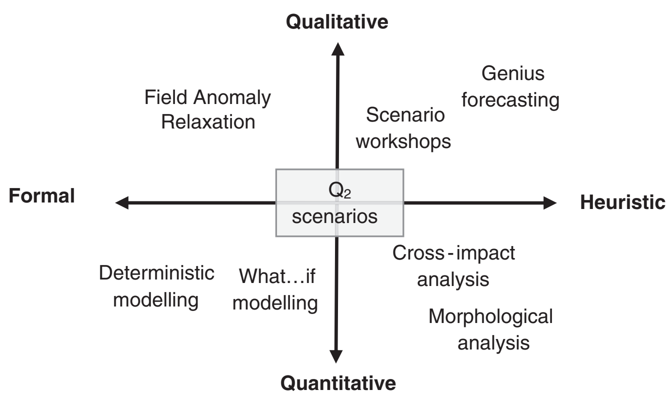


Fig. 1. Some methods for producing scenarios of the future. Modified from [6,25,26].

independent variables to explain dependent variables is a heuristic process) [7]. What…if modelling means a more heuristic process, where scenarios are more deliberately formed by choosing different sets of assumptions [7].

However, not all quantitative methods are formal. For example, in cross-impact analysis [27] and morphological analysis [12], the quantifications are heuristic estimates of the experts participating in the process. In turn, Field Anomaly Relaxation is a formal method although the material is exclusively qualitative [11]. Various types of scenario workshops are heuristic and usually deal with qualitative material only [28]. Individual futurist's heuristic scenarios are typically called Genius forecasting and are mainly, although not necessary completely qualitative [26].

The seminal book of Schwarz et al. [7] includes a sober-headed chapter on the uselessness of debating on which approach is better — quantitative models or qualitative scenarios. According to them, a quantitative model does not necessarily imply a deterministic view of the world. On the other hand, qualitative methods may include a systematic work with mental models and there is a complementary interplay between mathematical and mental models [6,7,12,29].

The combination of qualitative and quantitative materials and methods in scenario construction has recently been called for and developed, especially in environmental planning e.g. [6,30–33]. This can be done in many ways. For example, Muskat et al. [34] wished to increase the rigour of the scenario work by adding quantitative analysis to their data. However, they only used qualitative material (interviews) as their data.

Many scenario applications first produce qualitative storylines, and then quantify these for mathematical modelling e.g. [35,36], sometimes coming back later to qualitative meanings of the calculations e.g. [33]. Only few scenario techniques use qualitative and quantitative materials and methods in parallel, although there are exceptions e.g. [31]. For example, Westhoek et al. [36] first chose two dimensions in which differences were sought for, and through a 2 × 2 matrix created four qualitative scenarios that were later quantified with mathematical models. The Q_2 scenario method is used for exploring alternative paths, and dimensions that distinguish the scenarios from one another – or the storylines in general – are not set in advance.

Qualitative material is often provided by stakeholder workshops and other participatory methods e.g. [32,33,37]. The quantification, on the other hand, requires assumptions, simplifications and often quite complicated mathematical models, which tends to emphasise the role of the research team's own expertise. The combination of stakeholder workshops and mathematical modelling can be quite expensive and time consuming e.g. [32]. Therefore, many combinatory projects only study 3 or 4 scenarios. Although a large number of scenarios are not necessarily better than a small one, it is notable that the Q_2 technique is no more cumbersome for e.g., seven scenarios than three. The combined methods also often mean producing separate products (models, storylines), and linking the two is challenging, as the underlying assumptions of each might be different, see [31]. In the Q_2 scenarios, both qualitative and quantitative materials come from the same source, namely experts outside the research team. The two types of materials are first analysed separately but simultaneously, and then integrated equally to produce cohesive scenarios that contain both qualitative and quantitative elements. Complex models are not required as the technique uses the heuristic capabilities of experts to provide also quantitative estimates about the future.

The Q_2 scenario technique is based on an elaboration of the Disaggregative Policy Delphi [24,38] and Soft scenario [13] variants which seek to find a plurality of crystallised views of the future. The earlier versions started with a cluster analysis of the quantitative material which was then complemented with qualitative material. In Q_2, neither of the material types dominates the output. The Q_2 scenario technique aims for an agile, transparent and systematic way to combine quantitative and qualitative expert views with equal status.

3. Overview of the Q_2 technique

In short, the Q_2 scenario method includes a Delphi study and interviews for gathering expert views. The gathered data is analysed with cluster analysis of numerical material, qualitative content analysis of the interviews, and the combination of the materials using a futures table.

The required tools and softwares are easily available, well documented and commonly used. Their combination is original, however, in particular the explorative and disaggregative way both qualitative and quantitative materials are analysed and compressed into variables having alternative future states which are placed into the futures table and further developed into scenarios. The process is visualised in the flow chart of Fig. 2 and described in detail in Sections 5 and 6.

This application was for Finland, but the Q_2 technique could be used for smaller or larger geographical areas. In addition, while we developed the method in a transport project, we believe that it is applicable to any societal or industrial sector, where future development can be estimated both qualitatively and quantitatively. To gather quantitative material, it is possible to use questions framed on a Likert scale, but the method is particularly useful when there are absolute values or percentages that can be measured on interval or relative scale. Expert views can be sought about the direction and strength of changes in observed, statistically measured trends.

The Q_2 scenario technique is not based on models that quantify impacts of particular policies, for example. Instead, it is useful for mapping expert views, integrating stakeholders to discussion, and broadening views about the future. A more detailed discussion of the applicability of the method is given in Section 9.

4. Case: Finnish transport sector and the climate targets

The case topic, transport, is necessary for both the economy and for social needs, yet struggles to achieve a transition to environmental sustainability, especially due to emissions of carbon dioxide (CO_2), the most important greenhouse gas causing

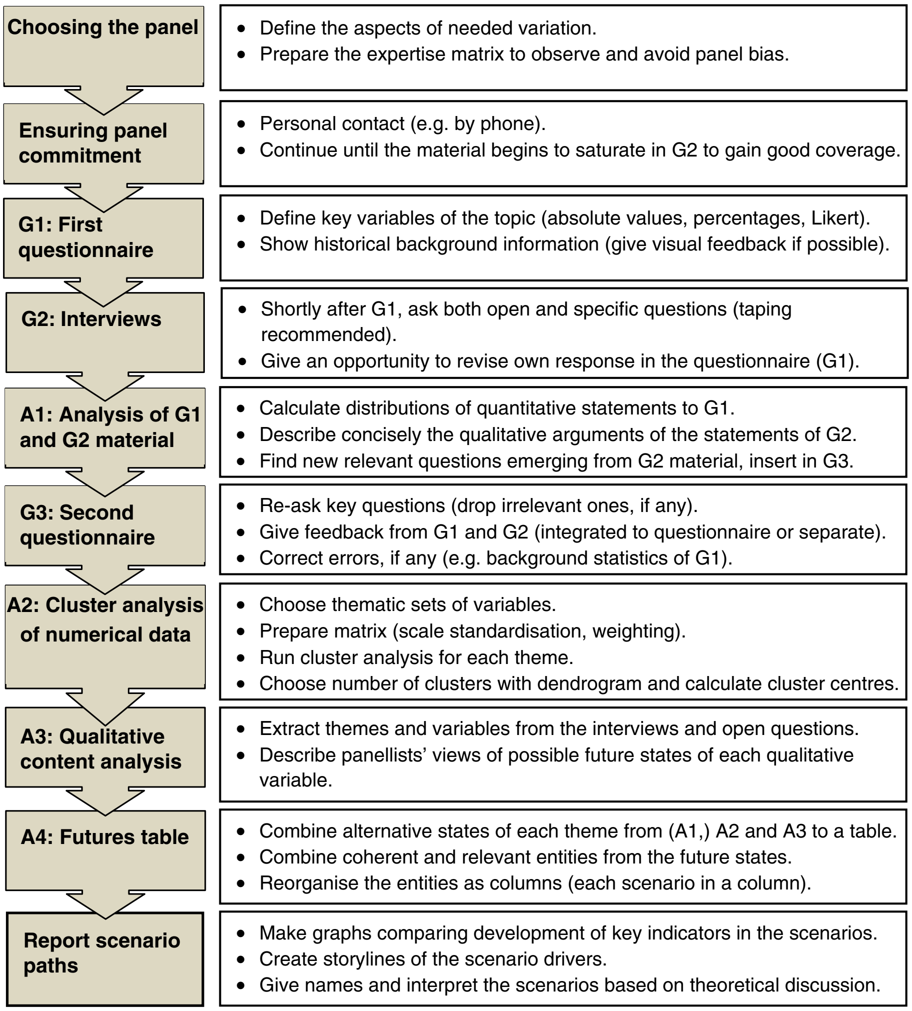


Fig. 2. The phases and elements of the Q_2 scenario process (G = data gathering, A = data analysis).

climate change [39]. The efforts to cut CO_2 emissions have increased recently in scope and intensity. For example, the European Union has introduced several traffic-related climate policies. In 2008, the EU agreed on a number of directives and other policies, commonly known as the Climate and Energy Package. The Package sets a 10% target for the share of biofuels in transport by the year 2020 [40]. Emission reduction target was set to activities outside the emission trading system, including the transport sector, allocated to each member country [41,42]. Based on the Package, the Finnish Government agreed on a specific transport sector emission target of 15% reduction of the 2005 level by 2020 [43].

Recently, the EU released a White paper [44] setting a Union-wide target of 60% reduction from 1990 levels by 2050 for the transport sector. Efforts to limit CO_2 emissions from the transport sector have not been as successful to date as reduction efforts in general (Fig. 3). How are the reductions to be achieved, or is it even possible to reach the targets?

The case area, Finland is a sparsely populated northern European country where the population is concentrated in and around larger cities, mainly in the south. Finns have many summer cottages in the countryside, which they visit during vacations and weekends. Outside the city areas, in particular, most of the passenger transport takes place in private cars (Fig. 4). The Finnish railway network is fairly extensive, and the volume of rail passenger transport has moderately increased due to urbanisation. The share of rail transport in freight is rather high, about a quarter of the ton kilometres (Fig. 4). Nevertheless, road transport dominates in freight, as well, accounting for 65–70% of the ton kilometres annually in 2000–2009 [46].

Scenarios have long been used in transport planning. Especially when created by transport officials, such scenarios have often been based on business-as-usual forecasts of past development [49,50]. These forecasts can become self-fulfilling prophesies, as the "predict and provide" concept by Owens [49] suggests. It is clear that looking at past trends alone is not useful, because the trends are unsustainable [51].

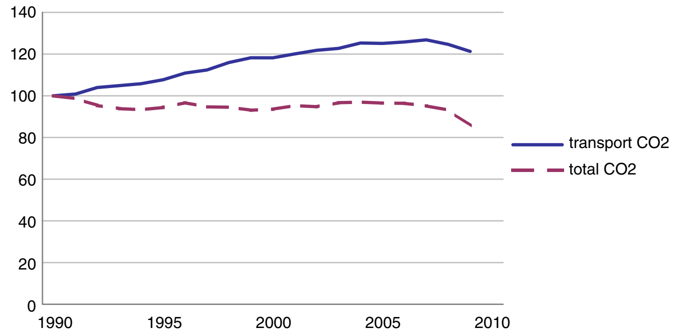


Fig. 3. Transport and total CO_2 emissions in EU-27 countries 1990–2009, index year 1990 = 100 [45].

Since many emission targets are set for countries, and much of the transport policy is made on the national level, we aimed for scenarios covering the whole country and for a sufficiently long time-period. Main goals of the process were to integrate transport stakeholders to a discussion of the future of transport and to report the findings as a set of alternative policy relevant scenarios up to 2030, not too dependent on business-as-usual. During the project, the Finnish Ministry of Transport and Communications became interested in it. The Ministry funds a sister project, where our scenarios are used [52]. Due to the interest of the Ministry, the time period of the scenarios was prolonged to 2050.

5. Methods for gathering data

5.1. Selection of participants

The quality of the results of any Delphi or Delphi-like study largely depends on the challenging task of defining the composition of the panel. Experts from various fields are needed to fully appreciate changes that may be forthcoming, e.g., in policies, technologies, or values. Different fields and organisations each have their own particular expertise to offer, but also their own "set of world-views and patterns of interpretation" [53, p.2]. This is represented in the increased calls for inter- and transdisciplinary researches [54]. In scenario construction, already in 1975 Linstone and Turoff [55, p. 566–567] called for the inclusion of diverse expertise and viewpoints (see also [13,56]). Kuusi [57, p. 181] calls this way of choosing Delphi panellists "plurality policy".

An *expertise matrix* (first introduced by Kuusi et al. [58]) is useful in ensuring that the panel demonstrates adequate variation. The matrix also makes the selection of panellists more transparent, even to international audiences who do not know local organisations. Relevant categories of expertise (as well as e.g., gender and age) are named in the matrix, where each panellist is characterised. Any gaps in the expertise are easily revealed and new experts may be invited. Some categories may have more "hits" than others, but no categories are left empty. Thus all relevant areas of expertise get at least some coverage.

In the transport study, we looked for representatives of various societal sectors, such as central government, local authorities, business sector, research, and politics (see Appendix A). It was also important to have experts of different modes of transport, including both passenger and freight transport. The experts were asked to give their personal opinions, instead of acting as official representatives of their organisations. They were promised anonymity in terms of individual answers.

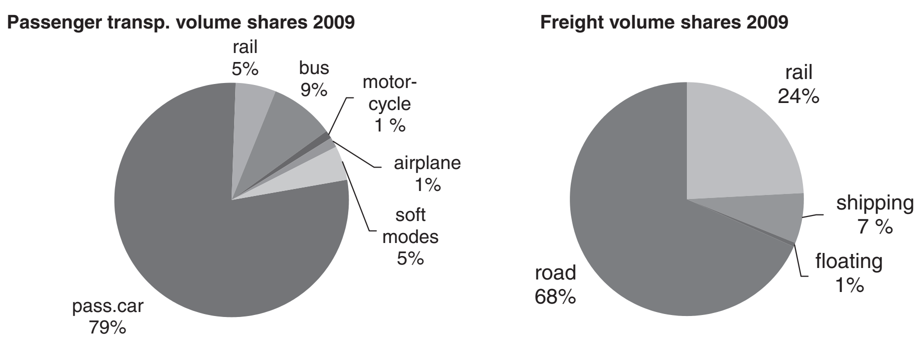


Fig. 4. Shares of transport modes in Finnish transport in 2009 (passenger-km and ton-km) [46,47] (soft mode volume is an estimate based on the national passenger transport survey 2004–2005 [48]).

The aim was to cover the views in the field rather than to have a statistically representative sample of experts cf. [57]. For example, there were considerably more men (n = 24) than women (n = 10) in our panel. This share reflects the reality in the transport sector which is still rather male-dominated. Similarly, the representatives of various engineering fields (42%) were highly but not exclusively represented.

We also wished to expand the panel to include expertise beyond the establishment, or “counter-expertise” [59]. Non-governmental organisations (NGOs) are a typical example. This reflects the call for widening the definition of expertise, made particularly in the environmental studies, in order to understand and solve complex problems that involve ecological, economic, and social aspects e.g. [59,60]. Although most panellists were professionals in transport issues, we even included e.g., a high-school student being interested in climate issues and able to discuss issues relevant to young people.

In our opinion, the variety in the panel was important for producing both more varied quantitative data and more viewpoints within the interviews. When looking 40 years into the uncertain future, it is important to separate somewhat from conventional wisdom.

The number of participants is limited by practical considerations, as interviews and their analysis are fairly time-consuming. It is possible to add new panellists during the process and to continue conducting interviews until the material is saturated, i.e. for as long as significant new viewpoints keep emerging.

It is important to get the participants committed to the process. They need to understand and accept the task of filling in two questionnaires as well as being interviewed. Even so, it is likely that some participants will fill in the questionnaire only partially or will drop out of the second round.

5.2. G1: the first round questionnaire

The first round of the Q_2 scenario method uses a questionnaire and interviews. The interviews are conducted (ideally, within a few days) after receiving the filled-in questionnaire from the expert. The questionnaire includes quantitative questions in the form of absolute values, percentages, or Likert-scales, typically key indicators of the topic. It is also good to offer some space in which the panellist can write his/her arguments, but in our experience, experts give few detailed written arguments in this process. The researchers choose the questions based on their theoretical and practical understanding of the field as well as the type of scenarios they wish to create. The panellist can then make the quantitative estimates in the questionnaire and describe the drivers of change in the interviews.

In our case, the aim was to cover all transport modes, but to focus on the largest contributor to CO_2 emissions, namely passenger cars. The experts considered how much people and goods move, what transport forms are chosen, and how the emission-relevant technologies may change. Therefore, the first round questionnaire included questions for passenger transport volumes, CO_2 emissions from passenger transport, passenger car density, total car density, the average emissions of new passenger cars, the share of biofuels in transport, freight volumes, freight transport CO_2 emissions, and GDP. The last question was chosen as the volumes of economy and transport have traditionally been closely linked in the EU, but the decoupling of the two could have important consequences for emissions [61–63].

The participants were asked to give their opinion for the future they considered most probable, as well as for the future they considered preferable. The preferred future was required to be possible, in the opinion of the respondent cf. [18].

When available, it is useful to show the respondents a sufficiently long past trend when asking for the future trend, see [64]. In the transport study, we gave the realised development of the variables for the years 1980–2007 (the latest available year) as numbers and as a graph. The respondent estimated a value for each variable for the years 2020 and 2030. The questionnaire was sent to participants and back to the researchers by e-mail in the summer of 2009.

The questionnaire was created as an MS Excel spreadsheet. It allowed the expert to immediately get a visual feedback on his/her response. When the panellist entered a value for a future year, the trend from 2007 onwards was automatically drawn on to the graph (Fig. 5). Therefore the panellist could use this visual aid in estimating the future development – continuing or changing trend – and alter his/her answer if desired.

The panellists were pleased with the design and functionality of the questionnaire. A few experts used the calculation possibilities of the MS Excel, estimating e.g. that the emissions per km would be reduced by 20% from 2007 to 2020, and writing a corresponding formula into the answer box. This feature is a positive side-effect of using Excel rather than a web-based questionnaire.

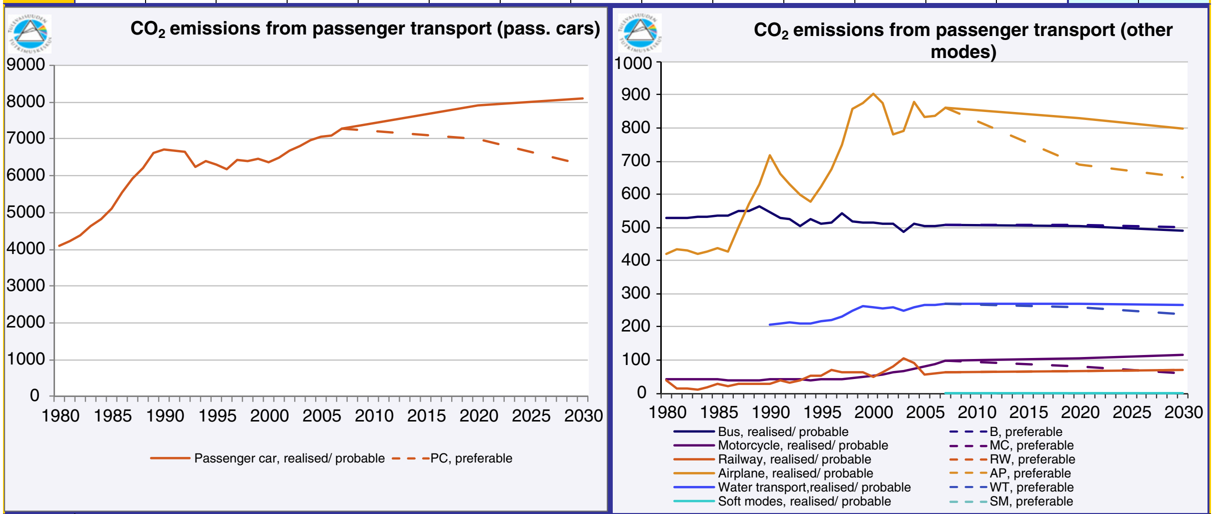
Some panellists were slightly uncomfortable giving numerical estimates to topics they felt more unfamiliar with, but the visual aid of a realised trend was useful. They were able to give an estimate of the direction of the future trend as well as the swiftness of the change. Since numerical scenarios are always only quasi-exact, the estimated direction and strength of the trend are more important descriptions of the respondents' views than exact numbers. The questionnaire design helped both “number crunching” and visually oriented types of panellists to give their estimates.

5.3. G2: interviews

The interview takes place shortly after the researcher has received the questionnaire from the panellist. Most practical is to arrange the time of the interview when the participant is first contacted. This effectively sets the deadline for the return of the questionnaire. The interviews are thematic and semi-structured, and may last 1–2 h. If possible, it is recommended that the

2. What will the CO2 emissions (1000 t/a) be in probable and preferable futures?
Insert your responses to the **white** spaces in the table, you will see your response in the graphs below. The total emissions will be in the columns on the right.

Year	Passenger car, realised/ probable	PC, preferable	Bus, realised/ probable	B, preferable	Motorcycle, realised/ probable	MC, preferable	Railway, realised/ probable	RW, preferable	Airplane, realised/ probable	AP, preferable	Water transport, realised/ probable	WT, preferable	Soft modes, realised/ probable	SM, preferable	Total, realised/ probable	Total, preferable
1980	4105		529		41		39		419						5133	
1990	6705		547		41		29		718		205				8245	
2000	6353		516		52		49		902		259				8132	
2007	7278	7278	508	508	97	97	63	63	862	862	271	271	0	0	9078	9078
2020	7900	7000	505	508	105	80	65	65	830	690	270	260	0	0	9675	8603
2030	8100	6300	490	500	115	60	70	70	800	650	265	240	0	0	9840	7820



Argu-ments	(You can write your arguments here)	**Argu-ments**

Fig. 5. A sample of the first-round questionnaire with a response.

interviews are audio-taped and transcribed as this makes their analysis easier. Our 32 interviewees contributed more than 650 pages of transcripts.

It is good to ask broader questions at first, which set the specific topics in a context and allow the expert a freer rein to consider future developments. It is also possible to ask tailor-made questions regarding the panellist's particular expertise. Then, the panellist should explain the quantitative estimates (e.g. “why do you think train travel will increase”, or “what prevents your preferable future image of car density from being probable”). It is useful to have the filled-in questionnaire available at this stage. The interview almost acts as another Delphi round, as it is possible to change or add to the answers at this stage. Sometimes there are inconsistencies or typos in the questionnaire answers, which can be discussed. The interviewer can even challenge the responses of the questionnaire by providing additional information or presenting arguments other interviewees have given. The interview should also allow the panellist to comment on the study. These characteristics reflect the active or even actively confrontational interview style (see [65]).

As in the questionnaire, the interview questions reflect the theoretical understanding of the scenario researchers. In the transport case, the interview questions were designed on the basis of the Environmental Protection Process framework [66]. The intention was to consider transport, its causes and environmental effects, as well as transport policy, in a holistic manner.

5.4. A1 and G3: the second round questionnaire

In Delphi studies, the results of the first round are shown anonymously to the panel during the second round [55]. In the Q_2 technique, the qualitative arguments and views are retrieved from the interview transcripts and possible written arguments. These are distilled into a reasonably concise form. In the transport project, a published summary report [67] was sent to the panellists together with the second round questionnaire.

The next step is to reconsider the questionnaire and, for example, to dismiss questions that have very uniform answers. Our second round questionnaire included the same questions as the first one except for total car density which had offered little information beyond what was received from passenger car density. A few modifications were also made, as the background statistical data used in two questions of the first questionnaire were discovered to contain errors. During the second round, we extended the questionnaire to cover the year 2050, to compare results with the official climate targets.

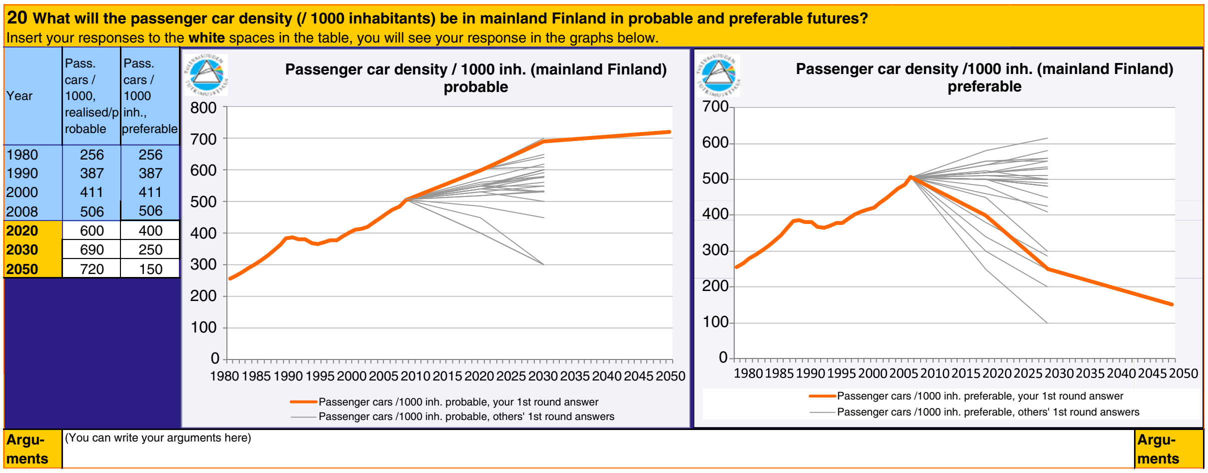


Fig. 6. A sample of the second-round questionnaire with a response.

The remaining questions must be modified to include the answers from the previous round. Here, the second round questionnaire graphs also included the first round responses of the whole panel in thin lines with the panellist's own answer emphasised (Fig. 6). This allowed the panellist to compare his/her previous answer visually to those of the rest of the panel.

It is also possible to add new questions to the questionnaire. Interesting or controversial topics that emerge from the interviews can be quantified, i.e. expressed as absolute values, percentages, or Likert scales. We added, e.g., the real price of gasoline, and how the taxation of cars will be developed. In order to keep the respondents' workload reasonable, these questions were asked for the midway point year 2030 only, which was the original target year of the study.

It would be possible to include a third questionnaire round. However, it is not recommended, as it would probably significantly increase the drop-out rate.

6. Methods for analysing data

Much of the literature of the Delphi method has focused on gathering the data whereas analysing the data has been left with less emphasis, the review of Turoff and Hiltz being a notable exception [68]. Scenario methods and standard social scientific methods offer help here but cannot be applied without particular thought to futures studies. In the Q_2 technique, the researchers identify themes and variables as well as their alternative future states from the material. The views of a panellist are itemised and categorised so that an individual's views on different themes can end up in different scenarios.

6.1. A2: cluster analysis of quantitative data

The quantitative material from the questionnaire is grouped with the help of cluster analysis [13,69]. Cluster analysis is a multivariate method to group similar units of analysis together. It is useful for Delphi studies since it does not require a random sampling unless the purpose is to test a theory [38,70,71]. Rather than being a single standardised procedure, several critical choices have to be made that affect the results: choosing variable types, potential standardisation of variables, weighing of variables, choosing dissimilarity measure between cases, choice of clustering algorithm, and the choice of the number of clusters [69,71–73].

6.1.1. Variable types

In the transport case, we chose as natural variables as possible — e.g., passenger kilometres, real fuel price, and share of biofuels, complemented with more fuzzy issues measured on the seven-step Likert scale. The variables are categorised under *themes* consisting of the sub-systems of the research object. For example, we included variables “passenger car density” (number of cars) and “average CO_2 emissions from new cars” (quality of cars) in the theme “vehicles”.

6.1.2. Standardisation

All variables were standardised linearly to the scale of 0…100 in order to make variables comparable to each other. With discrete variables having an absolute maximum (here percentage shares and Likert scale questions) this maximum value was set at 100 and the lowest possible value was set at 0. With continuous variables, the maximum response was set at 100 and the natural minimum was set at 0.

6.1.3. Weighing

Weighing was performed in order to reflect the relative importance of related issues. For example, cars were given a higher weight than trains in the passenger transport theme, due to their higher modal share.

6.1.4. Dissimilarity measures

The standardised Euclidean distance was used as a measure of dissimilarity. Squared Euclidean distance would have emphasised large differences between cases in few variables over systematic differences in many variables. Smaller systematic differences in transport volumes and emissions maintain gradual comparativity between scenarios. Squared distance could be useful when finding out “mini-scenarios” otherwise close to each other but differing with regard to a narrow range of issues under study, e.g. biofuels.

6.1.5. Clustering algorithm

We used the Furthest Neighbour (Complete Linkage) algorithm (in the PASW 18 software) that belongs to agglomerative hierarchical clustering methods [69]. It has a good performance in comparative studies on various algorithms [71]. The method uses Euclidean distance measure, the number of clusters is not predetermined by the researchers, it is available in most statistical softwares, and it is easily understandable. The algorithm starts by dealing with each case separately and clustering the two closest units of observation. Then each unit of observation (or made cluster) is compared to the furthest unit, or “furthest neighbour”, of each already made cluster. Distance to the furthest neighbour is minimised. In the end, all units and clusters merge in one cluster. The arithmetic means of the responses in a cluster for each variable in the theme are considered the cluster centre. One cluster therefore represents one future state of one theme.

6.1.6. Number of clusters

The most policy relevant critical question is when to stop clustering. Too few clusters might result in a rather unimaginative outcome. Too many clusters might either make it difficult to discern actual differences between scenarios or future states, or be too many for decision-makers to grasp. Robinson [10] has stated that the maximum useful number of alternatives is seven. Typically, one should avoid making two alternatives, that would easily connote “right vs. wrong”, “good vs. bad”, or “realistic vs. idealistic” [38]. We therefore suggest 3–7 alternative future states of each theme as long as the dendrogram or hierarchical tree plotted by the used software allows this many solutions. The number of clusters can differ between themes.

Another domain of cluster analysis literature has worked with statistical stopping rules e.g. [70,72,73]. We did not use statistical stopping rules since a) the Delphi panel is not a large, random sample, b) cluster analysis is here used to help in the generation of alternative future states, not to reveal the “true” number of clusters presented in the data, c) the statistical stopping rules have been tested when the structure of the data has already been predetermined artificially, and it is questionable whether real clusters in the real world are compatible with the artificial data.

Each panellist is asked to produce two views of the future — the probable and the preferred. Some participants may not fill in the questionnaire at all or only incompletely. Therefore the number of complete numerical responses for each theme can vary. In our project, we were able to analyse 24 questionnaires resulting in 48 views of the future, i.e. units of analysis. The probable and the preferable future images of an individual are asked for separately, but are analysed simultaneously. The scenarios can contain elements of both types of future images. Why are the views of probable and preferred futures mixed? First, both views concern the same key variables, and they are just two alternative future states of the same issue. Only if the views of the preferred and probable futures would contain different variables, is the mixing a problem [6]. Also, it is not probabilities that are sought, and the aim of the Q_2 technique is to produce rich, interesting, and sufficiently different scenarios. Finally, it can be difficult in every case to distinguish between arguments for the probable and the preferable future images in the interviews, which could otherwise cause difficulties in constructing solid scenarios.

In the Q_2 scenarios, the clusters and the scenarios based on them do not represent the thinking of grouped individuals but crystallised views of the future. This approach is, in fact, similar to qualitative content analysis, where various themes and different views regarding the themes are distilled from the collection of interviews, rather than from each interview individually e.g. [74]. With the help of the cluster analysis this approach can be applied to numerical data, too.

6.2. A3: qualitative content analysis

The qualitative material, i.e. the interview transcripts, is analysed separately. Before the second round, the arguments regarding the development of the quantifiable variables are grouped, summarised, and sent to the participants with the second round questionnaire. The more argued-about themes as well as weak signals may be included. The summary can later be used in constructing the futures table and in writing the scenarios.

The next step is to conduct a qualitative directed content analysis [75] in order to condense the views of the respondents into alternative future states of various qualitative themes. Relevant variables and concepts can be discovered with thorough reading and coding of the material. The qualitative variables can be based on theoretical understanding of the issue, but should not be completely determined beforehand. Instead, the researchers should let the material guide them, and the variables should be at least partly discovered and chosen during the analysis process. For example, the variable “car fashions” was not identified before the interviews but emerged in the case, referring to the type of cars that would become popular in the future. The analysis is an iterative process, a discussion between the research material and theory.

Table 1
Examples of the futures table variables and future states, columns reorganised according to the finalised scenarios.

Themes and variables	Developing degrowth	Urban beat	Transit-Finland	Eco-modernity	Small steps	Business as usual	Material growth
Policies −3…+3							
Public transport fares	−3.0 Decrease sharply	−3.0 Decrease sharply	−0.7 Decrease slightly	−1.6 Decrease significantly	0.8 Rise slightly	1.6 Rise significantly	1.6 Rise significantly
Vehicles							
Share of biofuels %							
2020	23	12	11	12	9	7	10
2030	40	24	23	24	20	13	18
2050	55	49	55	49	32	18	35
Other drivers −3…+3							
Urban form	2.4 Intensifies significantly	2.4 Intensifies significantly	1.6 Intensifies significantly	1.0 Intensifies slightly	−0.9 Disperses slightly	−0.9 Disperses slightly	−0.9 Disperses slightly
EU renewable energy targets	2.2 Rise significantly	2.2 Rise significantly	0.3 Stay the same	1.5 Rise significantly	1.1 Rise slightly	1.1 Rise slightly	1.1 Rise slightly
Freight							
The share of non-material consumption of GDP	3 Increases sharply	2.2 Increases significantly	3 Increases sharply	2.0 Increases significantly	0.8 Increases slightly	1.3 Increases slightly	0.9 Increases slightly
Road freight volume 2020	10.0	24.2	20.0	27.9	28.0	29.2	29.3
Road freight volume 2030	5.0	21.2	15.0	28.3	28.0	31.2	31.1
Road freight volume 2050	5.0	17.5	10.0	28.1	29.0	32.8	31.7
Road freight CO_2 2020	2000	3789	4000	4190	4244	4167	4686
Road freight CO_2 2030	1000	2739	3000	3642	3933	3873	4761
Road freight CO_2 2050	0	2167	2500	2663	3444	3383	4357
Passenger transport							
Passenger car vol. 2020	35.0	53.3	60.0	66.3	68.8	72.7	72.7
Passenger car vol. 2030	10.0	47.0	60.0	66.6	71.2	79.6	79.6
Passenger car vol. 2050	10.0	32.7	30.0	65.4	71.2	84.7	84.7
P. car CO_2 2020 (1000 tn)	4000	4563	7000	6638	7046	7484	7484
P. car CO_2 2030 (1000 tn)	1000	2086	7000	5537	6554	7263	7263
P. car CO_2 2050 (1000 tn)	0	567	5000	3375	5262	5500	5500
Qualitative variables							
"Car fashions"	Interest in emissions	Large cars unfashionable	Interest in emissions	Large cars unfashionable	Dismissiveness towards "little cars"	Based on maximum need	Idealisation of power
People's awareness of costs of mobility	Aware of environmental costs	Aware of both env. and econ. costs	Aware of environmental costs	Aware of both env. and econ. costs	Aware of economic costs	Aware of economic costs	Not aware

6.3. A4: futures table

The quantitative and qualitative materials are combined in the form of a table of themes, variables and their future states. This table forms the basis of the scenario construction. In the table, each row represents a variable, such as “passenger car density” or “car fashions”. Each variable has either quantified or qualitative alternative future states, marked in the cells of the row (see Table 1). The quantified variables are the ones used in the cluster analysis, and their alternative future states are the cluster means. Each row may have a different number of alternative future states. In the transport case, there were six clusters in the passenger and seven in the freight transport theme. The number of qualitative future states obviously depends on the content of the interviews. The table can be quite long, if there are e.g. several years for which the data has been asked for, as each of these should be on its own row.

The futures table owes much to the field anomaly relaxation (FAR) method, created initially in the 1970s by Rhyne and his colleagues who continued to develop it over several decades, see [11]. The FAR method involves a multidisciplinary research team to form sectors (or fields, themes, topics depending on the application) of the system under scrutiny, and to qualitatively describe alternative future states of the sectors in table form. Scenarios are constructed by first excluding impossible pairs of states in separate sectors (Filter 1) and then excluding impossible collections of states regarding all sectors (Filter 2). The method was developed further by Seppälä [76] with the Finnish name “tulevaisuustaulukko” (future table) which included also quantitative variables. Some simplified applications have been made by researchers at the Finland Futures Research Centre, sometimes using Seppälä's concept [77] and sometimes more international vocabulary — the Futulogic method [22] and the Futures Table [78]. The Q_2 application of the futures table is more complex, and forms the core of the scenario construction process.

The futures table applied in the Q_2 scenario process differs from the FAR method in some crucial aspects. First of all, in the futures table there is no thorough matrix of pairs, where the possibility of a co-existence of each pair of states would be considered. In the experience of the second author, users of the FAR method can have rather narrow views on what pairs they regard as compatible. In such a case, the FAR method can excessively reflect the users' prejudices on the subject. In the Q_2 scenario method, the future states on each row are reorganised in a theory driven way so that each column represents an internally coherent view about the future.

Second, the configurations produced by the FAR table are not dated before the actual scenario writing [11], whereas variables in the Q_2 futures table include examples like “car density in 2020” and “car density in 2050”. This is a natural result of the use of quantifiable variables, trends and clustering, and immediately fixes the work to certain dates.

Third, in the FAR table, each variable is dealt with as a single one. In Q_2 scenarios, cluster analysis can handle many variables at the same time and will produce a consistent future state for the whole theme consisting of several variables. This increases the number of variables that can be efficiently dealt with and thus gives a more detailed view on the future states. Clustering also gives a good ground to forming scenarios.

Fourth, Rhyne [11] has considered it useful to expand the research team by a senior advisory council that can contribute insights relevant to decision-makers. The Q_2 process takes this idea a step further since the actual data to the futures table comes from an independent Delphi panel, which is intended to make the scenarios more policy relevant. The technique has been used before at least by Linturi and Rubin [77], but without the cluster analysis.

Once the futures table is compiled, it must be reorganised so that each column represents one scenario. It is useful to write short overall descriptions of each theme, and to draw graphs of some variables. This helps to give form to the differences between clusters. Then, the alternative future states are grouped. Colour pens, for example, can be used to mark which future states can be considered to be part of the same scenario. Taking an important theme as the starting point helps this work.

In the transport case, we started the re-organisation from the largest set of variables, i.e. the passenger transport theme. The clusters represented six different views about the future. Qualitative variables were organised to reflect the quantitative information. These combinations formed the first part of the scenarios. Then we moved on to the next theme, considering what kind of futures seemed to be represented, and which already grouped cells they would best fit.

The whole table is worked through this way, until all, or almost all, alternative future states belong to some scenario and no new relevant scenarios emerge. This stage of the work requires a thorough familiarity with the material and a good understanding of the field in question.

Sometimes, it is necessary to use the same alternative state in more than one scenario if there are fewer alternative future states for a variable than there are emerging scenarios. It is also possible that more clusters were chosen for a theme than there are emerging scenarios. The number of clusters can be reduced by combining clusters and calculating new cluster centres. In the case, there were seven freight clusters, and we ended up having seven overall transport scenarios, where one of the six passenger transport clusters was used twice. Some variables only had three or four alternative future states, so the same state was sometimes used in several scenarios. Two qualitative variables had future states that did not fit well with a particular initial scenario. In these cases, the research group invented another future state based on the spirit of the scenario, and indicated it in *italics* in the final table.

Once all future states have been grouped, the table is reorganised so that each scenario is in its own column (see Table 1), possibly reflecting a continuum — e.g. growth promotion vs. growth criticism, or conservative vs. radical. The final step is to name and describe the scenarios. The process is fairly creative and free. The storylines can be short, in which case only key elements of the table are used in each scenario, or they can be more complete, using more variables of the table. The Q_2 method enables scenario descriptions both in writing and through graphs, as we will demonstrate in the following section.

7. Seven scenarios for the Finnish transport sector

7.1. Developing degrowth

In the first scenario, the economy, as measured by GDP, starts to decline and road transport volumes decline sharply as well. Nevertheless, the “Developing degrowth” scenario is not pessimistic. The economy becomes increasingly service-intensive and the share of non-material consumption rises sharply. This means an immaterialisation of the economy, which can lead to less freight. A strict climate policy directs the development of the society, and transport CO_2 emissions decline to zero by 2050. Domestic airplane use ends completely. The quality of public transportation improves sharply while at the same time the fares become much cheaper. Goods are bought from local stores. There are heavy investments into bicycle networks and sidewalks. The use and ownership of passenger cars are heavily taxed, and the number of passenger cars plummets. However, at the same time, car technologies develop rapidly, and new cars sold in 2030 are based on hybrid, electric, or hydrogen technologies. The share of biofuels of transport fuels is high, partly because the overall fuel demand is low.

7.2. Urban beat

In the “Urban beat” scenario, the economy grows steadily. Passenger transport volume does not change significantly, but the modal split changes towards soft modes and public transportation, particularly to trains. Urban intensification is significant and infrastructure for soft mode transport is improved. Services and shopping can be done close to the house or in the Internet, and goods are delivered home. Public transport and infrastructure for car-pooling is developed determinedly. The number of cars decreases fairly slowly but car technology improves fast and economic driving habits spread extensively. Domestic tourism increases, and the rise of railway transport is aided by the development of local train services around several cities. The co-ownership of trucks and combined loads become more common in the freight sector. Freight volume continues to grow, partly as a result of new mining initiatives, but the emissions are only half of the 2005 level by the year 2050. The CO_2 emissions from passenger transport decline sharply, so that in 2020 they are 35% less and in 2050 some 90% less than in 2005. Pressure from consumers and citizens drives the change in climate issues.

7.3. Transit-Finland

The “Transit-Finland” scenario gets its name from the decrease of passenger transport with the simultaneous increase of freight transport, particularly transit freight. A large volume of freight is transported in containers by rail from Asia through Russia and Finland to be shipped to European markets, or the other way around. The domestic economy grows only slowly and settles on a steady level after 2020. The use of private car decreases sharply. The change in the modal split is encouraged by better and cheaper public transportation methods and the higher costs of car use. Urban infill proceeds significantly, but car use is also diminished by strengthening environmental values and the increase of car-pooling. On-demand public transport is used in the rural areas. The pace of life slows down and local services are used increasingly. Unnecessary hurry is eliminated, so freight transport is organised in better time with slower modes: Freight transport moves from roads to rails and waterways. Technological change is slow in terms of emission reductions but considerable development is achieved in the field of biofuels. They are produced largely from domestic raw materials. Overall, Finland becomes a forerunner in climate policies but global expansive materialistic patterns are not changed.

7.4. Eco-modernity

In the “Eco-Modernity” scenario, the fairly small growth of transport volume goes to public transportation and, in freight transport, to railways. Economic driving style becomes the norm in the freight sector. The economy grows faster than transport volumes, as the share of non-material consumption grows significantly. Faster trains reduce the demand for air travel. Car technologies develop fast and transport emissions decrease by some 45% from the 2005 level by the year 2050. The EU targets for renewable energy use increase significantly, and the share of biofuels of liquid fuels is high. Public transportation is supported, and tendering increased, which improves and expands services. Car taxes focus on the use rather than the ownership of cars. Some communities start their own, more ambitious emission-reduction policies. Freight transport follows the same pattern of a relatively slow growth and a modal split from road to rail. This is a moderate version of the ideas applied fully in the Urban beat scenario above.

7.5. Small steps

This scenario clings to the present and is very cautious about any change. The economy grows slower than before in “Small steps”. Freight transport increases only on the railroads. The image and the ease of use of public transportation improve slightly. Nevertheless, urban sprawl continues slightly and car density increases a little up to the year 2030. Motorcycle use grows in this scenario slightly faster than in other scenarios, but in general, there are only small changes in the modal split. The CO_2 emissions decrease steadily but slowly, emission targets cannot be met. Policies based on voluntary action are in use, such

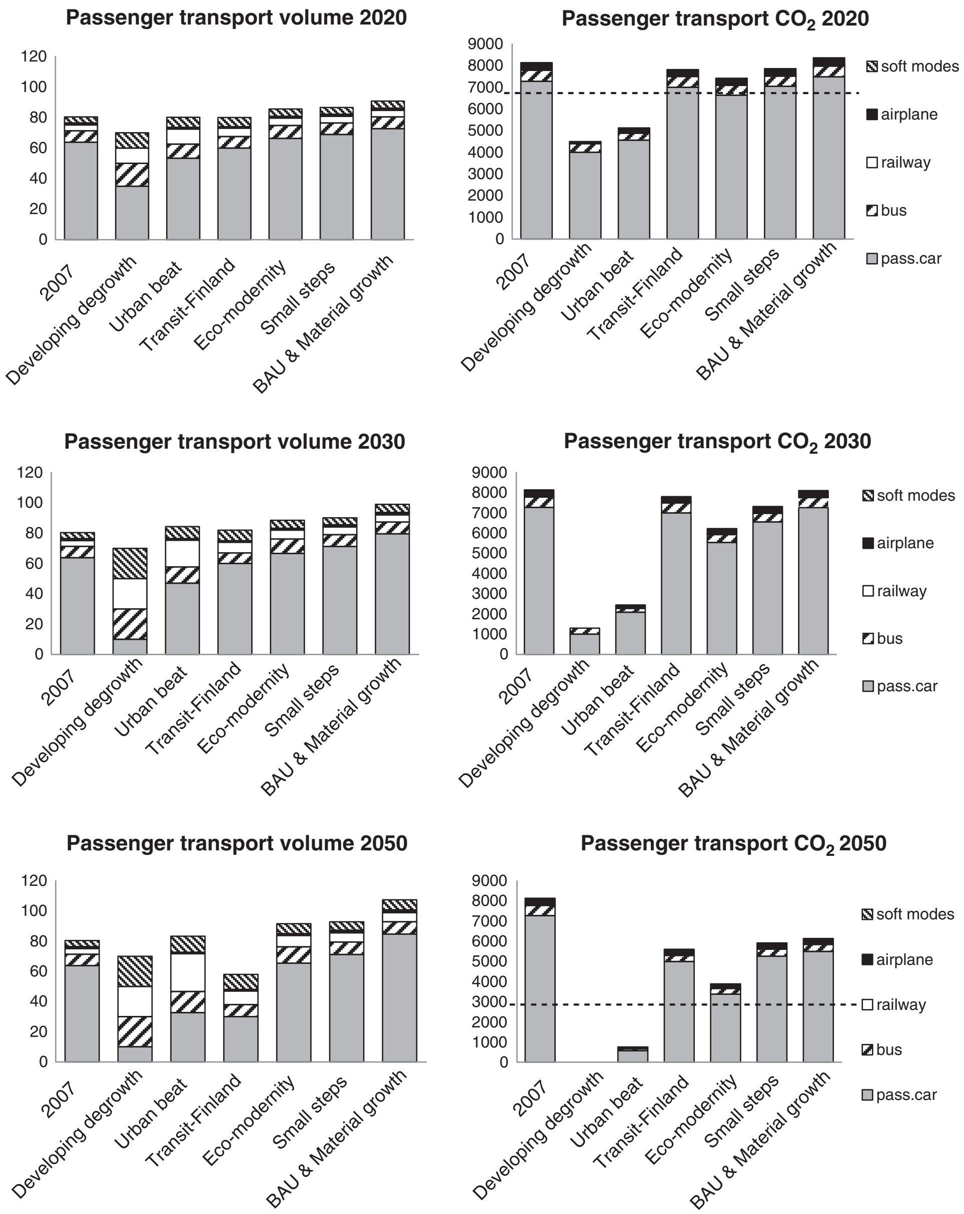


Fig. 7. Passenger transport volumes (bn pass. km) and CO_2 emissions (1000 tn) in 2007 and in seven scenarios in 2020, 2030, and 2050. Dotted lines signify (approximated) emission targets.

as energy conservation agreements between freight companies and the state. Overall, this scenario is close to maintaining the status quo.

7.6. Business as usual

This scenario is called "Business as usual", as certain improvements and new policies are introduced, but the vision of the future is still rather conservative. The economy grows fairly fast and the share of non-material consumption increases slightly. Freight volumes increase across transport modes. Taxes on energy and environment are raised and car owners are aware of the economic costs of driving, but the urban sprawl continues and the use of passenger cars increases. The social importance given to the private car prevents policies that could significantly reduce its use. The safety and fluency of traffic flows are emphasised. Public transportation loses popularity as its fares rise and services decline. Car density saturates at approximately the present

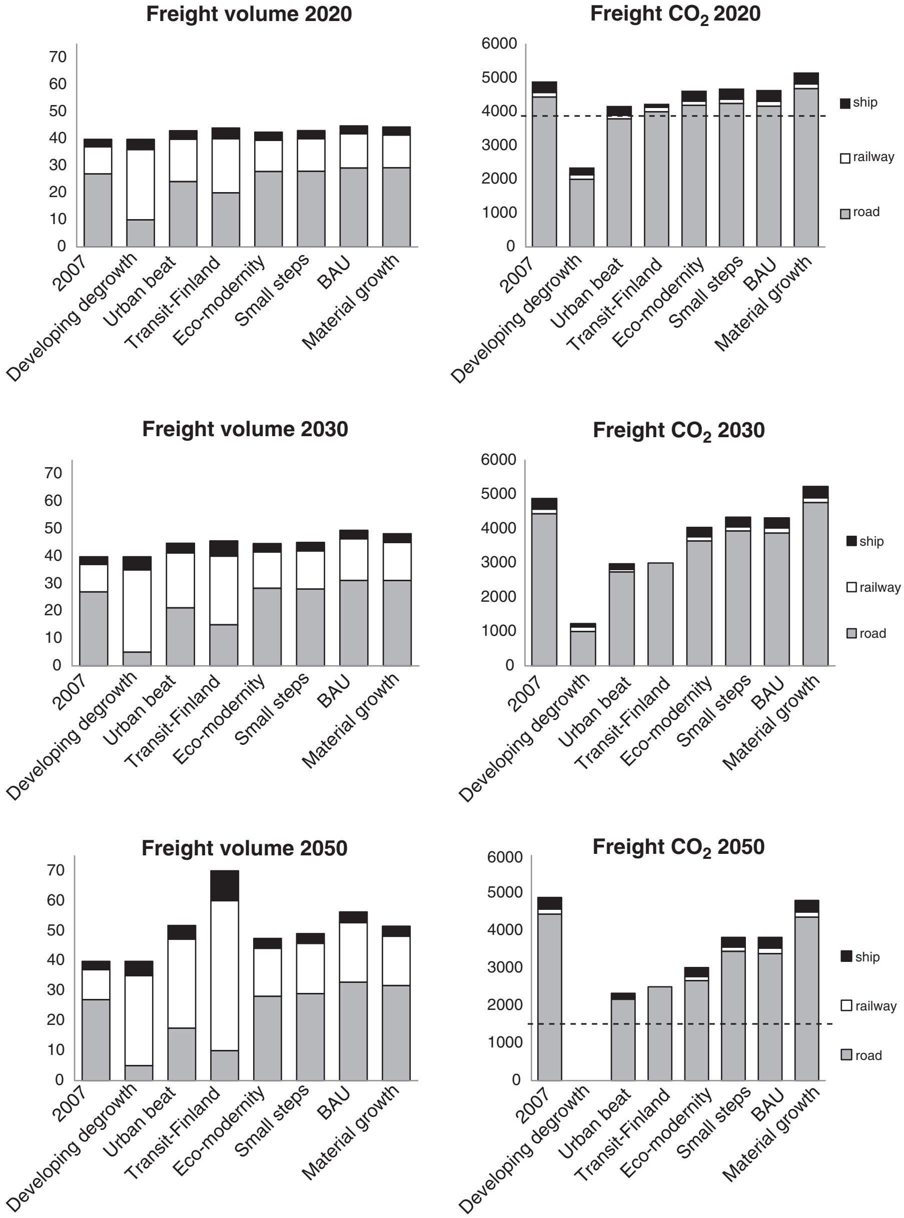


Fig. 8. Freight volumes (bn tn km) and CO_2 emissions (1000 tn) in 2007 and in seven scenarios in 2020, 2030, and 2050. Dotted lines signify (approximated) emission targets.

level, and the CO_2 emissions per km decrease as the technology improves. New car technologies spread fairly quickly, also to freight vehicles. While traffic volumes grow similarly to the next scenario "Material growth", emissions are lower. The share of biofuels rises more slowly than in the other scenarios, as the globally rising food prices, for example, slow down their production.

7.7. Material growth

The "Material growth" scenario is pessimistic in terms of emission reductions. The economy grows fairly fast. The urban sprawl continues, and two- or three-car-households become more common. Traffic volumes continue to grow, in particular the use of private cars. Automobile technology develops relatively slowly. Public transportation use develops slowly, compared to the other scenarios, as fares go up and the service declines. Airplane travel increases. The costs of driving rise due to higher taxation based

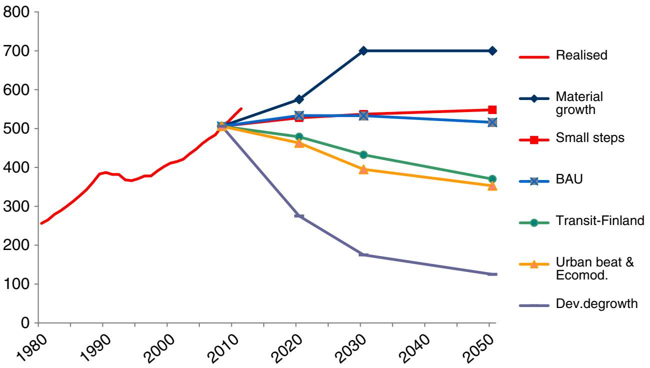


Fig. 9. Car density in mainland Finland in 1980–2011 [79,80] and six scenarios for 2008–2050.

on car use, and as a result of rising fuel prices. CO_2 emissions grow slowly at first and turn to a very slow decrease after the year 2020. However, the rising cost of oil supports the increasing use of biofuels. Overall, a very unambitious climate policy is adopted.

8. Comparison of scenarios

The passenger transport volumes and CO_2 emissions in the scenarios are shown in Fig. 7. Passenger transport volume growth rates are reduced in many scenarios and modal splits will change mostly in favour of public transport and soft modes. Domestic aviation has a seemingly low growth potential.

Similarly, transport volume and CO_2 emissions are shown in Fig. 8 for freight transport. The traditional pulp and paper industry was widely seen to be in decline in Finland, which might reduce freight volumes. However, new mining initiatives could bring a lot of heavy loads, particularly to railways. Certainly Finland aims to high technologies, such as nano- and bioindustries, but it is uncertain where the new growth is coming from, and whether it means less material-intensive economy in the future. Some scenarios include very high freight volumes. As most of the experts indicated that the service economy and other type of non-material economic growth are essential in the future, this is a rather confusing result. In the Transit-Finland scenario, the large freight volume would result from an increasing transit, e.g., between Russia and central Europe.

The emission targets are shown in Figs. 7 and 8 for 2020 (−15% from the 2005 level) and for 2050 (−60% from the 1990 level) as dotted horizontal lines. They are approximations, as the emission targets have been set for the whole transport sector, not for passenger and freight transport separately. Also, the 2050 target expressed in the EU White paper [44] has not been allocated for individual countries. In addition, our figures only consider the most important greenhouse gas CO_2 and only domestic transport, and the background data do not follow the IPCC guidelines exactly.

Even with these reservations, it is notable that in only two of the seven scenarios the emission targets are reached. Clearly, there is a significant doubt among the Finnish transport experts that the emission reductions will be achieved. However, a number of experts still consider it possible that transport volumes, modal split, and emissions will undergo radical changes.

Significant changes can occur in various ways. Technological change is clearly one driving factor. However, Finland is a small market for cars with practically no domestic car industry, and it is clear that other countries and their policies will have a larger role in determining the innovation process. CO_2-based car taxation (introduced in Finland in 2008) will help to increase the share of cars with lower emissions in the fleet.

Passenger car density has been rising for decades in Finland, although the severe economic depression of the 1990s slowed down the trend. According to one interviewee, with the increasing number of two or even three-car-households, the car is becoming a personal good rather than a household commodity. Assumptions about the car density differ greatly between the scenarios, as illustrated in Fig. 9. The realised development in 2008–2011 shows an even higher growth rate than the Material growth scenario. The growth is partly due to the reduction of average car acquisition tax when the CO_2 emission based progressive tax was introduced in 2008 [81].

It is also notable that no experts envisioned high transport volume growth and a technology leap that would solve the emission problems. Even in the long run, changes in infrastructures and behaviour that would reduce transport needs and change the modal split were seen to be of paramount importance. Sometimes experts are overly pessimistic about the environmental values of ordinary people, and assume that failure to choose environmentally benign options results only from lacking environmental consciousness, disregarding other factors influencing choice e.g. [82]. In this study, however, experts emphasised the importance of routines and practical difficulties involved in changing transport behaviour.

9. Discussion of methodology

In this final section we reflect on the risks, possibilities, and practical considerations of choosing or using the Q_2 scenario technique. First, we think that the method is best suited to situations where

- the topics addressed are at least partially quantifiable, particularly when there is data about past development of the quantified measures,
- the purpose is to create diverse scenarios by mapping different expert views rather than to draw the future images from the literature, workshops, etc.,
- mathematical modelling is not considered appropriate as, for example, it is expected or hoped that the relations of key variables will change in the near future, i.e. there can be radical changes in how the system operates,
- there is a willingness to add new topics into the process along the way,
- there is a willingness to integrate qualitative and quantitative data on an equal basis.

The method could be used in an enterprise to expand its strategic planning to consider the future of the whole business branch. In such a case, both internal and external expertise would be sought for to consider factors affecting the field. However, the most likely use for the technique is to examine the future of a relatively large and complex societal or economic sector. Examples of such are the education services of a large city, the paper and pulp industry in a country, or the activities causing nutrient emissions into an inland sea.

9.1. Broad expertise and quantified estimates

In the Q_2 scenarios, quantitative estimates are needed. It can be difficult for laypeople and experts of various fields to give estimates about numbers they do not normally have any contact with. Simultaneously with this project, there was a study exploring the views of Finnish high-school students about the future of transport [52]. The adolescents were able to vision many kinds of futures and to consider many trends and policies that might affect the future when writing a qualitative essay on the topic, but their numerical estimates were quite conservative. They seemed to be anchored much more in the background data provided by the researchers than the experts were in our case study.

In the case of the share of biofuels, showing the past trend to the experts caused some confusion. The share of biofuels of transport fuels was very low (under 0.05%) in 2007. After that, the share has been growing fast (some 2% in 2008), as a result of the EU biofuel policy. Those who relied on the past trend gave very low estimates also for the future, whereas others based their views on the policies and gave much higher estimates. Having the interview after the respondent has filled in the questionnaire in round one is useful: it was possible to address this issue, and respondents were able to change their answers if they wished. The interview acts much like another Delphi round. Interestingly, some respondents were very reluctant to change their answer, even when provided with new information.

In general, the experts exercised a form of self-critique: if feeling unable to estimate a trend, they chose not to answer. If the questionnaire was filled in only partially, it was still possible to use the given answers, thanks to itemising variables into themes and clustering the themes separately.

In some cases, the respondents did not give quantified answers at all. Their qualitative perceptions, arguments, and expertise could be included into the scenarios with the help of the Q_2 technique. Through interviews, also lay people might be incorporated into the scenario construction.

9.2. Risks and possibilities of the Q_2 technique

The Q_2 method carries within it a risk of *incoherence* in scenarios. A panellist may have difficulty in considering how all the answers to individual questions might affect one another. For example, we asked for the development of the volume of each transport mode separately, and a few respondents had some difficulty in considering the total transport volume. Itemising the variables through cluster analysis and combining them into scenarios may also cause slight inconsistencies. For example, the vehicle cluster with the lowest CO_2 emissions from new cars had the value of 25 g CO_2/km. Combining this with the concept of zero emissions in the Developing degrowth scenario is not entirely logical, unless all fuels would be emission free. A practical solution would be to simply make some minor adjustments to the scenarios, and not use only the exact numbers from the cluster analysis.

There are sources of *uncertainty* that are often considered in mathematical models, such as the statistical variation, or disagreement among experts about the form of the model e.g. [83]. These are important when e.g., the IPCC estimates impacts of CO_2 emissions to the global climate. However, our scenarios are based on the heuristic contribution of a panel of experts without formal models. The scenarios are used to broaden our concepts of what is possible and to inspire discussions about future possibilities and actions that could be taken to direct the future. Therefore the differing estimates of the experts should not be seen as indicators of sensitivity analysis of uncertainty, but rather as reflections of the fundamentally uncertain future.

However, there are elements in the technique that can affect the quality of the scenarios. These rise from the *intersubjectivity* of the research group. First, the way quantitative variables are combined into themes is based on the theoretical understanding of the research team. Second, the number of clusters chosen is a partly subjective process, as is the identification of qualitative variables and their alternative future states. Finally, there are myriad possible ways of combining the elements of the futures table, and it is necessary to limit the finished scenarios to a manageable and informative number. However, the inclusion of the futures table to the project report helps to counter this risk of "wrong" compilations, as it is always possible to create new scenarios from the existing future states.

A clear drawback of the Q_2 method is that it is fairly *time consuming*. If there are a lot of questions, it requires much time and effort on the part of the panellists, who need to fill in questionnaires as well as answer interview questions. When done properly, the analysis of the interviews is also quite time consuming. The use of the futures table to produce scenarios, on the other hand, is intensive but not particularly slow.

Despite the time they require, we believe that the interviews are extremely useful. First, they are likely to produce much more material and innovative arguments than open questions in the questionnaires do. Second, the qualitative material refers to the same future images as the quantitative material, and this can be assured by keeping the questionnaire handy and referring to it during the interview. Third, the interview can be used as a sort of extra Delphi round, as answers in the questionnaire can be modified during the interview. Fourth, as the interviews are conducted in between the rounds, it is possible to use them to find relevant Delphi questions for the final round. And finally, the interviews can later be used for additional analyses of expert views, and not just for the construction of the scenarios.

9.3. Quality criteria for scenarios

In all, we believe that the possibilities of the Q_2 scenarios make overcoming the abovementioned risks and practical problems a worthwhile pursuit. We consider these possibilities by addressing some quality criteria for scenarios that have been provided e.g. by Xiang and Clarke [23]. They consider "*plausible unexpectedness*" to be one of the most important. In our application, the Q_2 scenario methodology was able to produce scenarios that even surprised the research team, and yet were plausible. It is clear that some readers might not consider, for example, the Developing degrowth scenario plausible, as it combines economic decline with rapid technological development. If we only wanted scenarios that everyone could find believable, however, there would hardly be need for a Delphi panel at all. The unexpectedness is what makes the process worthwhile.

Unexpectedness is closely linked to another criterion that Xiang and Clarke [23] consider, namely *diversity*. Q_2 scenarios are particularly good for producing this, as the method looks for variety in views rather than consensus. Asking for both probable and preferable futures from each respondent is central in producing the variety of views as it allows the stretching of the imagination. Some of our respondents were clearly more able to make the distinction than others. A few respondents also confused the probable with a business-as-usual-scenario, describing a future they did not, after reflection, consider the most likely. Asking for two different views helped the respondents to envision what *might* happen, and what it would require. This was particularly evident in the interviews, where people often explained the differences between the two: "I hope that *x* happens, but I suspect that only *y* will happen, because…" This produced lot of interesting material for the scenario construction.

Transparency has also sometimes been considered an important criterion for scenarios [84]. Transparency of the scenario process can be increased by using an expertise matrix and the futures table. In the futures table, it is possible to see the alternative future states of each scenario variable, even though they cannot be named and detailed in such descriptive texts as we have used in Section 7. Similarly, having the expertise matrix as an Appendix in a research report, for example, allows an interested reader better understanding of the composition of the panel.

One important criterion for the quality of scenarios is whether they can effectively be used in *decision-making processes* [23]. The combination of qualitative and quantitative materials is particularly suited for this purpose. The quantitative elements make the scenarios comparable and, in many cases, allow them to be compared with policy targets. At the same time, qualitative elements such as policies and cultural changes can be incorporated into the scenarios.

However, the method is not suited for testing or showing causal relations. It is not possible to estimate, for example, what the probable quantitative impact of a given policy would be. The method is suited for producing alternative visions of a complex whole. These can be used in public discussion and policy-making as such, but they can also be used as the base for further analyses.

The 2050 end states of our scenarios are being used in the sister project run together with VTT Technical Research Centre of Finland. It is a backcasting exercise, commissioned by the Finnish Ministry of Transport and Communications. VTT estimates what kind of policies would be needed to reach the end states and when they would have to be applied [52,85]. It is a fascinating example of combining a Delphi study of rather comprehensive expert views with modelling.

Acknowledgements

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Appendix A. Expertise matrix

Respondent code		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	Total
Expertise on the topic																																				
Expertise in*	Freight							x	x							x						x									x				x	6
	Passenger				x		x	x	x			x					x	x			x	x					x			x					x	12
	Fuels		x																		x			x	x									x		5
	Motor technology											x					x				x															3
	Land use			x						x	x								x											x			x			6
	Behaviour													x																x						2
	Societal development						x	x							x																					3
	Other					x							x		x		x		x	x		x			x				x		x	x				11
	Generalist	x		x				x												x						x		x								6
Tr. mode that represents/is particularly familiar with	Car											x						x			x						x									4
	Bus																x																			1
	Truck															x																				1
	Rail							x														x														2
	Airplane								x														x													2
	Ship												x																		x					2
	Soft modes																		x	x																2
Field of education*	Transport engineering				x					x	x			x		x	x					x				x		x		x						10
	Other engineering												x						x												x		x	x	x	6
	Economic	x														x							x		x											4
	Social scientific and humanistic		x			x	x	x							x			x		x	x							x								9
	Environmental			x					x														x	x					x							5
	Other											x															x					x				3
Level of education*	PhD/licenciate							x					x	x																x	x					5
	MSc/MA	x	x	x	x	x	x		x	x	x				x		x	x	x	x			x	x	x	x		x	x				x	x	x	23
	BSc/BA											x				x			x	x								x								5
	High school etc.																				x						x					x				3
Background organisation	Administration	x	x	x	x	x	x	x		x	x	x	x																				x		x	13
	Politics														x																					1
	Interest group															x	x	x																		3
	NGO																		x	x																2
	Media																				x															1
	Business								x					x								x	x	x	x	x	x	x						x		10
	Research																												x	x	x					3
	Other																															x				1
Additional sample characteristics																																				
Gender	Male	x	x		x	x		x	x	x		x	x		x	x	x	x	x	x	x	x		x	x	x	x		x					x	x	24
	Female			x			x				x			x									x					x		x	x	x	x			10
Age	<30																															x				1
	30–39						x			x		x		x	x				x	x								x			x					9
	40–49		x	x												x	x					x	x		x	x	x			x				x	x	12
	50–59	x			x				x		x		x								x								x				x			8
	60+					x		x										x						x												4

*Some fields have a total larger than the number of respondents, because a few respondents had e.g. several degrees from different disciplines.

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