SUSTAINABILITY: SCIENCE, PRACTICE AND POLICY
2025, VOL. 21, NO. 1, 2446079
https://doi.org/10.1080/15487733.2024.2446079

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RESEARCH ARTICLE

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Feasibility of sufficiency-policy instruments: an assessment using impact chains for the German mobility sector

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ABSTRACT

The transport sector is not on track to meet the Paris Agreement climate targets. Rapid decarbonization of transport requires fuel switching and energy savings through modal shift and demand reduction – which are the aims of transport-sufficiency policy. We analyze passenger transport-policy instruments collected in the European Sufficiency Policy Database. Applying the concept of impact chains, we examine the ways in which proposed policy instruments function from cause/policy stimulus to effect/impact, with a focus on the factors relevant to the feasibility of policy implementation in Germany. This allows us to compare implementation feasibility by policy target and by instrument type. Based on our analysis of supporting factors, barriers, and risks, we find that policy instruments with many supporting factors also tend to have many barriers and risks. This is often the case with broad instruments that have diverse relevant factors. We observe that the policy targets "promotion of active modes" and "reduction of motorized individual transport" have the fewest risks because they tend to be less intensive in cost, material, and labor. Feasibility also varies between instrument types, with regulatory instruments unexpectedly showing the fewest risks and a similar number of barriers as economic instruments and as many supporting factors as fiscal instruments. This analysis enhances the understanding of which policies are easier to implement and how feasibility is interconnected with other instruments.

ARTICLE HISTORY
Received 30 July 2024
Accepted 19 December 2024

KEYWORDS
Policy instruments; sufficiency policy; impact chains; barriers and risks; Germany

Introduction

Increases in global temperature are rapidly approaching the target levels (WMO 2024) set by the Paris Agreement (UNFCCC 2021), and the remaining greenhouse-gas (GHG) emission budgets that can still be emitted without exceeding the limits are diminishing (IPCC 2022). In addition, the rates of decarbonization and decoupling emissions from growth of gross domestic product (GDP) are currently not on track to achieve climate targets (Vogel and Hickel 2023). Literature has thus highlighted the need to employ demand-side strategies next to supply-side strategies (Alfredsson et al. 2018; Creutzig et al. 2016; Sugiyama et al. 2024), and that these strategies are available (Creutzig et al. 2021, 2016) for the reduction of energy-consumption levels while at the same time maintaining high levels of well-being (Creutzig et al. 2022; Grubler et al. 2018; Millward-Hopkins et al. 2020).

Demand-side strategies can be differentiated according to technology-based energy efficiency and sufficiency approaches that focus on avoiding and reducing activities and services that need energy and resources (Lage 2022; Princen 2005). The Intergovernmental Panel on Climate Change (IPCC) defines sufficiency policies as "a set of measures and daily practices that avoid the demand for energy, materials, land, and water while delivering human wellbeing for all within planetary boundaries" (IPCC 2022). Parallel to the efficiency strategy, sufficiency also requires a consistent and conducive policy framework as an enabling condition (Spangenberg and Lorek 2019; Spengler 2018).

Other than renewables and efficiency-policy instruments, there is comparatively little research on instruments that promote sufficiency. In Germany, there is a discourse on the necessity of sufficiency, mainly led by nongovernmental organizations (NGOs) and scientific actors, backed by a recent paper by a governmental advisory council (Michaelis et al. 2024). The German Citizens' Assembly on Climate recommended quite a number of sufficiency

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/15487733.2024.2446079.

policies (Lage et al. 2023) and NGOs propose further instruments like Breidenbach et al. (2022). However, sufficiency currently plays almost no role in German politics (Zell-Ziegler et al. 2021) and sufficiency instruments are not systematically included in policy databases (Best et al. 2022). The European Sufficiency Policy Database (Zell-Ziegler et al. 2024) is the first collection and systematic categorization of sufficiency-policy instruments proposed in the literature. It encompasses more than 350 policy instruments from all sectors – industry/production, transport, buildings, land-use/food, and cross-sectoral – along with sources and, where available, additional information such as implementation examples and mitigation potentials.

For the implementation of policy instruments – from proposals to practice – two questions are key: 1) which instruments of this array are more or less feasible in their implementation and 2) what might their actual impact be? Answers to these research questions constitute a research gap because sufficiency-policy instruments have not yet been widely implemented (Lage et al. 2023) and ex-post evaluations are scarce. Through our work, we aim to close the first gap and to research the feasibility of implementing sufficiency-policy instruments by analyzing enabling and hindering factors, as well as needed inputs and potential revenues. To this end, we consider the chain from the initial decision to implement the policy instrument to its expected impact. However, a high feasibility of a policy instrument does not necessarily mean it has a high impact, or vice versa. Assessment of the size of impacts and cost-benefit analyses would require information on quantified impacts in their respective units, costs, mitigation potentials, and other side impacts. This is not available for proposed sufficiency policies and does not fall within the scope of this article. We thus use the qualitative assessment of the logic chains from stimulus to impact to analyze the feasibility of policies, without quantifying impacts themselves.

We thus add to the growing body of literature on the barriers and success factors of sufficiency-policy instruments from a German perspective. Existing literature analyzes case studies (Bocken, Niessen, and Short 2022; Böcker et al. 2021), use surveys, expert interviews. and other stakeholder engagement to assess potential barriers and success factors (Gaspar et al. 2017; Lage and Graef 2022; Tröger and Reese 2021). Our analysis adds knowledge by deploying a combination of literature-based evidence from case studies and expert interviews to assess the feasibility of selected sufficiency-policy instruments.

On the causal path from a decision to implement a policy instrument to its ultimate outcomes and impacts, a range of factors may either support or hinder its successful implementation, and required inputs vary widely (DeGroff and Cargo 2009). There is a broad set of possible evaluation methods in the field of policy evaluation (Sager et al. 2021; Varone, Jacob, and Bundi 2023). Using a qualitative approach, we chose the method of logic models that represents the theory of change in the form of impact chains. This approach allows us to analyze – and, if possible, quantify – the steps from a policy stimulus and induced activities to outputs and outcomes and final impacts. There is a range of publications with recommendations for policy evaluation, many of them explicitly highlighting impact chains like Gertler et al. (2016), OECD (2020), or for German public policy evaluation Schlomann et al. (2020). The concept of impact chains is frequently used in different contexts like international development aid (Wörlen 2023) or evaluation of local infrastructure improvements (Paar et al. 2023). Another broad application area for impact chains is risk assessment, for example climate or flood-risk appraisal (Piet et al. 2015). In the field of sufficiency, the impact chains have been proposed as an analytical tool (Zell-Ziegler and Thema 2022) that allows for an assessment of implementation feasibility for single policy instruments and points out possible adverse effects that need specific policy attention.

The transport sector is especially challenging to decarbonize. Ddespite increasing efficiency (decreasing specific per-kilometer (km) emissions), total German transport emissions have been largely stagnating (Umweltbundesamt 2024a), a consequence of an increasing car stock from 36.7 million in 1995 to 49.1 million in 2024 (BMVBS 2009; Kraftfahrt-Bundesamt 2024) and steadily increasing passenger and freight-ton kms (Umweltbundesamt 2024b). This calls for additional transport sufficiency-policy instruments.

We assess the implementation feasibility using the impact-chain method. Application of the method and analysis of required inputs, supporting factors, barriers, and risks is only possible with respect to a specific case, reflecting local infrastructure and stock conditions, political and public discourses and cultures, investment conditions, and existing policy frameworks. We thus analyze German passenger transport as a typically challenging decarbonization case in a high-income country and the largest GHG emitter in the European Union (EU). Our research questions are:

1. How might particular (proposed) policy instruments work from cause to effect, and what can be derived for implementation feasibility?

2. Within a particular policy target, how do individual policy instruments differ in terms of their implementation feasibility?
3. Does implementation feasibility vary between instrument types?

In the next section, we outline the method and data we use and the procedure to set up the impact chains in detail, including definitions and examples. We then present the results on different scales, from the perspective of single policies to the difference between policy targets or instrument types. In the final sections, we discuss the limitations of our method and draw conclusions, as well as future research needs, from the analysis.

Material and methods

Impact-chain concept

We apply the impact-chain method (Zell-Ziegler and Thema 2022) and set up chains for transport sufficiency-policy instruments that are focused on Germany. Figure 1 shows the impact-chain steps from stimulus-activity-output and outcome to impact, including definitions of the steps. The assessment starts with the decision to implement a policy instrument by, for example, changing a law, setting up a fund, or building new infrastructure under the current framework conditions in Germany. How the decision to implement a policy instrument is reached does not fall within the scope of this analysis.

According to our concept (Zell-Ziegler and Thema 2022), several factors are of high importance for the implementation feasibility of a policy instrument; see the elements linked to the main chain with thin arrows in Figure 1. First, inputs and revenue or reduced state expenses can be relevant at different stages of the chain. In our analysis, we define inputs as "all relevant means and efforts to reach the intended effect of the proposed policy." For this analysis, we differentiate between administrative, financial, staff, material (physical), and other inputs. Revenues are defined as government revenues that can take the form of higher or new tax revenues. Reduced state expenses can result from, for example, abandoning tax rebates.

Second, important external factors describe the interaction of the (potential) implementation of the policy instrument with society and the economy. The external factors are categorized as supporting factors, barriers, and risks; they are referred to as "factors" in the following discussion and defined as follows:

- Supporting factors: Circumstances and other factors that (can) contribute to the success of the policy. These can also be other policy instruments that have already been implemented.
- Barriers: These lower the effectiveness of the policy but can be overcome and will not lead to its failure.
- Risks: Essential factors that may lead to failure of the policy.

Examples of the factors are provided in Table 1. In addition to instrument-specific factors, there are factors that influence all transport policies in general. These include the high economic importance of the car-manufacturing industry (VDA 2024) in Germany and its vested interests (Haas and Sander 2020), or EU-level regulations influencing fuel-price structures. These general factors were not added to every policy impact chain because we focus on the differences in implementation feasibility, and factors relevant to all policies under study are not necessary within our method.

Data and sources

Our database is the European Sufficiency Policy Database of the Energy Sufficiency Research Group (EnSu) (Zell-Ziegler et al. 2024), which is continuously updated. We use a fixed version from June 6, 2023. By this date, it included 110 sufficiency-policy instruments in the transport sector. Entries included since

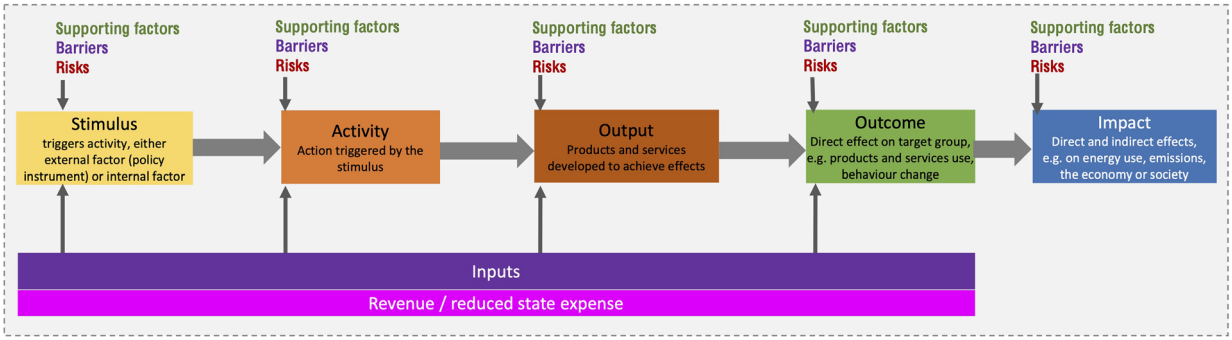

Figure 1. Impact-chain model.
Source: Adapted from Zell-Ziegler and Thema (2022)

Table 1. Coding of weighting factors of supporting factors, barriers, and risks.

Supporting factors		Rationale for coding	Example
Importance	High	Play an important role in the successful implementation of the policy instrument	Existing frequent public transport to enable mode shift when car access to cities is restricted or becomes more expensive
	Medium	Play a medium important role in the successful implementation of the policy instrument	Existing taxation or incentive schemes are already in place to support mode shift, but their price signals are often too weak to lead to behavior change
	Low	Play a subordinate role in the successful implementation of the policy instrument	Policies are promoted in media campaigns by NGOs
Factor typically in place/true	Yes	Is found in many places	Existing parking management in most German cities; implementation examples: implemented in very many places (like most of the neighboring countries)
	Partially	Is found in some German/other European cities	Good practice examples like car-free city centers implemented in a few places (in other European countries)
	No	Factor does not exist to date	Understanding of mobility provision as a common good
Barriers/Risks			
Influence	High	Very relevant hindering factors for the implementation of the policy instrument	Limited availability of (road) space for conversion to infrastructure for other modes/non-availability of staff for construction
	Medium	Medium-relevant hindering factors for the implementation of the policy instrument	Instrument-specific bureaucratic obstacles/safety issues from illegal parking associated with increased parking pricing
	Low	Subordinate hindering factors for the implementation of the policy instrument	Difficulties in setting up a company-internal sharing platform for mobility management/legal complications due to double taxation when introducing new aviation-carbon taxes
Occurrence probability	High	Will occur with a high likelihood	Political opposition against policies that limit car or air transport/lack of long-term financing for certain policy instruments
	Medium	Will occur with a medium likelihood	Low population density renders public transport uneconomic/rebound effect that, for example, reduces the net positive impacts due to resource needs for remote working equipment
	Low	Will occur with a low likelihood	Wild parking on the streets when reducing obligatory parking spaces per apartment/no good long-distance alternatives to air transport exist

the cutoff date are not expected to have a systematic effect on the results. The policy instruments either have already been implemented in at least one European country, region, or city or are proposed in the literature. They are grouped into seven policy targets, disaggregated into single measures/actions. The policy targets were derived by inductive categorization from the entries in the policy database by database authors. As an example, the policy target "reduce motorized individual transport" includes the measures/actions "reduce parking in public space," "disincentivize car acquisition/ownership," and 11 others. Four individual policy instruments, like a premium for car scrapping (ID 347, see more details in the Supplementary Material), are listed for the latter measure/action. The meta-level policy target "setting sector limits" was not considered in this analysis; the six other policy targets are included. An overview of these policy targets can be found in the six tables A1–A6 in the Appendix – one per policy target with all relevant information on the respective associated policy instruments.

In addition, the policy instruments are categorized into nine instrument types according to the United Nations Framework Convention on Climate Change (UNFCCC 2000). Sometimes, more than one instrument type applies. In this case, we selected the instrument type which leads to the outcome and impact of the policy instrument. The structure of the source-policy database, as well as the definition of the sufficiency types (including examples and more), is detailed in Best et al. (2022). From the 110 policy instruments, we excluded 17 due to their very indirect impacts, unspecific descriptions, or because they were too closely interlinked with other policy instruments, which did not justify a separate impact chain. With a view to the instrument-type categories, we also excluded 10 policy instruments with a very low number of entries (e.g., voluntary agreements), which would not allow for a reliable comparison. This left 83 policy instruments as our analysis base. Eleven of these policy instruments are of the economic instrument type (e.g., taxes, tradable certificates, market reform), 32 are fiscal (e.g., subsidies and grants, tax exemptions and public expenditures for infrastructure), and 40 are regulatory (e.g., laws, standards and product identification; all explanations according to UNFCCC (2000)). These numbers are sufficiently large to compare and draw conclusions for the overall policy target or instrument-type categories. We thus analyze regulatory, economic, and fiscal ones but exclude other instrument types with only a few entries. All details about the analyzed policy instruments can be found in the Supplementary Material.

Methods and procedures

For setting up the impact chains including their relevant factors for the feasibility assessment, we proceeded as follows (see Figure 2).

First, for each of the 83 impact chains, one member of the author team, who is an expert in sufficiency and/or transport policies, filled in the impact-chain template with the first draft based on the information in the European Sufficiency Policy Database and the primary sources referenced therein. Second, in an initial revision, additional information on the policy instrument was added from a literature search (peer-reviewed, grey literature, and news articles on existing implementation examples) by another person. We list 288 substantiating literature sources in the Supplementary Material and not in the reference section of this article as it is very extensive. Third, in a subsequent revision, all aspects of the individual impact chains were discussed in detail by the author team including adaptions based on literature from the first revision step. We then revised the chains by adding missing factors, harmonizing the level of detail, and weighting of factors (explanation of these below) to ensure consistency. We applied a four-to-six-eye principle in this step within the author team. Fourth, we discussed two-thirds (67%) of the chains with ten transport experts outside of the author team. We conducted five online validation meetings – one per policy target (and one for two policy targets), with two experts each. The experts were all from Germany, working on transport research with Fraunhofer ISI, ifeu, Technische Universität Berlin, T3–Transportation Think Tank, Öko-Institut, and the Wuppertal Institute. The validation sessions lasted two hours. Prior to the session, validators received the session sample of policy instruments and a presentation of the aim, background, methods, and preliminary results. This presentation was given at the beginning of each validation session with a question-and-answer session. Expert revisions and suggestions were taken up with a view to the impact-chain definition; the inclusion of additional supporting factors, barriers, and risks; the exclusion of factors considered not relevant; and the adjustment of weightings. Fifth, we carried out follow-up research on issues resulting from the discussion and added examples, sources, and so forth to the impact chains. Furthermore, the additions and changes resulting from the validation were transferred to the remaining third of the impact chains (again using the four-to-six-eye principle). Finally, we set up the impact chains as follows.

For an aggregated view of the policy instruments, we rate the input as high, medium, or low, compared to other instruments' input levels. In the tables of results (see Appendix Tables A1–A6), we show the highest rating that a policy instrument has for any of its inputs.

The feasibility comparison of policy instruments requires a comparison in numbers of enabling and hindering factors. However, simple sums are not suitable because not all factors are equally important. For this multicriteria assessment, we thus systematically applied the weighted sum-model method (Triantaphyllou 2000). For each supporting factor, barrier, and risk, we use two weighting criteria that are equally important. Each criterion has fulfillment levels on a 3-point scale.

For *supporting factors*, we used the following criteria and qualitative weighting:

a. Importance, with possible values of high-medium-low, and
b. Whether the factor is typically in place, with the options yes-partially-no.

For *barriers* and *risks*, we used the following criteria and qualitative weighting:

a. Strength of leverage for each factor ("influence"), with possible values of high-medium-low, and
b. Occurrence probability, with possible values of high-medium-low.

In a second step, these qualitative assessments were operationalized into numerical weighting factors to allow for weighted aggregation and subsequent comparisons (Dittmer 1995; Triantaphyllou 2000). Table 1 provides details and examples of the coding of supporting factors, barriers, and risks. All assessments are only point estimates for the current situation and will change if framework conditions

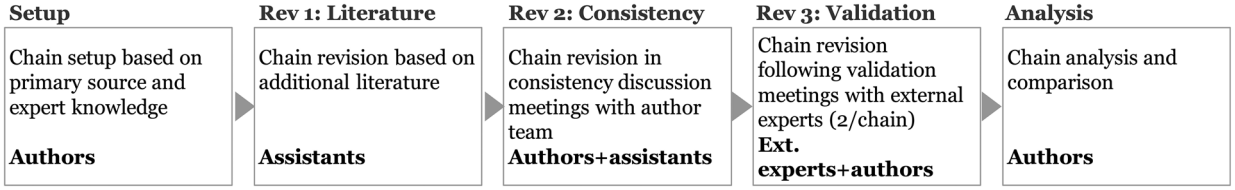

Figure 2. Steps of impact-chain setup and persons in charge.

such as infrastructure or political majorities change. In our assessment, we account for the sociodemographic and geographic heterogeneity within Germany: some factors are relevant only for certain subgroups (e.g., special circumstances of families and elderly or for low/high-income groups) or in certain regions like urban/rural regions or such with certain infrastructure availabilities. Our coding reflects this situation by coding these supporting factors as being partially in place and barriers/risks of medium influence and occurrence probability and specifying the respective subsets in the individual chain tables.

To operationalize the comparison of single policy instruments along the number of factors assessed and to properly visualize the results, we translate each qualitative assessment into quantified weights: the high-medium-low ordinal scale is turned into a 1–0.67–0.33 scale. We exclude zero from the scale as irrelevant factors that would not count in this case are not registered in our assessment. Respective values for importance, whether typically in place, influence, and occurrence probability, are then multiplied, yielding combinations of weighting factors of between 1 and 0.11. As an example, this is shown for supporting factors in Table 2. For barriers and risks, the same approach applies. Following the weighted-sum model (Dittmer 1995; Triantaphyllou 2000), the overall rating for each of the three types of factors (supporting factors, barriers, risks) is the weighted sum of all factors, applying their respective individual two weighting factors. To show our results, we translate the numeric outcomes of the weighting back into an ordinal scale, the three categories of which reflect the level of detail of our analysis, without suggesting a higher level of precision: * (low) means a result of weighted factors (supporting factors, barriers or risks) of less than 2; ** (medium) a result between 2 and 4, and *** (high) a result of more than 4.

Results

We present our results in four sections: 1) the structure of the filled-in policy sheets; 2) general-level findings from the analysis; 3) implementation feasibility results of single policies for each policy target and comparing policy targets; and 4) differences between policy instrument types.

Individual policy sheets

From our analysis of original sources along the steps outlined in the Methods section, we generated 83 table sheets with information on single transport sufficiency policy instruments, all available in the Supplementary Material. Individual policy sheets are referenced below using the unique ID of each policy instrument as applied in Zell-Ziegler et al. (2024). Here, we briefly outline the structure of the sheet. Figure A1 in the Appendix provides an example. The upper part of the table covers the core chain from the policy stimulus to impacts in a narrative description for most policies; GHG and energy savings; quality of life improvements in terms of air, noise, and green spaces; and fewer accidents. The second step in the chain, "activity," is the action triggered by the stimulus and, in most cases, involves administrative activity. The following "output" describes products and services developed to achieve intended effects. For certain policy instruments, this may also include the regulation or termination of certain products and services. Outputs then lead to "outcomes," the direct effects on the target group. This includes the use of products and services, behavioral changes, and so forth.

The middle part of the table covers the inputs required for each step in the impact chain and classifies them by type: administrative, financial, staff resources, material, or other. In addition, if the policy generates new or additional revenues, this is taken up.

Supporting factors, barriers, and risks are listed in the lower part of the table. We briefly describe each factor that is included in the column below the respective step in the impact chain. As outlined above and in Table 2, every included factor is qualitatively categorized regarding its importance and whether typically in place (for supporting factors) or regarding its importance and occurrence probability (barriers and risks). Key literature references are provided below the table. Qualitative assessments are operationalized into quantified weighted sums on the right-hand side of the table.

The description of policies in the original sources varies in depth of detail and specificity. Some are more generic and on a meta-level, others very specifically target existing regulations or, for example, propose concrete numbers for a mobility fund. We only included policies with a minimum level of specificity and tried to streamline the impact chains in this respect.

Table 2. Results of the combination of weighting factors, shown here for supporting factors.

		Importance		
		High (1)	Medium (0.67)	Low (0.33)
Factor typically in place/true	Yes (1)	1	0.67	0.33
	Partially (0.67)	0.67	0.45	0.22
	No (0.33)	0.33	0.22	0.11

Note: For barriers and risks, *importance* is replaced by *influence*; and *factor typically in place* by occurrence probability.

General findings on the impact chains and their characteristics

In our sample, the highest rating of weighted supporting factors and the highest rating of barriers (and of the sum of barriers and risks) come about for the policy instrument "target network plan and timetable" (see ID 247 in Supplementary Material and Figure 3). This policy comprises a package of different stimuli and aims to improve long-distance rail services in terms of network coverage and service frequency. The broadness of the proposed instrument explains the manifold factors that we identified because many supporting and hindering factors must be considered to assess its potential implementation feasibility.

We observe this as a general pattern: the broader a policy instrument, the more and diverse the supporting and hindering factors; the more concrete a policy instrument, the fewer the factors. This is true for many of the policy instruments analyzed in general, but not for every policy instrument: the scattered cloud shows a tendency toward a diagonal from the bottom left to the upper right corners in Figure 3, but with high variations. This figure plots the weighted sum of supporting factors on the x-axis with the categories few (*), medium (**), and many factors (***) against the weighted sum of barriers

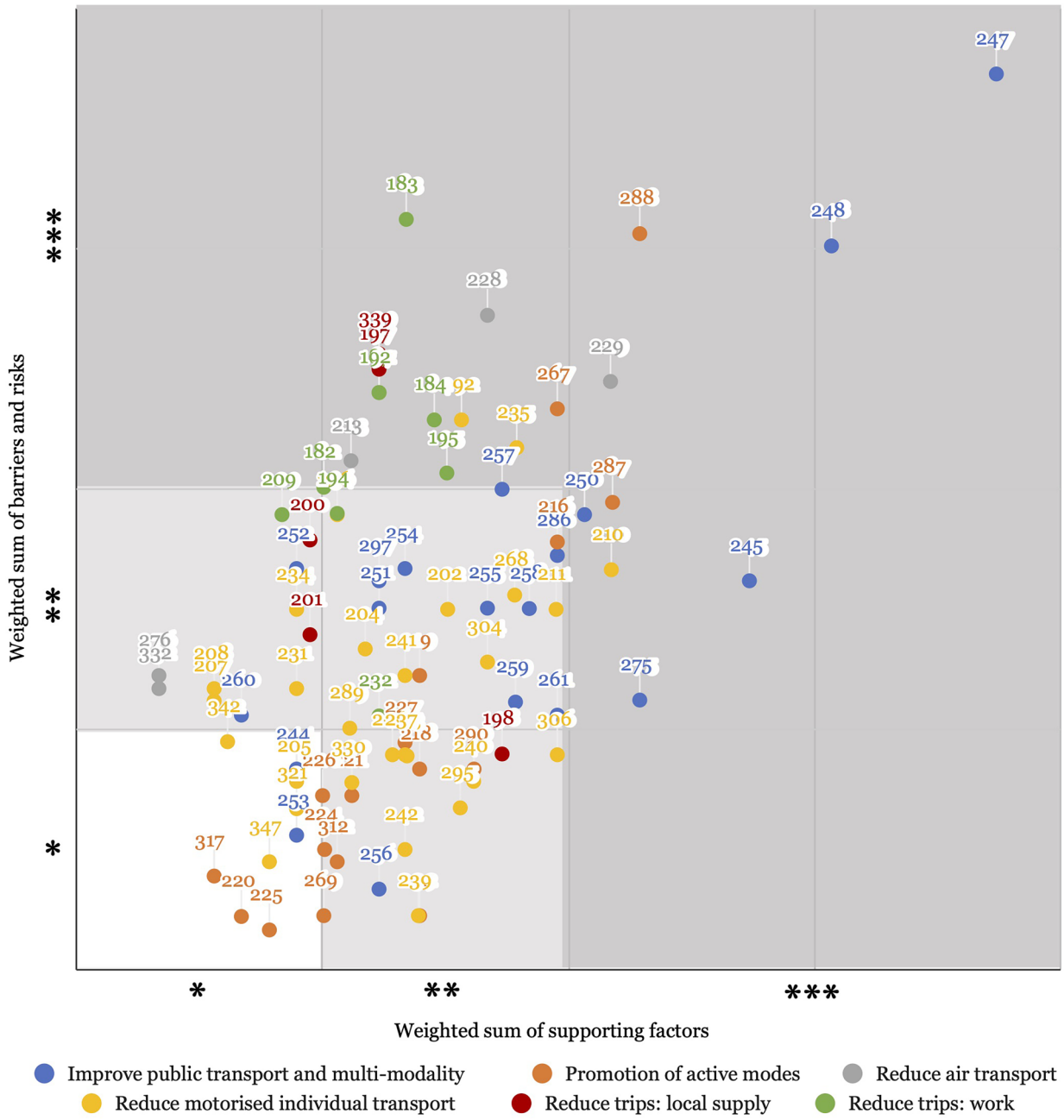

Figure 3. Weighted sum of supporting factors and of barriers and risks for all analyzed policy instruments, by policy target (color of dots).
Note: Numbers indicate Policy IDs according to Zell-Ziegler et al. (2024). * = few factors, ** = medium number of factors, *** = many factors.

and risks, with the same categories on the y-axis. Dot colors indicate the analyzed policy targets, and findings by policy targets are presented below.

The policy with the highest rating of weighted risks in our sample is "subsidized energy bills" (ID 183), a fiscal instrument by which employers compensate their employees when working from home in return for saved energy costs at the company site. Risks for this specific policy instrument include legal ones and potential rebound effects associated with working from home (see studies like Kreye et al. 2022) and additional income. Other risks for policy instruments are often a lack of qualified staff, very insecure long-term financing, and limits to the availability of rolling stock like additional buses.

We also observe policy instruments with none or very few factors, as indicated in the bottom-left quadrant in Figure 3. Particularly noteworthy is that 32 policy instruments (almost 40%) do not have risks at all, and one policy instrument ("electricity tax reduction," ID 256) does not have barriers.

Concerning the inputs needed to implement the policy instruments, 29% of all policy instruments need a high input, 47% a medium input, and 24% a low input. Thirty percent of the analyzed policy instruments generate revenue or lead to reduced state expenses.

The analysis of the impacts of covered policy instruments yields that all of them lead to GHG emissions and energy savings. This is not very surprising since mitigation of climate change is the precondition for being included in the European Sufficiency Policy Database. However, most policy instruments have additional expected impacts, mainly positive co-effects: almost 90% are expected to improve public health (e.g., less noise, better air quality), 20% to reduce (serious) accidents, 11% to generate other non-energy benefits like decreased land sealing and adaptation to climate change, and 10% with positive economic effects such as local employment generation or an increasing attractiveness of local city centers. One policy additionally leads to the protection of ecologically sensitive zones ("regulation on yachts, jet skis," ID 342).

Nevertheless, almost one-quarter of all analyzed policy instruments potentially lead to rebounds or other adverse effects like an increase in travel volumes (e.g., with a free public transport ticket) or displacement of flights to other airports (e.g., with a domestic flight ban). We included these effects as impacts in the main chain and as a risk factor. We furthermore find four policy instruments with unclear net impact on energy and resource needs, on which more research is needed. Taking these potential adverse impacts into account in the detailed development of the policy instrument is highly important to avoid them. A feasibility assessment based on our method can help to inform policy specifications.

Comparison of implementation feasibility by policy target

In this subsection, we present results based on the analysis of weighted supporting factors, barriers, and risks for all analyzed impact chains grouped by policy target. The results are visualized in three ways. First, Figure 3 shows policy instruments by policy target with colored dots, plotting weighted supporting factors against the sum of weighted barriers and risks. Second, for all six policy targets, we provide tables with the detailed results of all policy instruments concerning internal factors (inputs and revenues/reduced state expenses) and external factors (supporting factors, barriers, and risks) with an indication of the respective policy instrument type in the Appendix Tables A1–A6. The third and most aggregated visualization provides Figure 4, plotting weighted sums for supporting factors, barriers, and risks of all policy instruments as averages by policy target.

The following results present an assessment of the implementation feasibility of single policy instruments and not an impact assessment because impacts are not quantified. However, the results allow us to compare policies: many supporting factors and revenues and few risks and barriers, as well as low inputs, indicate a tendency toward the policies that are easier to implement than others. However, we cannot draw a direct recommendation for policy selection. This would require comparing the implementation feasibility and possible options to overcome barriers and risks with an assessment of impacts.

The policy target "improve public transport and multimodality" includes many fiscal policy instruments for improving infrastructures. These all need medium to high input (see Table A1 in the Appendix). Figure 3 shows that the policy instruments scatter widely. We find meta-level policy instruments (ID 247 "target network plan and timetable," and ID 248 "legal obligation for public transport frequency") with many supporting and also hindering factors in this policy target. We observe the highest averages for supporting factors for this policy target due to high stakeholder support for many policy instruments and co-benefits for health, see Figure 4.

For the policy target "promotion of active modes," the most striking is that 12 of 17 policy instruments

do not have any risks at all. This can also be observed in Figure 4, which shows that the average risks for this policy target are low. For barriers and supporting factors, the policy instruments mostly fall within the medium level, and inputs range from low to high. No economic instruments are included in this strategy.

For the policy target "reduce air transport," only low inputs are listed, but they all score above average in terms of the sum of barriers and risks (see Figure 3). This is because of counterproductive displacement effects or strategies by airlines to increase flights despite the possibility of a moratorium on airport expansion, as well as public and political opposition. No fiscal instruments are included here, and two out of five instruments generate revenues.

The policy target "reduce motorized individual transport" with most policy instruments shows a low average of risks (see Figure 4). Many respective policies exist in German cities or abroad that serve as good practice examples and thus support implementation. The main barriers are related to the opposition by car users, lobby organizations, and political parties. Half of all policy instruments generate revenues or lead to reduced state expenses.

Both policy targets to reduce the absolute number and distance of trips either through local supply improvement or through reducing trips to work stand out with low or medium supporting factors and (with the exception of ID 198, "support of public and private childcare in villages") medium to high barriers and risks (see Figure 3). ID 183 was already mentioned above; other main risks include the lack of staff and funds for the re-localization of services like education and healthcare. For the policy target "reduce trips: local supply," we find high input needs for almost all five policy instruments; for the policy target "reduce trips: work," almost half the policy instruments lead to reduced state expenses from avoided commuter tax-allowance payments.

Comparison of implementation feasibility by instrument type

With a view to the feasibility of different instrument types of proposed policies, our analysis finds high variations in terms of the supporting factors vs. barriers and risks plot (Figure 5), but also differences in instruments. We observe the highest variations for regulatory instruments, from low supporting factors and barriers/risks to very high numbers. Fiscal and economic instruments also spread widely, but not to similar levels, especially with a view to supporting factors. No economic instrument has low supporting factors and low barriers/risks. On average, regulatory instruments unexpectedly show the fewest risks and as many barriers as economic instruments and as many supporting factors as fiscal instruments. Fiscal instruments have the fewest barriers. Many risks of fiscal and economic instruments relate to financing,

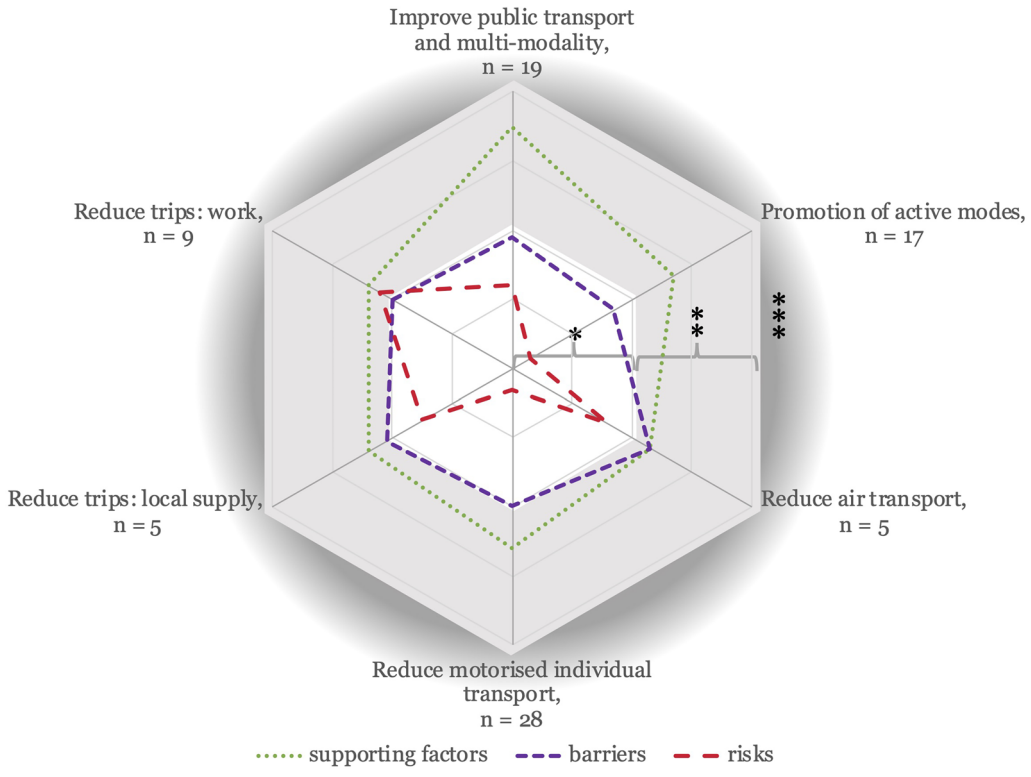

Figure 4. Supporting factors, barriers, and risks, average of weighted sums by policy target.

staff, or infrastructural requirements that are difficult to meet in the context of tight public budgets, shortage of skilled labor, and high construction prices. Many barriers to regulatory instruments relate to opposition by incumbent actors in the economy and politics and car users that constitute a majority of the population.

Discussion

In this section, we discuss the limitations of our method and, hence, the robustness of our results. The results of our analysis are time and context-dependent. The assessed factors may change following political and legal framework conditions, the implementation of complementary policy instruments, or other contexts. In particular, barriers can likely be reduced by implementing other policy instruments (Pahle et al. 2018). As an example, more attractive public transport will reduce barriers for car users to reach their points of interest without a car. Also, factors like opposition or support to policy instruments will vary over time, good practice examples of policy instruments will increase, thus promoting supporting factors. For the interpretation of our results, this context-dependency is important.

Regarding the validity of results, the feasibility assessment relies on the factors that we and the additional experts identified. The respective knowledge and mindset thus influence results. We

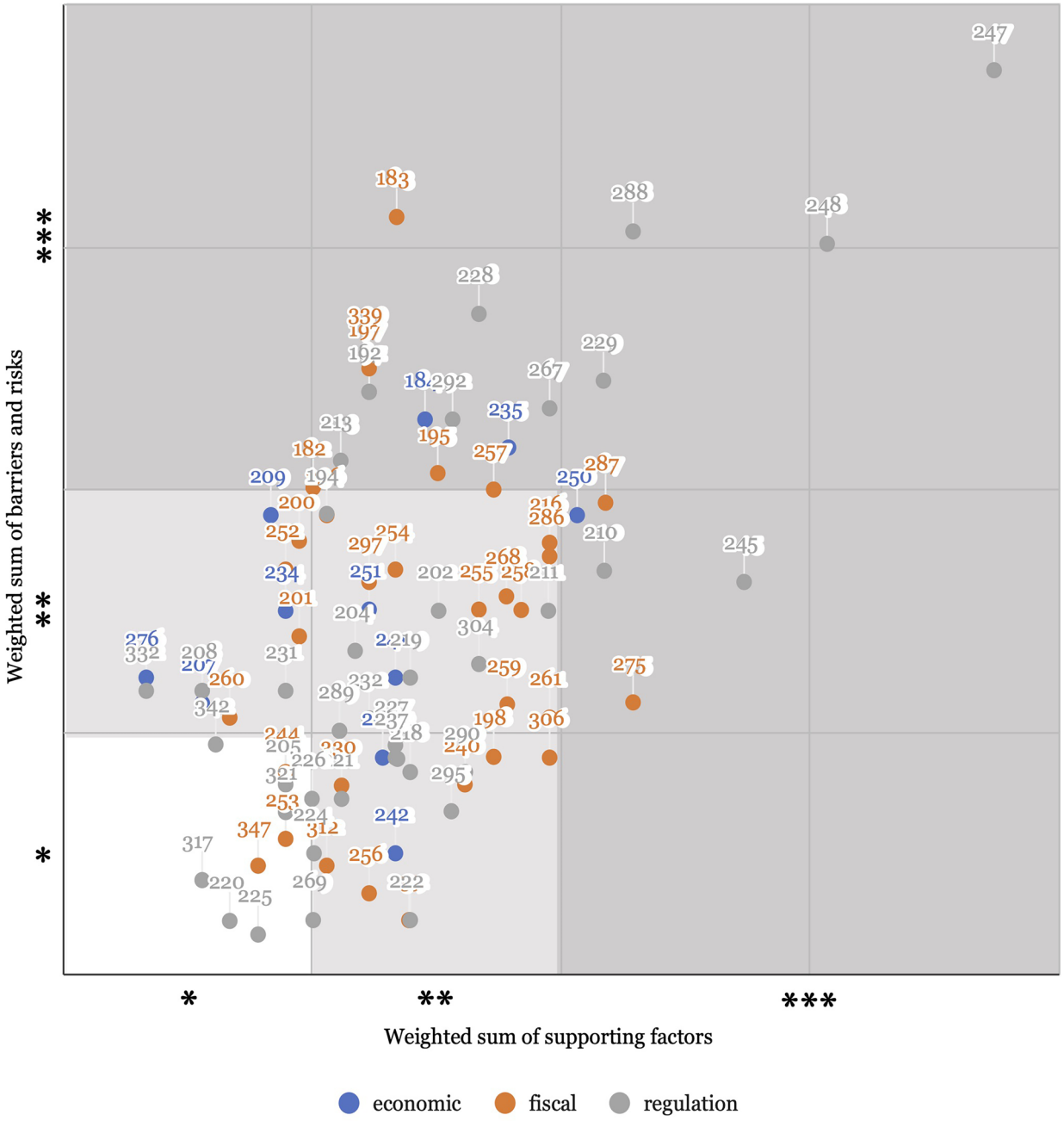

Figure 5. Weighted sum of supporting factors and of barriers and risks, by instrument type (color of dot).
Note: Numbers indicate Policy IDs according to Zell-Ziegler et al. (2024). * = few factors, ** = medium number of factors, *** = many factors.

transparently state that all contributors to this article work in scientific institutions, some of us for extended periods, and are concerned with climate change and planetary boundaries and convinced of the need for a socioeconomic transformation. This higher-level scientific viewpoint can complicate the identification of barriers and risks associated with actual implementation on the ground. To counter this potential shortcoming, to reduce subjective bias, and to increase the robustness of our results, we streamlined all impact chains in terms of detail, used a four-to-six-eye principle for all entries, and carried out expert validation with a total of ten independent transport experts.

Time, context-dependency, and the potential influence of our own and the additional experts' subjectivity, also led to limited replicability of the analysis. We counter this through maximum transparency of individual policy-chain assessments in the Supplementary Material. Our higher-level conclusions can be considered more robust due to the large number of impact chains on which they are based.

For the impacts at the end of impact chains, we focused on those related to climate change and energy consumption, as well as improvements to public health, safety, and local economic impacts. There are, however, more indirect impacts that we could include, such as social participation through free public transport. Adding all potential indirect impacts was outside the scope of our analysis.

Finally, our approach allows for a feasibility assessment but not a full impact assessment. This is due to the lack of quantified GHG and energy-saving potentials, which are not yet available for many proposed sufficiency policies. Our impact chains can, however, serve as a basis for future impact assessments for the policies under study.

Conclusion

We analyzed 83 policy instruments for decarbonizing the transport sector in Germany using the concept of sufficiency policy-impact chains (Zell-Ziegler and Thema 2022). This allows for policy analysis in a transparent and fact-based manner, utilizing information from literature, and setting up transparent open-access impact-chain tables. We assess these impact chains with associated factors for single policy instruments to analyze the feasibility of implementing the proposed policy instruments in a specific context. The approach also allows us to compare policy instruments with a view to supporting factors, barriers, risks, inputs, and revenues and to draw conclusions on policy instruments that are found to be implementable with a few inputs or barriers/risks. On a more aggregate level, we compare which policy targets or instrument types seem most feasible in terms of the mentioned factors.

We find no strong differentiated pattern for implementation feasibility in the proposed transport-policy instruments by policy targets and instrument types. However, we can draw a number of specific conclusions.

First, in responding to our initial research question, specific policies, whether existing or proposed, can be analyzed using our method. When chains and factor assessments are openly available and validated, they can serve to stimulate fact-based discussions on the implementation feasibility, detailing the necessary inputs and factors that support or hinder their implementation. This is helpful for policymakers and policy consultancy in comparing policy instruments.

Second, policy instruments with many supporting factors often also have many barriers and risks, and additionally, they tend to have a higher need for inputs. In many cases, these are broader and more complex high-level policies or policy mixes (Axsen, Plötz, and Wolinetz 2020) with more diverse relevant factors and more varied structural input needs. However, these policy instruments may also have high GHG and energy-saving potential and should, therefore, not be dismissed. An example instrument that we analyze is ID 288, "quit legal prioritization of cars over cycling/walking" with many factors (see Figure 3). Studies like Dross et al. (2021) describe the complexity that the implementation of this strategically important instrument would entail.

Third, some policy instruments, such as incentives or infrastructure improvements, have fewer barriers than regulatory instruments, such as a ban on air travel or the conversion of road space to cycling and walking space, consistent with the literature on instrument types (Bemelmans-Videc, Rist, and Vedung 2011) or on push and pull policies (de Groot and Schuitema 2012; Loukopoulos et al. 2005). However, the aforementioned policy instruments, in most cases, require higher financial and other input, which puts them in a less favorable position in our analysis with regard to implementation feasibility.

Fourth, generally applicable rules in the area of policy design can also be supported by this analysis: increasing the stringency of an existing policy instrument (such as "residents parking fee increase" (ID 206), "adequate green phases" (ID 226), and "yearly car tax" (ID 242)) appears to be more feasible than the introduction of completely new policy instruments. This is because potential barriers and risks for the introduction have already been overcome and are

thus not as relevant for the tightening of a measure. This is consistent with literature findings that argue that targeted sequencing options can overcome barriers that previously constituted constraints (Pahle et al. 2018). We also conclude that the initial introduction of pull instruments such as infrastructure expansion and subsequently ambitious push instruments (such as "legal moratorium for road expansion" (ID 210), "Domestic air travel ban" (ID 229), or "car access restriction to city quarters" (ID 330)) seems favorable. This is because we find many barriers or risks to push policies associated with insufficiently developed alternative infrastructures. Other literature (Wicki, Fesenfeld, and Bernauer 2019) has found that introducing push-pull policy packages is favorable over isolated introduction; however, this does depend heavily on the specific context.

Fifth, regarding our second research question on feasibility differences by policy targets, we find the "reduce trips: local supply" policy target, which aims to reduce trips and distances, has the most risks, while the "promotion of active modes" and the "reduction of motorized individual transport" targets have the fewest. As a low number of risks indicates no-regret policy instruments, this leads to the conclusion that mode-shift policies are more readily feasible. Literature on a direct comparison of "avoid and shift" strategy feasibility is lacking, but the comparatively larger body of literature on mode shift rather supports our conclusion. Furthermore, literature on support for, or rather rebuilding local supply structures in Germany (Kokorsch and Küpper 2019), emphasizes major challenges that are in accordance with the risks that we identified (it is cost-, material-, and labor-intensive).

Sixth, from the comparison of instrument types, we find in response to our third research question little difference in supporting factors and that fiscal instruments have the fewest barriers while regulatory instruments have the fewest risks. In the general policy discourse, regulation is rather unpopular (Bemelmans-Videc, Rist, and Vedung 2011; Loukopoulos et al. 2005), resulting from a rather myopic perception of being coercive. When fairness and long-term considerations are included, regulatory instruments experience relatively high support, at least among informed members of the public (also concluded by Lage et al. (2023)). This is because they apply equally to everyone and are therefore perceived as fair and because they typically have few financing or staff needs.

Finally, one-fourth of the analyzed policy instruments have potential rebound or other adverse effects that need to be addressed in policy design, as also suggested by the literature on individual sufficiency measures (Caldarola and Sorrell 2022; Marz and Sen 2022; Sorrell, Gatersleben, and Druckman 2020). Our method is useful for identifying and counteracting these effects when planning to implement the policy instrument.

There is a large body of literature on diverse barriers and risks regarding the implementation of climate-mitigation options, for differentiated cases in all sectors including transport – for example on electric mobility (Biresselioglu, Kaplan, and Yilmaz 2018), institutional barriers (Curtis and Low 2016), drivers and barriers for mobility as a service (Alonso-González et al. 2020), and so forth. There is some research on sufficiency policy (Schneidewind and Zahrnt 2014; Thomas et al. 2019); however, no comprehensive analysis of concrete transport sufficiency-policy instruments or of their implementation feasibility has been conducted. We fill this gap by analyzing hindering and enabling factors along the impact chain to the introduction of individual policy instruments, which enables an assessment of the feasibility of political implementation.

We thus add a new aspect to the existing climate mitigation-policy literature, indicating new tasks for research featuring (1) the analysis of sufficiency policy (in addition to renewables and energy efficiency policy), (2) analyzing instrument-specific impact chains, and (3) assessing which policies are more/less easily feasible by analyzing barriers, risks, and supporting factors. Demand-side and sufficiency options have been widely deemed necessary in the literature (Alfredsson et al. 2018; Creutzig et al. 2016; Lage et al. 2023; Sugiyama et al. 2024; Zell-Ziegler et al. 2021); however, sufficiency policy is scarcely part of current policy plans in the transport sector (Zell-Ziegler et al. 2021). This analysis thus takes one step toward bringing policies into practice by analyzing their implementation feasibility.

From our analysis, we draw research needs for the future: to achieve the objectives of each policy target, different policy instruments need to be compared, and policy mixes need to be set up that can support each other by mutually reinforcing supporting factors and overcoming barriers (see also Pahle et al. 2018). As an example, investment in public transport frequency and quality will remove barriers and risks for car-access restrictions. The method we developed and applied is useful for this assessment. Complemented with future GHG and energy-saving potentials of the policy instruments, broader impact assessments can be conducted for better conclusions on policy recommendations. However, impact assessments of policy instruments that are proposed but have not yet been implemented are currently difficult. This is because implementation details such as the amount of funding and the extent of car-free zones are not known from

our database. Recommendations of policy instruments hinge on the inclusion of the expected saving potential in the analysis.

Future research can build on this article and add, for example, gender and social inequality issues, governance aspects, and the degree of transformation needed with regard to the published impact chains to increase their applicability for different areas.

Acknowledgements

Both authors, Carina Zell-Ziegler and Johannes Thema, have jointly led this research and equally contributed to this article. We thank Diah Putri and Lola Delfosse, who supported the literature research and discussion of impact chains during their internships at the Öko-Institut. We also thank Mahsa Bagheri and Leila Siebke from Fraunhofer ISI for discussions on the impact-chain concept during the application of the method to the building sector. Special thanks go to our external validators Paul Schneider, Ulrich Jansen, Miriam Müller, Frederic Rudolph, Marlin Arnz, Wolf Görtz, Dennis Seibert, Fabian Bergk, Claus Doll, and Josephine Tröger, who reviewed the chains in five validation meetings and provided their expertise on supporting factors, barriers, and risks. We thank our colleagues Frauke Wiese, Benjamin Best, Jonas Lage, and Luisa Cordroch from the EnSu project and the members of our doctoral colloquium as well as Stefan Heiland at TU Berlin and Katja Schumacher at the Öko-Institut for inputs and feedback at different stages of this research. We also thank Vanessa Cook at the Öko-Institut for the professional proofreading. Two anonymous reviewers provided very helpful and record-breaking fast feedback and questions that helped substantially to improve this work, and we are indebted to the journal editor for his final very thorough copyediting.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This research was conducted as part of the research project "The role of energy sufficiency in energy transition and society" funded by the German Federal Ministry of Education and Research (BMBF), within the framework of the Strategy Research for Sustainability (FONA), as part of its Social-Ecological Research funding priority [grant numbers 01UU2004B (JT) and 01UU2004C (CZZ, KD)]. We acknowledge financial support from the Wuppertal Institute for Climate, Environment and Energy within the funding program Open Access Publishing.

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Appendix

Table A1. Feasibility assessment of policy instruments for the policy target "improve public transport and multimodality."

Policy-Instrument Details			Internal Factors		External Factors		
Instrument Type	ID	Policy-Instrument Name	Highest Rating of Inputs	Revenues / Reduced state expense	Weighted Sum of Supporting Factors	Weighted Sum of Barriers	Weighted Sum of Risks
economic	250	Employer pay local public transport fee	high	yes	***	**	*
economic	251	Accessability fee for building owners	high	yes	**	**	*
fiscal	244	Investment in public transport efficiency increase	high	–	*	*	–
fiscal	252	Lower network tariffs	high	–	*	*	*
fiscal	253	VAT rebate for rail travels	medium	–	*	*	–
fiscal	254	Ticket reform, price reduction	medium	–	**	*	*
fiscal	255	Cheaper rail abonnements	medium	–	**	**	*
fiscal	256	Electricity tax reduction	medium	–	**	–	*
fiscal	257	National grants for light rail construction	high	–	**	**	**
fiscal	258	365€ ticket or cheaper	high	–	**	*	**
fiscal	259	Free local PT tickets, alternative financing, service expansion	high	–	**	*	*
fiscal	260	Network enhancement for overtaking long freight trains	medium	–	*	**	–
fiscal	261	P&R + mobility hubs	medium	–	**	*	*
fiscal	275	Investments in infrastructure	medium	–	***	*	*
fiscal	286	Higher national & departmental funds	high	–	**	*	**
fiscal	297	EU rail harmonization	high	–	**	**	–
regulation	245	Revision of legal basis, line reactivation	high	–	***	**	*
regulation	247	Target network plan and timetable	high	–	***	***	**
regulation	248	Legal obligation for public transport frequency	high	–	***	**	**
Average for Policy Target "Improve Public Transport and Multi-Modality"					**	*	*

Notes: * = few SF, B, R, ** = medium, *** = many SF, B, R; - = no revenues, SF, B or R

Table A2. Feasibility assessment of policy instruments for the policy target "promotion of active modes."

Policy Instrument Details			Internal Factors		External Factors		
Instrument Type	ID	Policy-Instrument Name	Highest Rating of Inputs	Revenues / Reduced state expense	Weighted Sum of Supporting Factors	Weighted Sum of Barriers	Weighted Sum of Risks
fiscal	216	Active mobility fund	high	–	**	**	*
fiscal	287	Higher national & departmental funds	medium	–	***	**	*
fiscal	312	Bicycle acquisition incentive	low	–	**	*	*
regulation	218	Mandate increased staff/budget at local level	medium	–	**	*	*
regulation	219	Bicycle priority streets	medium	–	**	**	–
regulation	220	Green wave for bikes	medium	–	*	*	–
regulation	221	Opening up one-way streets for bicycles	low	–	**	*	–
regulation	222	Minimum sidewalk width	low	–	**	*	–
regulation	224	Facilitate implementation of zebra crossings	medium	–	**	*	–
regulation	225	Elimination of mandatory sidewalk use	low	–	*	*	–
regulation	226	Adequate green phases	medium	–	**	*	–
regulation	227	Higher sanctions for road rule infringements	medium	yes	**	*	–
regulation	267	Conversion of road space to bicycle & pedestrian infrastructure	high	yes	**	***	–
regulation	269	Doubling assistant for freight vehicles	low	–	**	*	–
regulation	288	Quit legal prioritization of cars over cycling/walking	high	–	***	***	*
regulation	290	Speed limit in cities	low	–	**	*	–
regulation	317	Parking ban around schools	medium	–	*	*	–
Average for Policy Target "Promotion of active modes"					**	*	*

Notes: * = few SF, B, R, ** = medium, *** = many SF, B, R; - = no revenues, SF, B or R

Table A3. Feasibility assessment of policy instruments for the policy target "reduce air transport."

Policy-Instrument Details			Internal Factors		External Factors		
Instrument Type	ID	Policy-Instrument Name	Highest Rating of Inputs	Revenues / Reduced state expense	Weighted Sum of Supporting Factors	Weighted Sum of Barriers	Wei ghted Sum of Risks
economic	276	Aviation carbon tax	low	yes	*	*	*
regulation	213	Airport expansion moratorium	low	yes	**	*	**
regulation	228	Air travel ban	low	–	**	**	**
regulation	229	Domestic air travel ban	low	–	***	**	*
regulation	332	Change travel cost law	low	–	*	**	–
Average for Policy Target "Reduce air transport"					**	**	*

Notes: * = few SF, B, R, ** = medium, *** = many SF, B, R; - = no revenues, SF, B or R

Table A4. Feasibility assessment of policy instruments for the policy target "reduce motorized individual transport."

Policy-Instrument Details			Internal Factors		External Factors		
Instrument Type	ID	Policy-Instrument Name	Highest Rating of Inputs	Revenues / Reduced state expense	Weighted Sum of Supporting Factors	Weighted Sum of Barriers	Weighted Sum of Risks
economic	206	Residents parking fee increase	medium	yes	**	*	–
economic	207	Company car taxation reform	low	yes	*	**	–
economic	234	Road charge	medium	yes	*	**	*
economic	235	City road charge	medium	yes	**	**	*
economic	241	Car admission tax	low	yes	**	**	–
economic	242	Yearly car tax	medium	yes	**	*	–
fiscal	236	Free school transport	high	–	**	**	*
fiscal	239	Car tax reform	medium	yes	**	*	–
fiscal	240	Mobility Voucher	medium	–	**	*	*
fiscal	268	Eliminate environmentally harmful subsidies	low	yes	**	**	–
fiscal	306	Car sharing promotion	medium	–	**	*	*
fiscal	330	Car access restriction to city quarters ("Superblocks")	medium	–	**	*	*
fiscal	347	Premium for car scrapping	medium	–	*	*	*
regulation	202	Re-assignation of parking spaces	high	yes	**	**	*
regulation	203	General restriction of allowed parking	high	–	**	*	*
regulation	204	Red. obligatory parking space/ appartment	medium	–	**	**	–
regulation	205	Less privileged parking space planning	low	–	*	*	*
regulation	208	Incentivising regulation for ride sharing/pooling	medium	–	*	*	*
regulation	210	Legal moratorium for road expansion	medium	yes	***	**	–
regulation	211	Legal basis for infrastructure needs planning (national)	medium	–	**	**	–
regulation	231	Car access restriction	medium	–	*	**	–
regulation	237	Digital parking controls	medium	yes	**	*	*
regulation	289	Parking pricing introduction and fee increase	low	yes	**	**	–
regulation	292	Prioritise public transport	high	–	**	***	–
regulation	295	Restriction on surface sealing	medium	yes	**	*	–
regulation	304	Road speed limits	low	yes	**	**	–
regulation	321	Car-free days	medium	–	*	*	–
regulation	342	Regulation on yachts, jetski	low	–	*	*	*
Average for Policy Target "Reduce motorized individual transport"					**	*	*

Notes: * = few SF, B, R, ** = medium, *** = many SF, B, R; - = no revenues, SF, B or R

Table A5. Feasibility assessment of policy instruments for the policy target "Reduce trips: local supply."

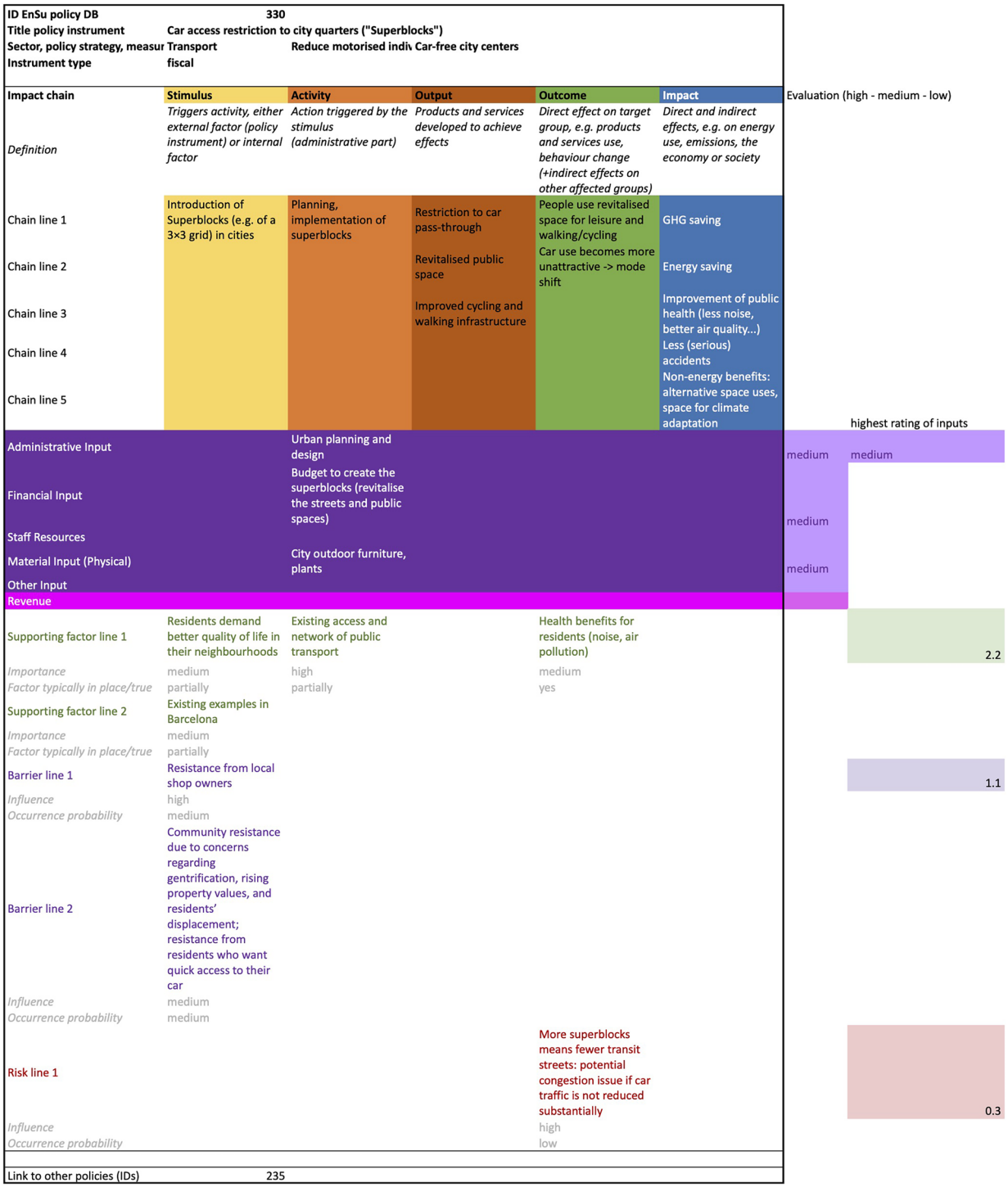
Policy-Instrument Details			Internal Factors		External Factors		
Instrument Type	ID	Policy-Instrument Name	Highest Rating of Inputs	Revenues / Reduced state expense	Weighted Sum of Supporting Factors	Weighted Sum of Barriers	Weighted Sum of Risks
Fiscal	197	(Re-) opening of local schools	high	–	**	**	**
Fiscal	198	Support of public and private childcare in villages	medium	–	**	*	*
Fiscal	200	Incentives for local and excess charges for decentralized shops	high	yes	*	**	*
Fiscal	201	Securing decentral medical & elderly care	high	–	*	**	*
Fiscal	339	Securing local living space	high	–	**	**	**
Average for Policy Target "Reduce trips: local supply"					**	**	*

Notes: * = few SF, B, R, ** = medium, *** = many SF, B, R; - = no revenues, SF, B or R

Table A6. Feasibility assessment of policy instruments for the policy target "reduce trips: work."

Policy-Instrument Details			Internal Factors		External Factors		
Instrument Type	ID	Policy-Instrument Name	Highest Rating of Inputs	Revenues / Reduced state expense	Weighted Sum of Supporting Factors	Weighted Sum of Barriers	Weighted Sum of Risks
economic	184	Company tax credits for teleworking	high	yes	**	*	**
economic	209	Cancellation of commuting allowance	low	yes	*	**	*
fiscal	182	IT equipment subsidies for working from home	medium	–	**	*	**
fiscal	183	Subsidised energy bills	low	–	**	**	***
fiscal	195	Tax acknowledgement of expenses for working from home	medium	–	**	**	*
regulation	187	Right to work from home for civil agents	medium	yes	**	**	**
regulation	192	Right to work from home	medium	yes	**	**	**
regulation	194	Travel cost regulations (public & company)	medium	–	**	**	*
regulation	232	Mandatory company mobility management	medium	–	**	*	*
Average for Policy Target "Reduce trips: work"					**	**	**

Notes: * = few SF, B, R, ** = medium, *** = many SF, B, R; - = no revenues, SF, B or R



ID EnSu policy DB	**330**						
Title policy instrument	**Car access restriction to city quarters ("Superblocks")**						
Sector, policy strategy, measur	**Transport**	**Reduce motorised indiv**	**Car-free city centers**				
Instrument type	**fiscal**						
Impact chain	**Stimulus**	**Activity**	**Output**	**Outcome**	**Impact**	Evaluation (high - medium - low)	
Definition	*Triggers activity, either external factor (policy instrument) or internal factor*	*Action triggered by the stimulus (administrative part)*	*Products and services developed to achieve effects*	*Direct effect on target group, e.g. products and services use, behaviour change (+indirect effects on other affected groups)*	*Direct and indirect effects, e.g. on energy use, emissions, the economy or society*		
Chain line 1	Introduction of Superblocks (e.g. of a 3×3 grid) in cities	Planning, implementation of superblocks	Restriction to car pass-through	People use revitalised space for leisure and walking/cycling	GHG saving		
Chain line 2			Revitalised public space	Car use becomes more unattractive -> mode shift	Energy saving		
Chain line 3			Improved cycling and walking infrastructure		Improvement of public health (less noise, better air quality...)		
Chain line 4					Less (serious) accidents		
Chain line 5					Non-energy benefits: alternative space uses, space for climate adaptation		
							highest rating of inputs
Administrative Input		Urban planning and design				medium	medium
Financial Input		Budget to create the superblocks (revitalise the streets and public spaces)				medium	
Staff Resources							
Material Input (Physical)		City outdoor furniture, plants				medium	
Other Input							
Revenue							
Supporting factor line 1	Residents demand better quality of life in their neighbourhoods	Existing access and network of public transport		Health benefits for residents (noise, air pollution)			2.2
Importance	medium	high		medium			
Factor typically in place/true	partially	partially		yes			
Supporting factor line 2	Existing examples in Barcelona						
Importance	medium						
Factor typically in place/true	partially						
Barrier line 1	Resistance from local shop owners						1.1
Influence	high						
Occurrence probability	medium						
Barrier line 2	Community resistance due to concerns regarding gentrification, rising property values, and residents' displacement; resistance from residents who want quick access to their car						
Influence	medium						
Occurrence probability	medium						
Risk line 1				More superblocks means fewer transit streets: potential congestion issue if car traffic is not reduced substantially			0.3
Influence				high			
Occurrence probability				low			
Link to other policies (IDs)	235						

Figure A1. Policy-sheet example for "car access restrictions to city quarters" (ID 330, see more details and all other impact chains in the Supplementary Material).