European Journal of Futures Research

RESEARCH ARTICLE Open Access

Robust policy-mixes for land use management of commercial areas: policy-design and scenario analysis with CIB

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Abstract

Future-oriented policy-mixes for commercial land use management must address multiple goals simultaneously: (1) improve city-regional and inter-municipal cooperation, (2) reduce land take, and (3) assure the long-term economic development of a region. This paper is based on a case study of the Northern Black Forest region in Germany, where consistent and synergetic policy-mixes with cross-impact balances (CIB) had been developed, but without considering uncertain future developments. As a result, there is limited knowledge about the robustness of these policy-mixes and about how to use integrative scenario methods to identify not only consistent and synergetic, but also future-robust policy-mixes. We thus ask: What policy-mixes for commercial area management are robust, i. e. maintaining effectiveness under different future contexts with regard to the overarching regulatory framework of land use, the future of work, and overall economic development? To answer this question, we address the following sub-questions: a) How to integrate context scenarios until the year 2050 into the policy-mix design for commercial area management in the Northern Black Forest? b) How to measure robustness of policy-mixes in the face of contextual uncertainties? To this end, we use scenario-based context and performance variables that were also developed using CIB for commercial space management in the same region: a) we merged both CIB matrices, contexts and policies, and analyzed resulting policy-mix scenarios; b) we integrated performance indicator descriptors from the scenario analysis into the policy-mix scenario matrix; c) for the subsequent analysis, we developed a robustness concept that encompasses three elements and two degrees of robustness. Content wise, we find no "no-regret" policy that appears effective in all contexts, but the analysis points at a bundle of policies, that are well 'compatible' in very different future worlds. These are, in particular, regional policies such as a regional development concept, shared infrastructure, and a joint settlement strategy. Method wise, we demonstrate possibilities to integrate CIB based scenarios and policy-design. We propose a multi-dimensional concept with varying degrees of robustness to enhance the understanding of robustness in qualitative policy design studies.

Keywords Robust policy design, Policy-mixes, Scenarios, Cross-Impact balance analysis CIB

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Introduction

Recent policy design literature has increasingly addressed how to bundle policy instruments synergistically and adaptively, while avoiding counterproductive effects [1]. It also asks how policy instruments perform not only in interaction with each other, but also in the context of larger political processes and strategies [2]. An important question, which has not yet been the focus of policy design research, is how robust policy-mixes prove to be in different contextual developments [3]. In this article we outline how strategic policy design is enabled to identify robust policy-mixes with the help of the integration of scenarios and policy-mixes.

We apply this approach to a regional case study on future land use, where [4] examined the possibility of using policy-mixes to address goal conflicts in planning and management of new commercial areas in the Northern Black Forest. Commercial land use management that focuses on a future-oriented urban and regional development must address multiple goals. Effective policy-mixes need to simultaneously (1) improve city-regional and inter-municipal cooperation, (2) reduce land take, and (3) assure the long-term economic development of a region. In this case study [4], used Cross-Impact Balance (CIB) analysis to develop consistent and synergetic policy-mixes aimed at addressing these goal conflicts by constructing and evaluating a policy-interaction matrix.

However, they did not consider that these policy-mixes might perform differently under varying future context conditions. These uncertain future contexts comprise the structure of the national economy, legal conditions, and further societal developments as the future of work. We thus lack (a) knowledge about the robustness of these policy-mixes and (b) methods to identify not only consistent and synergetic but also future-robust policy-mixes. Our research question in this paper therefore is: What are robust policy-mixes for commercial area management under different future context conditions? To answer this question, we address the following sub-questions:

1. What different context scenarios are plausible for the future development of commercial area management in the Northern Black Forest region in 2050?
2. How to combine CIB based policy- design and CIB based scenario analysis?
3. How to measure the robustness of policy-mixes under different contexts?

For this purpose, we use context and performance variables from scenarios that were also carried out with the CIB for the future of commercial space management in the same region for 2050. We merged the scenarios with the policy-mixes in two ways: (a) we integrated context factors into the policy-interaction matrix and analyzed resulting integrated policy-mix scenarios, (b) we integrated performance indicators into the policy-mix matrix. For the robustness analyses we propose different elements and degrees of robustness in different contexts to go beyond a binary understanding of robustness: global and partial robustness of (1) individual policies and (2) of policy-mixes, as well as (3) robustness of the performance of system indicators in different contexts. With this paper, we thus demonstrate possibilities to integrate CIB based scenarios and policy-mixes and how to assess the robustness of different elements that are relevant for policy design.

The paper is structured as follows: in the next Sect. (2) we outline the state of research. Section 3 describes materials and methods. We then present the results (Sect. 4) and discuss them critically and point at future research avenues (Sect. 5). We end with a conclusion summarizing the contribution of this paper (Sect. 6).

State of research

Policy-Mixes

Debates on the effective combination of instruments, measures, or policies—often referred to as *policy-mixes*—are well-established across various policy domains, including innovation policy [2, 5, 6], mobility policy [7–9], and land use policy [10]– [11]. Policy research has increasingly focused on the interactions, conflicting objectives, and temporal dynamics of policies both within and across sectors. Empirical findings show that coherent and well-aligned policy-mixes remain the exception rather than the norm. Instead, policies are often "patched" together, resulting in inconsistencies and counterproductive interactions [12]– [13]. A growing body of literature [e.g. 14,2] emphasizes that policy effectiveness hinges on understanding these interactions. Isolated analyses overlook the complex interplay between old and new policies, across sectors, and across governance levels [14]. To enhance coherence and exploit potential synergies, policy design must take these combinations and their interactions into account. Using cross-impact balance analysis (CIB) [15], alternative policy-mixes for water management have been designed [16] and analyzed with regard to their internal consistency and degree of synergy. This approach was chosen for designing policy-mixes for commercial land use management in the region of the Northern Black Forest [4], too. The weakness of this (and other) policy-mix analysis was that it only considers the current situation but remains blind regarding future changes of context conditions.

A role for scenarios in policy formulation: robustness

Scenarios are images of possible futures (in the plural) (17). They describe alternative future situations and the paths leading to them. They thus open up a space of

possible futures. Scenarios are also being discovered in policy design research as an important tool for dealing with uncertainties, albeit only marginally at the moment. However, the emergence of increasingly complex and uncertain policy problems has triggered renewed interest in more sophisticated policy formulation tools, including scenarios and computer-based modeling [18]. They can help to identify possible solutions to policy problems or explore the different options available [19]. Scenario analysis can be used to increase the robustness of policies by assessing whether a policy is still effective in achieving a policy objective if the scenario assumptions are changed [20] [21]. suggests that in order to make policy-mixes as robust as possible, it is essential to include procedural elements that make it possible to improvise and react to shocks as soon as they occur. However, while policy design research often takes a narrow methodological view of the political space and considers robustness primarily with regard to changing power options and conflicting interests in the policy implementation process, scenario research opens up the uncertainty space further and emphasizes the explorative character of scenarios and considers changes in external driving forces that cannot be directly influenced by the considered policies [20]. While qualitative policy design research (3, 21) has already focused on designing robustness of individual policies and of policy-mixes, it does not necessarily provide measures for different degrees or intensities of robustness[1].

Conflictive objectives in land use planning and management at the example of commercial areas

The development of sustainable commercial areas is characterized by conflicting goals for the following cf. (4, 22). Reducing land take in urbanized areas and preserving open spaces and conservation land is necessary to preserve the soils with their diverse functions [23]. Land-saving urban development has, therefore, become a guiding principle in several countries around the world, including Germany. However, land is still required for housing and the expansion of infrastructure, as well as for commercial development and renewable energies. At the same time, competition between different land uses is increasing [24].

Both environmental authorities and the scientific community recommend inter-municipal or even regional cooperation for the development of commercial areas (22), as they create synergies [25–27] and thus generate economic, social and ecological benefits [28]– [29]. Nevertheless, inter-municipal or even regional cooperation in commercial space management remains rare. This is due to the municipal planning sovereignty in Germany [30] and the dependence of municipalities on trade tax revenues [31], which results in intense location-based competition [32]. Therefore, cooperation especially between urban and suburban or rural municipalities are often conflictive and inhibit sustainable land management [33].

Materials and methods

CIB

This paper combines policy-mixes to minimize goal conflicts in regional commercial space management and regional scenarios for the same region. The method of cross-impact balance analysis (CIB) was used to create both. Figure 1 illustrates which data and processes the paper only refers to and which data and processes are the focus of this paper.

CIB is a qualitative but semi-formalized form of system analysis. The method requires identifying system elements and the interrelationships between them. This results in a conceptual (impact network) model. A specific balance algorithm [15] then identifies Nash equilibria of the impact network [34] and thus represents a method of multi-goal optimization. The solutions of a policy interaction matrix consist of policy-mixes in which the selected policies ensure an optimal net balance of synergistic and conflicting effects for each policy field. Typically, a policy-interaction matrix provides several solutions.

The CIB has been explicitly developed as a method for constructing future scenarios [34–39]. It is now also used for qualitative system analyses [40, 41] and in the field of policy design to evaluate policy-mixes ex post and ex ante [4, 16].

A case in the Northern black Forest, Germany

As a case study [see also in the following 4], our analysis addresses the area of Pforzheim, a regional center of ca. 120.000 inhabitants in South-Western Germany, and its 22 surrounding communities belonging to a county named Enzkreis (with ca. 3000-12.000.000.000.000 inhabitants each). Together they form a sub-region (Mittelbereich Pforzheim) of 500 km^2, abbreviated by PFENZ. PFENZ, as we argue in the following, is an exemplary case that is typical for several other cases and will prove to be more so in the future.

First, the initial situation in PFENZ is challenging, and therefore, particularly instructive (Yin 2009). There is not only competition in commercial land planning between city and surrounding municipalities, but also historically, a rather poor and conflict-laden relation between the central city and the surrounding municipalities [42]. There is a severe lack of suitable areas for new commercial areas (greenfield development) due to topography as

[1] A *numerically* measure of robustness of policy-mixes under different contexts has been developed within for the CRISPA approach, also based on CIB, by the Mobilise research group: www.crispa-sis.eu.

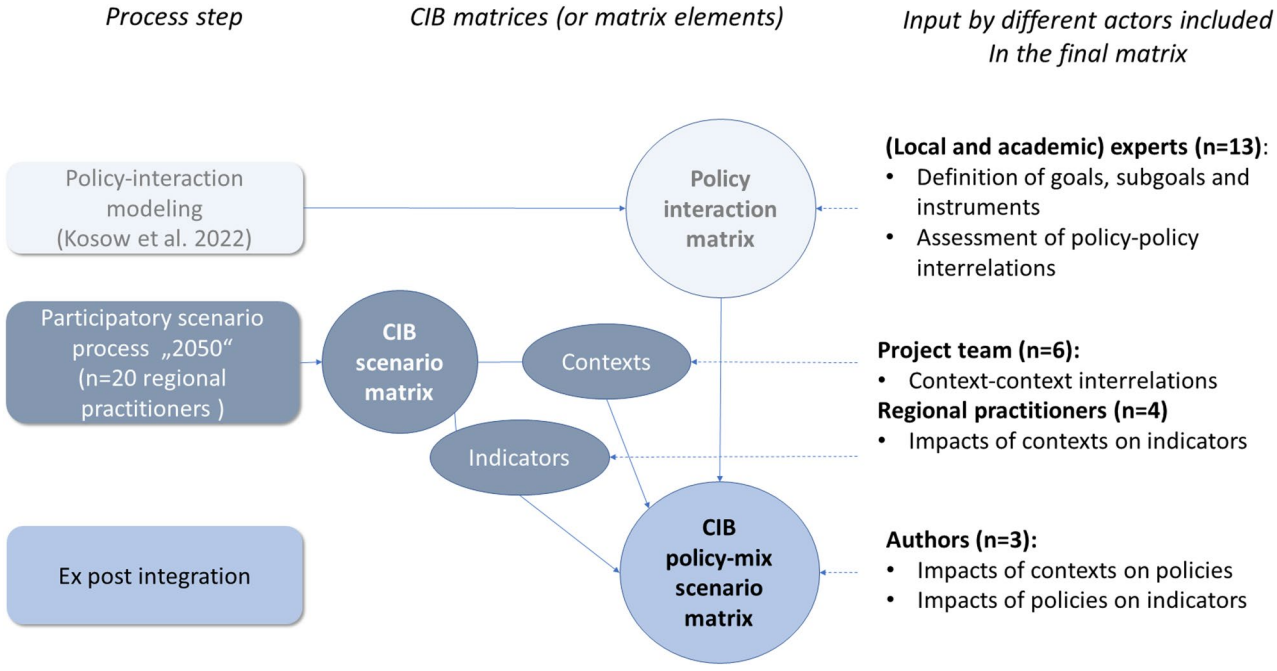

Fig. 1 Flowchart: Data and processes. Grey and white font: prior processes and data. Black font: processes and data considered in detail in this paper

well as natural and regulatory constraints. Despite this, there is still a high demand for additional commercial space [43]– [44].

Second, PFENZ can be considered a typical case for many other densely populated and prospering sub-regions in Germany and in other European countries. The current situation of instruments and policies in place is rather typical. The particular challenges in relation to land scarcity in the case study area are issues that most regions face, given the EU targets of (1) reducing net land take to zero by 2050; (2) increasing the share of renewable energy in the energy mix to 42.5% by 2030; and (3) Member States facing a major housing shortage [45].

Policy-mixes to cooperate regionally, save land and promote the economy

Consistent and synergetic policy-mixes have been developed for this challenging situation, which has three partly contradictory goals, namely improve city-regional cooperation regarding commercial areas, reduce land-take for commercial purposes and to ensure long-term economic development [4]. With the help of local and academic experts, three sub-goals were then defined for each overarching goal, as well as two alternative (innovative) policies (Options A and B) to achieve the goals. The respective currently implemented status quo policy was also considered. Through expert elicitation, fostering and hindering interrelations between all policies have been assessed pairwise resulting in a policy-interaction matrix [4] Table 1.

Out of a total of 19,683 theoretically conceivable configurations of these individual policies, CIB identifies two policy-mixes as fully consistent (IC0 in CIB parlance, $n=2$) and further $n=58$ policy-mixes exhibit a very slight inconsistency (IC1). In total, $n=60$ different policy-mixes can be described as consistent. In Supplement A we show a diversity selection of the policy-mixes. All policy-mixes achieve the three overarching objectives to varying degrees. But we do not know yet, how these mixes perform under different future contexts, i.e. if they are robust.

Context scenarios

To add to the analysis published by [4], we used alternative context scenarios, developed in a scenario process [46], in which all steps were carried out in a participatory manner involving the relevant scientific partners of the project as well as regional practitioners. On the basis of literature research, a preselection of central context factors (external developments that cannot be influenced in the region) and system factors in the region and their possible alternative future developments (ranging from very negative developments over developments maintaining the status quo to very positive developments) were identified and formulated. A digital scenario workshop with 20 regional practitioners was conducted,

Table 1 Overview on goals, sub-goals and alternative policies

Goal	Sub-goal	Status quo (S)	Option A	Option B
I Improve city-regional cooperation regarding commercial areas	1 Improve communication and trust	*1 S Irregular exchange between city and individual surrounding municipalities*	1 A Informal expert group PFENZ	1B PFENZ mayors' group
	2 Joint development perspective for PFENZ	*2 S Priority areas for commerce & industry (regional plan)*	2 A Joint statement of the municipalities in PFENZ on the regional plan	2B Regional development concept commercial areas in PFENZ
	3 Develop commercial areas in inter-municipal cooperation	*3 S Informal preliminary talks for inter-municipal commercial area development*	3 A Cooperation agreement for the cooperation between the city and the surrounding municipalities in the development of commercial areas	3B Special-purpose association for joint commercial area development between city and surrounding municipalities
II Reduce land take for commercial purposes	4 Reduction and control of land use for commercial areas	*4 S Regional plan as a corridor for land use*	4 A Regional plan + regional land use monitoring	4B Regional plan + land use monitoring PLUS regional quantity target with tradable quotas
	5 Mobilize existing commercial land and buildings	*5 S Innovative purchase agreements (individual municipalities)*	5 A Leasehold; interim acquisition (Basic approaches of municipal land policy)	5B Extended approaches to municipal land policy as interim acquisition, urban development contracts and deconstruction obligations etc.
	6 Use of commercial areas in a land-saving and multifunctional way	*6 S Information on land-saving and multifunctional use*	6 A Municipal incentives for multi-story and multifunctional construction	6B Lower land prices in return for multifunctional and public areas
III Ensure long-term economic development	7 Future-oriented commercial area planning and implementation	*7 S Commercial areas planned from a municipal perspective*	7 A Tools for cost-benefit analysis and monitoring of commercial area projects	7B Shared infrastructures within commercial areas
	8 Securing and creating (sustainable) jobs	*8 S Regional start-up consulting; cluster strategy of the city*	8 A Promotion of research & development (R&D) in PFENZ	8B Joint innovative settlement strategy and skilled labor strategy in PFENZ
	9 Improve regional location quality	*9 S Individual municipal location marketing*	9 A Gain and communicate a sustainability label for PFENZ	9B Joint (collaborative) commercial area management and location marketing PFENZ

Variant labels: S and italic print = status quo policy, A = more innovative policy compared to status quo, B and underlined = very innovativepolicy compared to status quo

during which twelve key factors (three context factors and nine system factors) were selected. The most diverse and plausible developments up to the year 2050 were defined and transferred to a CIB-matrix. The interactions between the context factors were then analyzed in a workshop with the scientific project partners. In an interview-series with some of the regional practitioners, the influence of the context factors on the system factors as well as interactions between the system factors were determined. System analyses were subsequently conducted and scenarios were generated using the CIB software. These scenarios were used for further analyses of the robustness of policy-mixes.

Integrating context scenarios and policy-mixes

This paper focuses on how the previously developed policy-mixes were integrated with those context scenarios and how these mixes would affect land take and the regional economic structure under the various contextual conditions. In a first step, the policy matrix was supplemented by the context factors (A- Legal framework of the federal and Länder governments for land efficiency and land use; B- Importance and structure of the German economy; C- Future of work) from the scenario analysis, see Table 2[2]. Then, an internal assessment of the influencing relations of context factors on the effectiveness of the policy variants was carried out. In a second step, two system factors "competitiveness of the regional economic structure" (D) and "net-zero land use by commerce" (E) were added as passive descriptors[3] and the respective influences of the policy variants as well as of the context descriptors on both factors were evaluated. Those variables were subsequently used as performance indicators. The impact sum of promoting and hindering impacts is referred to as the performance of the solution with regard to the goal.

[2] For the analysis, we assumed that the variants are mutually exclusive. In fact, it would be conceivable in practice that combinations of variants could also occur at the same time, for example in the legal framework.

[3] The two performance indicators correspond to two of the three overarching (contradictory) goals of the originally developed policy-mixes. The third goal "regional cooperation" considered there was not included because there is a hierarchy of objectives between this procedural objective and the two main objectives.

Table 2 Context descriptors and variants

Context descriptor	Variant 1	Variant 2	Variant 3	Variant 4
A - Legal framework of the federal and "Länder" governments for land efficiency and land use	A1: Municipalities receive additional funding opportunities as compensation for environmental measures (fiscal incentives)	A2: Strict regulatory requirements for land efficiency and land use	A3: Nationwide quotas for all land uses and their trade	*A4: Reduction of land use remains a non-binding political goal (status quo)*
B - Importance and structure of the German economy	B1: Germany with technology leadership in green technologies etc. (qualitative growth)	*B2: Importance and structure of the German economy roughly as in 2022 (status quo)*	B3: Deglobalization and relocation of manufacturing back to Germany	B4: Germany is losing its strong economic importance in the world
C - Future Work	C1: Work beyond gainful employment as self-realization for all	C2: Significant change in the world of work: digitalization and flexibilization	*C3: "Work remains work": little changes compared to the 2020ies (status quo)*	C4: Precarious conditions

The variants A4, B2, and C3, marked in italic print, roughly correspond to the status-quo context conditions in Germany

Robustness elements and degrees

Consistent with the political science understanding, robustness is defined as "…the ability to maintain the consistent delivery of a desired set of policy outputs. (…) In line with this view, a robust policy has been defined as one that is able to perform or work well across a range of plausible futures or scenarios" [3, pp.423–424]. Robustness, defined as the ability to contribute to the achievement of objectives under different contexts, can be considered regarding three elements: robustness of individual policies, robustness of policy-mixes, and robustness of the performance of policy-mixes under different contexts.

Furthermore, robustness of policies and policy-mixes can appear in different gradations. A policy would be globally robust if it occurred in all consistent policy-mix scenarios. Even if a policy is not globally robust, it can be partially robust. A partially robust policy either occurs in all policy-mixes under a certain context. Or, it is not included in all policy-mixes, but appears at least once in every context Figure 2.

Results

Combined policy-mix scenarios

In a first step, the contexts were examined. The evaluation leads to $n = 10$ different consistent future situations ($n = 5$ IC0, IC1 adds $n = 5$). The context development A3 – Nationwide quotas for all land uses and their trade – is

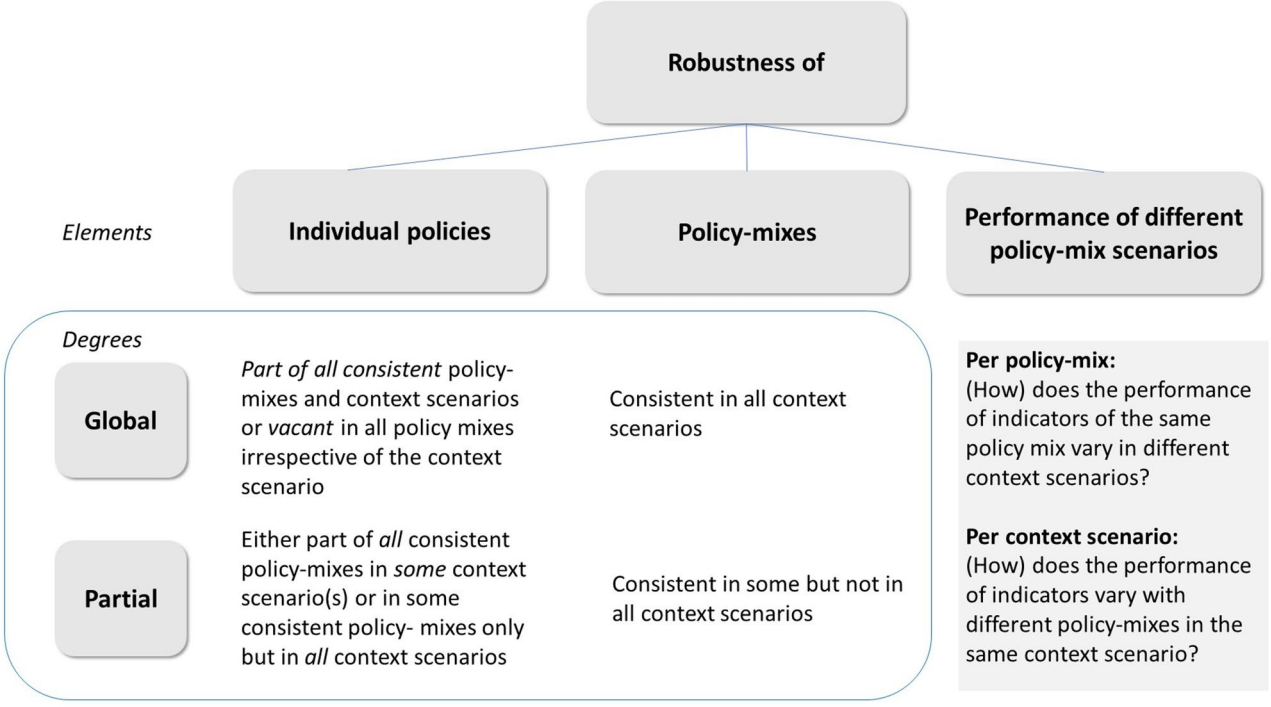

Fig. 2 Overview on three elements and degrees of robustness in policy mix-scenarios

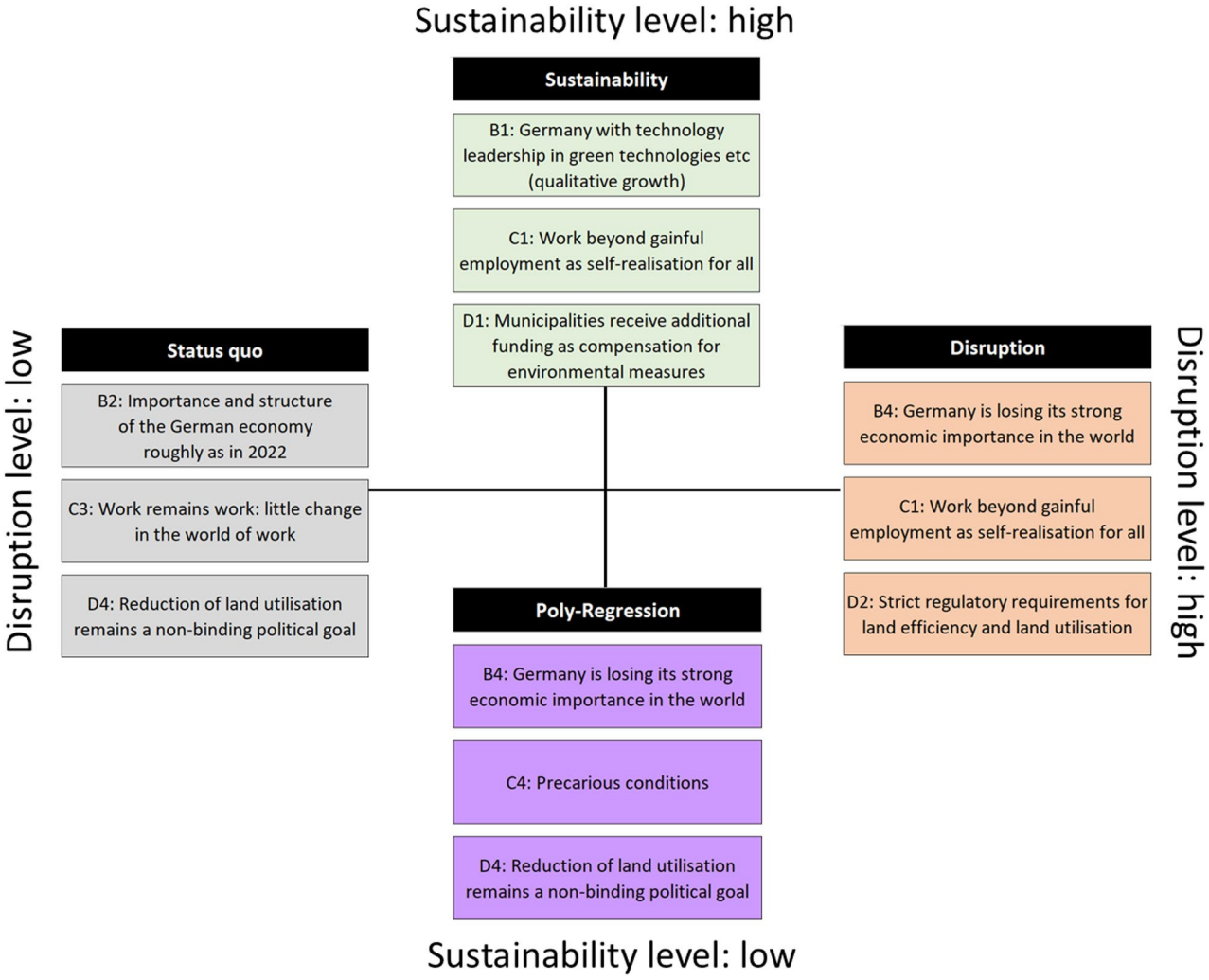

Fig. 3 Extremes of the context scenario space (diversity sampling four out of n=10 context scenarios IC0 and IC1)

vacant, i.e. there are no consistent context scenarios with this variant. Figure 3 schematically illustrates two dimensions of the context scenario space: how context scenarios differ in terms of their scope of change (x-axis) and the sustainability of the changes (y-axis). At the ends of these axes, we show the four context scenarios that are particularly strong or particularly weak in terms of these criteria.

The policy-mix scenarios matrix results in n = 16 fully consistent policy-mix scenarios, thus significantly more than in the initial analysis not considering context uncertainty (n = 2 IC0 in [4]) (A list of the fully consistent policy-mix scenarios can be found in supplementary material B). Allowing slightly inconsistencies leads to n = 278 policy-mix scenarios, which means that each of the ten context scenarios allows for an average of 27.8 consistent policy mixes. Table 3 shows two examples of fully consistent policy-mix scenarios. The degree of synergy within a policy-mix scenario is quantified by the net balance of positive and negative impacts within each mix, that is to say, the sum of interactions (in CIB parlance: the total impact score (TIS)). With a TIS value of 239 and 178, they are comparatively synergetic, but vary greatly. In the first example policy-mix scenario, the context develops positively, the German economy experiences qualitative growth, work changes significantly and the land-related legal framework of the federal government works with tax incentives for municipalities and regions. New, innovative policies dominate this mix. In the second example, the context develops negatively and the policy-mix is dominated by not-ambitious status-quo policies.

Figure 4 shows the number of consistent policy-mixes for each of the n = 10 context scenarios.

The number of policy-mixes per context scenario varies greatly, as the contexts restrict the freedom of movement of the policy selection to varying degrees. In particular, most context scenarios with component A1 (additional funding opportunities) allow the policies a great deal of

Table 3 Example of two different policy-mix scenarios

		Policy-mix scenario 1	Policy-mix scenario 2
	Context descriptor	**Variants - Future developments**	
Context	A - Legal framework of the federal and "Länder" governments for land efficiency and land use	A1 Municipalities receive additional funding opportunities as compensation for environmental measures (fiscal incentives)	*A4: Reduction of land use remains a non-binding political goal (status quo)*
	B - Importance and structure of the German economy	B1 Germany with technology leadership in green technologies etc. (qualitative growth)	B4: Germany is losing its strong economic importance in the world
	C - Future Work	C2 Significant change in the world of work: digitalisation and flexibilization	C4: Precarious conditions
Goal	Sub-goal descriptor	Variants – Policies	
I Improve city-regional cooperation regarding commercial areas	1 Improve communication and trust	1 A Informal expert group PFENZ	1 A Informal expert group PFENZ
	2 Joint development perspective for PFENZ	2B Regional development concept commercial areas in PFENZ	2B Regional development concept commercial areas in PFENZ
	3 Develop commercial areas in intermunicipal cooperation	3B Cooperation agreement for the cooperation between the city and the surrounding municipalities in the development of commercial areas	*3 S Informal preliminary talks for inter-municipal commercial area development*
II Reduce land take for commercial purposes	4 Reduction and control of land use for commercial areas	4 A Regional plan + regional land use monitoring	*4 S Regional plan as a corridor for land use*
	5 Mobilize existing commercial land and buildings	5B Extended approaches to municipal land policy as interim acquisition urban development contracts and deconstruction obligations etc.	*5S Innovative purchase agreements (individual municipalities)*
	6 Use of commercial areas in a land-saving and multifunctional way	*6 S Information on land-saving and multifunctional use*	*6 S Information on land-saving and multifunctional use*
III Ensure long-term economic development	7 Future-oriented commercial area planning and implementation	7B Shared infrastructures within commercial areas	7B Shared infrastructures within commercial areas
	8 Securing and creating (sustainable) jobs	8B Joint innovative settlement strategy and skilled labor strategy in PFENZ	*8 S Regional start-up consulting cluster strategy of the city*
	9 Improve regional location quality	9B Joint (collaborative) commercial area management and location marketing PFENZ	9B Joint (collaborative) commercial area management and location marketing PFENZ
	Consistency	IC0	IC0
	Synergy (TIS -Total Impact Score)	239	178
	Frequency of consistent policy-mixes		

freedom. In fact, the influence of context A1-B2-C3 even extend the freedom of policies compared to the reference case without contextual influences, as n = 85 policy-mixes become consistent with this context scenario, compared to only n = 60 mixes according to [4]. This is understandable, as B2 and C3 describe status quo developments that exert little influence on the policies, while A1 is the only variant of descriptor A that does not introduce any restrictions on options for action, but pursues an "enabler approach".

At the other end of the spectrum is the A1-B4-C1 context scenario (containing two disruptive elements), which maximally restricts the freedom for consistent policy-mixes and leaves only two options open, although other B4-C1 context scenarios are also found remarkably frequently among the context scenarios with few consistent policy-mixes. This can be seen in connection with the fact that B4 and C1 introduce maximum disruptive environmental conditions into the system, which cause correspondingly strong impacts on the policies, forcing them in a specific direction.

A total of n = 113 different policy-mixes are addressed in the n = 278 solutions of the integrated matrix, which means that an average policy-mix is consistent with several context scenarios. A share of N = 39 of these policy-mixes is already included in the n = 60 consistent policy-mixes from [4], in which the context was not explicitly considered. All n = 10 context scenarios considered are compatible with at least one of these n = 39 policy-mixes. The other policy-mixes are so specifically adapted to "their" contexts that they would no longer be consistent without their influences. They would therefore no longer be Nash-stable and, from a game-theoretical perspective, would be threatened with dissolution if the context influences were removed. Conversely, from the perspective of the context-free matrix [4], this means that

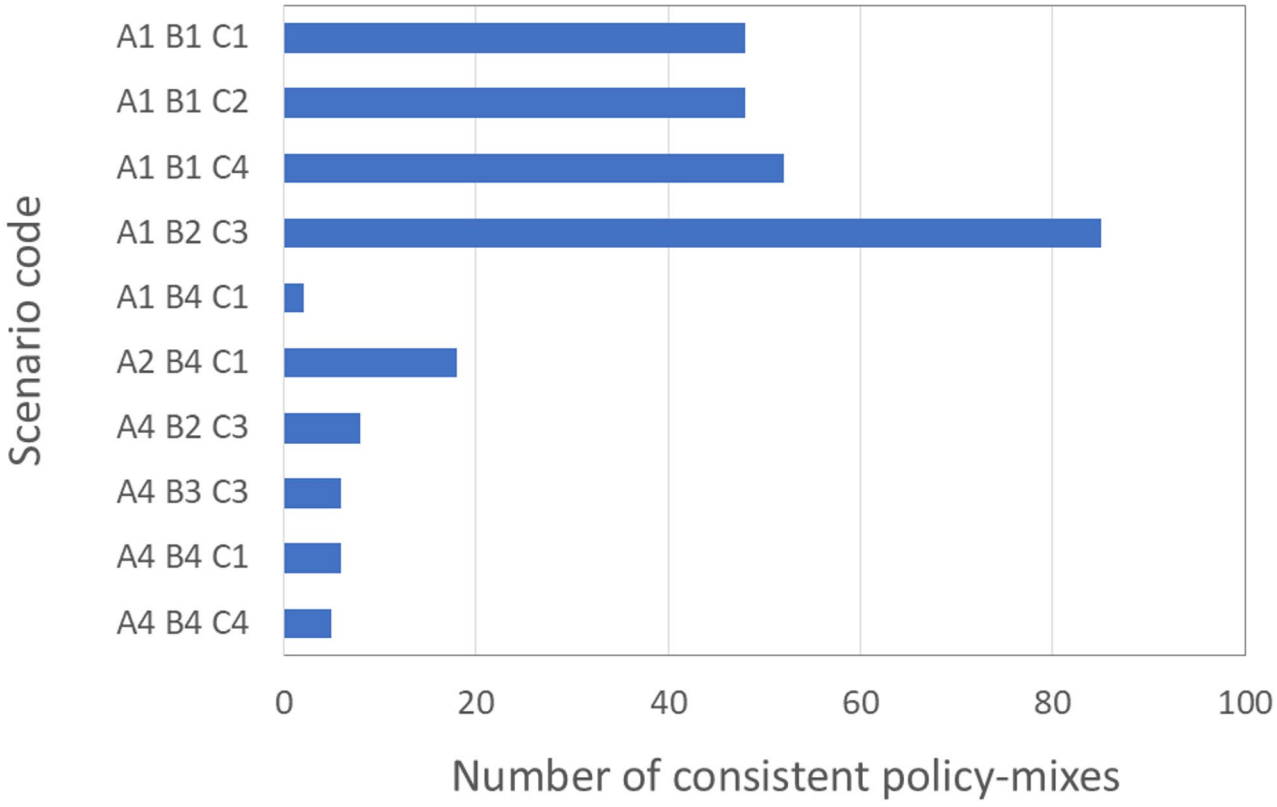

Fig. 4 Number of consistent policy-mixes per context scenario

n = 39 of their n = 60 consistent policy-mixes (65%) also retain their significance if the policies are exposed to the effects of the context developments considered here, but only if certain context developments occur.

Robustness of policy-mixes under different future assumptions

Element 1: analyzing the global and partial robustness of individual policies

Global robustness: A policy would be globally robust if it occurred in all consistent policy-mix scenarios. However, none of the policies are robust in this absolute sense (though one policy, 2B, comes close to this status with a frequency of 98.9% among the 278 policy mix scenarios) - on the one hand, the future uncertainties in our case are considerable, but on the other hand, the policy interactions also allow considerable freedom in the formation of a consistent policy-mix. Both together mean that there is no overall "safe" and in every case "no regret" policy decision in our case.

Global robustness can also mean that a policy *does not occur* in any consistent policy-mix scenario. Such policies would (within the scope of this analysis) be considered disproven and discouraged. In our analysis, there are actually four policies of this type:

- 2 A Joint statement of the municipalities in PFENZ on the regional plan.
- 4B Regional plan + land use monitoring PLUS regional quantity target with tradable quotas.
- 6B Lower land prices in return for multifunctional and public areas.
- 7 A Tools for cost-benefit analysis and monitoring of commercial area projects.

Three of these policies (2 A, 6B and 7 A) are vacant even without contextual influence [cf. 4 and explanations there], while the systemic infeasibility of 4B only arises due to the contextual influences. Test calculations show that A3 (nationwide quotas for all land uses and their trade) would be the prerequisite for 4B, but since A3 does not prevail in any policy-mix scenario, 4B is also missing.

None of the vacant policies is a status quo policy. Conversely, this means that all status quo policies can be a functional (consistent) component of a policy-mix under certain circumstances.

Partial robustness: Even if a policy is not globally robust, it can still be the robust companion of *a certain context development* and it can be concluded that the policy (from the perspective of this analysis) is a natural implication of "its" favorable context development. The partially robust

Table 4 The partially robust policies of the context developments

Context assumption	Obligatory policies
A Legal framework of the federal and "Länder" governments for land efficiency and land use:	
A1: Municipalities receive additional funding as compensation for environmental measures	2B
A2: Strict regulatory requirements for land efficiency and land use	2B, 7B, 8B
A3: Nationwide land quotas for all land uses and their trade	No solutions
A4: Reduction of land use remains a non-binding political goal (status quo)	*3 S, 4 S*
B Importance and structure of the German economy:	
B1: Germany with technology leadership in green technologies etc. (qualitative growth)	2B, 7B, 8B
B2: Importance and structure of the German economy roughly as in 2022 (status quo)	-
B3: De-globalisation and relocation of manufacturing back to Germany	2B, *3 S*, *4 S*, *6 S*, 7B, 8B, 9B
B4: Germany is losing its strong economic importance in the world	2B
C Future work:	
C1: Work beyond gainful employment as self-realisation for all	2B
C2: Significant change in the world of work: digitalisation and flexibilization	2B, 7B, 8B
C3: Work remains work: little change in the world of work (status quo)	-
C4: Precarious conditions	2B

The occurrence of a development listed on the left means that all policies listed on the right in the same row are obligatory components of aconsistent policy-mix under this context assumption. "No solution": no consistent context scenarios exist in this case. "-": in the case of therespective context development, there is no policy that is mandatory for consistency

policies found for the 12 context developments in this analysis are shown in Table 4.

Policy "2B Regional development concept commercial areas in PFENZ" is the most robust of the partially robust policies: Although it is not robust for all, it is robust for 8 of 11 non-vacant context developments. Two context developments (B2 and C3) show no partially robust policies, and A3, as described above, does not occur in any context scenario.

The following policy combination obviously plays a significant role:

- 2B Regional development concept commercial areas in PFENZ.
- 7B Shared infrastructures within commercial areas.
- 8B Joint innovative settlement strategy and skilled labor strategy in PFENZ.

It is robust under four context developments, which indicates a particular synergy effect between these policies. It is also striking that this robust association never appears under status quo context conditions, but always occurs in the wake of significant changes.

A particularly large number of partially robust policies occur under the conditions of B3 "De-globalization and relocation of manufacturing back to Germany". This development, which has particularly far-reaching consequences for the economy, obviously rules out a particularly large number of options and thus forces decisions without alternatives in many policy areas.

A conspicuous feature is also evident in the partially robust policies under A4 "Reduction of land use remains a non-binding political goal". This "no change" option causes a status quo policy for at least two policy areas and thus blocks more innovative approaches.

Robust options: Another type of policy robustness against environmental uncertainty is that a policy has a chance of playing a role in all context scenarios, i.e. it is not necessarily included in all, but at least in one consistent policy-mix of each context. Only five of the 36 policies included in the matrix possess this quality:

- 2B Regional development concept commercial areas in PFENZ.
- 4 S Regional plan as a corridor for land use.
- 6 S Information on land-saving and multifunctional use.
- 7B Shared infrastructures within commercial areas.
- 9B Joint (collaborative) commercial area management and location marketing PFENZ.

A policy could therefore be selected from this list of policies for which it is then certain, despite context uncertainty, that there will always be a way to establish a consistent policy-mix around this policy. However, this does not necessarily mean that several policies from this list can necessarily be combined.

Element 2: analyzing the robustness of policy-mixes

As described, the $n = 278$ complete solutions in the integrated matrix contain 113 different policy-mixes, which generally appear several times in the solution list in combination with different context scenarios. A globally robust policy-mix is consistent across all contexts; partially robust mixes are consistent in only some contexts, the more contexts they are consistent with, the more robust they are considered.

Figure 5 shows that more than 1/3 of the $n = 113$ policy-mixes (47 mixes) are only consistent in a single context scenario. They are therefore highly specialized and correspondingly highly vulnerable to unexpected context developments. On the other hand, there are no policy-mixes in this use case that are completely or largely robust. However, 12 policy-mixes are robust in half of the

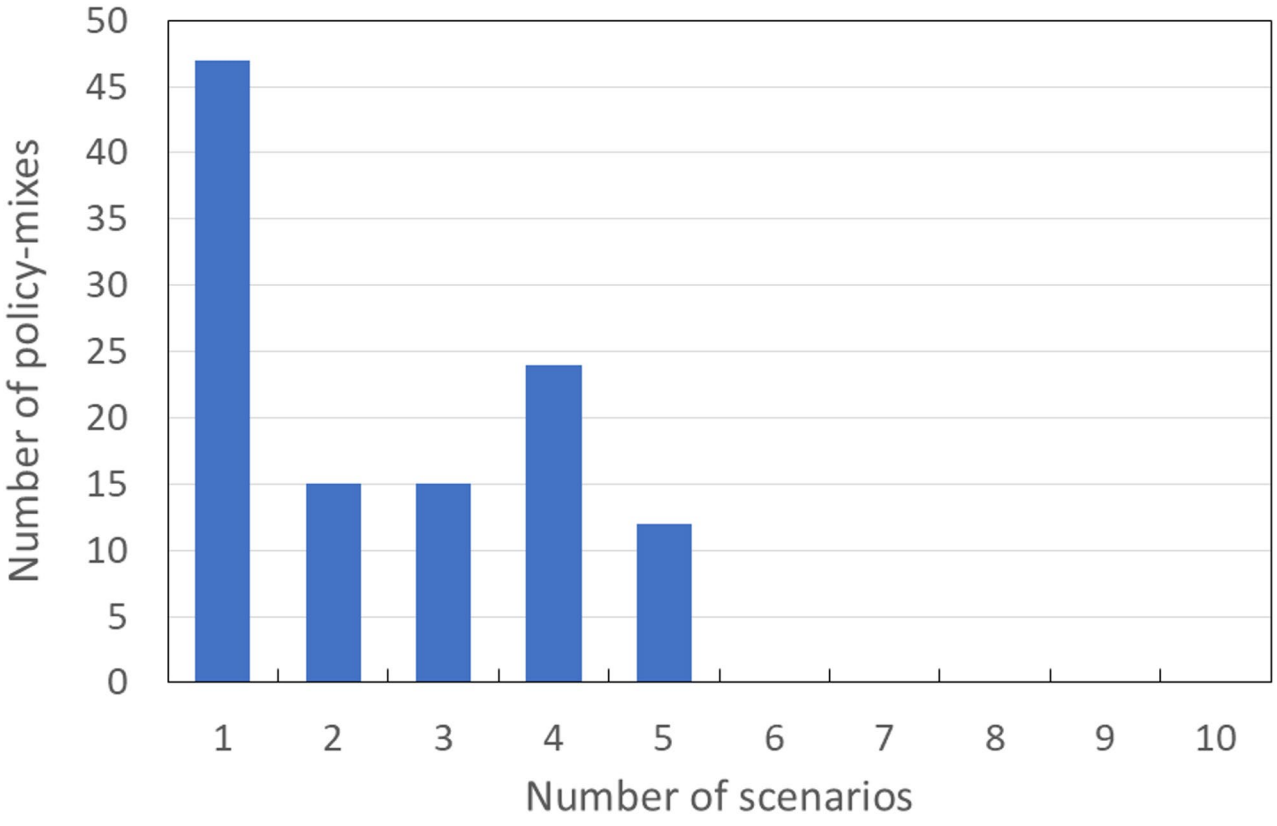

Fig. 5 Number of policy-mixes with consistency in n context scenarios

context scenarios and thus offer moderate prospects of durability (Table 5).

These twelve most robust mixes have some characteristics in common that can be interpreted as necessary (but not sufficient) prerequisites for their modest robustness level (Table 6). These are either policies that need to be systematically excluded or systematically included. Notably, none of the less innovative policies (option A) appear in this list.

Element 3: analyzing robustness regarding performance

In the previous chapters, the stability of the individual policies and policy-mixes against the future uncertainty of the context conditions was examined. Another key question, however, is what influence future uncertainty has on the ability of policy-mixes to achieve their overarching, systemic objectives. Two of the objectives are represented in this analysis by the indicator descriptors D (competitiveness of the regional economic structure) and E (net-zero land use by commerce). For each solution in the integrated matrix, the impact sum of an indicator descriptor indicates the balance of promoting and hindering impacts for the corresponding context scenario and policy-mix. This value is referred to below as the performance of the solution with regard to the goal.

In order to obtain information about the effects of context uncertainty on the performances of the two indicator descriptors, we determine for all $n = 278$ solutions of the integrated matrix which performances the two indicator descriptors achieve and assign the result to the context scenario that is active in the solution[4]. The results are shown in Fig. 6. The context scenario valid for a point group is identified by its code abbreviation.

Context uncertainty as the dominant cause of performance variance: A first observation regarding Fig. 6 is that the domains of the different context scenarios are largely separated from each other and overlap only slightly. This is by no means self-evident and expresses the fact that the collective freedom of action of the actors to choose between different consistent policy-mixes within a context scenario results in less performance variance overall than the uncontrollable context uncertainty. The context scenarios affect performance in two ways: (1) they have direct impacts on the indicator descriptors and (2) they can make it easier or more difficult to activate certain policies and thus influence the decision as to whether

[4] It should be noted at this point that other, more comprehensive modeling approaches (e.g., an economic model) may be even better suited to predicting the performance of a policy-mix more accurately. However, such an approach was not available for our analyses.

Table 5 List of most robust policy-mixes (robust in $n = 5$ out of $n = 10$ context scenarios)

Sub-Goal	Maximally robust policy mixes											
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12
1 Improve city-regional cooperation regarding commercial areas	1 A	1 A	1 A	1B	1 A	1B	1 A	1 A	1 A	1 A	1 A	1B
2 Joint development perspective for PFENZ	2B	2B	2B	2B	2B	2B	2B	2B	2B	2B	2B	2B
3 Develop commercial areas in inter-municipal cooperation	3B	3B	3 A	3 A	3B	3B	3 A	3B	3 A	3B	3 A	3 A
4 Reduction and control of land use for commercial areas	4 S	4 A	4 S	4 S	4 S	4 S	4 S	4 S	4 A	4 A	4 S	4 S
5 Mobilize existing commercial land and buildings	5B	5B	5B	5B	5B	5B	5B	5B	5B	5B	5B	5B
6 Use of commercial areas in a land-saving and multifunctional way	6 S	6 S	6 A	6 A	6 A	6 A	6 S	6 S	6 S	6 S	6 A	6 A
7 Future-oriented commercial area planning and implementation	7B	7B	7B	7B	7B	7B	7B	7B	7B	7B	7B	7B
8 Securing and creating (sustainable) jobs	8B	8B	8B	8B	8B	8B	8B	8B	8B	8B	8B	8B
9 Improve regional location quality	9 A	9 A	9 A	9 A	9 A	9 A	9B	9B	9B	9B	9B	9B

Table 6 Maximum-robustness-preconditions in the policy-mixes

Sub-Goal	Policies	
	Included	Excluded
1 Improve city-regional cooperation regarding commercial areas		*1 S: Irregular exchange between city and individual surrounding municipalities*
2 Joint development perspective for PFENZ	2B: Regional development concept commercial areas in PFENZ	
3 Develop commercial areas in inter-municipal cooperation		*3 S: Informal preliminary talks for inter-municipal commercial area development*
4 Reduction and control of land use for commercial areas		4B: Regional plan + land use monitoring PLUS regional quantity target with tradable quotas
5 Mobilize existing commercial land and buildings	5B: Ext. approaches to municipal land policy as interim acquisition urban develop. contracts and deconstruction obligations etc.	
6 Use of commercial areas in a land-saving and multi-functional way		6B: Lower land prices in return for multifunctional and public areas
7 Future-oriented commercial area planning and implementation	7B: Shared infrastructures within commercial areas	
8 Securing and creating (sustainable) jobs	8B: Joint innovative settlement strategy and skilled labor strategy in PFENZ	
9 Improve regional location quality		*9 S: Individual municipal location marketing*

goal-oriented policy-mixes can become consistent or whether they are prevented from doing so. In our case, the indicator performances are therefore more dependent on "fate", i.e. context developments, than on the decisions of the actors.

The context scenarios determine the performances to very different extents: The extent of the domains of the context scenarios in Fig. 6 varies greatly. Context scenario A4-B3-C3 (de-globalization, little change in the world of work, land use remains a non-binding political goal) (purple dots), for example, creates a very compact domain in the diagram. In other words, in this context scenario de-globalization strongly determines what performance

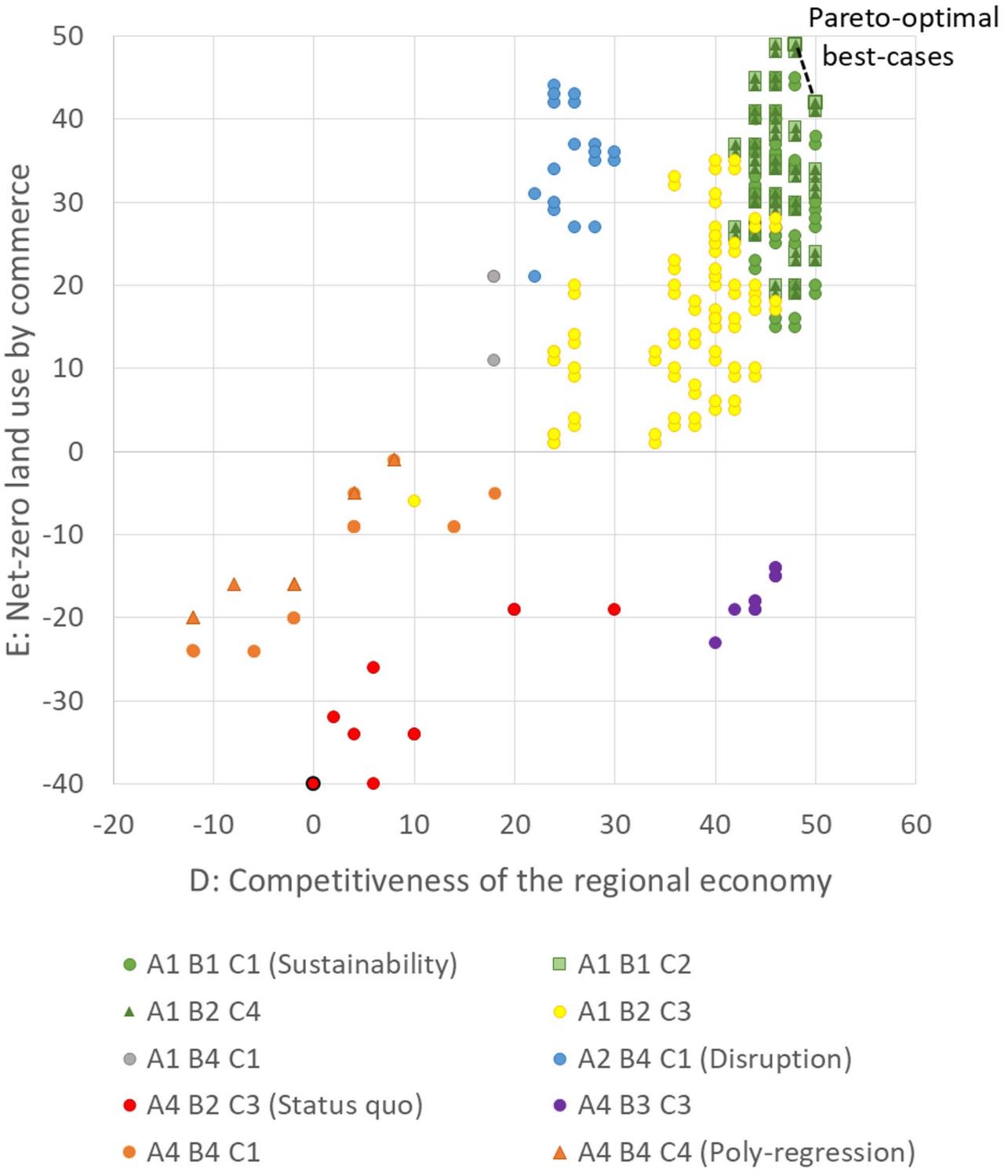

Fig. 6 The dependency of the goal performances from the context scenarios [5]

[5] The (best case) Pareto Front is formed by the Pareto-optimal solutions. Pareto-optimality implies that there exists no other solution that performs better for at least one index and at least equivalent for the other index [47].

can be achieved - namely a substantial performance for the regional economic structure, but a low performance for less land take. Which policy-mix is ultimately realized under these conditions is not insignificant, but is no longer decisive for performance.

Things are quite different for the context scenario A1-B2-C3 (status quo of the German economy, little change in the world of work, additional funding opportunities for municipal environmental measures) (yellow dots), which is shaped by additional funding opportunities. This contextual future leaves the actors with a particularly high degree of decision-making freedom (and thus a particularly high degree of responsibility). It results in a high number of consistent policy-mixes and also to a high variance in possible performances, although the performances - with one notable exception - are all in the acceptable to good range.

Among the context scenarios, there is a clear best-case in terms of performance The best-case among the context scenarios is case A1-B1 (additional financing options for municipal environmental measures, German technology leadership) (green dots), whereby there are no restrictions for context descriptor C apart from the consistency conditions. This group also includes the two Pareto-optimal policy-mixes of the total solution set (points highlighted by black rings in Fig. 6 top right, see Table in supplementary material C).

One of the Pareto optima in Fig. 6 is optimal if the goal of economic competitiveness (descriptor D) is given priority over the goal of "land use" (descriptor E). In the opposite case, the second Pareto optimum is optimal (see the table of Pareto Optima 1 and 2 in supplementary material C). However, both cases only differ in the policy choice of descriptors 3 and 9 with little impact on the goal performances.

In some context scenarios, the freedom of choice of the policy-mix essentially only affects one of the system objectives Some of the context scenarios lead to point clouds that are predominantly vertically extended. This can be observed in Fig. 6, especially in the context scenario family with "sustainability" elements A1-B1, which has a horizontal extent of 8 points and a vertical extent of 34 points. This means that the choice of a consistent policy-mix under this context scenario primarily has an impact on land use, but only a very limited impact on regional economic competitiveness. The latter is already largely determined by the context developments. The context scenarios A2-B4-C1 and A1-B4-C1 also follow this pattern. In contrast, the freedom of choice for the policy-mixes in the target-adverse context scenarios leads to balanced variances for both indicators. The case where the area target is significantly less sensitive than the competitiveness target does not occur.

Discussion

In the following, we discuss the implications of our study for the practice of policy design (5.1), for policy-mix scenario analysis using CIB (5.2), and for the policy design literature more generally (5.3).

Future contexts matter in the practice of policy design - in PFENZ and beyond

[4] already demonstrated (i) how regional commercial area-related policies interact, and (ii) that it is necessary to investigate whether the effectiveness of particularly innovative additional policies might be hindered by the already implemented status quo policy-mix. Our study expands this analysis and shows that context can significantly influence the consistency and performance of policy-mixes. In our case, the legal framework regarding land policy at the federal or state level can either impair or promote regional policies. Whether it enables freedoms (as in context A1) or severely restricts them (as in context A2) largely depends on the design of this overarching regulatory level.

For regional policy practice, it is crucial to highlight those policies that have proven particularly robust across all contexts. These policies are included in at least one consistent policy-mix in each context:

- 2B Regional development concept for commercial areas in PFENZ.
- 4 S Regional plan as a corridor for land use.
- 6 S Information on land-saving and multifunctional use.
- 7B Shared infrastructures within commercial areas.
- 9B Joint (collaborative) commercial area management and location marketing in PFENZ.

Thus, a policy selected from this list would, despite contextual uncertainty, always allow the formation of a consistent policy-mix around it. However, not all of these policies are mutually compatible. Therefore, it is also useful to highlight three policy-mix elements that can be synergistically combined, so that this combination occurs in ca. 90% of the policy-mix scenarios, and, accordingly, prevails across many (yet not all) contexts:

- 2B Regional development concept for commercial areas in PFENZ.
- 7B Shared infrastructures within commercial areas.
- 8B Joint innovative settlement strategy and skilled labor strategy in PFENZ.

Moreover, our analysis indicates that some policies cannot be consistently and effectively implemented at the regional level unless the federal or state level provides the necessary conditions. In our analysis, the context A3

— Nationwide quotas for all land uses and their trade — is absent from the consistent policy-mix scenarios. Thus, for policy design at both the regional and federal levels, a pivotal question is whether plausible context scenarios exist in which A3 could occur. A strong political will at the national level and/or obligations from the European level might be necessary — a question that future research should explore further by incorporating these factors into context scenarios.

While contexts can significantly impact the performance of policy-mixes, this influence should not lead practitioners to conclude that policy design is irrelevant. On the contrary, we observed that different, equally consistent policy-mixes under "status quo"-type context scenarios can vary significantly in their performance. Therefore, policy design *does* matter — particularly the design of robust policy-mixes — because we cannot predict which futures will unfold.

Building Policy-Mix scenarios with CIB

Our study shows that integrating active context descriptors and passive indicator descriptors ex post into a CIB policy interaction matrix is relatively straightforward. Integrated policy-mix scenarios with CIB thus contribute to the methodological toolbox of futures research: Assumptions on policy interaction have been generally rather missing from scenario analysis. Our approach allows to explicitly considering both, assumptions on future context scenarios and on policy interactions. In contrast, our analysis shows that regional system descriptors and policy descriptors overlap, as system descriptors often contain implicit assumptions about policies. Thus, integrating regional system descriptors from the scenario matrix beyond passive indicators is more challenging. Future research could explore methods to better depict the feedback dynamics between policies and (regional) system developments within the CIB framework.

Our study also hints at the implicit context scenarios assumed by experts and authors during the policy design process in [4]. It appears that the dominant implicit assumption was a context scenario closest to the status quo, which allows for particularly high degrees of decision-making freedom and results in a high number of consistent policy-mixes. In line with [16], we argue that if context scenarios are not explicitly assumed — in this case during policy design — they are implicitly assumed. Moreover, different participants in a policy design process may have divergent assumptions about possible future contexts, which could bias their assessment of policy effectiveness and interactions. Policy-mix scenario analysis using CIB enables to address such assumptions in a transparent and systematic manner.

A new conceptualization of robustness adding to the policy design literature

Our analysis contributes to the policy design literature, which already recognizes scenarios as an important tool [20], but does not yet comprehensively incorporate them into analyses. We further develop the concept of policy-mix scenarios and offer a methodological approach to systematically integrate scenarios into policy-mix design using CIB. We also refine the concept of robustness by considering three elements and two degrees: the global and partial robustness of individual policies and of policy-mixes, and the robustness of policy-mix performance under different scenarios. Future work could use this as a basis for even more in-depth robustness analyses and, for example, investigate the relationship between the partial robustness of individual policies and performance in a policy-mix scenario.

Content-wise, one notable finding is that the regional development concept (2B) proved particularly robust. A regional development concept is a strongly procedural element that must be individually defined and can be regularly expanded, revised, and adapted. This confirms [21] thesis that including procedural elements that enable improvisation and rapid response to shocks is crucial for designing robust policy-mixes (cf. also [3]). This also supports the findings by [48], that flexibility and adaptability of policies can increase the robustness of policies - and policy–mixes - especially in situations of deep uncertainty [48].

Conclusion

In our paper, we contribute to policy design research by asking how the robustness of policy-mixes can be analyzed using scenarios. To this end, we conducted a case study in the Northern Black Forest region, designing policy-mixes intended to minimize trade-offs in commercial land development. These policy-mixes were integrated with context variables from a scenario study also conducted for the region, and a performance analysis was undertaken.

Content-wise, we showed that no single "no-regret" policy remains stable under all scenarios. However, the analysis also highlights policies that are highly compatible with each other across very different future contexts:

- 2B Regional development concept for commercial areas in PFENZ.
- 7B Shared infrastructures within commercial areas.
- 8B Joint innovative settlement strategy and skilled labor strategy in PFENZ.

Methodologically, we demonstrated how to integrate CIB-based scenarios with policy design ex post. We also illustrated how to consider three elements for assessing

scenario robustness: at the level of individual policies (which policies are robust across different scenarios?), at the level of policy-mixes (which mixes are robust?), and at the level of system performance (which mixes provide robust performance across scenarios?).

Overall, our study contributes to advancing policy design under uncertainty. It does so by further developing a systematic approach using CIB to create policy-mix scenarios and refining the elements of robustness. These robustness considerations can benefit other CIB approaches to policy-mix scenarios and can also inform policy analysts, designers, and scenario analysts applying different methods that combine policy-mix design and scenarios.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40309-025-00263-7.

Supplementary material 1.

Supplementary material 2.

Supplementary material 3.

Acknowledgements
The authors would like to thank Stefan Vogele, Geert te Boveldt and Fabian Hölzlberger for their helpful comments on a preliminary version of the manuscript and two anonymous reviewers who provided very helpful suggestions for improving the paper. They also thank Julia Danzer for her help in preparing the final manuscript.

Authors' contributions
HK came up with the conceptual idea for the article. SW coordinated the writing of the article. All authors contributed substantially to the analysis and generation of data and wrote the article. SW was primarily responsible for the state of research. WWJ was primarily responsible for conducting the robustness analyses. HK was primarily responsible for writing the discussion and conclusion. All authors read and approved the final manuscript.

Funding
Open Access funding enabled and organized by Projekt DEAL. The research published in this article was funded by the Federal Ministry of Research, Technology and Space as part of the research projects KoOpRegioN and UBoPlus and by the Daimler and Benz Foundation as part of the ZuWaKo research project.

Data availability
All data generated in this study are included in this published article (and the accompanying supplementary files). The data analyzed in this study in relation to the policy mixes are available in [4]. The data analyzed in this study in relation to the scenarios for the northern Black Forest can be requested from the authors (data are only available in German).

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Received: 24 July 2025 / Accepted: 9 December 2025
Published online: 19 December 2025

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Publisher's Note

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