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Adaptive Design Evaluator: A Co-Assessment Tool for Early Planning Stages

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Abstract

Many municipalities face intense development pressures, challenging them to ensure spatial sustainability. Current assessment methods are designed for larger projects and are often time-consuming and resource intensive. Certification systems like ÖGNI, DGNB, LEED, and BREEAM use detailed but rigid criteria, making them unsuitable for dynamic co-creation processes. Smaller projects lack tools to visualize development impacts or generate tailored sustainability checklists. This article introduces the Adaptive Design (AD) Evaluator, an innovative, step-by-step methodology for sustainable impact assessment in building and planning projects. The AD Evaluator involves public and private stakeholders in a co-creation process, integrating questionnaires, system dynamics models and spatial analysis to efficiently assess project interventions. The results are presented visually, enabling adaptable, resource-efficient planning across four sustainability pillars. This approach supports quick assessments, offering perspectives from both developers and system owners (e.g., municipalities) and minimizes deviations from sustainable outcomes. The innovation of this approach lies in the introduction of the first conceptual scenario assessment generator for qualitative sustainability inventory and impact assessment in planning practice. The AD Evaluator supports the co-design of structured yet flexible planning pathways for sustainable and adaptive urban environments by mapping and visualizing the impacts of planning in a jointly negotiated framework.

Keywords

adaptive design; co-creation process; impact assessment; spatial life cycle; spatial sustainability; sustainable transformation

1. Introduction

Many municipalities face intense development pressures, which involve dealing with challenges based on social and technical needs and with limited financial capacities. In addition, they have to comply with overarching sustainability goals (e.g., sustainable development goals [SDGs], spatial planning concepts). Dealing with these challenges and thereby focusing on robust decisions for sustainable building developments demands expert knowledge.

The SDGs have also led to the accelerated development of certification systems and standards for circular economy and sustainable developments in the construction and planning sector, which "prove" the sustainability of building developments. Certification systems promise support in the creation of sustainable developments and, in addition to PR/marketing, are increasingly being used to assess the eligibility of sustainable developments for funding. These certification systems as well as currently available pre-assessments are able to evaluate actual projects based on detailed plans and designs and purport to offer planning and decision support.

In practice, however, decision makers often deal with different planning alternatives, not yet specified in detail. There are a multitude of different assessment systems that are rarely cross-sectoral. The assessments based on certifications are linked to external audits during the assessment process and do not focus on the involvement of decision makers or project developers. These external audits are time and cost-intensive processes and thus more likely to be considered for large projects. Life cycle assessments (LCAs) are standardized methods for the analysis of environmental aspects and potential impacts of products, processes, and organisations from a life cycle perspective. A LCA usually covers two dimensions of sustainability (ecological and economic). Many assessment methods also include the third dimension of sustainability: the social aspects.

This article introduces a new methodological approach—the Adaptive Design (AD) Evaluator, that includes a fourth dimension, "gestalt aspects" for adaptable spatial and social LCAs. We aim to fill the gap in the assessment tools for project ideas and rough concepts within early planning phases. In particular, we address the challenge that there is currently no scope for self-assessment of planning alternatives without requiring external audits. The innovative approach of the AD Evaluator focusses on the support of cooperative planning processes, in which the tool-supported evaluation of project plans and framework conditions provides immediate feedback in decision-making processes. The aim is to create a system with which the automated evaluation of input from local experts and citizens (in the form of project questionnaires and evaluation forms) provides input for system dynamics models (SDMs) for analyzing interactions. The automated preparation and processing of the evaluation results enables a step-by-step improvement of ideas and projects in co-operative processes.

The AD Evaluator underpins sustainable spatial transformation from the idea to realization with a focus on strategic co-design and co-assessment. Project developers and decision makers (municipality, state, federal government) can use the approach offered by the AD Evaluator to carry out independent assessments and compare alternatives. The AD Evaluator thus offers time- and cost-efficient planning support even for very early planning phases, where new ideas and innovations for sustainable spatial transformation can be introduced, and robust framework conditions and objectives can be strategically developed. This enables planning stakeholders in all planning phases to evaluate planning alternatives, considering impacts and interactions, and at the same time identifies necessary measures to achieve objectives in the form of checklists.

2. State of the Art

Within the field of spatial planning, we are dealing with long-term planning perspectives and envision various alternative spatial states. Sustainable development, introduced over 30 years ago with the "Brundtland Report" (WCED, 1987), has become an important planning objective, especially since the UN's commitment to the SDGs in 2015. A natural evolution process is attached to buildings and infrastructures as it is to biological organisms, which initiates continuous transformations within our built environments and allows for sustainable transition (Cairns & Jacobs, 2014) and circular economy thinking. The reorganization, renewal, and replacement of built environments within the boundaries of settlement areas are key elements for strategic pathways to sustainable transformation (Schartmann & Siedentop, 2024). However, the challenge for many involved in planning is not whether but how sustainable change can occur. The introduction of spatial sustainability in standards (ISO 59020, 2024) has raised awareness of soil as a resource and the intensity of material drain in the construction sector (35% of waste generation and up to 12% of GHG emissions based on European Commission, 2024). However, there is currently no practical methodology that ensures sustainable building development.

2.1. Spatial Assessment Procedures

On a formal, legal level assessment systems based on EU directives such as the strategic environmental assessment (SEA) or the environmental impact assessment (EIA) are well established. In Austria, they are applied to large projects often related to technical or social infrastructure developments covering time and cost-intensive processes. SEA and EIA are preliminary assessments, particularly in the early planning and design phase of a construction project or of a plan/program. These procedures aim to assess and optimize the sustainability and environmental compatibility of a project as well as planning alternatives at the conceptual level. Additionally, there are further spatial impact assessments for bigger projects in Austria in five federal states on the supra-local level (Upper Austria, Carinthia) and on local level (Lower Austria), as well as when preparing major projects (Salzburg, Burgenland; cf. Stöglehner, 2023). They focus on environmental assets and material assets (Fürst, 2008, p. 71, as cited in Stöglehner, 2023).

Certifications as mentioned above offer standardized approaches assessing projects within the LCA frameworks based on specified plans and building designs via thematic categories. Most certifications are based on the ISO 59000 family of standards for harmonizing understanding, implementation and measurement of circular economy. The ISO 59020:2024 document (ISO, 2024) explains that the system boundaries of the measurement and assessment should be considered in spatial and temporal manner and their impacts to social, environmental and economic systems. The assessment of impacts on these three pillars is based on LCAs.

There is a broad consensus in the scientific literature that certification and testing systems have successfully contributed to raising general awareness of sustainability principles (Garde, 2017). However, not all certification procedures fulfil all essential LCA criteria (Doan et al., 2017). At the same time, due to different evaluation criteria, the rating of a building differs between the various rating systems; the same building is rated "green" or "sustainable" depending on the rating system in question (Suzer, 2019).

In Austria, the "*klimaaktiv* building standard" is a seal of quality for sustainable construction and refurbishment, an initiative by the Austrian Federal Ministry (BMK, 2024). Property developers, planners, and builders can evaluate constructed or renovated buildings online and free of charge within a defined catalog of criteria. At neighborhood level, expert process support is offered to ensure that the quality criteria are met within the defined fields of action. While common certification systems (ÖGNI/DGNB, LEED, and BREEAM) can assess concrete projects based on detailed plans and designs, there is no assessment available for very early planning phases in the absence of specific building/project designs. All assessments based on certifications and testing procedures are linked to external audits during the assessment process (cf. BREEAM, n.d.; DGNB, n.d.; ÖGNI, n.d.; USGBC, n.d.).

As already mentioned, external audits are time- and cost-intensive processes. Thus, they are more likely considered for large projects as well as projects with great importance on high planning levels. However, it is important to evaluate the large number of medium-sized and small projects and ideas (having a cumulated large impact)—best at an early stage, since not much time and money has yet been spent on the exact planning and design implementation. However, in such cases, details are often lacking. Nevertheless, assessments within early planning phases are essential for efficient planning of sustainable transformations, allowing the definition of project target settings within the sustainability framework of superordinate institutions (municipality, nation, EU). While SEA and EIA enable the assessment of planning alternatives, there is no documentation of planning alternative assessment within building or neighborhood certifications systems. Moreover, available pre-assessments only prepare specified projects for easier assessment within defined categories in the continuing building certification process.

Figure 1 provides an overview of existing evaluation systems and shows their use in relation to the planning phase and project size. The boundaries between the different evaluation systems are blurred. The systems are not transparently documented and focus on diverse aspects. The diagram illustrates a gap within early planning phases on building and community level. This lack of opportunity for assessment in early planning phases, especially in the governance processes and in the informal planning and decision-making processes, has also been identified by the German Federal Office for Building and Regional Planning (cf. BBSR, 2020).

2.2. Digital Assessment Environments

Certification systems assess within fixed categorization grids. They are subject to extensive, rigid, but not project-specific evaluation systems. In addition, LCAs have a static structure which does not consider dynamic influences (Fouquet et al., 2015). Within environmental scenario analysis, dynamic effects and interactions must be taken into account (Yi et al., 2023). An SDM is described as a feedback control system using digital simulation for complex system analysis and improvement (Forrester, 1961). In recent years, the combination of SDM and LCA has been a common means of providing for decision support (Choong & McKay, 2014). The integration of SDMs into assessment processes in the field of LCA enables static relationships to interact dynamically with each other and thus to simulate changes directly, as well as to analyze the effects of a product throughout its entire life cycle (Yi et al., 2023).

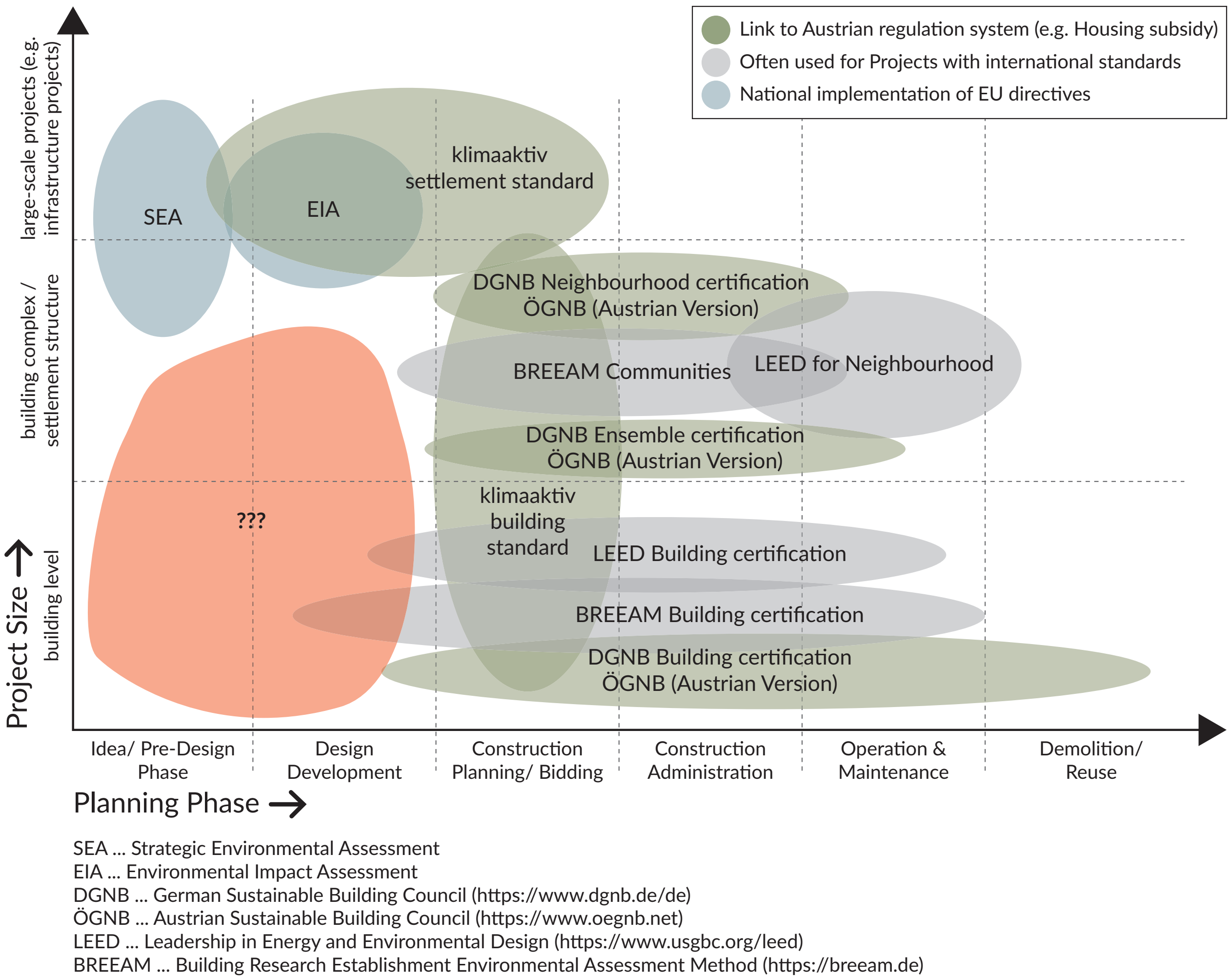

Figure 1. Positioning of the AD Evaluator concept study in relation to existing evaluation systems for the sustainable development of cities and buildings in the German-speaking planning area.

The methodological approach envisaged in this article involves using questionnaires to query and map objectives, as is in certification systems, but automatically transfers predefined categories, including their weighting, into simple SDMs. Assunção et al. (2020), Diemer and Nedelciu (2020), and Kiss and Kiss (2021) have already conceptually demonstrated such an approach in various studies. Automating these steps could efficiently provide assessments for planning practice "at the push of a button," in contrast to previous approaches, which have lacked transparent, transdisciplinary, digital tools (Stede et al., 2024).

Meanwhile, certification providers are increasingly offering digital tools that visualize the guidelines for sustainability certification as early as the pre-assessment phase. The digital integration of certification assessment systems aims to meet the demand for digitally driven sustainability transformation, as called for in a report by the German Advisory Council on Global Change (WBGU, 2019, p. 9). However, these procedures are designed for a defined project and are not used for joint project development but to fulfil the sustainability goals for an already defined project. There are currently no known assessment approaches that automatically create a comprehensible basis for decision making and list recommendations for action in a digital framework at a very early concept phase for the various stakeholders. Early involvement of communities or users is not provided within existing certification processes (Saiu et al., 2022). Inclusion of these stakeholders could go a long way to closing knowledge gaps in early planning stages. Schönwandt (1999) and Selle (1997) emphasize the need for cooperative processes for the development of robust planning decisions. D'Ignazio and Klein (2020) show how social and gender-relevant aspects in cooperative planning can also be integrated.

2.3. Gestalt Sustainability and AD

The term and concept of gestalt sustainability emphasizes the necessity of considering not only ecological, social, and economic factors but also the qualitative dimension of spatial design (Pansinger & Prettenthaler, 2023). This dimension acknowledges that the physical form and arrangement of spaces profoundly impact quality of life, social interaction, and ecological balance. Gestalt sustainability refers to the intentional design of spaces that fosters interactions between people and their environment, crucial for developing resilient urban structures that are both adaptable and sustainable (Gehl, 2011; Lefebvre, 2001; Sassen, 2000). A space designed according to the principles of gestalt sustainability facilitates harmonious interaction among various aspects of life, promotes community spirit and cultural identity, and supports ecological principles (Pansinger & Prettenthaler, 2023). We therefore adopt the term "adaptive design" in describing our approach.

The impact of digitalization and related technologies on spatial structures is analyzed by Radulova-Stahmer (2023). Based on the analysis of direct interventions (sharing concepts, energy production, waste management, etc.) and indirect drivers (changes in mobility behavior, intelligent lighting, shifts in use, etc.) spatial impact categories and their limits are identified. These spatial impact categories are differentiated by changes in human behavior, in the physical urban space, and in the overall spatial system. Organized into spatial impacts and potentials, they can form a broad basis for deriving qualities for a gestalt sustainability assessment.

3. Methodology

First, the main concept of the AD Evaluator is described, based on the methodological approach for its development. Afterwards the concept study of AD Evaluator is tested based on a case study area in Austria.

The overall research approach of the AD Evaluator is a test procedure that makes it possible to assess whether the objectives of the planning project fit into the overarching system and where there is potential for improvement, both at development (project organiser) and system level (municipality, country). The AD Evaluator employs a systematic approach to assessing and designing urban spaces, considering both quantitative and qualitative dimensions. Figure 2 presents the AD Evaluator process based on the four phases: base setup, preparation, assessment, and co-evaluation.

1. Base setup phase: The initial base setup is performed by planners and experts and creates the relevant test framework by selecting the (sustainability and policy) objectives. These shape the questionnaires and weighting tables that are filled in the following phases. First categories are defined, which allow spatial sustainability to be mapped. Based on the defined AD Evaluator criteria catalog a scheme for questionnaires is designed. All criteria are assessed based on linked measures as well as interconnections and connections with each other by expert groups also for further use within the evaluation phase.

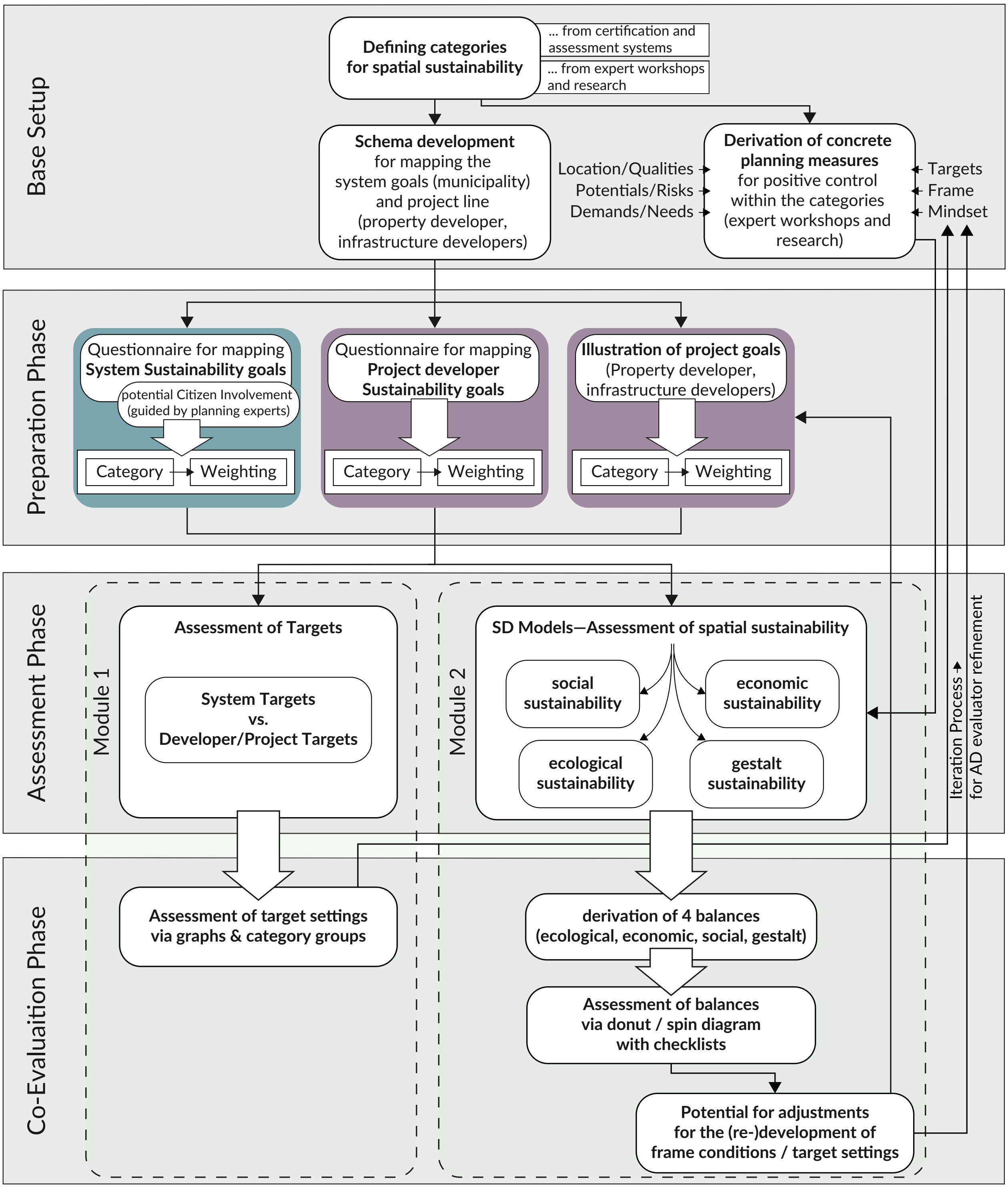

Figure 2. AD Evaluator concept—Methodological approach overview.

2. Preparation phase: Based on these categories, a three-stage “framing” approach is developed. The framing process enables a holistic systemic assessment of spatial sustainability by means of questionnaires, which allow us to derive the following objectives:
    - The superordinate system objectives (objectives of the municipality, country, SDGs);

- The project developer objectives (property developer, infrastructure developer, etc.);
- The specific project objectives.

The questionnaires are linked to the predefined categories and allow objective-based weighting.

3. The assessment phase consists of two main modules:
    - Module 1 allows comparison of system versus developer (project) targets based on category groups and weighting within each objective "frame."
    - Module 2 is based on the evaluation of SDMs, where the categories including weighting serve as input. The SDMs capture interactions and interdependencies and enable the assessment of spatial sustainability in social, ecological, economical and gestalt-related areas. The SDMs examine potential designs through defined rules of action. These defined effect mechanisms allow the development of comprehensible results and the comparison of results.
4. The co-evaluation phase is also divided into the two modules shown in the assessment phase.
    - Module 1: The outputs can be compared based on graphs which illustrate the superordinate system target settings versus the project objectives. The characteristics of individual evaluation areas are described by means of main groups containing several AD Evaluator criteria.
    - Module 2: The output of the SDM is a "SPace INdex (SPIN)" holding the main sustainability categories (ecologic, economic, social, and gestalt), assigned subcategories, and the characteristics of a specific development alternative within these categories.

Additionally, the output contains a checklist with the most important points for ensuring targeted implementation within the defined sustainability conditions from both a system and developer view. The visual and textual output allows evaluation and comparison of development alternatives as well as clear structural information online achievement.

In the following, each step from base setup, preparation phase, assessment phase, and co-evaluation phase will be described in detail.

3.1. Base Setup

The *criteria selection process for sustainability assessment* are derived from the three most important standards for building and neighborhood assessments in Austria, ÖGNI and *klimaaktiv* building standard, and are expanded with spatial impact categories defined by Radulova-Stahmer (2023).

Based on the criteria categories from building and settlement catalogs within these systems, a criteria list is extracted and prepared in such a way that multiple entries and overlaps are avoided. This step was executed with table sheets using a line-by-line manual preparation.

The resulting criteria list allows us to derive spatial measures. Based on these measures the AD Evaluator criteria catalogue (AD criteria catalogue) is defined, allowing project descriptions and scheme development. The criteria are clustered in five thematic categories:

1. Land use and urban fabric
2. Resources and environmental aspects
3. Mobility

4. Quality of stay
5. Governance and participation

Attachment 1 in the supplementary file presents a starting point for this catalog.

For the *scheme development* the sustainability assessment is built along the three dimensions of sustainability (ecology, economy, social) used in LCA approaches supplemented with the important fourth dimension "gestalt." In the context of the AD methodology, gestalt sustainability is viewed as an integral component of planning. Within the AD Evaluator, this integration is accounted for by embedding four main criteria:

1. *Recognizability/Clarity* (see Figure 3a): This dimension evaluates and promotes a transparent spatial organization and a clear identity that helps users intuitively navigate and utilize the space. "Connectivity clarity" is shown through the logical connection of function, space, and infrastructure, for example, by the deliberate arrangement of buildings and their connection to infrastructure. "Usage clarity" arises from clear organization that distinguishes historical and new functions while maintaining flexible usage without losing the building's identity. "Figure Clarity" is shaped by the functional and topographical anchoring of the spatial organization.
2. *Communication/Scale* (see Figure 3b): Evaluates the interaction of a space or building with its surroundings and the integration of different scale levels. "Field formation" creates clear boundaries and concise communication. "Affinity" ensures that the area harmonizes with its context, with material choices, shapes, proportions, and functions determining the relationship to the surroundings. "Mediating scale" ensures the harmonious interaction of different scale levels by balancing size differences and supporting both the functionality and aesthetics of the ensemble.
3. *Openness/Topological boundary* (see Figure 3c): Evaluates how a spatial system forms a boundary that separates and connects through physical, symbolic, and functional transitions, enabling the exchange of information and accessibility. "Contextuality" connects the spatial organization through symbolic and functional boundaries to its environment. "Permeability" creates smooth transitions between interior and exterior spaces, both physically and symbolically, opening communication with the surroundings. "Symbolic boundary" serves as a gateway to the history of the place.
4. *Adaptability/Transformability* (see Figure 3d): Evaluates a system's ability to adjust to changes while preserving its identity. It includes: "Place character" as the unique atmosphere of a place, shaped by architecture, nature, culture, and history; "Short-term and longevity" as the ability to adjust to new uses in the short term while maintaining cultural significance and flexibility in the long term; "Adaptability" as the ability to integrate societal and functional changes without losing the fundamental structure or identity.

The AD Evaluator approach leads to a tree-based scheme of four qualitative balance sheets, based on AD-criteria:

1. Ecological balance
2. Economic balance
3. Social balance
4. Gestalt balance

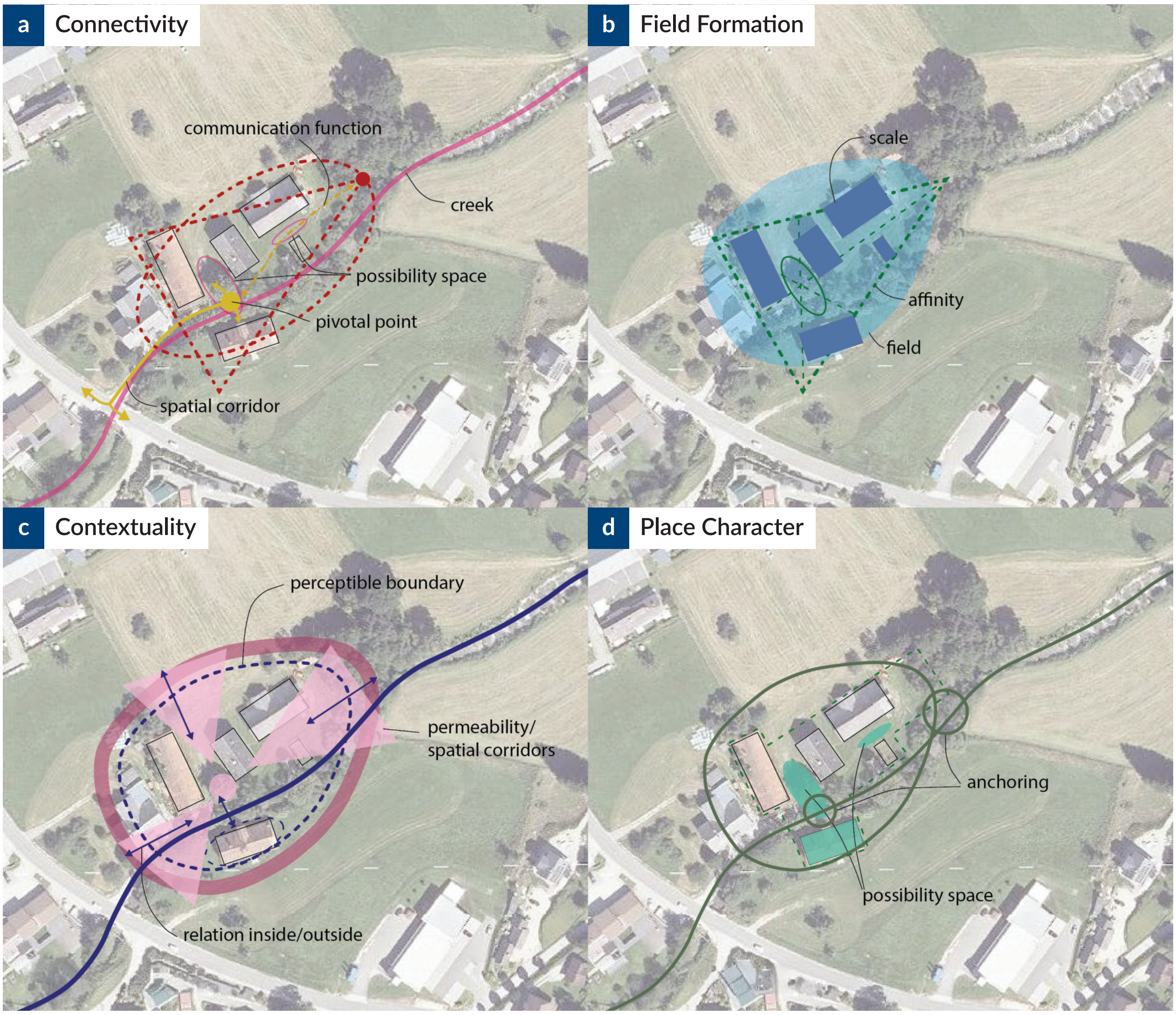

Figure 3. Four main criteria of gestalt: (a) Connectivity/Clarity, (b) Field Formation, (c) Contextuality, (d) Place Character.

These balance sheets are calculated via categories derived from the AD criteria catalog. The complexity and interrelationship of these balances and their influence on each other is illustrated in Figure 4 and demonstrates the need for an SDM. Their dependences and interconnections can be illustrated within tree diagrams (see Figure 4a). Within this step the innovation lies within the connection possibilities: The subtrees for the four thematic balances are not pure trees, but a complex system of directed acyclic graphs as they are connected in a causal loop diagram. A child node has several parent nodes (see Figure 4b-II) and at the same time can have several child nodes of its own (see Figure 4b-I). The diagrams show that cyclical relationships also arise, so-called feedback loops, which are represented in an SDM as reinforcing loops (r-loops) and balancing loops (b-loops), or also delayed loops. This makes it possible to recognize complex relationships and effects that may not be visible at first glance.

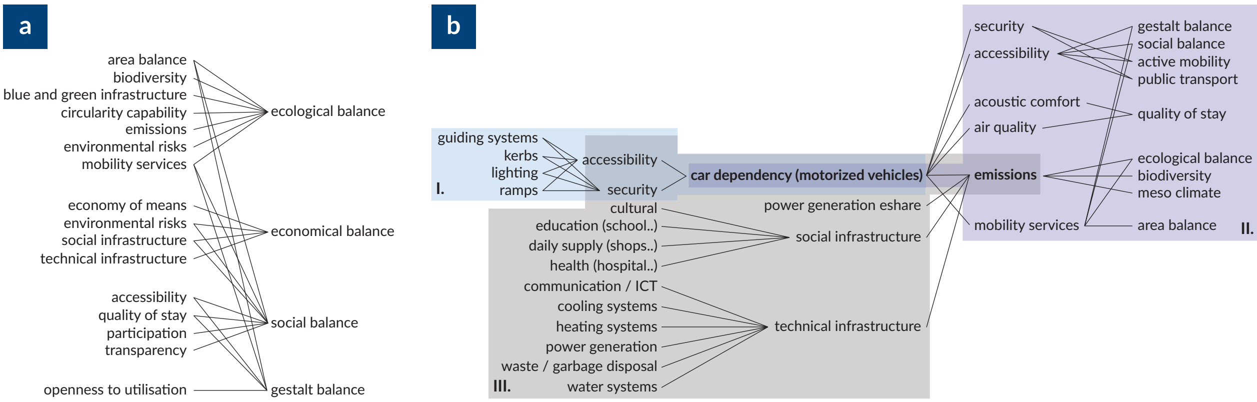

Figure 4. Sustainability concept on four pillars: ecological balance, economic balance, social balance, and gestalt balance (a) and node impacts based on example variable "car dependency" (example selection) (b).

3.2. Preparation Phase

The preparation phase initializes the user inputs to obtain system, developer, and project objectives. The questionnaires are set up based on the detailed scheme beforehand. Furthermore, a method for automated processing of questionnaires is described. In order to achieve this, the questions used to describe the project plans and their effects follow a predefined syntax, which is shown in Table 1. The property lists and objectives are fed for automatic processing from a growing pool that was initially created in the base-setup phase.

The following essential steps to enable project evaluation within the three-stage framing approach are necessary:

To obtain system objectives:

1. Set up the policy goals (e.g., SDGs, climate targets for Lower Austria, etc.) and describe their impact on the four sustainability pillars (see Table 2);
2. Weight the policy goals from 0 (not important) to 5 (very important; see Table 2) and assign temporal context.

To obtain project objectives:

3. Choose project activities/features from the "AD criteria catalog" to build the questionnaires that query specific projects and plans (see Attachment 1) and identify their impact (positive/negative/neutral) to the policy goals via a matrix.

To obtain developer objectives:

4. Query developer mindset on policy goals.

As already shown in the scheme development section, the project description is consistently based on the mapping of the effects in the four balances and the subgraphs with interconnections and different nodes.

The development of questionnaires is based on the nodes within the scheme graph. Some nodes show both location-related features and project-related features.

In our method, we derive three types of questions for the questionnaires:

- Type 1: General questions on the location, describing risks, potentials, and qualities including respective demands (like a SWOT analysis).
- Type 2: Questions related to project impact on location—specifically on risks, potentials, and qualities and demands. This question set forms the complementary question set for 1. to map the effects of the project.
- Type 3: Questions to describe the project qualities from AD-criteria catalog (can be extended as required).

These questions can be reduced and simplified for automated processing to the syntax illustrated in Table 1.

Notes related to Type 2: For the purposes of conceptual presentation, the time horizons are initially broken down into the categories short-term, mid-term, and long-term. The definition for the three units can be determined jointly by the stakeholders in the communication processes or, depending on the complexity of the SDMs used, must then be clearly specified in temporal contexts (e.g., years).

Notes related to Type 3: A list of qualities that were queried during the use case analysis (Chapter 4) can be found in Attachment 1.

3.2.1. Query System Objectives

While using the AD Evaluator, the objectives to be considered can be individually adapted to municipal, regional, and overarching objectives. Therefore, the actors representing the "system view" (representatives of municipalities or government administration, planning department) will describe their policies and assess the impact on sustainability (see Table 2). Table 2 shows an example of how the influence of the objectives/goals on the four pillars of sustainability (ecology, economy, social issues, gestalt) is assessed. The different objectives are also weighted in relation to each other from 0 (non-goal) to 5 (high importance) and placed in a temporal context (short-/mid-/long-term). Together these describe the sustainability and policy objectives that have been selected in the base setup.

3.2.2. Query Project Objectives

Type 3 question outputs describe project objectives and allow us to derive a connection to policy objectives. This allows us to rate single criteria and offers the option to display desired behaviors or project characteristics. The effects of project characteristics on the defined policy objectives can be presented in three categories: positive, neutral, negative. In a programmatic implementation of the AD Evaluator tool, this can also be shown as numerical values (e.g., from +5 to −5).

Table 1. Automated processing of question types.

Type	Question	Answer	Example
Type 1: General questions about location	"Risk xy in Area"	[No! | Don't know! | Yes + Risklevel 0–5] (level 5 high, e.g., annually; 0 not in a lifetime)	Q: Is your project location in a flooding zone? A: Yes—Risklevel 3 Q: Is your project location in a drought zone? A: No! Q: Is your project location in an earthquake zone? A: Don't know!
Type 1	"Potential xy in Area"	[No! | Don't know! | Yes+Potential level 0–5 (level 5 high, 0 not feasible)]	Q: Is your project location in a wind zone? A: Don't know! Q: Is the area suitable for solar power generation? A: Yes! Potential level 4
Type 1	"Quality xy in Area"/"Demand xy in Area"	[No! | Don't know! | Yes+Level 0–5 (level 5 high, 0 not existent)]	Q: Public transport quality in area? A: Yes, 3. Q: Accessibility quality in area? A: Yes, 2. Q: Demand for social housing in area? A: 5. Q: Demand for social infrastructure "elementary school"? A: 4.
Type 2: Project impact on risks, potentials, demands, qualities of location A1: [yes-increase]	Project effects "Quality xy/potential xy/risk xy"?	[yes-increase | yes-decrease | no-neutral]	Q1: Does project effect "quality of public transport"?
+ Impact estimation over time	How would you rate the impact of the project on XY over time?	[short-term 0–5, mid-term 0–5, long-term 0–5] (impact 5 high, 0 none)	Q2: How would you rate the impact of the project on "quality of transport" over time? A2: [2, 5, 5]
Type 3: Qualitative project description using predefined list of criteria/activities/features [A/F]	Does your project or plan involve [A/FAD criteria from AD criteria catalogue]?	[5–0] (Fully applies 5...does not apply 0)	Q: Does your plan involve "new building land dedication"? A: 0 Q: Does your project involve "improving walkability"? A: 3

3.2.3. Query Developer Objectives

Developer objectives are queried in the joint process related to project objectives and system objectives queries. For this purpose, an assessment of the developer is collected in relation to individual categories (from the project objectives questionnaire) that are linked to the system objectives (from the system objectives questionnaire) in the background. In this way, an assessment of the developer's mindset in relation to the system objectives can be created.

Table 2. List of (example) goals and their influence on the dimensions of sustainability resp. their priority of time.

Goal		Sustainability pillars				Priority (over time)		
ID	Description	Ecology	Economy	Social	Gestalt	short-term	mid-term	long-term
g1	Clean water and sanitation	0–5	0–5	0–5	0–5	0–5	0–5	0–5
g2	More social housing	0–5	0–5	0–5	0–5	0–5	0–5	0–5
g3	Reduce soil sealing	0–5	0–5	0–5	0–5	0–5	0–5	0–5
…								

Notes: Exemplary presentation for better readability: 5…high impact on pillar, 0…no impact on pillar; 5…high priority, 0…no priority.

3.3. Assessment Phase

The project is evaluated in parallel from both a system perspective (e.g., municipality) and a project perspective (e.g., developer). The questionnaires created serve as a means of communication for the evaluation and discussion between the stakeholders.

The assessment process can be processed in two different ways, represented within the AD Evaluator approach with Module 1 and Module 2. Module 1 allows the comparison of system and project perspective for the alignment of target settings within all planning actors. Module 2 calculates balances for holistic sustainability evaluation using SDM for detailed quantitative further assessments

3.3.1. Module 1: Assessment of System and Project Perspectives for Stakeholder Alignment

The project is evaluated in parallel from a project and system perspective using the project documents provided and the idea presented. Based on this, questions about the project characteristics (question type 3) are answered. The differences as well as the similarities can be (automatically) determined and highlighted.

Fields of actions and checklists including specific measures can be dynamically derived from evaluated differences. Different project alternatives (scenarios) can be individually addressed by also comparing project alternative objectives and system objectives, inducing a comparison of identified opportunities, risks and demands (question types 1 and 2). For cooperative planning support, different future scenarios can be stored and presented by modeling the system assessments in a programmatic implementation.

3.3.2. Module 2: SDM Concept

To enable mapping of interactions between the sustainability balances based on the desired activities and projects, the inputs of the programmatic implementation are transferred to an (initially simplified) SDM. That model can be built using the assignment trees and properties (nodes) of the location and project. Location related characteristics (spatial, social, etc.) are to be considered as stock variables in the SDM—they are represented in the questionnaires by question types 1 and 2. Project characteristics (questionnaire question types 3) affect these stock variables and form the input parameters for the description of inflows and outflows. To link the SDM to the policy goals, target variables need to be identified. They also need to be considered as stock variables in the SDM. If they are not already included in the SDM, they need to be created and integrated.

3.4. Co-Evaluation Phase

The co-evaluation phase is linked to the chosen module within the assessment phase. Each module enables visual output for quantitative and qualitative feedback.

Module 1: For cooperative planning support processes multiple diagrams based on main groups within the AD catalog (see Attachment 1) are generated (e.g., Figure 8 from case study analysis). Additionally, a checklist is produced to estimate environmental impacts. This also forms a basis for the time allocation and structuring of measures.

Module 2: The generated SPIN chart allows us to detect quantitative characteristics within specific sustainability balances, which in turn allows the detection of precise adaptation of measures. In cooperative planning processes, this can initiate an iterative improvement process for project adaptation on the one hand, and for the systemic framework conditions on the other, to create long-term holistic sustainability. The checklist of measures, which is also generated in this module for evaluation, creates a basis for communication of the impact analysis on the environment. At the same time, it also provides a good basis for early cost estimation, due to the derivability of construction requirements.

4. Case Study Analysis

4.1. Location and Embedding: Zellerndorf in Lower Austria

Zellerndorf is a small municipality (around 2,400 inhabitants) in the federal state of Lower Austria (Niederösterreich NOE) located 70 km north of Vienna. It has a line-oriented village structure with a school and sports center in the middle, defining a center for inhabitants and cultural interventions (see Figure 5), where just under half of the inhabitants live. The other inhabitants live scattered in smaller villages in the surrounding area. The municipality deals with challenges related to degrowth, an ageing population, and a lack of a central place for joint activities. Thus, the municipality wants to focus on sustainable development paths. Based on an empty plot (total area 4,000 m²) with a central location, a spatial assessment is stimulated. Within this case study analysis, two building developments with different usages are evaluated: Project 1—Multi-generation living, and Project 2—Supermarket—local supplier.

Project 1—Multi-generation living: Within the case study area, a project focusing on a multi-generational housing concept is evaluated. The project focuses on a vacant area of approximately 4,000 m². The project will cover about 1,800 m² and deals with four building complexes (each 450 m²) with 28 apartments for three generations (ages: 20–55, 55–75, 75+). The buildings form three atriums (450 m² each) enabling semi-public green spaces, offering shaded seating and social interaction. The remaining area will be used as a parking lot (750 m²).

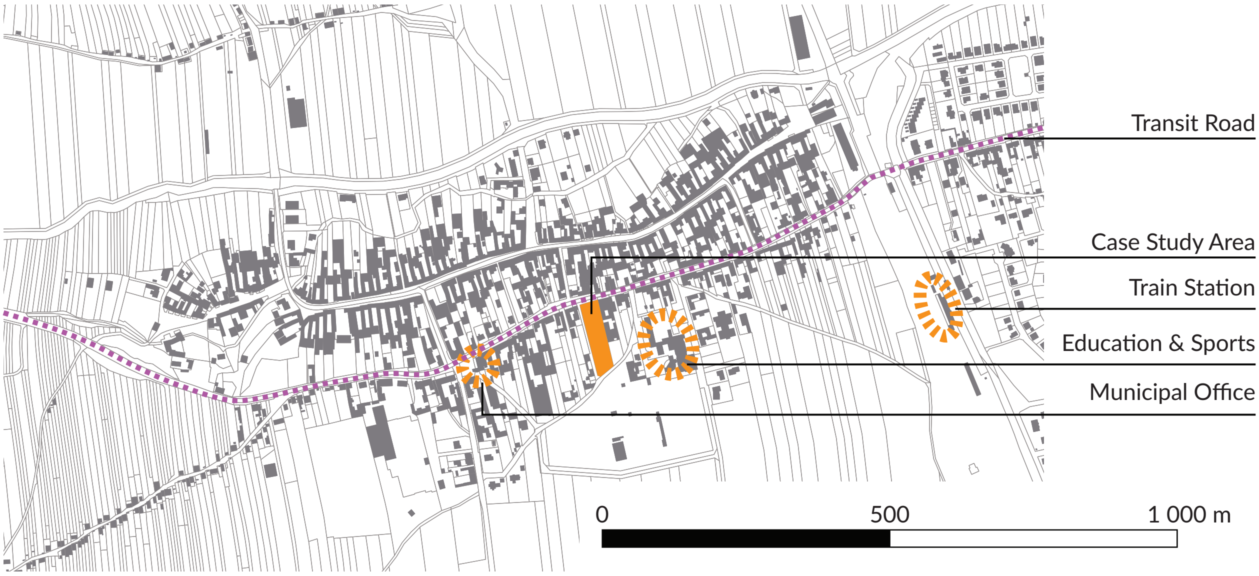

Figure 5. Plan of the village illustrating location of case study area related to structural embedding and accessibility.

Project 2—Supermarket: Within the case study area, a supermarket offering regional supply with food and essentials for daily life is evaluated. The project covers about 2,200 m² within one building and replaces the existing smaller supermarket in the neighboring building. The remaining area will be used as a parking lot (1,800 m²).

4.2. Preparation Phase

4.2.1. Description of Targets of the Specific Policy Framework

Both developments in the case study are evaluated on the basis of the policy goals (SDGs + NOE climate targets). The goals are entered in a table (analogous to Table 2) and prioritized from the perspective of the municipality. The definition of this perspective within the AD Evaluator was carried out by us, based on discussions with community representatives, the local planner, citizens, and the existing regional development strategy. The resulting weighting of the policy goals is shown in Figure 6 and applies to both tested projects. The priority of goals is shown in short-, medium-, and long-term as well as in a cumulative presentation. The darker the colour of the entry, the more important the target is considered to be. The priority shown refers only to the project characteristics selected for evaluation (= subset of Attachment 1; see Step 3 in preparation phase description) and shows the relevance of the goals for the chosen evaluation setup.

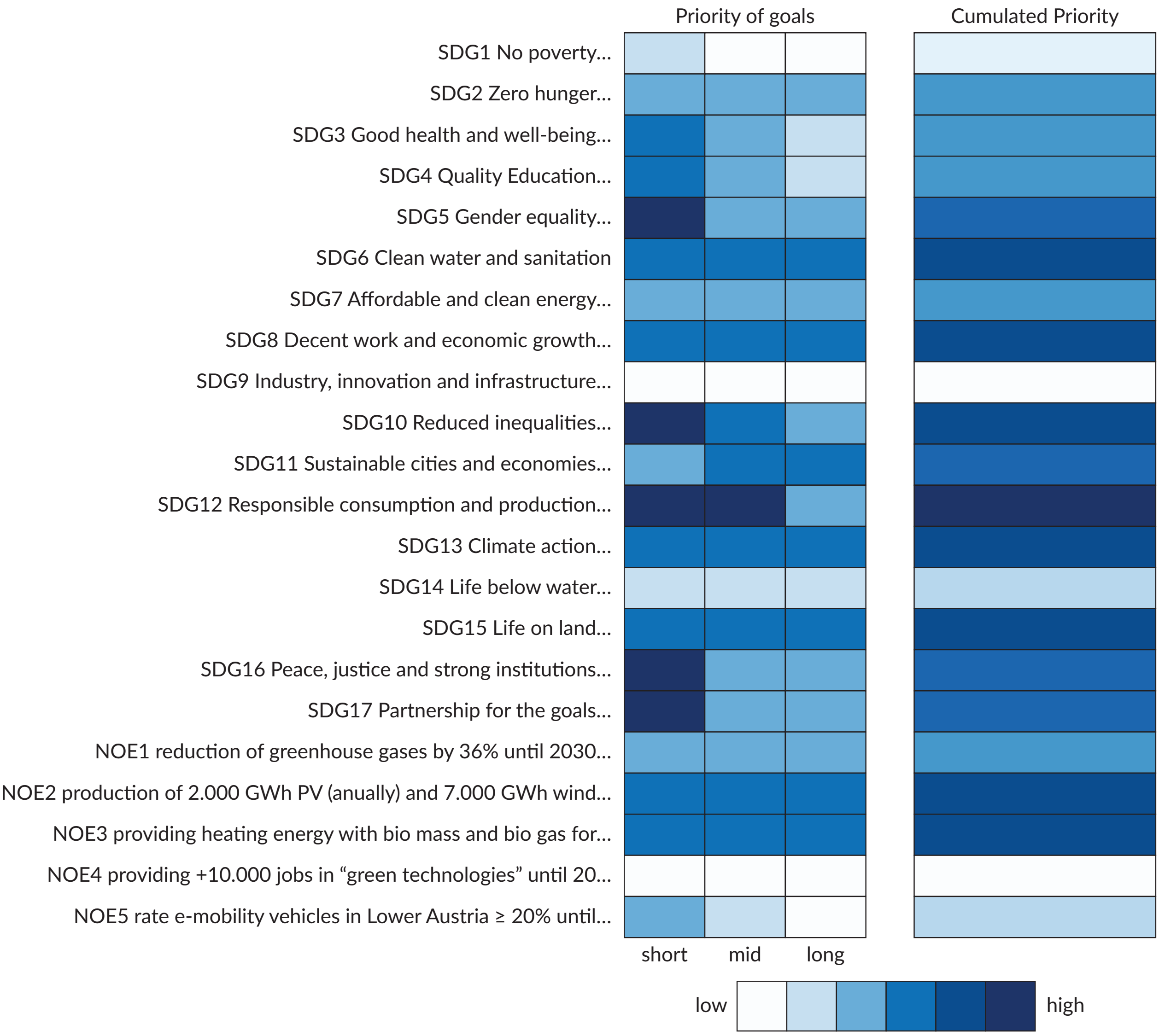

Figure 6. Weightings of the sustainability/policy goals from the perspective of the municipality for the project characteristics selected for evaluation and their priorities in short-, mid-, and long-term perspective.

4.2.2. Description of the Project Activities and Features

As the case study involves two different project plans and uses for a specific property and not theoretical concepts and plans, the criteria catalog in Attachment 1b is used. After defining the effects [positive|neutral|negative] of project characteristics/activities on political goals and expectations (“system perspective”), it is also possible to analyze the derived impacts of activities and characteristics over time. Figure 7 shows the effect of a selection of the project characteristics/activities on the objectives of the municipality. A distinction is made between expected short-, medium-, and long-term impacts. This allows us to identify those measures that have a major influence (positive or negative) on the municipality’s objectives. For example: While the project characteristic “unsealing soil” (#2017) has a positive effect in terms of the defined goals of the municipality, projects that have “fossil fuel heating systems” (#2036) have a negative effect on the formulated objectives.

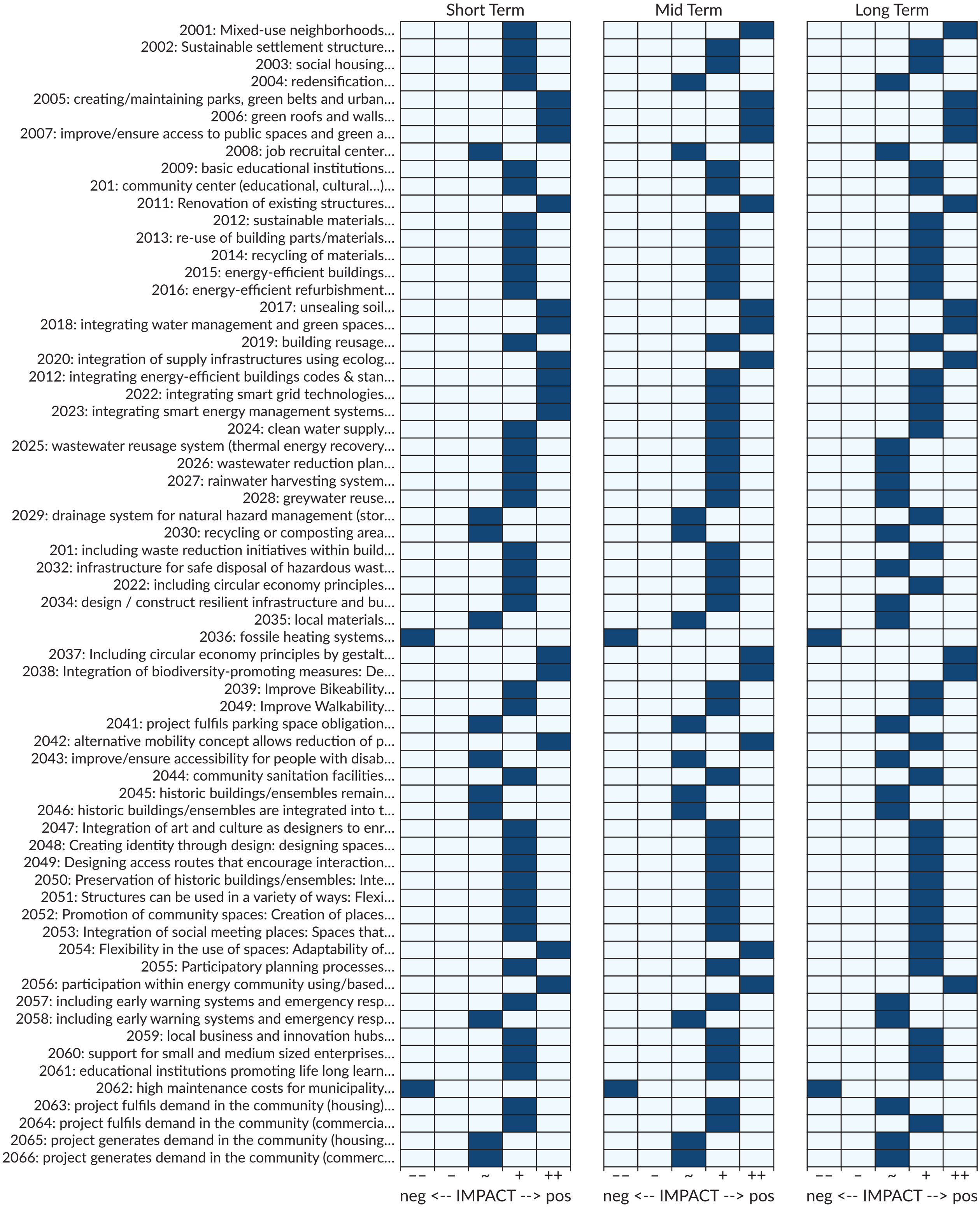

Figure 7. The impact of (a subset of) project feature characteristics, derived from the priority of the policy goals in the short-, mid-, and long-term.

4.3. Assessment Phase

The challenges, qualities, and objectives of the project area are briefly outlined below. Based on these descriptions, the respective project characteristics are evaluated, and it is shown that each of the two projects addresses different criteria.

4.3.1. Risks, Potentials, Qualities, Demand in Area

There was a slight demand for starter flats for young people and for small flats. There is no institutional care for the elderly. Property prices are still favorable compared to the immediate surroundings of Vienna and the journey time by S-Bahn to Vienna is around one hour. The current supermarket will be closing as the owner is retiring.

4.3.2. Project Impact on Risks, Potentials, Demands, Qualities of Location

The housing project could meet the need for housing and stimulate demand. The supermarket project would secure local supplies in the municipality for the coming years. The location in the centre of the built-up town center is very suitable for both uses.

4.3.3. Assessment of Projects

The separate and individual evaluation of the project characteristics based on the known project information yields the following initial findings for Project 1: 54 characteristics were used for the evaluation, whereby eight criteria were assessed equally from a system and developer perspective. In a further seven criteria, the expectation/requirement was exceeded from a system perspective. In 16 criteria, there were minor deviations, whereas the requirements were clearly not met in 23 criteria.

For project 2, 52 criteria were considered in the evaluation, whereby eight were assessed equally and four exceeded the requirement from a system perspective. Minor deviations were detected on 13 criteria and 27 criteria clearly do not fulfil the requirements. Two characteristics were not considered for evaluation as they apply specifically to residential construction projects only.

4.4. Co-Evaluation Phase

4.4.1. Module 1: Evaluate Targets and Objectives

To ensure that the participants in cooperative settings do not get bogged down in details, the biggest differences and deviations in the assessments are prioritized for discussion as a planning base. The differences between the project activities expected and the project activities determined are analyzed statistically based on the project assessment. Various key performance indicators were analyzed so that this can be done automatically. The standard deviation, variance and mean value of the differences are determined for each thematic cluster (see Section 3.1 base setup). Figures 8a and 8b show that the variance and standard deviation are best suited to determining the need for action or discussion.

While the assessments of multi-generation housing (Project 1) differ mainly in Cluster 5: Governance and participation aspects (Cat5 in Attachment 1), the differences in the planned supermarket (Project 2) are mainly in the assessment of the Cluster 4: Quality of stay (Cat4 in Attachment 1). The next step is to take a closer look at the differences in the respective assessments: Figure 8c and 8d show the respective expectations (system view) for the two projects in comparison to the project assessment by system and developer.

Analyzing these differences provides the basis for defining and designing new agreements or modified project specifications. This is to be implemented programmatically in future (see Section 7 Outlook). By digitally recording the questionnaires and entries, the individual measures and expectations can be compared based on a traffic light system on the deviation. Suggestions for improvement, warnings, or recommendations for action can initially be pre-formulated in general terms and then automatically improved using algorithms. By prioritizing the objectives and linking them to the activities, expenditure can be quantitatively limited to a sensible level.

4.4.2. Module 2: SDM

A simple SDM was created based on the assumptions made. The years 2030/2040/2050 were assumed as thetime horizons for the short-/medium-/long-term analyses. However, the selected use case is too small for the two projects to generate different effects in the very generalized model. In general, the model shows that the reduction in motorized traffic leads to a reduction in emissions, and that the improvement in accessibility and the quality of stay in public spaces make a positive contribution to the social balance and the design balance.

The comparison of the projects based on the four sustainability balances in the AD Evaluator shows that Project 1 performs slightly better than Project 2 (see SPIN graph in Figure 8e). The points achieved in the respective balance sheet are normalized based on the expectation value (= 100) from a system perspective. The graph also shows a utopian Project 3, which achieves all possible points. In this result, however, the interactions in the SDM between the individual balances hardly play a role.

Figure 8 shows the evaluation results for the two projects. Figure 8a shows the average of the absolute values of the deviation between system expectation and evaluation, while Figure 8b shows the standard deviation of the evaluation between system and developer evaluation: High values show a high discrepancy between the evaluation of the project from the perspective of the municipality and the evaluation from the perspective of the project applicant. The statistical measures (average, median, standard deviation, and variance) are to varying degrees suitable for identifying the deviations of the different assessments in the respective assessment categories. It turns out that the mean deviation in absolute values of the deviation between the perspective of the municipality and that of the project applicant best highlights the respective differences.

Figures 8c and 8d show the project evaluation of the system and the developer's perspective within the categories with the largest differences (Project 1: "Quality of stay," Project 2: "Mobility"). Figure 8e compares the results of projects in the 4 balances with the expectations of the municipality. The grey line in this figure illustrates a utopian project development, where all points in the respective balance sheets are achieved.

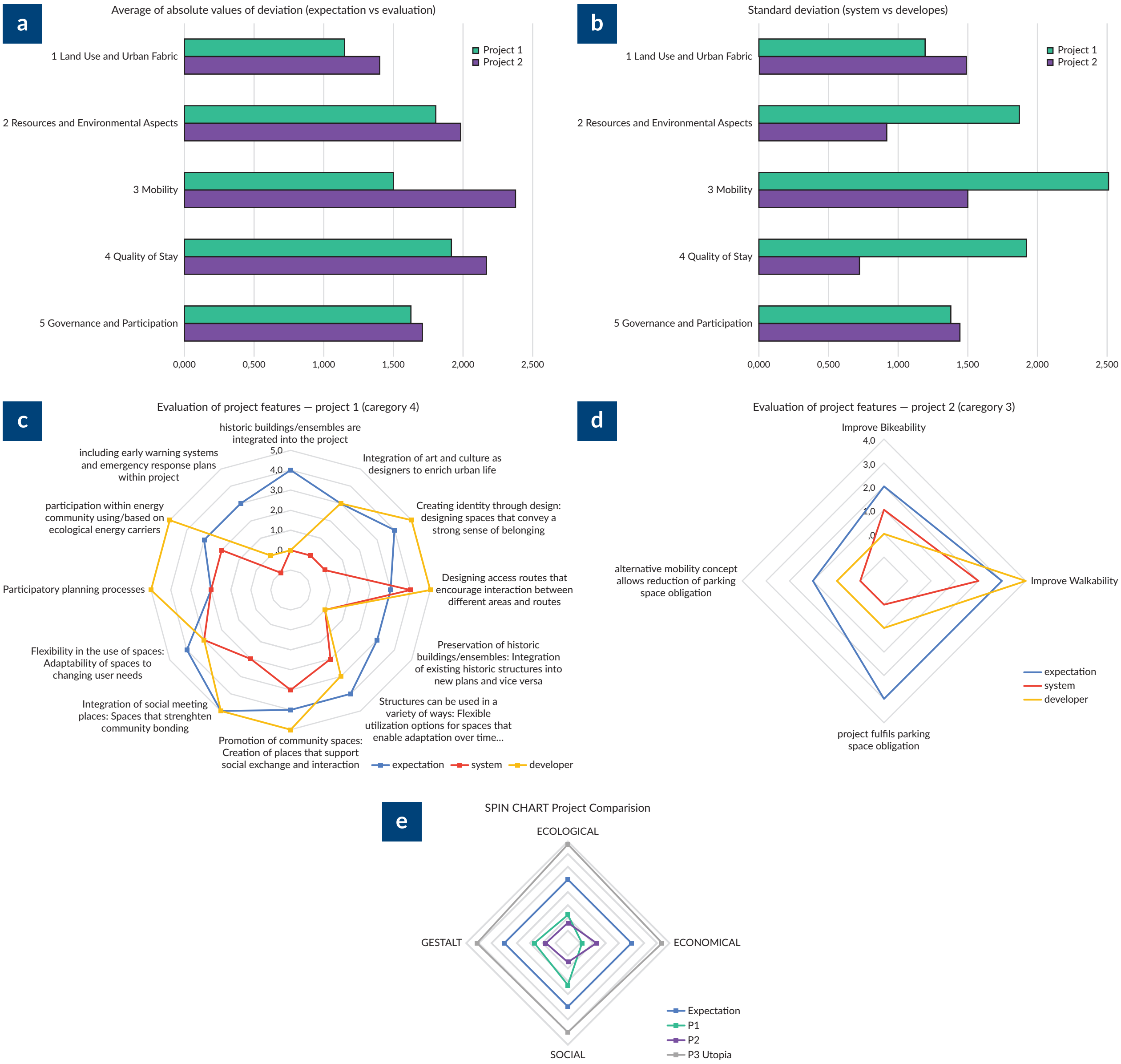

Figure 8. Statistical analysis of thematically clustered differences between expected activities and results of project assessment (a, b); concrete differences in the evaluation of project features/activities between expectations and project assessment: Project 1—Cat 4 (c) and Project 2—Cat 3 (d); and comparison of projects along the four sustainability balances (e).

5. Results

Section 4 has reported the main outputs illustrated in Figures 6, 7, and 8 of the AD Evaluator. Based on these figures, an estimation of the different effects and interactions of each project alternative is possible. The figures constitute a decision support base and allow us to initialise co-operative processes including planners, decision-makers, and citizens. Within these cooperative processes new ideas arise, which iteratively can be assessed again.

The results in Figure 8 show whether there is agreement between project developers and the municipality on the project qualities (see Figures 8a and 8b), where the differences in assessment lie (see Figures 8c and 8d) and how many points the projects score overall (Figure 8e). Figure 8 shows that the five thematic categories are effective in highlighting areas where the municipality's expectations diverge from the evaluation results: For instance, the lower the values in Figures 8a and 8b, the greater the agreement between expectations and evaluation (a), and between the municipality and the project applicant (b). In general, there is greater agreement in the evaluation of Project 1 and the project is closer to expectations.

Figure 8e shows that Project 1 scores higher than Project 2 in three aspects of sustainability (ecological, social, and gestalt) and that Project 2 is "better" only in the economic sustainability pillar. Overall, both projects do not achieve the desired qualities and should be improved. Figure 7 shows that certain project characteristics and impacts, such as No. 2036 "fossil heating systems" or No. 2062 "high maintenance costs," have a particularly negative impact on the municipality's objectives. These findings can subsequently be translated into automated recommendations for action.

Figures 8a and 8b also identify the thematic areas that need to be given special attention in cooperative processes. If there is agreement on a negative assessment, another project option should be considered. If there is disagreement, the project developer may be asked to provide further documentation to clarify critical issues. This will help to determine the extent to which a project fits into the framework conditions and objectives of the municipality. In addition, further steps and recommendations for action can be derived from these findings: The different evaluations in comparison to system expectations in Figures 8c and 8d allow us to determine whether the projects can generally be developed in line with the objectives and where there are levers for improving the project proposal. For example, Project 1 lacks the integration of existing structures, buildings, and social meeting places. The main weaknesses of Project 2 in the area of mobility are the lack of parking and the lack of alternative mobility concepts. Automating this process allows us to generate checklists and suggestions for project developers, and thematic evaluations of the main sticking points for decision makers.

The case study analysis (Section 4) illustrates the innovative approach of the AD Evaluator in enabling planning to support cooperative processes by enabling assessment in early planning phases and generating a communication basis for holistic system views. Even without integrating SDMs into the assessment, the structured questionnaires and illustrations can be used to implement a constructive communication basis for planning and assessment processes. However, at the current stage of implementation, the SDMs are only indicative, as they can only show whether stocks are rising/falling or whether there are positive or negative interactions.

Based on structured questionnaires and visual representations, the AD Evaluator creates a concept that encourages dialogue about holistic sustainability, and which includes different perspectives. These perspectives allow us to identify specific spatial design elements that contribute to the promotion of resilience, identity and mixed use in settlements. Because of its flexible nature, the AD Evaluator can easily adapt to changing circumstances within a planning process. It can therefore support AD that is adaptable to changing needs and contexts, thereby promoting long-term sustainability.

The evaluation approaches in Modules 1 and 2 allow for the visualization of interactions between measures. The impact of design decisions on social, ecological, economic, and gestalt balances can be analyzed and made transparent. By introducing gestalt sustainability into the assessment framework, the AD Evaluator addresses the lack of integration of design aspects in existing sustainability assessment systems, which often only consider technical and environmental criteria. It discusses the need to integrate gestalt sustainability as a fourth dimension into the sustainability discourse in order to ensure sustainable spatial quality and quality of life.

The AD Evaluator differs from traditional systems by including early planning stages for the evaluation of ideas or concepts. It also incorporates design criteria and enables qualitative assessment of spatial developments. The focus on gestalt sustainability contributes to the creation of robust and adaptable spatial structures that can meet future challenges in urban contexts. Most importantly, the AD Evaluator promotes a design approach that is responsive to the needs of the community, thereby strengthening social cohesion and participation. This can be done autonomously, without the need for costly audits. The AD Evaluator is therefore a practical tool to support strategic planning, even for small- and medium-sized municipalities.

6. Conclusion and Directions for Further Research

The AD Evaluator tool-concept supports planning and decision-making processes and offers the following innovations:

- Enables the evaluation of planning alternatives/scenarios as early as the concept development stage
- Can be used even before a concrete project exists and promotes cooperation between different stakeholders
- The early definition of sustainable framework conditions minimizes and avoids potential conflicts of interest in later phases and increases acceptance through participatory processes
- Allows the integration of existing certification categories
- Allows progressive adaptation of categories to project-specific objectives
- in addition to the assessment of "visible" elements, "non-visible" aspects, for example, of uses and interactions, can also be considered in terms of design sustainability
- Can be used as a monitoring tool within transformation processes raising transparency and cooperation awareness

The approach is low-threshold and does not require external audits. This reduces time and costs and makes it suitable for smaller projects and for representatives of municipalities, property developers, and infrastructure developers. The AD Evaluator concept presented here allows the level of detail to be refined as required, depending on the planning documents available, and the complexity of the simulations and forecast calculations to be increased step-by-step, without making major changes to the basic system.

The management of existing criteria of the different labelling and certification systems in a transparent way has proved to be very challenging. Due to the often poor documentation of the criteria, the need to translate these criteria into concrete planning measures and the need for specific project information does not allow automated criteria collection. The analysis of criteria of the most important certification system in Austria (ÖGNI, *klimaaktiv* building standard) has shown the need for a clear, temporal, spatial (including to scale) and thematic delimitation of the criteria, which must be documented in a comprehensible manner.

Integrating SDMs into assessment processes to dynamically link the interdependencies between assessment criteria and to allow the estimation of impacts of measures within automated processes needs to be further investigated. The use of SDMs in the current conceptual state of the method is the biggest limitation for practical application: The SDM used in this use case was too simple to be able to make concrete statements about the projects analyzed. More in-depth research and development is needed to find the right level of refinement of the SDM in order to derive concrete interactions between project activities and characteristics for sustainability assessment. More detailed SDMs are required, but it is important to find the right balance between the complexity of the models and their applicability in participatory and cooperative planning and decision-making processes. The case study analysis shows the need to further iteratively test the procedures with changing and, ideally, interdisciplinary planning actors for a broad bandwidth of application areas.

7. Outlook

The technical and content-related requirements for municipalities to integrate a wide range of sectoral concepts into their strategic planning are very high. In future, the proposed AD Evaluator should make it possible to assess interactions and evaluate different planning decisions against municipal objectives.

The proof-of-concept implementation of the AD Evaluator will be programmed in Python and thus can be implemented transparently in a free development environment. This enables continuous methodological and content-related improvement through the expansion and refinement of assessment criteria, based on new research findings and standardization knowledge. The development in a separate environment will also enable versatile connection options to existing assessment and analysis tools (e.g., existing certifications, test procedures), which will contribute to the expansion of the method set and to a better comparison of the assessment results. Necessary and useful functionalities are: (1) realization of the checklists and questionnaires in the form of dynamic digital forms or outputs; (2) saving and loading of ready-made activity and property lists; and (3) saving and loading ready-made policy objectives/goals.

The application of the tool will initially be tested in research projects and collaborations to make it suitable for strategic planning instruments in municipal planning.

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Conflict of Interests

The authors declare no conflict of interests.

Data Availability

The research data can be provided on request.

Supplementary Material

Supplementary material for this article is available online in the format provided by the authors (unedited).

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