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An integrated sustainability performance assessment tool for civil engineering projects with a small spatial scale - an action design research approach

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An integrated sustainability performance assessment tool for civil engineering projects with a small spatial scale - an action design research approach

Susan Groenia

Abstract

Sustainability is becoming more important in the design of the public space and in the civil engineering sector. The usage of sustainability assessment (SA) tools is important for addressing, managing, and improving the project sustainability performance of civil engineering projects of municipalities. However, the major drawback of most SA tools is that they perform an ex-post assessment on the project, while there is a greater need for SA tools which assist the decision-making to increase the project sustainability performance. Especially for projects with a small spatial scale, a solution is needed to overcome the main barriers of municipalities and companies in the civil engineering sector.

In this study, the cycles of the elaborated Action Design Research (ADR) method were performed in cooperation with an organisation in the civil engineering sector, to develop and evaluate an integrated sustainability performance assessment (ISPA) tool for civil engineering projects with a small spatial scale in the Netherlands. The prototype ISPA tool integrates the three dimensions of sustainability with the key sustainability themes for municipalities, and the tool assists in the decision-making process, by directing and aligning the project decisions and activities throughout the whole project process. In this way, the developed prototype ISPA tool is a comprehensive solution for the fragmentation of the project process and to the inclusion of sustainability performance objectives which are relevant for both municipalities and companies in the civil engineering sector. Next to the prototype ISPA tool itself, this research also describes the problem context and the application domain of the tool, the design principles for the development of the tool, the user feedback of multiple user groups and the recommendations for further improvement. Ultimately, this study advances previous SA research and the development SA tools in the civil engineering field.

1. Introduction

Sustainability is becoming more important in the design of the public space and in the civil engineering sector. Both public and private parties in the sector are increasingly concerned about the impact of construction projects on the environment, society, and the economy (Rodríguez López & Fernández Sánchez, 2011). However, the adaptation of a sustainable development perspective goes slow in the sector (Griffiths et al., 2018; World Economic Forum, 2016). Sustainable development is broadly defined as ''the development that meets the needs of the present without compromising the ability of the future generations to meet their own needs'' (World Commission on Environment and Development, 1987, p. 16). Within large scale infrastructure and civil engineering projects different enablers are applied to foster sustainable development, such as the usage of integrated contracts, green procurement, and sustainability rating- and certification tools (Lenferink et al., 2013). However, for small scale civil engineering projects, traditional tendering criteria are often used as regular commissioning procedure, and sustainability criteria are excluded from the project (Rincón et al., 2021). This is a problem for achieving a better project sustainability performance for small scale civil engineering projects in the Netherlands, which are mostly led by municipalities.

To improve the project sustainability performance of these projects, both municipalities and companies in the civil engineering sector have to overcome their main barriers. The major barriers in the sector are the multidisciplinary nature of ''sustainability'' and the lack of standardised directives, definitions and criteria for project sustainability inclusion (Munyasya & Chileshe, 2018; Rincón et al., 2021). Moreover, the fragmentation of the project process, where project decisions and activities are siloed and poorly coordinated, is a problem in the construction sector for achieving sustainability performance objectives (Hai et al., 2012; Shen et al., 2007). This fragmentation of the project process in combination with the lack of directives for project sustainability inclusion, leads to late inclusion of sustainability objectives and ineffective decision making during the project process (Rincón et al., 2021). As a result, improving the project sustainability performance of small scale civil engineering projects, is a complex challenge for both municipalities and companies in the sector.

1.1. Research context

In this research, the above-described barriers and challenges are perceived and experienced by a regional civil engineering and consultancy company in the Netherlands. This organisation mainly performs projects where they assist the municipalities in the early planning and design stages of a project. In these stages, many decisions have to be made, which also (in)directly influence the inclusion of sustainability performance objectives and the project sustainability performance. According to the organisation, the major challenge is to assist the decision-making process actively and systematically, in such a way that measurable sustainability performance objectives are set, managed and obtained throughout the whole project process.

A possible solution for the projects of municipalities to enable project sustainability inclusion, could be the usage of a sustainability assessment (SA). Sustainability assessment (SA) can broadly be defined as ''any process that directs decision-making towards sustainability'' (Bond et al., 2012, p. 53). However, the SA tools which are currently used in the civil engineering sector do not fulfil the needs of municipalities and companies in the sector. A major problem of most SA tools is that they perform an ex-post assessment on the project (Bueno et al., 2015; Griffiths et al., 2018), which is too late to substantially improve the project sustainability performance. Therefore, it is needed to assist the decision-making process and align the project decisions and activities of the different project phases for project sustainability inclusion.

1.2. Research objective and scope

At present, there is no SA tool or other solution which is focussed on assisting the decision-making process for sustainability inclusion and improving the sustainability performance of civil engineering projects with a small spatial scale of municipalities. Especially, for these type projects of municipalities, the usage of sustainability certification- and rating tools and/or the usage of integrated contracts is often not feasible. Sustainability certification- and rating tools are not attractive for small scale projects since these tools are mostly designed for large scale projects, they require a high time investment and the certification costs are often too high for a limited project budget (Munyasya & Chileshe, 2018). Integrated contracts put a substantial risk on the main contractor, which is often not feasible for the smaller projects where the margins are very low (Lenderink et al., 2022; Lenferink et al., 2013). Therefore, the development of a new tool is needed, since ''the imposition of assessment processes in context for which they were not designed has been found problematic in the past'' (Bond et al., 2012, p. 60). The research objective is:

Explore how municipalities can address, manage and improve the project sustainability performance of their civil engineering projects, by developing and evaluating an integrated sustainability performance assessment tool for civil engineering projects with a small spatial scale in the Netherlands.

The terms ''sustainability'' and ''integrated'' can have different meanings, so these terms are further defined. To make the term ''sustainability'' more manageable, the well-established three dimensions of sustainability - environment, economy and society - are adopted (Sala et al., 2015). The ''integrated'' assessment should be more than the sum of separate sustainability themes, by also requiring the identification of interlinkages and the co-benefits of interventions (Pope et al., 2004). Furthermore, the assessment should be integrated with the decision-making process, by providing directives for project sustainability inclusion and requiring the decision makers of the different project phases to align their project decisions and activities. These two integration approaches are adopted from Scrase & Sheate (2002), which categorize these two approaches as (1) ''the integration among assessment tools'' and (2) ''the integration of the assessment into governance''.

To accomplish the research objective and to produce a contribution that is relevant for both practice and research, the cycles of the elaborated Action Design Research (ADR) of Mullarkey & Hevner (2019) were performed, in cooperation with an organisation. The research scope is limited to small scale civil engineering projects of municipalities, which are mainly situated within the built environment of the municipality or new-build neighbourhoods. These projects are often complex, due to the limited space and the large amount of sustainability ambitions and requirements which must fit in.

The rest of the paper is structured as follows. Section 2 discusses the relevant literature on SA tools. Section 3 presents the research methodology detailing the ADR approach. Section 4 explains the problem context and the relevance of the proposed solution. The proposed ISPA tool is presented in Section 5 and evaluated in Section 6. Suggestions for further improvement of the prototype ISPA tool are provided in Section 7. Section 8 discusses the theoretical and practical contributions of this study, acknowledges research limitations, and suggests future research directions.

2. Theoretical background

To assess the sustainability performance, a sustainability assessment tool is often used. Sustainability assessment (SA) can, more specific, be defined as ''a methodology that can help decision-makers and policy-makers decide what actions they should take and should not take in an attempt to make society more sustainable" (Devuyst, 2001, p. 9). Therefore, SAs are one of the most complex types of appraisal methodologies, according to Sala et al (2015). SAs entail multidisciplinary aspects, as well as cultural and value-based elements. Performing SAs requires both integrating sustainability principles, objectives and targets in the evaluation and moving towards a more solution-oriented, holistic, and participatory approach (Sala et al., 2015). At present, there is not yet an SA tool in the civil engineering sector, which has adopted this approach. This is substantiated by describing the current SA tools in civil engineering sector and by explaining the critique on these tools.

2.1. Current SA tools in the civil engineering sector

Sustainability assessment tools can be categorized into three categories (Ness et al., 2007). These are (1) (non-)integrated indicators, (2) product-related assessments and (3) integrated assessments. The overarching category of ''monetary valuation'' contains tools which are not SA tools themselves, but which ''assist other tools when monetary values are needed for goods and services not found in the marketplace'' (Ness et al., 2007, p. 505). Indicators are simple measures, which represent a state of economic, social and/or environmental development (Ness et al., 2007). Examples of integrated indicators are the Gross Domestic Product (GDP) and the Ecological Footprint. Indicators are often used to track long-term sustainability trends at the national level, which makes them very suitable for policymaking, but less suitable for civil engineering projects.

The usage of product related SAs and the monetary valuation tools are the most common in the construction industry. The product-related assessment is focused on the environmental aspects of sustainability by evaluating the impact of products over their life cycle or along the production chain (Ness et al., 2007). Typical examples of a product-related assessments are the Life Cycle Assessment (LCA) and the Product Energy Analysis (PEA), which are often used to assess the environmental impact or the required energy for the production and use of construction materials. When the total costs of a product are discounted over its lifetime, it also becomes a monetary evaluation tool such as the Life Cycle Costs Analysis (LCCA). Furthermore, the Cost-Benefit Analysis (CBA) is often used in the civil engineering sector to evaluate project proposals by weighing the costs against the expected benefits of the project.

The integrated SA tools can provide a systematic and comprehensive approach to address and assess sustainability in civil engineering projects (Griffiths et al., 2018; Ness et al., 2007). The building, infrastructure and urban SA certification and rating tools clearly state their sustainability targets with sustainability criteria, which makes sustainability measurable and manageable (Berardi, 2012; Bueno et al., 2015; Griffiths et al., 2018). The development and usage of integrated SA tools in the civil engineering sector, was started by the building industry (Ameen et al., 2015; Berardi, 2012; Sharifi & Murayama, 2013). Well-known building and construction SA tools are BREEAM, LEED, CASBEE and SBTool. Next to the integrated SAs for buildings, the scope has recently expanded towards urban and infrastructure sustainability certification and rating tools. Urban SA tools are specifically developed for the assessment of the urban design for cities and neighbourhoods (Ameen et al., 2015). Well-known urban SA tools are spin-offs from the building SA tools, such as BREEAM Communities, LEED-ND (neighbourhood development) and CASBEE-UD (urban development). The usage and research of SA tools for buildings highlighted ''the lack of similar tools for infrastructures beyond buildings'' (Griffiths et al., 2018, p. 2). This led to the development of multiple infrastructure SA tools such as CEEQUAL and Envision, and transport SA tools such as Greenroads, BE^{2}ST-in-Highways and INVEST (Bueno et al., 2015; Griffiths et al., 2018; Mattinzioli et al., 2020).

Despite of the development and usage of multiple types of SA tools, the current sustainability practices in the construction sector mainly focus on construction materials, transportation, and energy, waste and water management (Boz et al., 2015; Kaur & Garg, 2019). The integrated SA tools provide a more comprehensive approach, but they also have drawbacks and limitations.

2.2. Critique of current SA tools in the civil engineering sector

The SA tools which are currently used in the civil engineering sector do not fulfil the needs of municipalities and companies in the civil engineering sector for addressing and improving the project sustainability performance of small scale civil engineering projects. Moreover, performing integrated SAs requires both integrating sustainability principles, goals and targets in the assessment and moving towards a more solution-oriented, holistic, and participatory approach (Sala et al., 2015). Currently, there is not an SA tool in the civil engineering sector, which considers the needs of municipalities, and which has adopted these approaches.

The integrated SA tools are suitable to address, manage and improve the sustainability performance of the project to a certain extend. The sustainability criteria of these tools provide an overview of how sustainability can be addressed in the project, and they make sustainability manageable and measurable. However, the mandatory requirements and rating thresholds of the integrated SA tools also create a checklist approach, instead of a solution-oriented approach. A solution-oriented approach should entail a proactive, ex-ante process focussed on improving and maximizing the sustainability performance of a project, within the boundaries of the project. However, the checklist approach of integrated SA tools often results in a tendency to ''point chase'' and to ''minimize unsustainability'', rather than promoting an integrated design strategy for a better sustainability project performance (Griffiths et al., 2018, p. 3). Furthermore, the SA tools cannot easily be adapted to the project type, size, phase, and other characteristics, without losing the value of the tool.

The integrated SA tools seem to perform the assessment with a holistic approach, since they consider interactions between systems and interdependencies between the dimensions of sustainability (Kaur & Garg, 2019). However, the critical reviews of multiple authors such as Ameen et al (2015), Bueno et al (2015), Kaur & Garg (2019) and Sharifi & Murayama (2013), show that integrated SA tools also have multiple drawbacks. The tools mainly focus on the environmental and social dimension, while the economic and the institutional dimension are underrepresented (Ameen et al., 2015; Mattinzioli et al., 2020). Especially, the institutional dimension is important to incorporate in the SA of civil engineering projects. The local governments, which are often the client in these projects, are organised in a different way compared to private companies such as project developers. However, this importance of the institutional setting is not reflected in the urban SA tools (Kaur & Garg, 2019; Sharifi & Murayama, 2013). Other relevant elements such as innovation, technology, cultural elements, and the local context are also not, or very limited, included in the urban SA tools (Ameen et al., 2015; Kaur & Garg, 2019; Sharifi & Murayama, 2013).

The broad participation of stakeholders throughout the whole project process is not directly required or promoted in the integrated SA tools. The SA tools perform an ex-post assessment on the project, which makes these tools less suitable for the early involvement of the stakeholders in the decision-making process, and to gain commitment of the stakeholders across the assessment procedure (Griffiths et al., 2018). Furthermore, the assessments of the SA tools are mostly focused on the design and construction stages, rather than the whole project process (Bueno et al., 2015).

The current well-known SA tools for buildings, infrastructure and urban development projects do not fulfil the needs of municipalities and companies in the civil engineering sector for addressing and improving the project sustainability performance of small scale civil engineering projects. The integrated SA tools mainly provide an ex-post assessment of the environmental and social sustainability of a project with a standard set of criteria, which does not (1) allow for adaptation and optimalization of the sustainability performance to the project characteristics, (2) includes a well-balanced composition of all relevant sustainability dimensions and elements, and (3) promote early stakeholder involvement and broad participation during the whole project process. In summary, a more solution-oriented, holistic, and participatory approach is needed.

3. Research Methodology

The research objective is to develop and evaluate an integrated sustainability performance assessment (ISPA) tool for civil engineering projects within the Netherlands. The ISPA tool is the artefact of this design science research (DSR). Design science is used for the development and evaluation of artifacts (Hevner et al., 2004). An artifact is a solution to a field problem, where the goal of the artifact is to improve the problem context (Wieringa, 2014).

For deriving design knowledge in this study, the elaborated Action Design Research (ADR) method of Mullarkey & Hevner (2019) is adopted. The elaborated ADR method of Mullarkey & Hevner (2019) is based on the ADR concepts and principles presented in the seminal paper of Sein et al (2011). The elaborated ADR approach unpacks the building-intervention-evaluation (BIE) cycle from Sein et al (2011) into the separate design, implementation, and evolution stages. This separation of the process stages provides more structure to the development process of an artifact.

The elaborated ADR method consist of four stages - *Diagnosis*, *Design*, *Implementation* and *Evolution* - which allows for multiple iterations to revise and refine the design of the artefact. First, the ADR project setting and the artefact development process are briefly explained. In the second section the research activities, methods and outputs are explained per ADR stage.

3.1. The ADR project setting

The ADR method fits best to this research, because the proposed ISPA tool is developed in cooperation with a single organisation (Venable et al., 2017). The organisation in this ADR study is a consultancy and engineering firm within the civil engineering sector, which mainly performs projects commissioned by municipalities. Currently, the organisation can support the municipalities with their knowledge on sustainability, BREEAM assessments and experiences of previous projects, but this is not sufficient for systematically addressing and incorporating sustainability. Therefore, the organisation would like to have a practical solution that assists the decision-making process for the sustainability inclusion in all types of small scale projects of municipalities.

The ADR team consisted of the researcher and an expert team of the organisation (Figure 1). The expert team consisted of two project managers, the advisor on sustainable area development and the owner of the company. The municipalities were considered to be the end-users of the ISPA tool. As represented in Figure 1, the artefact is mainly designed by the researcher and tested by the expert team and the municipalities in multiple iterative *Design* and *Implementation* cycles.

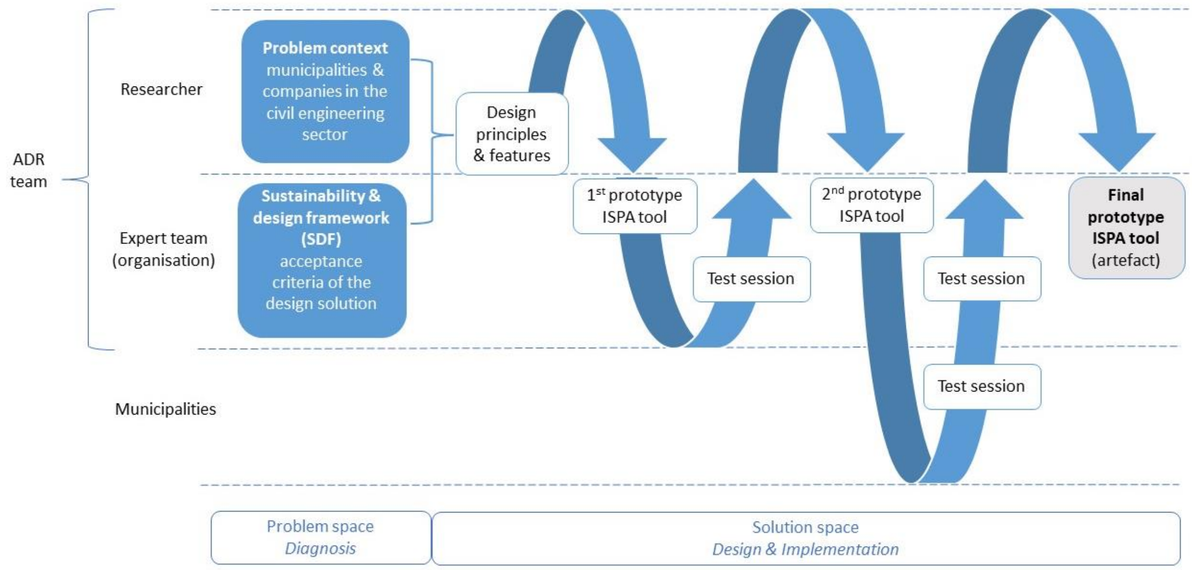

Figure 1: The ADR team and the artefact development process. The artefact development process is in line with the Diagnosis, Design and Implementation cycles of the elaborated ADR method (Mullarkey & Hevner, 2019) and with the DK model (vom Brocke et al., 2020)*. The figure itself is adopted from Sein et al* (2011, p. 42)*.*

The research activities and the artefact development process are further explained per ADR stage in the next section.

3.2. The ADR stages and activities

The ADR stages and the output of each stage in this research are presented in Figure 2. Per ADR stage, the data collection methods and activities are explained in this section. An elaborate description of all research activities and methods can be found in Table 4 in Appendix A. For this DSR study, the methods and activities were chosen and balanced in such a way that information is derived from both the knowledge base and from the application domain (Hevner, 2007; Hevner et al., 2004).

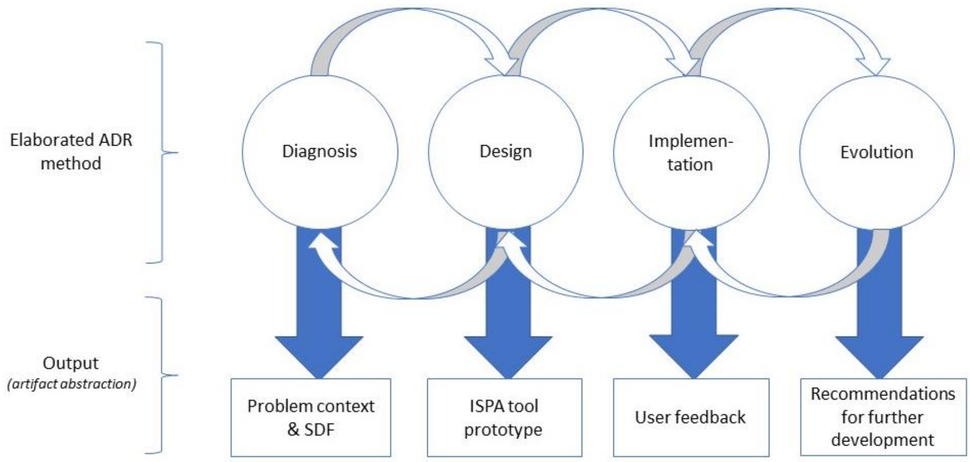

Figure 2: Elaborated ADR methodology and research outputs per ADR stage. Based on Mullarkey & Hevner (2019).

3.2.1. Diagnosis

The ADR project started with the *Diagnosis* stage, where the problem space and the objectives of the ADR project were further investigated. The problem space entails two elements, namely (1) the problem context and (2) the acceptance criteria for the design solution, according to the design knowledge model of vom Brock et al (2020, p. 522). In this study, the problem context of the municipalities and the companies in the civil engineering sector were investigated. The acceptance criteria for the design solution were specified in a sustainability and design framework (SDF).

Problem context

A literature review on sustainable development policy in the Netherlands was conducted to describe the problem context of the municipalities. To investigate the problem context of the companies in the civil engineering sector, data was collected from both literature and practice. A literature review was conducted to identify the main barriers and enables for implementing sustainability objectives and solutions. The experiences from practice were collected by conducting semi-structured interviews with the project managers on five different completed civil engineering projects of the organisation. The findings, from literature and practice, were combined to describe the problem context of the companies in the civil engineering sector.

Sustainability & design framework (SDF)

The ISPA tool is the design solution of this study. An expert opinion workshop, with the expert team of the organisation, was conducted to define the acceptance criteria for the design solution. When describing the solution acceptance criteria for the problem, the design requirements for satisfactory solutions ''should include a rich mix of objectives from the categories of technology, information quality, human interaction and societal needs'' (vom Brocke et al., 2020, p. 522). The design solutions of most DSR studies are IT-artefacts, and their solution acceptance criteria are often described with objectives and/or requirements. However, since the solution of this ADR study is a SA tool, the standard DSR methodology was complemented with the SA framework of Sala et al (2015) in this study. This SA framework is more specifically developed for SAs, by supporting SA researchers and practitioners to ''follow logical, consistent procedural steps'' (Sala et al., 2015, p. 317). The first steps of the SA procedure are to define (1) the sustainability values and principles, (2) the sustainability objectives, and (3) the decision context of the assessment. Especially, the sustainability values and principles are important since they define the sustainability framework of an assessment, and they are ''crucial for ensuring credibility and robustness of the SA method'' (Sala et al., 2015, p. 318).

Therefore, the solution acceptance criteria of the ISPA tool are defined in a sustainability and design framework (SDF).

The SDF consists of four aspects, namely (1) the sustainability values and principles of the organisation, (2) the decision context, (3) the objectives, and (4) the requirements of the new ISPA tool. These aspects are in line with the SA framework (Sala et al., 2015), the elaborated ADR method (Mullarkey & Hevner, 2019) and the Design Knowledge (DK) model (vom Brocke et al., 2020). The SDF was drafted by the expert team of the organisation within an expert opinion workshop. In this workshop, each aspect of the SDF was addressed with a question by the researcher, and for each question the expert team had to (1) individually produce ideas and/or answers, (2) present the ideas one-by-one, (3) discuss all ideas and (4) couple and prioritize the ideas with the whole group. The questions were formulated, based on the four aspects of the SDF, as follows:

- What are the sustainability values and principles of the organisation?
- What are the objectives of the ISPA tool?
- What are the mandatory, essential, nice-to-have and not essential yet requirements of the ISPA tool? (see also MoSCoW method, Appendix A)
- What are the (possible) sustainability impacts and indicators of interest? [decision context]
- What should be the complexity/uncertainty ratio of the ISPA tool? [decision context]

The coupled and prioritized answers of the expert team were combined and connected by the researcher into an SDF for the design of the prototype ISPA tool. The results of the *Diagnosis* stage are the problem context and the SDF, which describe the relevance of the proposed solution, increase the understanding of the application domain and describe the solution acceptance criteria for the design and development of the tool in the *Design* stage (Figure 1).

3.2.2. Design

The prototype ISPA tool was developed in the *Design* stage. The basis of the design and development of the ISPA tool, are the design principles and features. The tool was developed by following the general guidelines for constructing scoring rubrics, and with input and ideas of the expert team. The prototype of the ISPA tool was revised and refined in two iterations (Figure 1).

Design principles and features

Design principles prescribe ''what and how to build an artifact to achieve a predefined design goal'' (Chandra et al., 2015, p. 4040). These principles are considered to be the prescriptive knowledge of DSR projects (Chandra et al., 2015), so they can be used to guide the design of other artefacts in similar problem domains. Design principles are fundamental and are mostly used to make design choices, and to select design features. These design features describe the artefact characteristics, with detailed design and technical descriptions (Bilgeri & Zurich, 2019). Therefore, design features close the gap in the artefact development process from design principles into an actual artefact (Meth et al., 2015). The design features can be instantiated into a concrete artefact. The usage of design principles and design features is common in ADR and DSR projects, since they guide the design process and provide traceability in design choices (Bilgeri & Zurich, 2019; Pan et al., 2020; Schoormann et al., 2021).

For this ADR project, the design principles were derived from the SDF (see also Figure 7 in Appendix C). The SDF describes the acceptance criteria for the design solution of the expert team, but these general criteria are not formulated in a specific, structured manner and the SDF does not includes the problem context of the municipalities. Moreover, there is a trade-off for every SA developer between addressing science-based, sustainability principles and providing a SA tool that is understood by and accessible to practitioners (Bartke & Schwarze, 2015). Therefore, design principles were formulated at the beginning of the design stage, to provide a comprehensive, balanced, and structured basis for the development of the prototype ISPA tool.

The design principles were formulated according to the structure of Chandra et al (2015) for design principles, which consists of (1) material property, (2) activity of users and (3) boundary conditions. The template of the design principles is demonstrated as follows:

> Provide *features* which [**material property** – in terms of form and function], so that the ISPA tool can afford users to [**activity of users** – in terms of action], for [**boundary conditions** – user group's characteristics or implementation settings]

The material properties define how the artifact should be designed in terms of form and function. Therefore, the material properties of each design principle were further specificized in design features. These design features were instantiated into the prototype ISPA tool, and they were revised and refined during the development process of the prototype ISPA tool.

Prototype ISPA tool development

The prototype ISPA tool is based on the design principles and was developed by following the general guidelines for constructing scoring rubrics (Roell, 2019; Stevens & Levi, 2013). The rubric development steps are: (1) determine performance objectives, (2) chose a rubric type, (3) determine dimensions and criteria - rows, (4) create performance levels - columns, and (5) create descriptions for the criteria along the performance levels - cells. An extra step was added to provide a final score: (6) create a final score overview.

The rubric format was chosen since it fits to the design principles, and it (1) provides transparency, (2) defines the things that matter, (3) defines what different levels of performance look like, (4) integrates expectations, policy, data sources and evidence, and (5) keeps the evaluation focused on the things that matter (King et al., 2013). These benefits apply the most to the analytic rubric type, which is a standard grid rubric. Due to this grid with specific descriptions, the analytical rubric is suitable for complex assignments, and for providing feedback on areas of strengths and weakness. Holistic rubrics have a single rating scale, which makes them more suitable for quickly providing general feedback, but which makes their reliability also very dependent on the assessor (Galti et al., 2018; Jonsson & Svingby, 2007). Therefore, the analytic rubric type was chosen for the ISPA tool.

Throughout the design and development process of the prototype ISPA tool, multiple design feedback sessions were organised to collect input and ideas of the expert team. In these sessions, a conceptual, intermediate version of the prototype ISPA tool was presented by the researcher. The expert team was asked to provide input and ideas on major design issues, viable solutions and decisions, and were asked to fill in knowledge gaps of the researcher on the application domain.

The intermediate and final result of the *Diagnosis* stage is the prototype ISPA tool. In the *Implementation* stage the prototype ISPA tool is demonstrated and evaluated to receive feedback of multiple users and to validate the tool. The final prototype ISPA tool is a performance assessment rubric, formatted in a spreadsheet and supported by a manual.

3.2.3. Implementation

In the *Implementation* stage, the prototype ISPA tool is demonstrated and evaluated within the organisation and together with municipalities to ensure both internal and external validity. The prototype ISPA tool was first tested by the expert team, and thereafter by the municipalities and the expert team (Figure 1). Hence, the prototype ISPA tool is not fully implemented in such a way as known with IT-artefacts in DSR projects, but evaluated with test sessions. With the test sessions the user feedback is collected via tool reviews, semi-structured interviews and the User Experience Questionnaire (UEQ).

Internal test sessions
The aim of the internal test sessions was to get early qualitative feedback on the content, quality, and consistency to improve the ISPA tool. The test sessions with the expert team consisted of two parts, in which (1) the rubric tool was tested on a completed project by indicating the sustainability performance level for all criteria and (2) the rubric was reviewed on five performance qualities and the overall impression for the (sub)categories. By assessing a completed project, the expert team members could practice with the tool, and they could provide feedback on the tool itself. Furthermore, the indicated performance levels per expert member could be compared, to gain insights in the clarity and unambiguity of the performance assessment rubric. Next to the clarity and unambiguity, the expert team reviewed four other performance qualities, to gain insights on the quality, reliability, and content of the performance assessment rubric. These performance qualities are based on the qualities which are found to be important by the expert team (in the SDF), and by SA and rubric literature, so from both practice and science (Table 1).

Performance qualities	Description	References
Practicability & feasibility	Are the criteria user friendly, easy to understand and feasible to assess and/or obtain?	(Bartke & Schwarze, 2015; Sala et al., 2015; Stevens & Levi, 2013)
Clarity & unambiguity	Are the criteria and descriptions along the performance levels clear, and formulated in such a way that a second assessor/assessment would give the same result (inter-reliability)?	(Jonsson & Svingby, 2007; Sala et al., 2015)
Logic & objectivity	Are the criteria sound, underpinned and is the quality sufficient?	(Bartke & Schwarze, 2015; Sala et al., 2015; Stevens & Levi, 2013)
Relevance	Are the criteria relevant and important, or superfluous?	(Bartke & Schwarze, 2015; Sala et al., 2015; Stevens & Levi, 2013)
Performance level classification	Are the descriptions along the performance levels consistent and do they fit to the performance level?	(Jonsson & Svingby, 2007; Stevens & Levi, 2013)

Table 1: Performance qualities for the tool review (internal test sessions). The performance qualities are based on SA and rubric literature (references), and on the tool qualities which are found to be important by the expert team (in the SDF).

All members of the expert team individually tested the first prototype tool with the same completed project. The second prototype ISPA tool was tested in the same way as the first prototype tool, except for some small adjustments. Since the second prototype tool was tested by the expert team after the external test sessions with the municipalities (Figure 1), the second internal test session was performed with the projects of the municipalities of these external test sessions and with the same pairs of expert team members (see also the next section).

External test sessions
After the development of the second prototype, two external test sessions were held in cooperation with the organisation and the municipalities of Oldenzaal and Haaksbergen. From each municipality, at least the project manager of the civil engineering projects participated in the test session. The external test session consisted of two parts, where (1) the project intake meeting was performed,

and (2) the representatives of the municipalities were interviewed. The aim of the test session was to collect feedback from the municipality on the prototype ISPA tool and the usage process.

The project intake meeting is the first usage step of the ISPA tool in the project process. For the municipality, this meeting is aimed at introducing the tool and addressing sustainability in a simple and accessible way. For the organisation, this meeting is aimed at performing a quick scan of the municipal project and identifying the sustainability ambition (level) for the project. Therefore, the intake meeting of the test session consisted of an introduction with an explanation of the ISPA tool, a short exploration of the project, quick scan questions per category and questions directed towards the identification of ambitions. The project intake meeting was conducted by two expert team members of the organisation and the intake meeting was performed with a self-chosen project of the participating municipality. After the project intake meeting the participant(s) of the municipality were interviewed by the researcher. The interview consisted of two parts, which were (1) a semi-structured interview (SSI) with open questions and (2) the User Experience Questionnaire (UEQ). The UEQ was applied to test if the user experience was sufficient, in a fast and immediate manner. The interview contained open questions to obtain more insights and feedback on the ISPA tool.

The result of the *Implementation* stage is the meaningful user feedback from both the expert team and the municipalities, and the validation of the prototype ISPA tool. The verification of the final ISPA tool was performed in the *Evolution* stage.

3.2.4. Evolution

In the *Evolution* stage, the opportunities and recommendations for further development of the prototype ISPA tool are provided. These are based the final evaluation of the ISPA tool and on a qualitative uncertainty analysis of the prototype ISPA tool.

Final evaluation

The final version of the prototype ISPA tool was evaluated, by conducting a verification of the ISPA tool against the design principles and the sustainability and design framework (SDF). The recommendations for further development of the ISPA tool are based on the requirements which are not met, yet.

Qualitative uncertainty analysis

To identify, classify and characterise the uncertainties in the prototype ISPA tool in a structured, qualitative way, the analytical framework of Bodde et al (2018) was adopted. In this analytical framework, the uncertainties of a SA tool are categorised into four uncertainty types, namely (1) inherent uncertainties, (2) scientific uncertainties, (3) social uncertainties, and (4) legal uncertainties. In this study, after the identification and classification of the uncertainties of the ISPA tool, the uncertainties are characterised and scaled as ''low'', ''medium'' or ''high''. Similar to a risk assessment, the likeliness and the size of the impact are estimated and multiplied to determine the scale of the uncertainty. So, uncertainties which are characterized as ''high'' are highly likely to occur and the have a significant impact on the usage and/or the results of the assessment. The recommendations for further development of the ISPA tool are based on the major uncertainties, and how these can be reduced.

The result of the *Evolution* stage are recommendations for further improvement of the prototype ISPA tool. The results of each ADR stage are presented in the next chapter.

4. Results

The results of each stage - Diagnosis, Design, Implementation and Evolution - are presented in this chapter.

4.1. Diagnosis: the problem space

The ADR project process started with the diagnosis stage. This section provides a description of the problem context and the sustainability and design framework (SDF), as the foundation for the design stage of the ADR project.

4.1.1. The problem context

The two major parties in the smaller civil engineering projects in the Netherlands are the municipalities and the companies in the construction sector. Mostly, the municipalities are the initiator of the project the companies execute the project. These two parties have their own problem context.

Municipalities

From a policy review, it appears that the national government in the Netherlands has delegated a large part of the responsibility of achieving national climate change and sustainable development goals to municipal authorities. At a national level the sustainability goals are split up into three themes which are (1) energy transition, (2) climate change adaptation and (3) circular economy (Oosters et al., 2017). The national objectives and plans on these three concepts are captured in the (1) *Klimaatakkoord, (2) Deltaplan Ruimtelijke Adaptatie (DPRA)* and (3) *Rijksbreed programma Circulaire Economie* (Ministerie van Economische Zaken en Klimaat et al., 2019; Ministerie van Infrastructuur en Milieu & Ministerie van Economische Zaken, 2016, 2018). The execution of these plans is, for a large part, the responsibility of municipalities. Furthermore, municipalities are facing the Environmental law (Dutch: *Omgevingswet).* This law aims to support an integral approach for initiatives and developments in the physical environment. Two major aspects of the environmental law are the obligations for municipalities to (1) have an environmental vision and (2) motivate their participation policy (Informatiepunt Leefomgeving, n.d.; VNG, n.d.). The environmental vision (*Omgevingsvisie*) and the participation policy should not only describe the physical environment and the participation policy in general, but they should provide a tailored approach to the local characteristics and should stimulate to make conscious choices. To execute the three national sustainability plans, to implement the Environmental law and to realise local sustainability goals, municipalities need to incorporate these into their projects in the built environment, thus into their civil engineering projects. Therefore, based on this policy review of the Dutch context, five topics are identified as the key sustainable development topics of interests for municipalities. These are (1) circular economy, (2) climate change adaptation, (3) energy transition, (4) environmental vision and (5) participation.

Companies in the sector

Companies in the civil engineering sector which would like to foster the sustainability performance of their projects are facing multiple challenges. According to Munyasya & Chileshe (2018), there are four main barriers which influence the implementation of sustainable infrastructure development in the construction industry. The barriers are (1) the lack of a steering mechanism (facilitated by the government), (2) the multidisciplinary nature of the word sustainability, (3) the lack of cooperation and networking and (4) increased costs associated with sustainable construction.

These barriers correspond with the findings from the semi-structured interviews with the project managers of the organisation, on five completed civil engineering projects. The interviews confirm that the barriers occur in practice and show what the impact of the barriers is. In every project, there was not a standardised steering mechanism (1), municipalities had different views on (the implementation of) sustainable development (2) and the lack of cooperation between actors in different project phases often led to a lower project sustainability performance (3). According to the project managers, a typical example of the lack of cooperation is the is the late involvement of the department ''maintenance and asset management'' at the end of the design phase, which often leads to design revisions with a lower sustainability performance. In some projects, sustainable development did not play a role, because of a limited project budget (4) and other factors such as a lack of knowledge (2), lack of capacity (1) and requirements of the municipality (e.g., visual quality).

Based on the findings from both literature and practice, it can be said that it is important to provide steering mechanisms and a common understanding of what sustainable construction entails to overcome the main barriers of companies in the civil engineering sector. Within the projects, it is needed to ensure close interaction among the involved actors from the start of the project and in all project phases, to ensure that the project sustainability performance ambitions are achieved and communicated throughout the project process. These enablers are important acceptance criteria and must be integrated into the design of the proposed solution of this ADR project.

4.1.2. The sustainability & design framework

The sustainability and design framework (SDF) is composed to further increase the understanding of the application domain, to define the acceptance criteria of the design solution and to inform the design stage. As explained in methodology section *3.2.1 Diagnosis*, an expert opinion workshop was organised to address the following four aspects: (1) the sustainability values and principles of the organisation, (2) the decision context, (3) the objectives and (4) the requirements of the new ISPA tool. The results of the workshop are presented in Table 5 in Appendix B. These results were combined and connected by the researcher into a SDF, which is graphically presented in Figure 3.

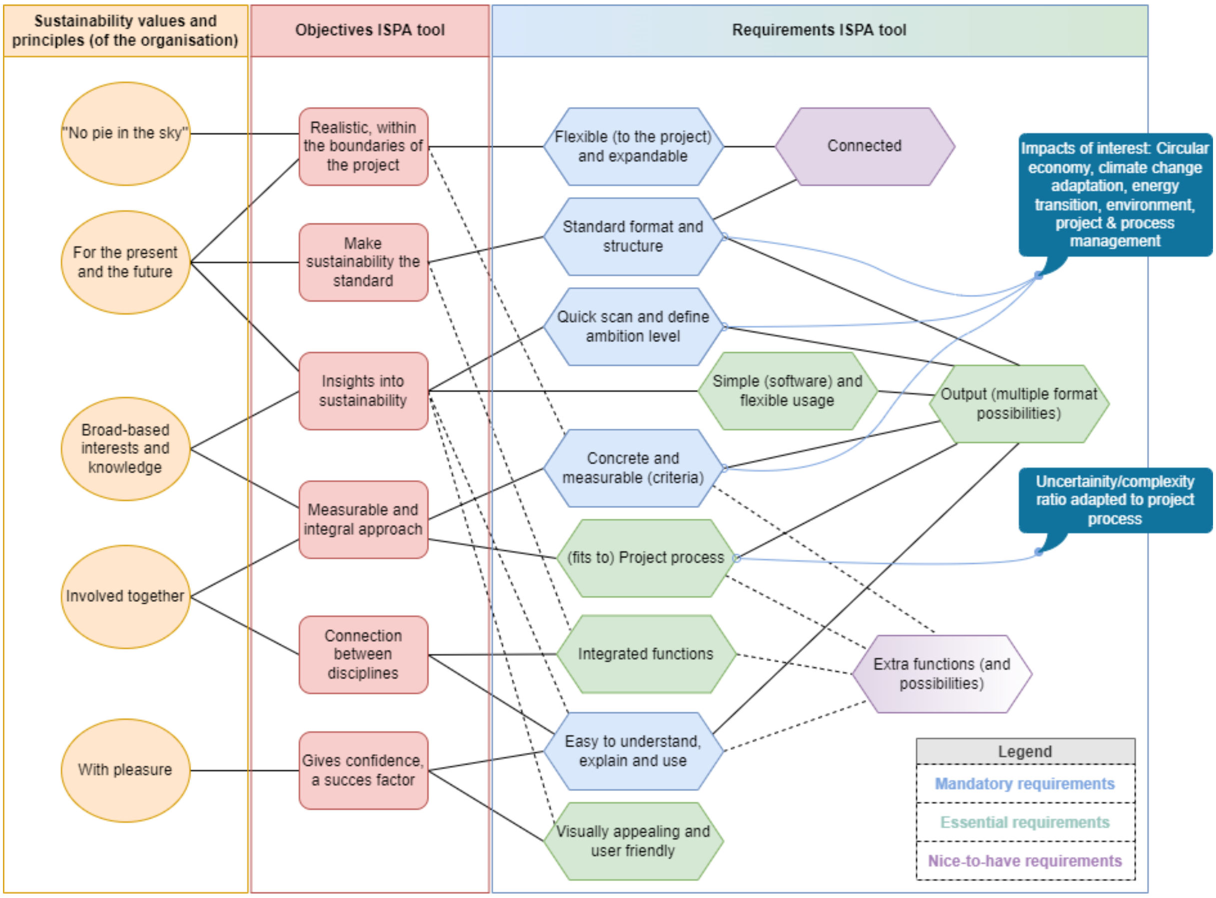

Figure 3: Sustainability and design framework (SDF) for the ISPA tool, which is based on an expert opinion workshop with the expert team of the organisation. In this workshop, the most important values & principles, objectives and requirements are formulated and prioritized by the expert team and connected to each other into this framework by the researcher. The major SDF aspects (values & principles, objectives and requirements) are based on the SA framework (Sala et al., 2015)*, the elaborated ADR method (Mullarkey & Hevner, 2019) and the DK Model* (vom Brocke et al., 2020).

The sustainability values and principles of the organisation, which are presented in the left column, are mostly related to their broad perspective on sustainability and their preferable way of working internally and with the client. The objectives can be found in the middle, red column. The main objectives, according to the expert team, are that the ISPA tool (quickly) provides (1) insights into different aspects of sustainability, (2) an integral and measurable approach to sustainability and (3) a realistic ''design/result'' within the boundaries of the project. Furthermore, the higher-level objectives of the ISPA tool are to connect different disciplines, to create confidence and to make a sustainability approach the standard within civil engineering projects. The requirements for the ISPA tool are presented on the right side of the framework and are categorized as mandatory, essential or nice-to have. The requirements of the expert team for the ISPA tool are mainly focussed on usability, practicability, flexibility, visuals and functions.

Overall, the SDF provides the framework for the design and development of the ISPA tool in the design stage. Since the SDF entails a lot of aspects, the most important solution acceptance criteria for the ISPA tool, according to the expert team of the organisation, are as follows:

- The tool must provide a sustainable and realistic design/result within the boundaries of the project, by providing a practical approach to sustainability and allowing adaptation to the project characteristics.
- The tool must provide (quick) insights into different aspects of sustainability, by introducing and using the tool directly at the start of the project, doing a quick scan on the project and defining the project (performance level) ambitions on a broad range of sustainability topics.
- The tool must provide an integral and measurable approach to sustainability, by integrating the tool into (the decision-making activities of) the project process and by having underpinned, concrete, and measurable criteria.
- The tool must provide a standard sustainability approach for municipal projects, by having a standard format and structure which is (visually) appealing, and easy to understand, explain and use.

To conclude, the results of the *Diagnosis* stage are the problem context and the SDF, which describe the relevance of the proposed solution, increase the understanding of the application domain and describe the solution acceptance criteria for the design and development of the ISPA tool in the *Design* stage.

4.2. Design: the prototype ISPA tool

The design stage is the core stage of the ADR project, since it covers the development and design of the prototype ISPA tool. The development and design of the ISPA tool is based on the formulated design principles and features. The designed artefact - the prototype ISPA tool and its intended usage - are described and design choices are underpinned.

4.2.1. Design principles and features

The basis of the design and development of the ISPA tool, are the design principles and features. As explained in methodology section *3.2.2 Design*, an initial set of design principles and features was formulated at the start of the design stage. The design principles are formulated based on the objectives and requirements stated in the SDF, as visualised in Figure 7 in Appendix C. So, the design choices and the features of the ISPA tool can be traced back all the way back to the SDF. The final set of design principles and design features are presented in Table 2.

Design principles (DP)	Design features (DF)
DP1: Provide features which integrate sustainable development key topics of municipalities and project process management aspects **[material property]**, so that the ISPA tool can afford users to create connections between disciplines and to address, manage and assess the whole project (process) for sustainability inclusion **[activity of users]** for civil engineering projects of municipalities **[boundary condition]**.	DF1a: The tool must have suitable (sub)categories, which represent the key topics of municipalities for sustainable development and the project process management phases
	DF1b: The tool must have criteria, which have linkages within a category and with criteria in other categories
	DF1c: The tool must have a usage process for the tool in the whole project process
DP2: Provide features which quickly provide insights into the current sustainability performance level of the project **[material property]**, so that the ISPA tool can afford users to easily indicate shortcomings, guides for improvement and ambitions in a concrete and practical way **[activity of users]** for civil engineering projects of municipalities **[boundary condition]**.	DF2a: The tool must have a project intake meeting, and must make use of open-source data for quick insights
	DF2b: The tool must have performance levels and descriptions along those performance levels, which can be used to indicate shortcomings and guides for improvement
DP3: Provide features which allow adaptation to the project type, size, phase and other characteristics **[material property]**, so that the ISPA tool can afford users to realise a sustainable project within the boundaries of the project **[activity of users]** for every type of small-scale civil engineering project at any given project phase **[boundary condition]**.	DF3a: The tool must be able to leave out certain categories and criteria (of the assessment), without losing the value and comprehensiveness of the tool (see also the score types of DF6b)
	DF3b: The tool must have criteria, which are not related to the project size, type and/or other specific characteristics
DP4: Provide features which allow flexibility in the uncertainty/complexity ratio **[material property]**, so that the ISPA tool can afford users to start on a simple/rough level with a little amount of knowledge and data and requires users to end on a complex/specific level with adequate data and knowledge **[activity of users]** for civil engineering projects of municipalities **[boundary condition]**.	DF4a: The tool must have descriptions per criterium, which gradually increase for each performance level from low complexity/high uncertainty to high complexity/low uncertainty
	DF4b: The tool must have a project intake meeting, which does not require a high level of knowledge and data
DP5: Provide features which define what different levels of sustainability performance look like **[material property]**, so that the ISPA tool can afford users to compare options and to underpin project decisions with concrete, logical and measurable criteria and indicators **[activity of users]** for civil engineering projects of municipalities **[boundary condition]**.	DF5a: The tool must consist of rubric(s) with criteria, performance levels and descriptions per criteria/performance level cell
	DF5b: The tool must have (extra) explanation and examples of the (sub)categories, performance levels, criteria and evidence
	DF5c: The tool must have criteria, which relate to existing legislation, policy, methods and tools where municipalities and civil engineers can relate to (institutional dimension)
DP6: Provide features which visualise the project (intermediate) results **[material property]**, so that the ISPA tool can afford users to easily draw a conclusion at one glance and to communicate the results of the project **[activity of users]** for civil engineering projects of municipalities **[boundary condition]**.	DF6a: The tool must have a score overview per category and a diagram with shows the results for all categories
	DF6b: The tool must have a score overview of the (intermediate) project score, the context score and the maximum tool score

Table 2: Final set of design principles and design features. The design principles are formulated based on the SDF. The design features are a further specification of the material property of each DP, which are instantiated into a concrete artefact - the prototype ISPA tool.

The six design principles cover the needs of the organisation and municipalities, for addressing, managing, and improving the project sustainability performance. DP1 represents the research objective of this ADR project, with a strong focus on the integration of multiple sustainability objectives and connection between disciplines and project phases. DP2 represents the objective of the organisation to quickly provide insights into the project sustainability performance and ambitions, for the client. It also represents the need for a tool which assist the decision-making process of the project from the start, instead of performing an ex-post assessment of the project. DP3 relates to the type of projects and the needs of municipalities. Most civil engineering projects of municipalities have a small spatial scale, but they also have very different characteristics. Therefore, the ISPA tool must remain useful and attractive to use within the boundaries a project, by providing room for adaptation and flexibility. DP4 refers to the need to assist in the decision-making process and to have flexibility, by focussing on the alignment of the complexity and uncertainty ratio during the project process, as defined in the SDF (see also Appendix B). DP5 represents the need for a measurable and concrete approach to sustainability for both the organisation and the municipalities. Furthermore, it is important to define what different levels of sustainability performance are, to enable the users to compare options and to make conscious choices in a project. DP6 refers to the need to summarise, visualise and communicate the (intermediate) results in a standardized and user-friendly way. This also makes the ISPA tool more attractive to use and may set a standard for measuring and presenting the sustainability performance level of a project.

These design principles and features are the basis of the prototype ISPA tool and the development process of the prototype tool. In the next section, the prototype ISPA tool itself is explained.

4.2.2. Artefact description - the prototype ISPA tool

As stated in the research objective, a solution is needed to enable municipalities to address, manage and improve the project sustainability performance of their civil engineering projects. Furthermore, this solution should integrate multiple sustainability dimensions, topics, and policies, as well as it should be integrated into the decision-making process. Current SA tools and other solutions to do fit to the needs and the problem context of municipalities, and the typical small spatial scale of municipal civil engineering projects. The major problem is that most SA tools provide an ex-post assessment of the project, whereas there is more need for a SA tool which assists the decision-making process for project sustainability inclusion.

Therefore, the core of the prototype ISPA tool is a performance assessment rubric, which is integrated in the whole project process in four usage steps (Figure 4). These four usage steps provide directives for the decision-making process and a standard procedure for the usage of the tool throughout the whole project. Moreover, they require the decision makers of the different project phases to align their project decisions and activities. This section first describes the four usage steps of the ISPA tool in the project process, to explain the intended implementation of the prototype ISPA tool. Next, the prototype ISPA tool itself is described. The section is concluded with a synthesis and an example of the usage of the ISPA tool.

The four usage steps of the ISPA tool

The usage steps of the ISPA tool are formulated in close cooperation with the expert team and are based on the design principles, and the objectives and requirements stated by the organisation in the SDF. The four steps enable the actors to integrate and align project decisions and activities throughout the whole project process for sustainability inclusion. This first step is aimed at addressing sustainability, the second and third step are aimed at improving the project sustainability performance, and the last step is aimed at managing the realisation of the project sustainability performance ambitions and objectives (Figure 4). So, the four steps are in line with the research objective and integrate the ISPA tool into (the decision-making activities of) the project process.

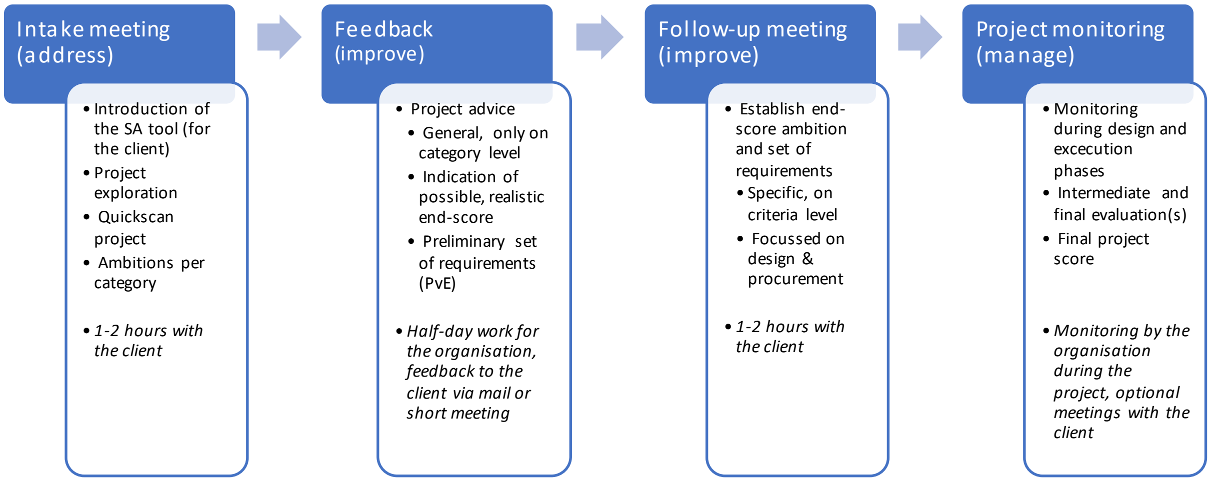

Figure 4: Usage steps of the ISPA tool in the project process. These steps are formulated in cooperation with the expert team and are based on the design principles and the SDF. The four steps enable the actors to integrate and align project decisions and activities throughout the whole project process for sustainability inclusion. All the steps/meetings are initiated and organised by the organisation, where the municipalities are considered to be the client. The four steps are in line with the research objective and integrate the ISPA tool into (the decision-making activities of) the project process.

All the steps/meetings are initiated and organised by the organisation, where the municipalities are considered to be the client in the project. The first step is the project intake meeting, which is aimed at quickly providing insights into the current sustainability level of the project with a quick scan and identifying the sustainability ambitions of the client. During the intake meeting, the organisation askes the municipality simple and more general questions, since detailed information is not available and project decisions does not have to be very specific yet in the first phase of the project. Afterwards, the client receives a project advice from the organisation containing an indication of which sustainability performance levels could be obtained per category and what a realistic end-score would be. Furthermore, the client receives a preliminary set of requirements, based on the rubric criteria of the ISPA tool. In a follow-up meeting, the organisation and the client establish the final ambition score and a set of requirements for the design and procurement. In this stage of the project process, the client should have more detailed information and data, to be able the make decisions on a specific, criteria level. During the design and execution phase of the project, the project is continuously monitored by the organisation to track if the projects' sustainability performance objectives are realised and achieved. In this last step, the ISPA tool is used by the organisation to perform intermediate and/or final evaluation(s) for and/or with the client. A final project score for the obtained project sustainability performance is provided at the end.

The prototype ISPA tool - a performance assessment rubric

As explained in methodology section *3.2.2 Design*, the prototype ISPA tool is based on the design principles and was developed by following the general guidelines for constructing scoring rubrics. The final prototype ISPA tool is a performance assessment rubric, formatted in a spreadsheet and supported by a manual. The first prototype of the ISPA tool was revised and refined in two iterations (Figure 1). An elaborate description of the development process, the design decisions and the instantiation of the design features can be found in Appendix E.

The main structure of the ISPA tool, and a brief underpinning per level, is provided in Figure 5. In line with the research objective, the prototype ISPA tool consists of two key themes which are *Sustainable goals* and *Sustainable process*. These two themes represent the importance of addressing and integrating sustainable development topics in the project and assisting the decision-making process during all project phases, for improving the sustainability performance of the project. The sustainable goals are dived among five categories which are (1) Resources & Circular Economy, (2) Climate Change Adaptation, (3) Nature & Soil, (4) Mobility and (5) Energy Transition. The sustainable project process consists of four categories which are (1) Participation & Spatial quality, (2) Ideation & Design, (3) Execution and (4) Maintenance & Asset management. These categories were derived from the problem context of both the municipalities and the companies in the civil engineering sector (see section 4.1 Diagnosis), and underpinned with the results of a review of related SA tools (see Figure 8 and Table 7 in Appendix D). The underpinning of the categories can be found in Table 6 in Appendix D.

To provide a tool which is flexible, adaptive and structured, the design decision has been made to create for each category an own rubric (Figure 5). The rubric of each category consists of subcategories, criteria, performance levels and descriptions along those levels. The design choices and the content of the rubrics are based on the review of related SA tools, a mixture of literature and input from the expert team. Filling in each rubric provides a sustainability score per category. The scores per category are equal to the performance levels, which are ''poor'', ''fair'', ''good'' and ''excellent''. The scores are calculated with a simple 1-2-3-4 rating scale. These design choices are made together with the expert team and are in line with the SDF and the design principles. An elaborate description of the design decisions and the instantiation of design features can be found in Appendix E.

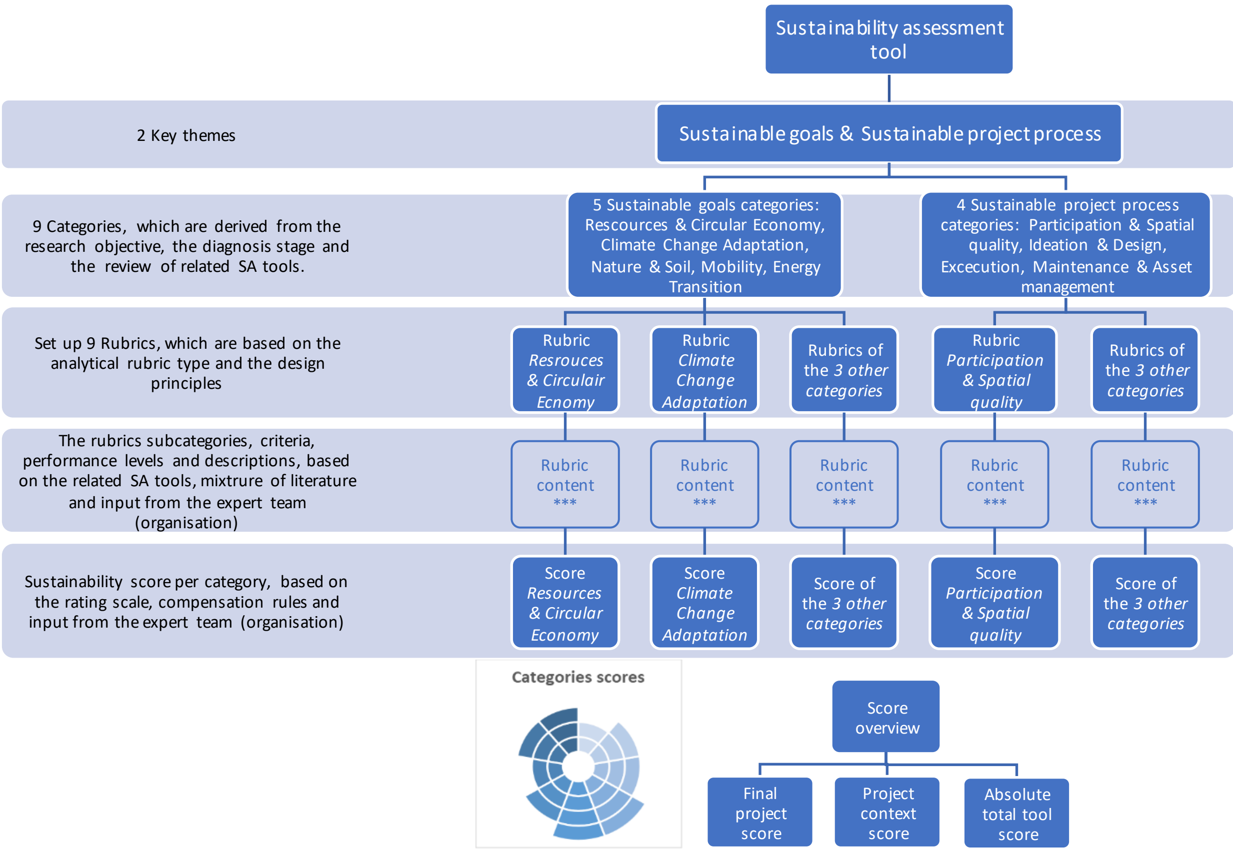

Figure 5: Overview of the rubric tool structure and brief underpinning per level of the prototype ISPA tool.

The final score overview consists of two parts which are (1) the final score per category in a sunburst diagram and (2) the score overview with the final project score in relation to the context score and the maximum tool score (Figure 6). The context score represents the maximum score within the boundaries of the project. This representation of the final result of the prototype ISPA tool was suggested by the organisation, and further developed and implemented in the tools' spreadsheet by the researcher.

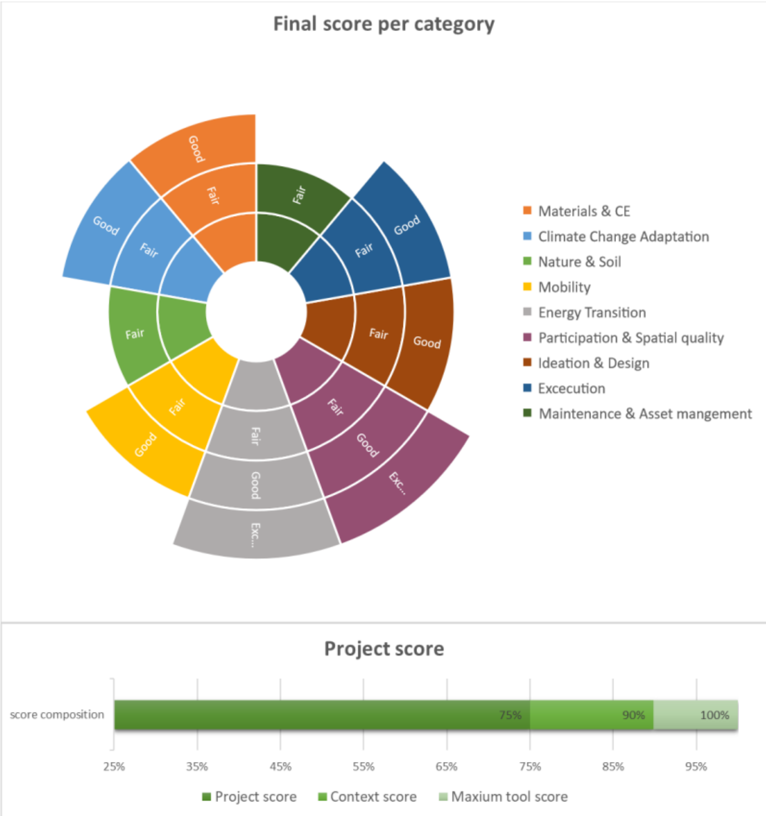

Figure 6: Score overview of the ISPA tool. The score overview consists of a sunburst diagram, which shows the final score per category, and a bar chart which shows with the project score in relation to the context score and the maximum tool score.

The usage and synthesis of the ISPA tool

As stated in the research objective, the main purpose of this ADR study and the development of the ISPA tool is to explore how municipalities can address, manage and improve the project sustainability performance of their civil engineering projects. The three aspects are obtained by following the usage steps, for the usage of the protype ISPA tool throughout the whole project process (Figure 4).

During the project intake meeting, the municipalities are introduced to the ISPA tool, and they are asked short, simple questions per tool category by the organisation. This quick scan allows the municipality to address the projects' sustainability in a relatively simple and accessible way. Since the quick scan questions per category are directly linked to the criteria and performance levels in the rubric ISPA tool, the organisation can indicate the current project sustainability performance with the answers of the municipality on these questions. Furthermore, the organisation can already determine which criteria do not fit to the project type, phase and/or other characteristics, and should be left out of the assessment (context score). With the ambition questions per category, the organisation can fill in the rubric per category of the ISPA tool, and determine which sustainability performance levels could be obtained per category and what a realistic end-score would be.

In the follow-up meeting, the organisation and the municipality establish the final ambition score and a set of requirements for the design and procurement. This set of requirements are formulated based on the criteria of the ISPA tool, and the corresponding performance level which the municipality want to obtain in the project. An example, for one tool category, is provided in Table 3.

Subcategory	Criteria	Performance levels				Score
		Poor	Fair	Good	Excellent	
Slow traffic	Attractive routes and facilities for slow traffic. X measures (see list)	<4	>4	>8	>12	4
Public and multimodal transport	Public transport stops at (walk)distance X (bus) and/or (cycle)distance Y (train)	>700m, 15min	≤700m, 15min	≤450m, 10min	≤350m, 5min	2
	~~At least X (alternative) modes of transport at transfer station~~	~~1~~	~~2~~	~~3~~	~~≥4~~	-
Sustainable transport	At least X measure(s) for sustainable transport (see list)	0	1	2	≥3	3
					Sustainability score (mobility)	Good (9/12p)

Set of requirements (mobility)

- The design must contain (at least) 8 measures for attractive routes and facilities for slow traffic (see list with slow traffic measures)
- The public transport bus stop is located at maximum 700 meter walking distance and/or the train station is located at maximum 15 minutes cycling distance
- The design/plan contains (at least) 1 measure for sustainable transport (see list with sustainable transport measures)

Table 3: Usage and result example of the rubric ISPA tool. In this example, a few subcategories and criteria of the mobility category are showed. In this example, one criterium is left out of the assessment, because this criterium is not applicable for the project. One criterium scores ''fair'', one as ''good'' and one as ''excellent''. This brings the sustainability score to a ''good''. The set of requirement follows from the criteria and the corresponding performance level.

In the project monitoring phase, the organisation and the client can manage the project, by monitoring if the set of requirements is implemented and if sustainability performance objectives are obtained. In this way, the ISPA tool provides a measurable and comprehensive approach to address, manage and improve the sustainability performance of the project. The prototype ISPA tool addresses different aspects of sustainability and can be adopted to the project characteristics to provide realistic ''design/result'' within the boundaries of the project. The ISPA tool integrates the three dimensions of sustainability with the key sustainability themes for municipalities. Ultimately, the ISPA tool assist in the decision-making process, by directing and aligning the project decisions and activities for project sustainability inclusion throughout the whole project process.

4.3. Implementation: user feedback

In the implementation stage of the ADR project, the prototype ISPA tool is demonstrated, tested and evaluated to collect user feedback from the expert team and the end-users. The prototype ISPA tool was tested within the organisation and also with the municipalities to ensure both internal and external validity. The findings of the test sessions were used as input for the design iterations, in which the prototype ISPA tool was refined and revised (Figure 1).

4.3.1. Internal test sessions

As explained in methodology section *3.2.3 Implementation,* the internal test session consisted of two parts, in which (1) the rubric tool was tested on a completed project by indicating the sustainability performance level for all criteria and (2) the rubric was reviewed on five performance qualities and the overall impression. The results of the tool reviews can be found in Table 10 in Appendix F.

The first test session with the expert team was held after the development of the first prototype ISPA tool (Figure 1). The main finding from the expert team was that *''it was difficult to assess the project with the prototype ISPA tool, and (therefore) the assessment took too much time''*. In line with this finding, the results on the indicated sustainability performance level for all criteria differed a lot per expert team member. The difficulties mainly related to the clarity & unambiguity, the practicability &

feasibility and the performance level classification of the tool. Some criteria were found to be less relevant and not feasible. Most criteria were found to be reliable and logical by the expert team.

The second test session with the expert team was held after the development of the second prototype ISPA tool and the external test sessions (Figure 1). The feedback of the first test session was used to decrease the difficulty and the required time for the assessment. The main experience of the expert team was that *''it was easier and convenient to assess the projects with the improved ISPA tool, and the assessment took less time''.* So, the internal test sessions with the expert team provided meaningful user feedback and helped to improve the efficiency and user experience of the ISPA tool.

4.3.2. External test sessions

The external test session with the municipalities were held after the development of the second prototype ISPA tool (Figure 1). As explained in methodology section *3.2.3 Implementation,* the test session consisted of two parts, where (1) the project intake meeting was performed, and (2) the representatives of the municipalities were interviewed. This interview consisted of a semi-structured interview (SSI) with open questions and the User Experience Questionnaire (UEQ). The results of the interviews with the municipalities can be found Table 11 and in Figure 12 in Appendix G. In this results section, the user feedback is directly related to the design principles (DP) to validate the tool.

The project meeting consisted of an introduction of the tool, a short project exploration, quick scan questions per category and questions directed towards the identification of ambitions. The project managers of the municipality of Haaksbergen and Oldenzaal could follow the introduction of the ISPA tool, and they could easily answer the questions of the quick scan, because they are related to the current activities and sustainability topics of the municipality. This showed that the project intake meeting is provides an accessible approach to the ISPA tool and sustainable development at the beginning of the project (DP4). Both municipalities indicated that the intake meeting provides quick insights, and it supports the identification of feasible and realistic ambitions (DP2). As stated by the municipality of Haaksbergen *''the ISPA tool provides a trigger and quick focus''*. Furthermore, both municipalities stated that the ISPA tool makes sustainability concrete and measurable, which is a great advantage for supporting project decisions and allows for project monitoring (DP5). In addition, the municipality of Oldenzaal stated that *''the usage of the IPSA tool during the whole project process creates awareness and the IPSA tool has potential to connect and integrate different departments within the municipality''* (DP1). However, a concern of both municipalities was the time and capacity needed for the realisation of the sustainability objectives and the set of requirements.

The municipality of Haaksbergen already had experience with *BREEAM-NL Gebied* (SA tool), but stated that: *''this ISPA tool works a lot better. Especially for smaller projects, since you can adapt it to the project characteristics''* (DP3). However, the municipality of Haaksbergen also added that *''it is important to put more emphasis on the added value of the tool for smaller projects, when the tool is explained at the start of the project intake meeting''.* Since the tool is adaptable to the project characteristics and flexible in the project process, both municipalities stated that it is important to provide an indication or advice in advance about which (kind of) persons/positions of municipality can best attend the meeting(s). Other tips for the improvement of the tool and the presentation were to add visualisations, concrete examples, and a clear end-result of every meeting (DP6).

To conclude, the common reaction of the municipalities on the ISPA tool was that it is a practical, pragmatic, and comprehensive tool and that it integrates different themes and project processes. The prototype ISPA tool and its usage steps in the project process assist the decision-making process in clear steps and help the municipalities to address, manage and improve the project sustainability performance in a structured and transparent way. The municipalities provided meaningful feedback for the improvement and further development of the prototype ISPA tool.

4.4. Evolution: recommendations for further development of the tool

In the evolution stage of the ADR project, the opportunities and recommendations for further development of the prototype ISPA tool are provided. These are based on the final evaluation and on a qualitative uncertainty analysis of the prototype ISPA tool.

Final evaluation

The development of the prototype ISPA tool is based on the design principles and design features which were formulated at the start of the design stage. The implementation of the design principles and features can be found in Appendix E and is validated in the previous section. Initially, the design principles were derived from the objectives and the requirements of the SDF. During the development of the ISPA tool, these requirements were taken (in)directly into account. The requirements were prioritised by the expert team of the organisation into four categories: (1) mandatory, (2) essential, (3) nice-to-have, and (4) not essential yet (see also the MoSCoW method in Table 5 in Appendix B). The verification of the requirements can be found in Table 12 in Appendix H. This verification shows that all the mandatory requirements and almost all essential requirements have been implemented into the prototype ISPA tool. The other requirements of the SDF can be used as input for further development of the prototype ISPA tool.

Qualitative uncertainty analysis

As explained in methodology section *3.2.4 Evolution*, the uncertainties of the ISPA tool are identified and categorized into four uncertainty types, namely (1) inherent uncertainties, (2) scientific uncertainties, (3) social uncertainties, and (4) legal uncertainties. The results of the uncertainty analysis are presented in Table 13 in Appendix I.

The major uncertainties of the ISPA tool are the social uncertainties. Social uncertainties occur due to organizational factors, resources, coordination among stakeholders and procedures (Bodde et al., 2018). The four usage steps of the ISPA tool in the project process are designed to guide the inclusion of sustainability into the project and to make intermediate adjustments, but the tool is still quite dependent on its users and the application context. The project design, management and resources are essential for project failure or project success. Furthermore, legal uncertainties can have an impact on the content and the relevance of the ISPA tool. Changes in policy and legislation can have an impact on the justification of certain criteria and performance levels of the ISPA tool, and may change the relevance of the ISPA tool for municipalities. The same applies to scientific uncertainties, where changes and errors in scientific theories, data, models, and tools also can have an impact on the justification of the content of the ISPA tool. Therefore, it is important that other experts and researchers also critically evaluate the tool outside of the ADR team. Especially with a complex topic as sustainability, the quality of the assessment framework is of significant importance.

Further development of the prototype ISPA tool

The tool can be further developed by extending its functionalities and reducing the uncertainties. The nice-to-have and not essential (yet) requirements, which were stated by the organisation in the diagnosis stage of this ADR project can be used as input for further development of the prototype ISPA tool. To reduce the uncertainties and to improve the quality of the ISPA tool, it is needed to further apply, test and evaluate the tool in multiple type of projects and with different municipalities. Continuous monitoring and development are needed to keep the ISPA tool relevant and valuable of municipal civil engineering projects. A list of recommendations for further improvements for the ISPA tool is provided in Appendix J.

5. Discussion

In this article, prescriptions are proposed for the development and evaluation of an integrated sustainability performance assessment (ISPA) tool that provides a solution for the need of a tool which improves the project sustainability performance of small scale civil engineering projects and which is fits to the problem context of municipalities. To accomplish the research objective and to produce a contribution that is relevant for both practice and research, the cycles of the elaborated ADR of Mullarkey & Hevner (2019) were performed. The research contributions are two-folded by (1) presenting the prototype ISPA tool, which utility has been evaluated for the given target group and research scope and (2) presenting design knowledge, which addresses the research gaps in ADR projects and SA tools in the civil engineering sector.

5.1. Research contributions to the knowledge base

Few prior ADR studies are dedicated to the design of SA tools for civil engineering projects. Therefore, a deeper understanding of the problem space was needed (vom Brocke et al., 2020). The study contributes to descriptive knowledge by abstracting, from the diagnosis stage, the problem context of both municipalities and companies and the SDF for the ISPA tool. Instead of only defining the objectives and requirements of the artefact itself as common practice in DSR projects, the sustainability values and principles of the organisation are also defined (in the SDF) and taken into account as advised in the methodological framework for SA's by Sala et al (2015). In this way, design science (ADR/DSR) and SA methodologies are combined to design and develop a new SA tool. Furthermore, the requirements from the organisation highlight a difference in the prioritization and valuation of different quality criteria by decision makers and researchers. In practice, there is a trade-off for SA tool developers between adequately addressing sustainability principles and providing a SA tool that is understood by and accessible to practitioners (Bartke & Schwarze, 2015). However, this trade-off is not often taken into account or clearly discussed in ADR studies.

The developed and evaluated prototype ISPA tool provides a solution for municipalities to address, manage and improve the sustainability performance of their civil engineering project with a small spatial scale. The ISPA tool shows how a SA tool can designed to be an assessment tool, which can support the decision-making process, and which also provides a concrete and measurable approach to sustainability in every project phase. Furthermore, the tool is adaptive and flexible to the project characteristics, to provide realistic ''design/result'' within the boundaries of the project. Especially for small scale projects, this solution-oriented approach is of added value, according to the municipalities and the expert team. The ISPA tool integrates the three dimensions of sustainability with the key sustainability themes for municipalities, and provides a more holistic approach by taking into account the institutional setting, cultural values, technology, and innovation. Furthermore, the tool requires early stakeholder involvement and broad participation during the whole project process. In summary, the research contributions to the knowledge base of this study are of value for both the ADR and the SA research domain.

5.2. Practical contributions to the application domain of the prototype ISPA tool

There are few SA tools in the Netherlands which are specially developed to fulfil the needs of municipalities and companies in the civil engineering sector, and to overcome their main barriers for a better project sustainability performance. Typical barriers are the lack of standardized directives and criteria for project sustainability inclusion, a narrow vision of sustainability with a lack of attention for interdependencies between sustainability dimensions and a lack of systematic integration and collaboration among functional units (Rincón et al., 2021). The prototype ISPA tool provides a comprehensive view, directives, criteria, and systematic integration for project sustainability inclusion. Furthermore, the tool is used throughout the whole project process to align the project decisions and activities of the different project phases and to foster the communication and collaboration among the stakeholders. This combination of an assessment tool and a process management tool is needed to tackle the complexity of sustainability and very valuable for both municipalities and companies in the Dutch civil engineering sector.

On an international scale, the industry ''needs to adopt new thinking, practices, and approaches, and designing and building for sustainability need to become the norm'' according to Griffiths et al (2018, p. 2). The development and usage of new SA tools for civil engineering projects can support the industry to bridge the current gap and to take a stronger role in contributing to sustainable development (Griffiths et al., 2018). The prototype ISPA tool may first have only a national purpose, but as suggested by Harré (2011, p. 50) ''the more that sustainable practices are in the air, the more salient they become, and the more likely individual people and groups of people are to replicate them.'' So, if the prototype ISPA tool and this research will lead to more sustainable practices in the Netherlands in the civil engineering sector, it can be replicated, adopted and used in other countries.

5.3. Limitations and future research directions

For the development of the ISPA tool, the cycles of the elaborated ADR of Mullarkey & Hevner (2019) were performed. One major challenge of DSR and ADR in general, is the dependency on specific design decisions of the research team (Lukyanenko et al., 2015). In this research, the design decisions are based on the problem context, the SDF, the design principles and on user feedback, but another ADR team could develop another tool with different design features and functions. Another limitation is that the user feedback was mostly retrieved as qualitative data. In future studies, the performance qualities of the tool reviews can be transformed into a set of monitoring and evaluation criteria to continuously revise and refine the rubric tool. For the further development and usage of the prototype ISPA tool, it is crucial to use and test the ISPA tool with multiple projects along the whole project process. It is also recommended to perform the UEQ multiple times during the project process to track the user experience along the project stages.

6. Conclusion

Sustainability is becoming more important in the design of the public space and in the civil engineering sector. The usage of SA tools is important for addressing, managing and improving the project sustainability performance of civil engineering projects of municipalities. Especially for projects with a small spatial scale, a solution is needed to overcome the main barriers of municipalities and companies in the civil engineering sector. In this study, the cycles of the elaborated ADR method were performed in cooperation with an organisation in the civil engineering sector, to develop and evaluate an integrated sustainability performance assessment (ISPA) tool for civil engineering projects with a small spatial scale in the Netherlands. The prototype ISPA tool integrates the three dimensions of sustainability with the key sustainability themes for municipalities, and the tool assists in the decision-making process, by directing and aligning the project decisions and activities throughout the whole project process. In this way, the prototype ISPA tool is a comprehensive solution for the fragmentation of the project process and to the inclusion of sustainability performance objectives which are relevant for both municipalities and companies in the civil engineering sector. This study advances previous SA research and the development SA tools in the civil engineering field. Furthermore, the development of the prototype ISPA tool is based on an ADR approach, which provides insights and prescriptive knowledge on how the theories and methods of ADR and SA can be fruitfully combined. This study is relevant to respond to the present-day challenges in sustainable development and we hope to contribute to the understanding of how to develop and evaluate practical solutions for multiple stakeholders in the civil engineering sector, in their quest for environmental, social and economic sustainability.

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Appendix A

ADR activities and data collection methods

	Methods & activities	Description	References
Diagnosis	Review of the sustainable development policy (and problem) context of municipalities. Based on: - Dutch policy plans and legislation literature	The goal of the (policy) review is to gain insights into which sustainable development policy plans and legislation, from the national government of the Netherlands, the municipalities have to follow, implement and execute. This review is used to identify the major sustainable development topics of interests for municipalities. These topics are to be included (in some way) in the prototype ISPA tool.	*Dutch policy plans and legislation literature - see main text for references*
	Review of the problem context of the companies in the sector, performing (small scale) civil engineering projects Based on: - Semi-structured interview(s) with project manager(s) on completed civil engineering projects of the organisation (with municipalities as client). - Literature findings	The goal of the review is to identify the main barriers and enables for companies in the civil engineering sector for implementing sustainability objectives and solutions, from literature and from the experiences - from previous civil engineering projects - of the project managers of the organisation. Common barriers and enablers for the implementation of sustainable infrastructure development in the construction industry were identified via literature. Five completed projects of the organisation were selected and their (corresponding) project managers were interviewed. The findings from the interviews were used to confirm the findings from the literature and to gain more insights from practice. The selected projects purposely differed in terms of project type and in the extent to which sustainability or sustainable development was a key subject in the project. In this way, the projects provided insights into the variety of civil engineering projects, the common barriers and enables, and where the ISPA tool should be suitable for. Furthermore, the project manager was asked how the sustainability level could have been improved and what the role of the ISPA tool could have been in the project.	*Semi-structured interviews (SSI)* *Projects* - Het Brugje, Odijk - Zuivelstraat, Oldenzaal - Stationsplein Zwolle - Havezate Es, Hardenberg - Stepelerveld, Haaksbergen *Literature* (Munyasya & Chileshe, 2018)

	Expert opinion workshop with the owner, project managers (2) and advisor sustainable area development of the organisation. Based on: - NGT procedure - MoSCoW method - SA framework	The goal of the expert opinion workshop is to define the sustainability & design framework (SDF) together with the organisation, since they are the most experienced and knowledgeable in the (sustainable) civil engineering projects with the municipalities and they are going to work the most with the ISPA tool. The SDF consists of four aspects, namely (1) the sustainability values and principles of the organisation, and (2) the decision context, (3) the objectives and (4) the requirements of the new ISPA tool. These four aspects are based on the SA framework. In this SA framework, the decision context consists of multiple elements, where the most of these elements were already defined at the start of the ADR project, so only (the last) two elements had yet to be addressed: - the objective(s): research objective - the actors: the organisation and municipalities - the scale: civil engineering projects with a small spatial scale, mostly within built-up areas - the activity affected by the decision: the decision-making process during the whole project - the approach: scenario planning ''what if'' - the impacts of interests: t.b.d. (broad perspective on sustainability: three dimensions & Dutch policy) - the uncertainty and complexity of the decision: t.b.d. The Nominal Group Technique (NGT) has been chosen as group consensus method for the workshop, to generate and prioritize ideas in a structured manner. The NGT procedure involves four steps, which are (1) silent generation of ideas, (2) round-robin recording of ideas, (3) discussion of ideas and (4) prioritization of ideas. Benefits of the NGT procedure are: - it limits the influence from group dynamics and the influence from the researcher in the discussion; - it promotes equal input and opinions from all participants; - it prevents participants from dominating the discussion from the start; - it enables the researcher to easily collect and process the data So, for each question the expert team had to (1) individually produce ideas/answers, (2) present the ideas/answers one-by-one, (3) discuss all ideas/answers and (4) prioritize the ideas/answers with the whole group. The questions were formulated, based on the four aspects of the SDF, for the tool: - what are the sustainability values and principles of the organisation? - what are the objectives of the ISPA tool? - what are the mandatory, essential, nice-to-have and not essential yet requirements of the ISPA tool? - what are the (possible) sustainability impacts and indicators of interest? [decision context] - what should be the complexity/uncertainty ratio of the ISPA tool? [decision context] The MoSCoW method has been used to prioritize the requirements (step 4) of the ISPA tool. With this method the requirements are categorized into four groups, namely (1) must have, (2) should have, (3) could have and (4) won't have. This method is highly suitable in the diagnosis phase, since the requirements are specified in a low level of detail and the organisation has only a general idea of the tool and what they need out of it.	*NGT-procedure* (Laenen, 2015; Manera et al., 2019; Mukherjee et al., 2018) *MoSCoW method* (Hatton, 2008) *SA framework* (Sala et al., 2015)

Design	Formalisation of design principles. Based on: - Structure format of design principles - Sustainability & design framework	The initial set of design principles is derived from the objectives and requirements of the SDF of the diagnosis cycle. The formalisation structure of design principles consists of (1) material property, (2) activity of users and (3) boundary conditions. The initial design principles are further specified to design features and instantiated into a prototype SA tool.	*Formalisation structure of design principles* (Chandra et al., 2015) *Design features* (Bilgeri & Zurich, 2019; Meth et al., 2015)
	Formalisation of two key themes and the categories for the prototype ISPA tool. Based on: - Research objective and results of the diagnosis stage - Review framework for related SA tools - Review of related SA tools, which are (1) CEEQUAL, (2) Envision, (3) BREEAM-NL and (4) LEED-ND.	The two key themes of the ISPA tool are derived from the research objective and the results of the diagnosis stage. The categories of the ISPA tool are derived from the problem context of both the municipalities and the companies in the civil engineering sector (see also Diagnosis) and underpinned with the results of a review of related SA tools. The goal of the review of related SA tools is to gain insights into which extent current well-known integrated SA tools address sustainable development topics of interest of municipalities, to define suitable categories for the tool. For the review of the related SA tools, two infrastructure SA tools (CEEQUAL & Envision) and two urban SA tools (BREEAM-NL Gebied & LEED-ND) are selected. These SA tools provide an integrated approach by addressing multiple dimensions of sustainable development and the manual is online available. In the review framework, the criteria of each SA tool are reviewed in relation to the three sustainable development dimensions, extra dimension(s), energy transition, climate change adaptation, circular economy, environmental vision and participation. The criteria are labelled as 'not applicable', 'semi-applicable' and 'fully applicable' per theme. The inclusion of these themes is summarized per theme and per SA tool, to compare the different criteria and SA tools.	*Review framework related SA tools* (Ameen et al., 2015; Kaur & Garg, 2019) *Related SA tools* (BRE Global Limited, 2020; Dutch Green Building Council, 2018; Institute for Sustainable Infrastructure, 2018; USGBC, 2021)
	Development prototype SA tool (rubric per category). Based on: - Steps for the construction of (scoring) rubrics - Scientific literature - Grey literature - Input of the organisation	Rubrics are common assessment tools in education and used for evaluating student performances, but rubrics are also suitable for evaluating sustainability performance in civil engineering projects, in a practical way. The prototype SA tool is developed by following the general guidelines for constructing scoring rubrics. The steps are (1) determine performance objectives, (2) choose a rubric type, (3) determine dimensions and criteria - rows, (4) create performance levels - columns, and (5) create descriptions for the criteria along the performance levels - cells. The dimensions, criteria and descriptions are derived from a mixture of scientific literature and grey literature on the topic of sustainable development and sustainability legislation, policy, methods and tools in the Netherlands and in the civil engineering sector. The justification of the criteria is based as much as possible on open-source literature to ensure the accessibility and usability of the ISPA tool. Furthermore, the expert opinion team of the organisation provided input and feedback, via multiple design feedback sessions. In these sessions, a conceptual, intermediate version of the prototype ISPA tool was presented by the researcher. The expert team was asked to provide input and ideas on major design issues, viable solutions and decisions, and were asked to fill in knowledge gaps of the researcher on the application domain.	*Rubrics: steps for the construction* (Roell, 2019; Stevens & Levi, 2013) *Rubrics: background literature* (Allen, 2020; Allen et al., 2018; King et al., 2013; Stevens & Levi, 2013; Stone-Jovicich, 2015)

		The last step of rubric construction is testing, refining and revising. This is done in the iterative development process.	
	Formalisation of the final sustainability project score. Based on: - Analytical rubric scoring method & rating scale - Compensation (literature/theory) - Discussion with the expert team of the organisation	The end result of the usage of the prototype ISPA tool is represented in the final sustainability project score. A lot of different scoring methods are available. The analytical scoring method is chosen, since it fits the chosen rubric type and it is able capture performance differences over multiple categories. The method is also suitable for enhancement of the reliability and accuracy of scoring. Together with the expert team, other features are discussed and decided upon. These were the rating scale, the compensation rules (in relation with weak vs strong sustainability), the visual representation, and the possibilities for adding weights to categories (in the future).	*Analytical rubric & rating scale* (Galti et al., 2018; Gentile, 2018; Jonsson & Svingby, 2007; Li & Wang, 2021; Molkenboer, 2017) *Compensation* (de Mare et al., 2015; Sironen et al., 2015)
	Formalisation of the four usage steps of the ISPA tool in the project process. Based on: - Research objective, SDF and design principles - Input expert team - Questions for intake meeting are derived from the rubric ISPA tool	The usage steps of the ISPA tool are formulated in close cooperation with the expert team and are based on the design principles, the objectives and requirements stated by the organisation in the SDF. The four steps are created to enable the actors to integrate and align project decisions and activities throughout the whole project process for sustainability inclusion. The usage steps complement other SA tools by focussing specifically on assisting the decision-making process for project sustainability inclusion, instead of providing an ex-post assessment of the project. The main objective of the usage steps is to provide a structure to the usage of the tool throughout the whole project and to assist the actors in the decision-making process. The four usage steps follow the changes in the uncertainty and complexity ratio during the project process. For the first usage of the ISPA tool in the project process with the municipalities, the project intake meeting has been set-up. For the quick scan of the current sustainability level of the project and the ambitions of the municipality, relatively simple and more general questions with explanatory notes and examples are formulated per category. These questions are derived from the prototype ISPA tool and knowledge (for the organisation) about which topics and kind of questions municipalities can relate to. In this way, the abstraction level of the rubric ISPA tool fits to the start of the project, where detailed information is not available and project decisions does not have to be very specific yet.	
Implementation	Prototype SA tool (rubric) testing and reviewing with(in) the organisation. Based on: - Rubric and SA tool qualities - Completed project(s) - IT dominant BIE cycle	After the development of the first version of the prototype ISPA tool (rubric), the tool is first tested with the expert team of the organisation. This corresponds with the IT dominant BIE cycle (of ADR) and ensures internal validity. The internal test sessions at the organisation consisted of two parts, in which (1) the (rubric) tool was tested on a completed project by indicating the sustainability performance level for all criteria and (2) the rubric was reviewed on several performance qualities. The evaluated performance qualities in this tool review are: - Practicability & feasibility: are the criteria user friendly, easy to understand and feasible to assess and/or obtain? - Performance level classification: are the descriptions	*Rubric and SA tool qualities* (Bartke & Schwarze, 2015; Jonsson & Svingby, 2007; Sala et al., 2015; Stevens & Levi, 2013) *IT dominant BIE cycle* (Sein et al., 2011)

		- along the performance levels consistent and do they fit to the performance level? - Clarity & unambiguity: are the criteria and descriptions along the performance levels clear, and formulated in such a way that a second assessor/assessment would give the same result? - Relevance: are the criteria relevant and important, or superfluous? - Logic & reliability: are the criteria sound and is the quality sufficient? The second prototype is tested in the same manner, but then after the external test sessions with the municipalities to simulate the usage process of the ISPA tool. The tool is tested in the same expert team member pairs of the intake meeting and with the project, which was chosen by the municipality and discussed during a project intake meeting. The advantage of testing and reviewing the tool in pairs, instead of individually, also provokes discussion and can lead to other feedback compared to the first tool evaluation.	*Project* Sluiskade & the self-chosen projects of the municipalities of Haaksbergen and Oldenzaal (test session, intake meeting)
	Tool test/pilot sessions with municipalities. Based on: - Experimental evaluation approach of DSR - Self-chosen project by the municipality - Semi-structured interview - User Experience Questionnaire (UEQ) - IT dominant BIE cycle	After the development of the second prototype, test/pilot sessions were held in cooperation the organisation and municipalities. This corresponds with the IT dominant BIE cycle (of ADR) and ensures external validity. During these test sessions, the project intake meeting was performed for a project of the participating municipality. The project intake meeting consists of an introduction, a short exploration of the project, quick scan questions per category and questions directed towards ambitions. The project intake meeting was carried out by two expert team members of the organisation, so they could practice the use of the tool and the researcher could observe the session. After the project intake meeting the participants were interviewed. The interview consisted of two parts, which were (1) the User Experience Questionnaire (UEQ) and (2) a semi-structured interview with open questions. The UEQ is applied to test if the user experience is sufficient, in a fast and immediate manner. The semi-structured interview contained open questions to obtain more insights and feedback on the tool itself and to check whether the tool meets the research objective.	*Experimental evaluation approach* (Hevner et al., 2004) *UEQ* (Schrepp et al., 2014) *IT dominant BIE cycle* (Sein et al., 2011) *Projects* - De Stakenbeek, Oldenzaal - Oude N18, Haaksbergen
Evolution	Final evaluation: verification of the ISPA tool against the design principles and (requirements of) the SDF	The final version of the prototype ISPA tool was evaluated, by conducting a verification of the ISPA tool against the design principles and the sustainability and design framework (SDF). From the SDF, the requirements are compared to the final ISPA tool, to compare which requirements have been implemented in the ISPA tool, and which requirements have not been met (yet).	

	Qualitative uncertainty analysis - Three step approach - Analytical framework for the identification of uncertainty sources - SA framework and other authors (underpinning)	When the functional performance of the ISPA tool was satisfactory, the uncertainty analysis was performed. Uncertainties and sensitivities in a SA should be systematically analysed and clearly communicated to the users of the SA, according to multiple authors. To assess the uncertainties in a structured, qualitative way, a combination of the three-step approach and the analytical framework were chosen. The analytical framework is used, because it is developed for strategic environmental assessments, which relates closely to integrated sustainability assessments for decision-making processes. In this analytical framework, the uncertainties of a SA tool are categorised into four uncertainty types, namely (1) inherent uncertainties, (2) scientific uncertainties, (3) social uncertainties, and (4) legal uncertainties. In this study, after the identification and classification of the uncertainties of the ISPA tool, the uncertainties are characterised and scaled as "low", "medium" or "high". Similar to a risk assessment, the likeliness and the size of the impact are estimated and multiplied to determine the scale of the uncertainty. So, uncertainties which are characterized as "high" are highly likely to occur and the have a significant impact on the usage and/or the results of the assessment.	*Three-step approach* (Salway & Shaddick, n.d.) *Analytical framework* (Bodde et al., 2018) *Underpinning analysis for SA* (Ciuffo et al., 2012; Sala et al., 2015; Singh et al., 2009)

Table 4: Data collection methods and activities, per ADR stage.

Appendix B

Results of the expert opinion workshop

Question: what are the sustainability values and principles of the organisation?	
"No castles in the air/pie in the sky"	Stay realistic, honest and reliable
"For the present and the future"	Working on challenges of the present, with a forward-looking view and future-oriented solutions
"Broad-based interests and knowledge"	Sustainability and sustainable development (projects) are broad topics, so it is important (and almost required) to be broad-minded and have broad knowledge
"Involved together"	Well-connected and long-term relationships with the clients and partners, with good cooperation before, during and after the project(s)
"With pleasure"	Work pleasure between colleagues and with partners (during projects)
Question: what are the objectives of the ISPA tool?	
"Insight into sustainability"	The ISPA tool provides insight* into (a broad range of different aspects) sustainability/sustainable development. *First insight(s) should be "quick"
"Measurable and integral approach"	The ISPA tool provides an integral and measurable approach to sustainability/sustainable development
"Realistic, within boundaries project"	The ISPA tool provides a realistic "design/result" within the boundaries of the project (in terms of time, money etc)
"Connection between disciplines"	The ISPA tool connects different disciplines (of sustainability/within municipalities/within civil engineering)
"Gives confidence, success factor"	The ISPA tool gives confidence, by being an important success factor within the project
"Make sustainability the standard"	The ISPA tool will ensure that sustainability/sustainable development becomes standard/completely normal within projects (in the future)
Question: what are the mandatory, essential, nice-to-have and not essential yet requirements of the ISPA tool?	
Mandatory	

Easy to understand, explain and use	The ISPA tool is unambiguous and only be used/explained in one way. Criteria and indictors are logical, underpinned and easy to explain.
Flexible and expandable	The ISPA tool is scalable to the type, the size and the current phase of the project. The tool is expendable with new components and knowledge.
Concrete and measurable	The criteria of the ISPA tool are concrete and make sustainability/sustainable development measurable.
Quick scan & ambition level	With the usage of the ISPA tool, a quick scan can of the project can be performed and the ambition level(s) of the project can be defined.
Standard format	The ISPA tool is presented in a standard and structured format
Essential	
Visually appealing and user friendly	The (output of the) ISPA tool is visually appealing, ''quickly'' provides a good overview of (different) sustainability aspects and make it easier to draw a conclusion in one glance. The interface of the tool is user friendly.
Project process	The ISPA tool fits into the design processes of the organisation and the process of civil engineering project of municipalities.
Simple and flexible usage	The ISPA tool can be used with standard/commonly used software. The tool can be used with clients physically/on-the-spot and digitally/online survey (intake project).
Output (format)	The output of the ISPA tool is/can be a programme of requirements, one page/A4 with the key points, report, and advice.
Integrated functions	Responsibilities, actions, and changes can be defined and updated throughout the project process. These functions are integrated in the ISPA tool.
Nice-to-have	
Connected	The ISPA tool is connected to (standard) measure- and calculation methods, subsidies and funding possibilities, and other certifications (not SA tools).
Extra functions	Traceability of input (notes participants and talking points), data export function (for a trade-off matrix/TOM) and a filter function
Not essential yet	
Possibilities	Possibility to substantiate the decision-making process with costs as criteria/indicator
	Possibility to define focus/scores per category
	Possibility for the client to do an online assessment or quick scan
Question: what are the (possible) sustainability impacts and indicators of interest? [decision context]	
Circular economy	Indicators: circularity level (e.g., 10R method), (re)use and recycling of materials, LCA & MKI, lifespan of materials, and waste streams.
Climate change adaptation	Indicators: water storage and heat stress. Possible solutions/measures: extra infiltration, retention and uncoupling drainpipe (rainwater).
Energy transition	Indicators: renewable energy, energy usage, and CO_2 emission reduction.
Environment	Indicators: nature and ecology, biodiversity, cultural and geological history/heritage, land contamination and remediation, noise and vibrations, creative design and lay-out of public space, and mobility.
Project & process management	Indicators: MVO, SROI, actor participation (ladder), progressive policy goals, method/way of tendering, flexible and adaptive (subsurface) way of designing, linkage opportunities with other projects, and ''make work, with work'' (smart project planning & phasing). Integration: process from idea up till maintenance & management phase

Question: what should be the complexity/uncertainty ratio of the ISPA tool? [decision context]	
The ratio (and the tool) should be flexible, to be suitable for the whole project process. *	
Start of the project	Low complexity, high uncertainty (accessible, less data and knowledge)
End of the project	High complexity, low uncertainty (reliable, more data and knowledge)

Table 5: Results of the expert opinion workshop, with the expert team of the organisation.

*Extra explanation flexible complexity/uncertainty ratio: To achieve the research objective and to fit the ISPA tool to the problem context, the complexity and uncertainty level of the ISPA tool should not be fixed, but should fit and adapt to the project phase, according to the expert team. Generally, a project process develops from a very conceptual level to a very detailed and sophisticated level. At the start of the project, there is little information and knowledge available of the project, which causes a high level of uncertainty. This results in very conceptual ideas, relatively simple solutions and draft designs. When the project process proceeds, more information and knowledge becomes available. The ideas, solutions and designs become more concrete, specific and detailed. This results in a higher level of complexity, but also a lower level of uncertainty.

As discussed in the problem context (section 4 Diagnosis), it is important for the organisation to focus on (sustainable) project and process management, because the ISPA tool should provide directives and assist the decision-making process for sustainability inclusion. Therefore, it is needed to integrate the project process from the beginning up till the end of the project, by aligning the different project phases. The project decisions and activities of every project phase are dependent on the available knowledge and data. Therefore, the allowed complexity is low, and the uncertainty is high - due to little data and knowledge - at the start of the project, which is required to ensure the accessibility of the ISPA tool. At the end of the project, the required complexity is higher, and the uncertainty is lower due to more sophisticated data and knowledge on the project, which is required to improve the reliability of the ISPA tool.

Appendix C

Relation between the design principles and the design framework

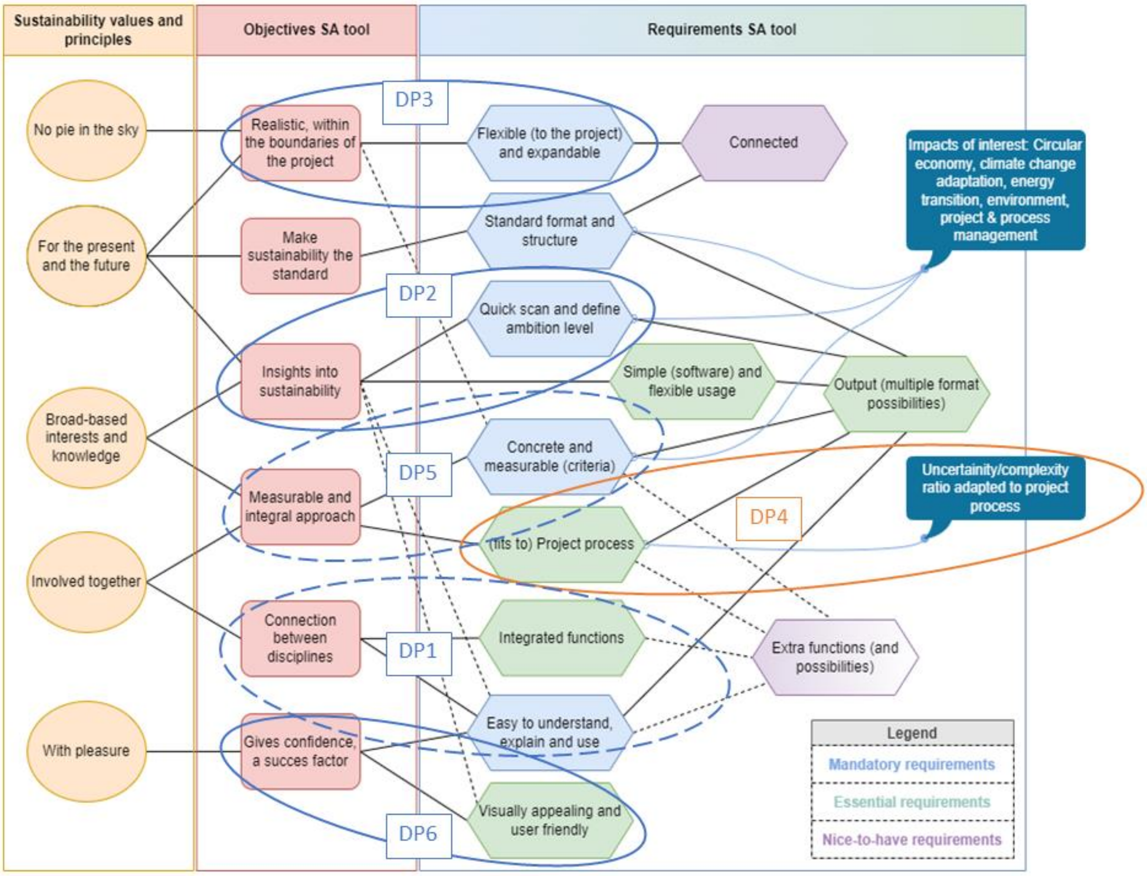

Figure 7: Relation between the design principles and the SDF. All design principles are based on a combination of an objective and a requirement for the ISPA tool. Only DP4 is an exception, because this DP is based on a combination of a requirement and the uncertainty/complexity ratio (of the decision context). In this way, almost all (important) elements of the SDF are incorporated in the design principles.

Appendix D

Categories of the ISPA tool, underpinned with results of the diagnosis stage and the review of related SA tools

	Categories	Diagnosis stage	Review related SA tools
Sustainable goals	Circular economy & resources	- Key sustainability topic municipalities - National plan on circularity (100% circular in 2050)	- Medium addressed in SA tools - Often addressed with (a category) "resources" - Focussed on environmental and economic dimension
	Climate change adaptation	- Key sustainability topic municipalities - National plan on climate change adaptation (DPRA)	- Little addressed in SA tools - Focussed on water, and (risk)assessment & management
	Energy transition	- Key sustainability topic municipalities - National plan on energy transition	- Very little addressed in SA tools - Only fully applicable criteria
	Nature & Soil	- Important part in the environmental vision - Close relation with climate change adaptation	- Often addressed in all SA tools - Represents the environmental dimension (focussed on protection and improvement)
	Mobility	- Important aspect in built-areas, where transport by foot, bike and public transport	- Often addressed in area-development SA tools. Focus on

		can be prioritized above motorized transport (*Dutch: langzaam verkeer*) - Mobility plan municipality, which is closely related to environmental vision	accessibility, slow traffic and integrated networks - Represents social and environmental dimension
Sustainable process	Participation & spatial quality	- Key sustainability topic municipalities (participation & environmental law) - Early involvement of stakeholders	- Represents the social dimension - Participation often addresses public space and design choices
	Ideation & design	- First project phase - Important to include sustainability objectives as early as possible - Important to focus on adaptability and future-proof design	- Represents the major extra dimension (project management) - (area) SA tools (also) focus on the project location: cultural heritage, smart/efficient use of land and social functions
	Execution	- Project phase where communication and collaboration are very important - Project phase where sustainability aspects are important (not only design)	- Represents the social, environmental and project management aspects - Construction impacts (air, noise, light) are addressed by all SA tools
	Maintenance & asset management	- Often too late involved in the project - Asset management is important for the life cycle sustainability performance	- Very little addressed in SA tools - Often relates to ''innovation'' (extra dimension)

Table 6: Categories of the tool, underpinned with results of the diagnosis stage and the review of related SA tools

Review of related SA tools

To gain insights how the tools address the problem context of this ADR project, four well-known tools - CEEQUAL, Envision, BREEAM-NL Gebied and LEED-ND - are reviewed into which extent they address sustainable development topics of interest of municipalities, the three dimensions of sustainability and extra dimension(s). All criteria were assessed and labelled as ''fully-applicable'', ''semi-applicable'' or ''not-applicable''. The result is presented in Table 7 visually presented in Figure 8, which combines the fully- and semi-applicable criteria in one figure.

Percentage of criteria per SA tool which (fully or semi) address:	**CEEQUAL**		**Envision**		**BREEAM**		**LEED**	
	Fully ●	Semi ○	Fully ●	Semi ○	Fully ●	Semi ○	Fully ●	Semi ○
Environment	27%	47%	22%	47%	15%	45%	20%	44%
Social	13%	33%	15%	39%	17%	34%	30%	22%
Economy	7%	17%	6%	24%	4%	17%	0%	8%
Extra dimension(s)	13%	7%	19%	7%	9%	6%	10%	2%
Energy Transition	3%	3%	8%	0%	6%	0%	10%	0%
Climate change adaptation	7%	3%	10%	14%	6%	9%	10%	6%
Circular economy	20%	10%	17%	14%	13%	4%	10%	4%
Environmental Vision	17%	23%	17%	31%	26%	26%	36%	28%
Participation	3%	33%	12%	14%	11%	17%	2%	6%

Table 7: Results of the review of related SA tools

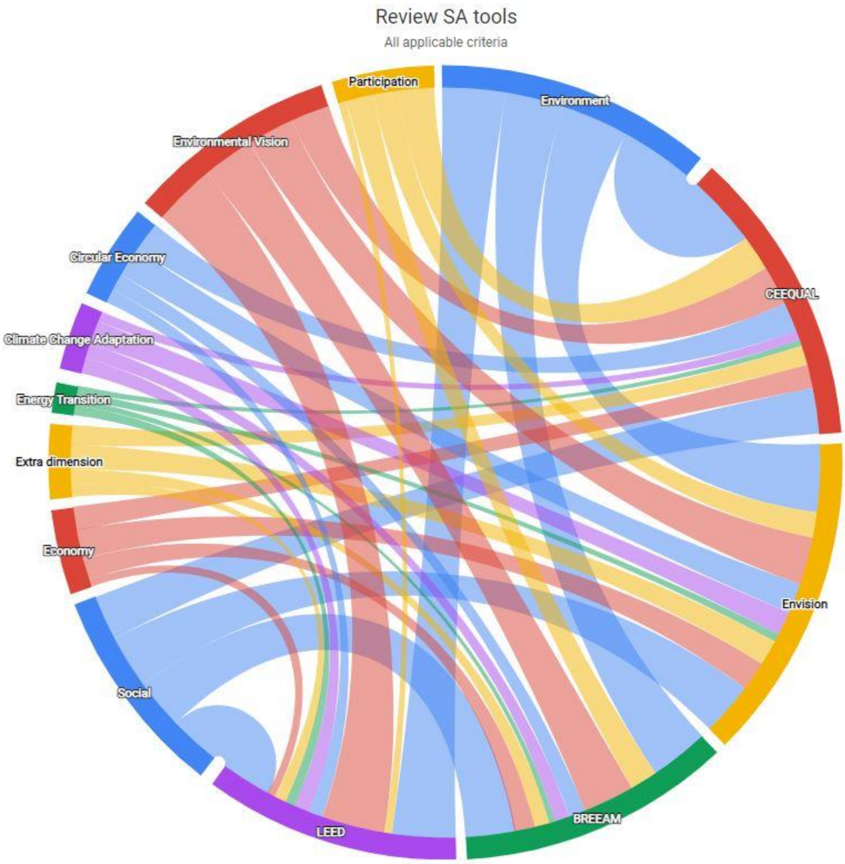

Figure 8: Applicability and division of SA tools criteria on the sustainability dimensions (environment, social, economy and 'extra'/other) and key sustainability topics (circular economy, climate change adaptation, energy transition, environmental vision and participation). The four SA tools are CEEQUAL, Envision, BREEAM-NL Gebied and LEED-ND.

The review showed that, for the sustainability topics, energy transition and climate change adaptation are the least addressed by the SA tools. Although, criteria which addressed these themes, are often fully applicable. Circular economy is addressed a bit more, also often with fully applicable criteria, and it is addressed by the categories or criteria containing the word ''resources''. The low percentage of criteria which address these three topics - energy transition, climate change adaptation and circular economy - show the lack of attention for these topics and make it also difficult to properly address these topics when there is a lack of suitable and comprehensive criteria and indicators. The other sustainability topics, participation and the environmental vision, are addressed often with semi applicable criteria. Environmental vision is addressed the most in the area development SA tools (BREEAM and LEED). This is not a surprising result, since the environmental vision covers a lot of aspects in general and specifically in area development.

From the sustainability dimensions, the order of occurrence in the tools - from high to low - is (1) environmental, (2) social and (3) economy and project management (extra dimension). They are mostly addressed with semi-applicable criteria because these dimensions are not very specific and can be interpreted quite broadly. This is also caused by the lack of the theoretically rigorous description of these dimensions, since they have gradually emerged from various ideas and critiques in academic literature (Purvis et al., 2019). It is important to create a balance between the dimensions in the new tool.

Appendix E

Artefact development - implementation of design principles and features

The implementation of the design principles (DP) and design features (DF) is mainly indicated, by putting it at the end of the sentence within brackets. The list of design principles and features can be found in the main text in Table 2.

The prototype ISPA tool - a performance assessment rubric

For the development of the prototype ISPA tool a specific format has been chosen, namely the performance assessment rubric. According to Allen et al (2018) rubrics are useful for addressing complex tasks, while they are also easy to use and explain. Rubrics have five beneficial characteristics, namely that they (1) provide transparency, (2) define the things that matter (with criteria), (3) define what different levels of performance look like, (4) integrate expectations, policy, data sources and evidence, and (4) keep the evaluation focused on the things that matter (King et al., 2013). Rubrics are often used in education to provide meaningful feedback to students, because rubrics provide the students insights into their strengths and weaknesses (Gentile, 2018; Stevens & Levi, 2013). This is also beneficial for civil engineering projects, because rubrics can support the project team to ''articulate system shortcomings in a concrete way and provides guides to look for improvement'' (King et al., 2013, p. 290). These characteristics of rubrics suit to the research objective, the SDF and the design principles. Therefore, the prototype ISPA tool is developed by following the general guidelines for constructing scoring rubrics (Roell, 2019; Stevens & Levi, 2013). The steps are (1) determine performance objectives, (2) choose a rubric type, (3) determine dimensions and criteria - rows, (4) create performance levels - columns, and (5) create descriptions for the criteria along the performance levels - cells. An extra step is added to provide a final score: (6) create a final score overview. The rubric structure, which corresponds with these steps, is visually represented in Figure 9.

		Performance levels			
		Poor	Fair	Good	Excellent
Dimensions, categories	Criterion A	*description*	*description*	*description*	*description*
	Criterion B	*description*	...	...	...
	Criterion $_n$	*description*	...	...	...

Figure 9: Rubric structure

Choose a rubric type

Holistic rubrics have a single rating scale, which makes them more suitable for quickly providing general feedback, but which makes their reliability also very dependent on the assessor (Galti et al., 2018; Jonsson & Svingby, 2007). The analytical rubric type is chosen, because this rubric type breaks down an assignment into multiple categories and it is two-dimensional (criteria and performance levels). Therefore, it is suitable for complex assignments and useful in providing feedback on areas of strength and weakness.

The choice has been made to create one rubric for each category (Figure 5), to keep the assessment organised and to create flexibility. If one or multiple categories do not apply to the project, they can easily be left out without losing the value of the tool and the tool results (**DF3a**). The categories are identified and formulated based on a combination of the results of the diagnosis phase and an additional review of related SA tools, as presented in Table 6 in Appendix D (**DF1a**).

Determine dimensions and criteria - rows

The subcategories form the dimensions of each rubric. For the formulation of subcategories, all criteria of the reviewed SA tools were used. The fully- and semi-applicable criteria per theme were organized in subthemes, by clustering criteria with the same words or synonyms around a subtheme.

Table 8 shows an example where criteria with the term 'renewable energy' are clustered in the subtheme 'renewable energy' and criteria with 'emissions' are clustered in the subtheme 'emission reduction'.

Theme	Subtheme	Criteria	SA tool	Applicability
Energy Transition	Renewable energy	Generate renewable energy	BREEAM	●
		Renewable energy production	LEED	●
	Emission reduction	Reduction of GHG emissions	Envision	●
		Reducing whole life carbon emission	CEEQUAL	○
● = fully applicable ○ = semi applicable				

Table 8: Example creating subthemes, by clustering criteria

The initial subcategories were discussed with the expert team and refined in the iterative design process. The final subcategories for all categories are represented in Figure 10 and represents **DF1a**.

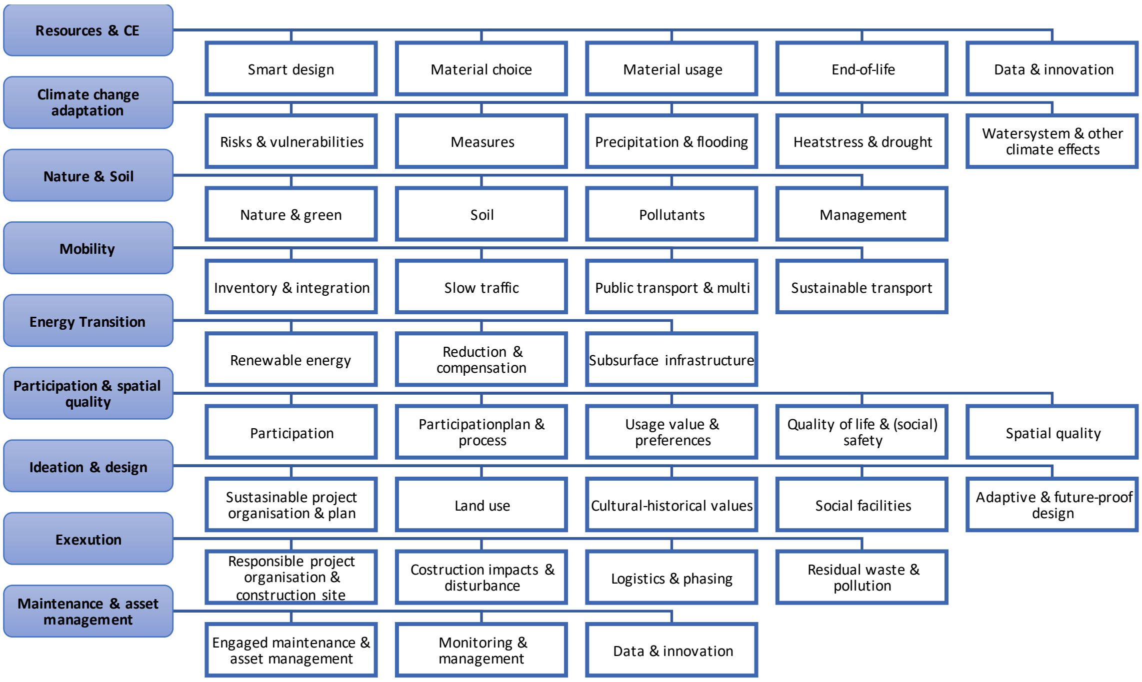

Figure 10: Categories and subcategories of the ISPA tool

The identification and formulation of criteria and indicators is related to the design features, as presented in Table 9.

Criteria characteristics	Design feature
The criteria and indicators are derived from a mixture of scientific literature and grey literature on the topic of sustainable development and sustainability legislation, policy, methods and tools in the Netherlands and in the civil engineering sector. The criteria are formulated as concrete and straightforward as possible.	DF5c
The justification of the criteria is based as much as possible on open-source literature to ensure the accessibility and usability of the ISPA tool.	DF2a
The criteria are set-up in such a way that they have logical linkages with other criteria within the category, but also with other categories.	DF1b
The criteria do not relate to the project size (within small scale municipal projects).	DF3b
The criteria which are related to the project type and/or other specific characteristics can be left out of the assessment.	DF3a

Table 9: Criteria characteristics and their related design feature

Create performance levels - columns

The next step of the rubric development was the creation of performance levels, to define what different levels of sustainability performance look like (**DF5a**). The chosen amount of performance levels is four, which is appropriate amount for an assessment rubric (Stevens & Levi, 2013). The four levels are ''poor'' *(onvoldoende)*, ''fair'' *(basis), ''*good" *(goed)* and ''excellent'' *(uitstekend)*. ''Poor'' indicates what is insufficient and ''fair'' indicates what the minimum requirements are. This level aims to ensure that the project does not causes unacceptable negative impacts. ''Good'' and ''excellent'' indicate that the project has provided a signification contribution to the project sustainability performance.

Create descriptions for the criteria along the performance levels - cells

The required sustainability performance level gradually increases from ''poor'' till ''excellent'' and is stated in the descriptions for the criteria along the performance levels. These are formulated in such a way that (1) the users can indicate shortcomings and guides for improvement (**DF2b**), and that (2) they allow flexibility in the uncertainty/complexity ratio (**DF4a**). For some of the rubric criteria, it is needed to underpin why and how the performance level is obtained. For these criteria, the description per criterium gradually increases for each performance level from low complexity/high uncertainty to high complexity/low uncertainty, so that the users can start on a simple/rough level with a little amount of knowledge and data and encourages users to end on a complex/specific level with adequate data and knowledge. To obtain the performance level ''poor'' and ''fair'', the descriptions for these criteria state that little usage of specific knowledge, data, and tools, and just a rather brief and simple underpinning of choices is required. In cases where data and tools are required, these are open source and accessible for free (**DF5c**). To obtain the performance levels ''good'' and ''excellent'', the descriptions for these criteria, state that the usage of (specific) data, models, and tools, the knowledge and/or advice from experts and quantitative, detailed and elaborate underpinning of choices is required.

Create a final score overview (extra step)

The rubric(s) define the sustainability performance level for the criteria, but these are not very valuable and user-friendly measuring and visualising the sustainability performance level for the whole project. Therefore, the end result of the usage of the prototype ISPA tool is represented in a score overview (DP6), which is shown in Figure 11.

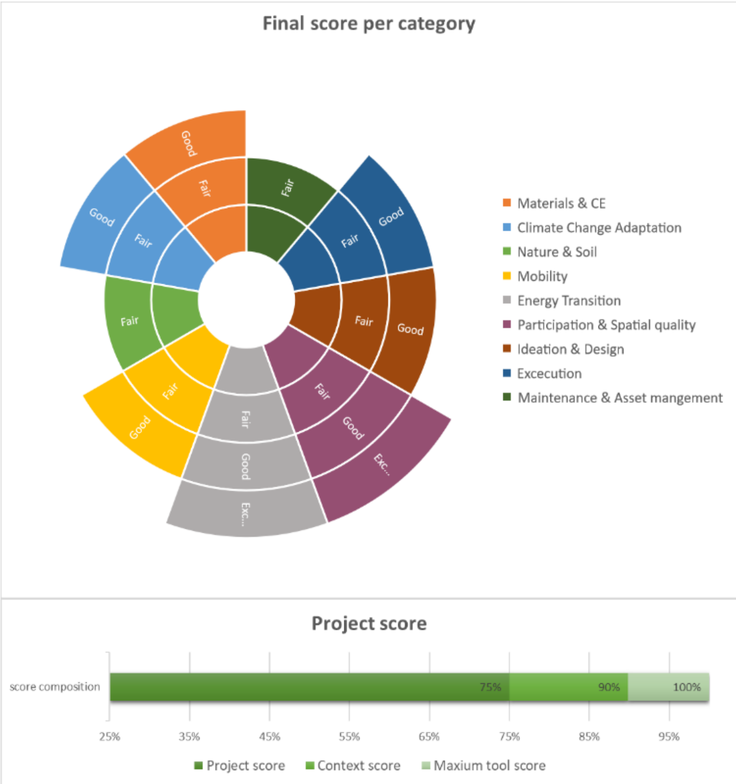

Figure 11: Score overview of the SA tool. The final score per category shows the scores per category in a sunburst diagram. The project score is presented in relation to the context score and the maximum tool score in a bar chart.

The score overview consists of two parts which are (1) final score per category in a sunburst diagram and (2) the project score in relation to the context score and the maximum tool score, in a bar chart. The first part gives an overview of the performance scores per category (DP2), to show on which categories the project has obtained a high score and on which categories the project scored less (**DF6a**). The second part gives an overview of what could have been done within the boundaries of the project (DP3), with the context score, and what has been done at the end of the project (**DF6b**). These two visual representations are chosen together with the expert team of the organisation.

The analytical scoring method is chosen to obtain the end-scores, since it fits the chosen rubric type and it is able capture performance differences over multiple categories. The method is also suitable for enhancement of the reliability and accuracy of scoring (Jonsson & Svingby, 2007). Together with the expert team, the rating scale and the compensation rules were discussed and decided upon. To keep the scoring method as simple and attractive as possible, the 1-2-3-4 rating scale and minimal compensation rules were selected. Compensation is allowed, to make it more attractive for the end-users to increase their sustainability performance. However, some constraints were formulated, and a few criteria were marked as mandatory for obtaining the ''excellent'' score.

The final rubric ISPA tool is formatted as a spreadsheet with one worksheet per category and a worksheet presenting the score overview. Each category worksheet is a rubric, where per criteria the obtained performance level can be selected via multiple choice buttons. The button returns a 1, 2, 3 or 4 in the score column, depending on the selected performance level. The mandatory criteria for the ''excellent'' performance score and the constraints are represented as checkbox. As stated in **DF3a**, criteria should also be allowed to be left out if they do not fit to the project type, phase and/or other characteristics. So, the number of applicable criteria can be adjusted to the project in each category sheet. This number is included in the calculation of performance score per category, and it directly changes the context score in the bar chart. The context score defines what the maximum obtainable score is, within the boundaries of the project. The project score is the sum of the category scores, divided by the maximum achievable, absolute tool score.

Design and development iterations

During the ADR project process, the prototype ISPA tool is tested and evaluated to indicate shortcomings and other types of weaknesses. These provided input for the improvement of the prototype ISPA tool. In this way, the development process of the prototype ISPA tool moved from the Design cycle, to the Implementation cycle, and iterated back to the Design Cycle. The first prototype is revised and refined in two iterations. The first prototype was only the performance assessment rubric in a spreadsheet. The second prototype also included also the four usage steps of the tool in the project process. The third prototype included the final, elaborate score overview.

The first and second prototype performance rubric tools were both times further improved by adapting and deleting subcategories, criteria and descriptions along the performance levels. Extra explanations, definitions and examples (of evidence) were added for more clarification, when necessary (**DF5b**). Furthermore, the instantiation of the design principles became more concrete with every iteration. Therefore, the design features were revised and refined a lot. An illustrative example is the change of DF6 from just ''a score overview'' as initial design feature into two concrete and specific design features.

Appendix F

Feedback of the expert team on the first prototype tool - internal test session

Feedback	Recommendation	Performance qualities
Too little guidance, due to the lack of definitions, examples and extra explanation	Addition of definitions, examples and extra explanation.	Clarity & unambiguity, practicability & feasibility
Too little difference/contrast between performance levels ''poor'' and ''fair''	Revise and re-formulate the descriptions along the performance levels	Performance level classification
Assessment takes too much time	Delete less relevant, not feasible and time-consuming criteria	Relevance, practicability & feasibility
Assessment of criteria is difficult when they are not or partially applicable to the project	Addition of explanation when criteria can be left out and reformulation of criteria (no double-sided criteria)	Clarity & unambiguity, practicability & feasibility
The vague terms, such as ''as much as possible'' and ''fit to'' gives the assessor too much room for interpretation	Remove vague terms from the criteria, by revising and reformulating the criteria	Clarity & unambiguity
The resources which substantiate the criteria cannot be found in the rubric, which requires extra effort to look it up	Relocate the resources, which substantiate the criteria, to the rubric	Reliability & logic

Table 10: Feedback and recommendations, in general, for improvement of the first prototype. The feedback is provided by the expert team members in the first internal test session. The (main) findings are summarized by the researcher.

Appendix G

The SSI and UEQ results of the external test sessions

Characteristics of the (second) prototype ISPA tool & intake meeting	
Strong	**Weak**
Practical & pragmatic	Lack of visualisations and concrete examples (presentation)
Realistic & feasible	
Integrative & comprehensive	No indication of which (kind of) persons/positions of the municipality are needed at the first meeting
Quick insights and identification of ambitions	
Measurable and concrete decisions	Introduction (of the tool) is too short
Suitable/good for multiple types of small (scale) projects	No (extra) explanation of the added value of the tool for small projects/lowest price
Awareness of the complete project process	A clear and concrete end-result is not (yet) provided at the end of the intake meeting
Project monitoring & control	
Fits to current activities and topics of the municipality	May take too much time and/or capacity during the project process (implementation of requirements)

Table 11: Summarized interview results of the two external test sessions with the municipalities of Haaksbergen and Oldenzaal.

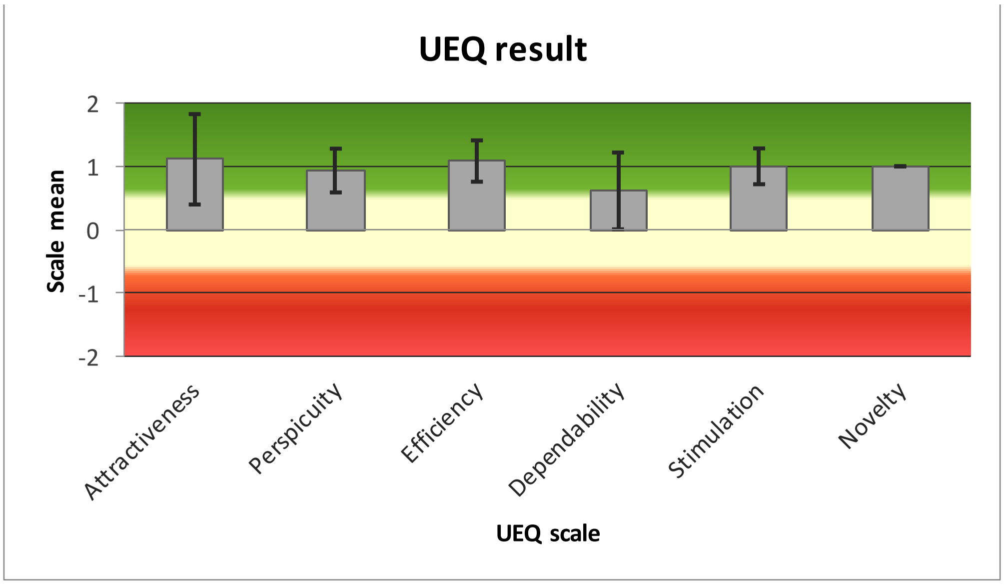

Figure 12: UEQ result (n=3)

All six scales - attractiveness, perspicuity, efficiency, dependability, stimulation and novelty - show a positive evaluation, which indicates that the user experience of the municipalities is sufficient. The attractiveness, which indicates the overall impression of the product, has been evaluated the best. The dependability has been evaluated the lowest, which indicates that the users do not feel enough control while interacting with the prototype ISPA tool. This can probably be explained by the fact that during the project intake meeting the organisation leads the session and the client mainly provides information as input for the ISPA tool. So, the client does not have a lot of direct interaction with the ISPA tool in the first session.

Appendix H

Verification of the ISPA tool requirements (from the SDF)

Requirements (SDF)		Implementation in the prototype ISPA tool	
Mandatory	Easy to understand, explain and use	V	The ISPA tool is unambiguous and only be used/explained in one way. Criteria and indictors are logical, underpinned and easy to explain.
	Flexible and expandable	V	The ISPA tool is scalable to the type, the size and the current phase of the project. The tool is expendable with new components and knowledge.
	Concrete and measurable	V	The criteria of the ISPA tool are concrete and make sustainability and /or sustainable development measurable.
	Quick scan & ambition level	V	With the usage of the ISPA tool, a quick scan can of the project can be performed and the ambition level(s) of the project can be defined.
	Standard format	V	The ISPA tool is presented in a standard and structured format (spreadsheet).
Essential	Visually appealing and user friendly	V	The (output of the) ISPA tool is visually appealing, "quickly" provides a good overview of (different) sustainability aspects and make it easier to draw a conclusion in one glance. The interface of the tool is user friendly.
	Project process	V	The ISPA tool fits into the design processes of the organisation and the decision-making process of civil engineering project of municipalities.
	Simple and flexible usage	V	The ISPA tool can be used with standard/commonly used software. The tool can be used with clients physically/on-the-spot and digitally (intake project).
	Output (format)	V	The output of the ISPA tool is/can be a set of requirements, one page/A4 with the key points, report and advice.
	Integrated functions	X	Responsibilities, actions and changes cannot be defined and updated throughout the project process. These functions are not integrated in the SA tool.
Nice-to-have	Connected	X	The ISPA tool partly connected to (standard) measure- and calculation methods and tools. The ISPA tool is not connected to subsidies and funding possibilities, and other certifications (not SA).
	Extra functions	X	Traceability of input (notes participants and talking points), data export function (for a trade-off matrix/TOM) and a filter function are not implemented in the ISPA tool
Not essential	(extra) Possibilities	X	It is not possible to substantiate the decision-making process with costs as criteria/indicator, with the ISPA tool
		V	It is possible to define focus/scores per category
		X	It is not possible for the client to do an online assessment or quick scan

Table 12: Verification of the ISPA tool requirements. The requirements are retrieved from the expert opinion workshop (Table 5).

Appendix I

Uncertainty analysis

Uncertainty type	Tool uncertainty	Uncertainty scale
Inherent uncertainties in the full range of impacts - "we cannot know"	The precise, full impact of the ISPA tool is unclear and depends on the application context and related systems [**variability**]	Medium
	Cause-effect mechanisms and **cumulative effects** of the measures (which follow from the tool) are unknown, but could have significant, unforeseen impacts (on the system)	Low
Scientific uncertainties due to limited	The **assessment framework** - the ISPA tool - may not be the best representation (e.g., quality, objectivity, reliability) of sustainability and/or sustainable development. Uncertainties occur in the (design)	High

or incorrect information - ”our information and understanding could be wrong and/or incomplete”	choices of methods, criteria, indicators and data.	
	Errors may occur in the **data and models** which are used to determine the **baseline** conditions.	Medium
	Errors may occur in the **data, models and tools** which are used as evidence (to obtain a certain performance level)	Medium
	The ISPA tool is (partly) based on the **knowledge base** on sustainability theories and methods (e.g., existing SA tools). Uncertainty increases when this knowledge context changes.	Low
Social uncertainties due to doubt or ambiguity about information by stakeholders - ”we do not agree on what information is/will be relevant”	The **values, interests and perceptions of the stakeholders** may conflict with these of the ISPA tool. This can entail a subjective selection of categories and criteria in the ISPA tool.	Medium
	The sustainability **knowledge base and capacities** of the stakeholders (e.g., project managers) may be insufficient to be able to understand and use the ISPA tool	Medium
	The **political climate** of the municipality influences which elements of sustainability are addressed in their projects (including funding). These could be elements which are not part of the ISPA tool.	Low
	The **political climate** of the national/European government influences whether and which sustainability topics are found to be important (including funding). This could influence the relevance of the ISPA tool.	Low
	Social uncertainties in the **project design** can influence the use and impact of the ISPA tool. E.g., organisational factors, procedures, resources and coordination among stakeholders.	High
Legal uncertainties in the (legal) justification of decisions - ”we do not know what information we should (legally) provide”	The ISPA tool is (partly) based on and designed for the implementation of national plans, objectives and legislation (related to sustainability) in civil engineering projects. Uncertainty increases when this legal context changes [**institutional setting**]	Low
	Descriptions of criteria along the lowest performance levels (poor and low) are often based on **legal requirements**. Uncertainty increases when this legal context changes.	Medium
	The public servants of the municipalities, which use the ISPA tool in the project can be held **liable for their actions**. Uncertainties in the assessment can have consequences for the public image, social trust, legitimacy and political acceptability.	Low

Table 13: Results of the uncertainty analysis of the prototype ISPA tool. The uncertainty types are adopted from the analytical framework of (Bodde et al., 2018). *The tool uncertainties and their scales are estimated by the researcher, based on the final prototype ISPA tool.*

Appendix J

Recommendations for further improvement of the prototype ISPA tool

The results of the uncertainty analysis can be used to reduce the uncertainties, and thus to improve the quality and the reliability of the ISPA tool. Recommended strategies for the reduction of uncertainties are:

- To limit the scientific uncertainties (medium-high), the content of the ISPA tool should be critically assessed by a large(r) group of experts and researchers in the field, which were not involved in this ADR project to collect feedback and new perspectives.
- To limit the social uncertainties (medium-high), the key barriers, enablers and other influencing factors in the project organisation and the involved stakeholders should be identified and investigated to optimise the effectivity of the ISPA tool, which could entail the reduction or the deliberate increase in impact of social and contextual factors on the usage of the tool.
- To limit the other uncertainties (low-medium), it is important to continuously monitor the changes in the socio-political and legal context and to update and maintain the ISPA tool.

The nice-to-have and not essential (yet) requirements, which were stated by the organisation in the diagnosis stage of this ADR project can be used as input for further development of the prototype ISPA tool. These are mainly functionalities such as the possibility to:

- filter (sub)categories and criteria, based on different project characteristics (e.g. size, type, project phase);
- offer an online assessment or quick scan to clients;
- report and update responsibilities, actions and changes throughout the project per (sub)category and/or criterium;
- trace the input of other project team members (e.g. notes, talking points);
- export the data for other purposes (e.g., trade-off matrix, cost-benefit analysis);
- substantiate the decision-making process with costs as criterium/indicator;
- connect the ISPA tool to subsidies and other funding possibilities, and to other certifications (not SA tools).