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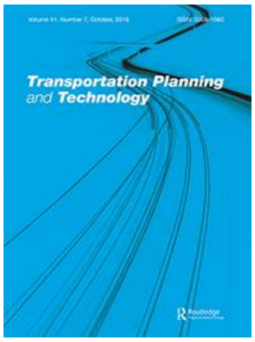

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The changing role of decision support instruments in integrated infrastructure planning: lessons from the Sustainability Check

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ABSTRACT
This article draws lessons about recent innovations in decision support for coping with challenges in integrated infrastructure planning strategies. After setting up a conceptual framework for the scope of analysis and the use of information in infrastructure planning, the empirical section explores the introduction of early-stage sustainability assessment tools. Data collection draws on experiences gained in the Netherlands with a new tool: 'Sustainability Check'. We conclude that such instruments have a number of capacities that address the challenges of area-oriented planning: (a) bringing together information about the comprehensive value of alternatives, (b) facilitating the generation of alternatives, (c) addressing institutional fragmentation by learning about referential frames, and (d) adding contextual perspectives to the 'hard' outcomes of conventional tools. We also conclude that tools such as Sustainability Check should not be seen as a replacement for conventional decision support tools, but rather as complementary to them.

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Road infrastructure planning; integration; area-oriented planning; functional interrelatedness; institutional fragmentation; frames; decision support; assessment

1. Introduction

The tools used for analysing the merit of alternatives in infrastructure planning and decision-making are being revised (Ruth et al. 2015). Conventionally, such analysis is carried out by means of quantitative assessment instruments. Usually these instruments are employed to facilitate choice, after plans and designs have been generated. Cost-benefit analysis (CBA) is probably the best-known example of such instruments (De Jong and Geerlings 2003; Næss 2006). In Dutch infrastructure planning, the set of instruments for assessing the merit of infrastructure plans was recently expanded with a new tool: the Sustainability Check (SC: Omgevingswijzer in Dutch; RWS 2014). This instrument responds to infrastructure planning's efforts to include all facets of sustainability (people, planet, profit) in the planning process. The popularity of the instrument is surprising: it is being applied by national, regional and local governments as well as private

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actors (Sjauw En Wa and Arts 2016). Moreover, the Ministry of Infrastructure and Water Management is considering including the instrument in its planning system (Sjauw En Wa 2015). The development of SC is part of a wider trend regarding the use of assessment instruments in infrastructure planning. Other examples are the development of an increasing number of project-rating systems, such as LEED, GreenRoads and Stars in the USA, CEEQUAL and BREEAM (infra and area versions) in the UK, and DuboCalc in the Netherlands (Arts and Faith-Ell 2012; Tillema 2012). These instruments may be characterized as early-stage sustainability assessment tools.

Over the past decade, Dutch infrastructure planning has developed an interest in so-called 'area-oriented' strategies. The introduction of SC fits the emergence of these strategies. The interest in such strategies is not limited to the Netherlands. Other examples include context-sensitive strategies in the US, regional packages in Sweden and a transport revolution in Finland (Amekudzi and Meyer 2006; Heeres, Tillema, and Arts 2012). The underlying common purpose of these strategies is to deal with the problems that emerge from a mismatch between, on the one hand, the functional interrelatedness of road infrastructure and different land uses, and the institutional interdependence between the responsible actors on the other hand (Alexander 1995; Baccarini 1996; Williams 1999; Zanon 2011; Heeres, Tillema, and Arts 2016). The main difference with conventional infrastructure planning (referred to in this article as 'line-oriented' planning) is that these strategies proactively apply a broad scope and that actors in other domains of planning are involved from the early stages onwards (Graham and Marvin 2001; Healey 2006). Line- and area-oriented strategies should be regarded as the extremes of a continuum of planning approaches (Heeres, Tillema, and Arts 2012).

The outcomes of area-oriented infrastructure strategies serve interests at multiple geographical scales. In addition to the infrastructure network level, the local level is served as well (Zanon 2011; Rozema 2015; Arts et al. 2016). And besides addressing the initially targeted planning issue (e.g. traffic flows and network capacities, road safety or nuisance issues), the quality of the local areas surrounding the infrastructure is also improved (sustainability, liveability etc.). These ancillary positive outcomes of area-oriented infrastructure planning are referred to as co-benefits. The opposite of co-benefits are co-costs (Ruth 2011). One of the main challenges for area-oriented infrastructure planning is inter-organizational co-production of these co-benefits. Planning at the infrastructure-land use interface is characterized by the co-existence of fragmented referential frames. This fragmented planning landscape complicates co-production of integrated visions, plans and designs (Kaufman and Smith 1999; Matos-Castaño, Hartmann, and Dewulf 2015).

The challenges that accompany area-oriented strategies enlarge the demands for planning and decision support (Walker 2000). Bertolini (in Ruth et al. 2015) observes a deep-seated tension between the intrinsically place-based nature of infrastructure projects and the generic ways in which they are often evaluated. Place-based application of multi-criteria methods in decision support has been explored before (cf. Beria, Maltese, and Mariotti 2012). However, little is known about the effects of early-stage sustainability assessment tools on co-production processes. The objective of this article is therefore to explore how these instruments address the challenges for decision support that exist in area-oriented road infrastructure planning practice. For that purpose, we study the application of the Sustainability Check. Additionally, we pay attention to the instrument's relations and interactions with established methods. We use the example of Cost-

Benefit Analysis (CBA). CBA is an example of the established methods for involving the merit of alternatives in decision support.

The purpose of both types of planning instruments is to support the generation and choice of alternatives through the systematic collection and communication of information about these alternatives. Therefore, we started our explorations with a literature review on the need and role of information within area-oriented planning strategies. We conceptualized the information needs of line- and area-oriented strategies by means of decision support functions. After that, this study took an empirical approach. We explored the application of the instrument Sustainability Check in practice. SC is an example of the above-mentioned group of innovative assessment tools. Moreover, much experience with the instruments has been obtained over the past years. The fieldwork was based on an action research approach. The maintain methodological rigour and a clear research scope, our fieldwork on this instrument took place over an extensive period (August 2011–early 2014). Two pilot applications of the instrument were studied: the N309 road project and the A1 motorway extension project. Additionally, to gain insight into the effect and added value of the instrument, the findings about the application of SC were contrasted with ideas about Cost-Benefit Analysis. For that part of the study, we built on documented studies about CBA and expert interviews.

Section 2 of the article presents the outcomes of our literature review and concludes with a conceptual model about the content and role of information within two infrastructure planning traditions (line- and area-oriented planning). In section 3, we define our empirical approach. Section 4 presents the outcomes of two case studies on practical applications of SC. Section 5 takes a broader view and explores the contrasts between SC and CBA. In section 6, we discuss the outcomes of the empirical part of the article in order to formulate general recommendations. Section 7 summarizes the main conclusions that can be drawn based on this study.

2. Theory: decision support for integrated infrastructure planning

The introduction of this article has outlined the characteristics of area-oriented planning strategies. Dealing with an expanded scope and pursuing potential synergies between land uses, brings about challenges with regard to the use of information in planning. What kind of functional-spatial information is needed for area-oriented planning and decision-making? What is the role of such information in area-oriented planning processes?

2.1. The functional-spatial scope of assessment

A first challenge concerns the content of the information used in choices and decision-making regarding project alternatives. To make deliberate choices, planners and decision-makers use estimations of the problem-solving capacity of alternatives. The main question that planners and decision-makers ask is whether the proposed actions sufficiently meet the objectives that have been set (Walker 2000). Arguably, an alternative's problem-solving capacity consists of its primary costs and benefits and its co-costs and benefits (Ruth 2011). In the case of infrastructure planning, the primary costs/ benefits are formed by the transport effects of an alternative. A much-used indicator is, for example, reduction in vehicle loss hours. Such effects may be seen as the transport value of alternatives. Effects outside the primary scope may be seen as the co-costs and co-benefits: the area value of alternatives (cf. Beria, Maltese, and Mariotti 2012). The comprehensive value of an infrastructure plan consists of its transport value and its area value.

Theoretically, the merit of an infrastructure planning alternative depends on the chosen planning approach (i.e. line- or area-oriented planning). It may be presumed that the applied planning approach does not influence the estimated transport value of planning proposals. Optimization of the transport value is always part of the scope of infrastructure planning, regardless of the chosen planning approach. This is different for the area value. On the one hand, within a line-oriented approach the negative area effects theoretically outweigh the positive area effects. To avoid negative outcomes, negative area effects are compensated or mitigated. The outcome of these actions is a low or neutral area value. Consequently, within line-oriented approaches the area value adds little value to the comprehensive value of alternatives. An area-oriented approach, on the other hand, pursues optimization of the area value, similarly to the way in which it pursues a maximized transport value. Consequently, the area value of an area-oriented alternative enhances the comprehensive value of these alternatives. Figure 1 illustrates this theoretical line of argumentation. It shows how the applied planning approach influences the value of infrastructure planning alternatives.

In addition to influencing the value of alternatives, the chosen planning approach also influences which values are analysed. The volume of co-benefits and -costs that are actually accredited to an alternative depends on the scope of analysis that is taken (Walker 2000). Within a line-oriented practice, the scope is mainly limited to the transport value of a proposal. Within an area-oriented practice, decision-makers take a broader look and fully include the area value in their considerations. When the emphasis of assessment is strongly on the transport value, the difference between line and area-oriented alternatives remains indistinct for planners and decision-makers. Only when a broader scope of observation is applied can the positive and negative area effects be comprehensively incorporated in planning and decision-making. Therefore, defining of project boundaries (functional and geographical scope) is an important aspect of planning at the infrastructure-land use interface.

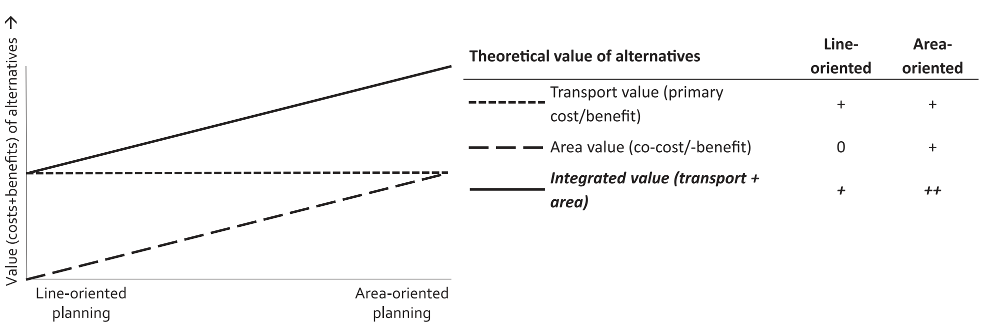

Figure 1. Theoretical view of the value of planning alternatives: line-oriented vs. area-oriented planning.

2.2. The role of information in co-production processes

A second challenge concerns the role of information in the planning process. Within a line-oriented approach, the generation of plans in infrastructure planning has been positioned as a rather mono-disciplinary effort: an engineering task (De Block, De Kool, and De Meulder 2016). In such processes, the role of information is limited to facilitating choice and decision-making about plans. However, an area-oriented planning process shifts the balance between stakeholders. Infrastructure planning then becomes more of a collaborative effort: co-production (Albrechts 2013; often also referred to as co-creation: Voorberg, Bekkers, and Tummers 2015). The essence of co-production is a focus on enhancement of the integrated whole, rather than on the integration of sectoral policies (Stead and Meijers 2009). Co-production processes are characterized by learning and negotiation between actors (Pahl-Wostl et al. 2008). Nooteboom and Teisman (2003) describe such processes as where both sides learn how to reach both objectives at the same time.

However, learning and negotiation at the infrastructure-land use interface is challenging due to the differing referential frames that actors at this interface have (cf. Schön and Rein 1995; Pahl-Wostl et al. 2008; Van den Brink 2009). Kaufman and Smith (1999) describe frames as devices that individuals use to characterize situations, problems or adversaries. These frames emerge from different perceptions of what planning is about (Nooteboom and Teisman 2003). Planning for major road infrastructures is often perceived as a civil engineering task at the scale of a transport network, whereas planning for other land uses is mainly carried out by planners with a spatial focus on the area (Graham and Marvin 2001; Schwarz 2006; Graham 2009; Rozema 2015). Kaufman and Smith (1999) observe that frames may prompt solutions that do not respond to actual needs and conditions. Moreover, they state that frames influence actors' willingness to act, participate, take a stand, or join a group (cf. Matos-Castaño, Hartmann, and Dewulf 2015). Nevertheless, the existence of varying referential frames may be also a merit. Other studies illustrate that the capacities of contrasting frames, if smartly brought together, strengthen each other (Teisman and Edelenbos 2011; Heeres et al. 2017). The involvement of multiple referential frames facilitates negotiation about interests and optimization of win-win outcomes (Nooteboom and Teisman 2003). The challenge for area-oriented processes is therefore to facilitate interaction rather than to merge different frames into one comprehensive frame.

Conventionally, assessment instruments are employed reactively. After alternatives have been crafted, instruments are employed to assess their merit. The emphasis of conventional assessment is therefore strongly on reactive *decision-making*. However, area-oriented planning requires a pro-active focus on *plan-making*. The front-end of planning processes is an essential phase in the exploration of potential synergies between spatial interests. Few decisions have been made, which leaves room for problem analysis and determination of the scope of the project (Elverding 2008; Williams and Samset 2010). Authors such as Jeon, Amekudzi, and Guensler (2010), Magee et al. (2013), and Cousins and Earl (1992) consider a pro-active approach as an addition to the reactive solution-oriented perspective. Jeon, Amekudzi, and Guensler (2010) explain the consequences of this enriched perspective for assessment instruments as follows: to effectively support processes at the infrastructure-land use interface, assessment instruments should not be restricted to *testing* proposals against standards, rules and legislation. Rather, instruments also need to explicitly pursue the *generation* of feasible alternatives.

2.3. Synthesis: towards a conceptual model for decision support in area-oriented planning

In practice, a fragmented array of decision support instruments is used in area-oriented planning. Each of these instruments has a different focus and purpose. The application of fragmented but interlinked planning and decision-making instruments for the facilitation of interaction and collaboration between various stakeholders has been intensively explored by academics working on so-called 'decision support systems' or DSS (cf. Holsapple and Whinston 1996; Walker 2000; Courtney 2001; Shim et al. 2002; Wijnen, Walker, and Kwakkel 2008; Te Brömmelstroet and Schrijnen 2010). DSS can be defined as systems that assist decision-making and the selection of a course of action from multiple alternatives (Holsapple and Whinston 1996).

DSS support the various steps that precede decision-making about alternatives (Langley et al. 1995; Holsapple and Whinston 1996; Courtney 2001). As such, DSS support:

(1) Collection and communication of spatial intelligence: collection and clear communication of available information in order to include relevant interests in the planning process;
(2) Generation of alternatives: development of multiple feasible alternative solutions to the problem identified in the first step. In the case of infrastructure-land use integration this involves co-production of alternatives; and
(3) Choice: selection of one preferred alternative that is – after comparison and ranking – considered most feasible and appropriate.

Studies by Langley et al. (1995), Shim et al. (2002) and Courtney (2001) argue that, in current planning practice, these three steps are not necessarily sequential. In line with their views, we consider the trichotomy as key functionalities of DSS, rather than strict steps that should be followed.

Below, we discuss the contrasts between line- and area-oriented planning strategies for each function (Heeres, Tillema, and Arts 2012). This discussion is based on the conceptual ideas from section 2.1 and 2.2. It illustrates the content- and process-related modifications to DSS that are proposed by area-oriented planning.

2.3.1. Intelligence

Line-oriented planning has a strong focus on assessing the primary effects of planning proposals. This reflects its main purpose, i.e. the improvement of the functioning of transport networks. In contrast, area-oriented planning has a broader purpose. In addition to improvements at the level of the transport network, it is concerned with other spatial improvements at the area level (co-costs and benefits). Area-oriented planning enlarges the functional and geographical scope of planning and analysis.

2.3.2. Generation

Within line-oriented strategies, the main purpose of decision support is mainly limited to the testing of earlier generated plans or designs. The generation of alternatives is seen as an engineering effort. Decision support is applied reactively. Within area-oriented strategies, the role of assessment instruments is expanded. Proactive application of these instruments may facilitate co-production processes and the generation of alternatives. Proactive application is believed to support dealing with the differences between referential frames and making the best use of these differences.

2.3.3. Choice

With regard to choosing between alternatives, line- and area-oriented infrastructure planning each have their own practices. On the one hand, line-oriented planning emphasizes the quantification of the primary themes of infrastructure planning. Assessment of need and value is consequently based on a detailed assessment of a narrow range of themes at the network scale (transport, economy). The goal of area-oriented planning and decision making, on the other hand, is to base choices and decisions on an integrated perspective. However, not all these effects can be expressed in hard, quantitative terms. Moreover, quantification is a costly, time-consuming, sometimes complicated and therefore non-transparent process. Area-oriented strategies therefore prefer qualitative assessments of the need and merit of proposals.

Table 1 summarizes the different interpretations for each function of DSS, as discussed above.

3. Research approach

3.1. The introduction of the Sustainability Check in the Netherlands

Our empirical explorations focus on the Dutch instrument 'Omgevingswijzer', which can be translated as 'Sustainability Check' (RWS 2014). The Dutch government agency that deals with infrastructure, public works and water management (Rijkswaterstaat, or RWS) has been developing this instrument since 2011 in order to substantiate its policy aim of 'integrated area development' (RWS 2011; Cobouw 2014). The Sustainability Check has two main purposes: 1) to challenge the scope of infrastructure planning in order to enhance chances for sustainable development of the areas surrounding the infrastructure, and 2) to identify the relevant internal and external stakeholders of a project and to facilitate meaningful stakeholder interaction (Sjauw En Wa 2015; Sjauw En Wa and Arts 2016). The application of the instrument comprises the systematic rating and

Table 1. Interpretations of functions of decision support systems within sectoral and area-oriented planning approaches.

Decision support function	Line-oriented planning	Area-oriented planning
Collection of intelligence	Usually narrow scope: focus on primary costs/ benefits. Single scale (transport network)	Usually broad scope: inclusion of co-costs and -benefits. Multiple scales (network and area level)
Generation of alternatives	Engineering efforts dominate planning.	Focus on co-production, with learning as a means to overcome the divide between referential frames
Choice between alternatives	Based on mainly quantitative assessment	Based on mainly qualitative assessment

collaborative discussion of a project alternative (or several project alternatives). The instrument uses terms of 12 different themes, equally distributed across social, economic and ecological topics. Each theme is operationalized by means of a number of principles, which are translated into a list of standardized questions. Appendix 1 elaborates on the themes and underlying principles. A sustainability score for each theme is generated by answering the questions. Scores are instantly visualized in a 'synergy wheel' consisting of the 12 sustainability indicators (see Figure 3 and Appendix 1 for examples of the wheel). The collaborative use of a wheel to visualize sustainability outcomes allows for an accessible and comprehensive overview of sustainability effects and provides insight into the positive as well as the negative effects of different alternatives (see also Magee et al. 2013 and other recent initiatives: SPeAR [ARUP], Adaptive Capacity Wheel by Gupta et al. 2010).

Prior to being formally introduced as part of the Dutch infrastructure planning process, the Sustainability Check has been tested in pilot applications (see also section 4). During this period the instrument was applied in a number of projects in order to be developed further, and to get to know how the instrument could be applied effectively.

3.2. Analytical approach

This article explores the application of new decision support instruments to deal with interrelatedness and fragmentation in infrastructure planning. The preceding conceptualization of the three functions of decision support (intelligence-generation- choice) is used as an analytical framework (section 2.3).

The research for this article was conducted over a long period (August 2011–early 2014). As members of a specific task force of Rijkswaterstaat, the authors have been actively involved in the introduction of the Sustainability Check to the Dutch road infrastructure planning process (in different roles, both knowledge-oriented and practice-oriented). The use of this active involvement of the authors as a research strategy may be seen as action research (O'Leary 2010). One of the advantages of action research is that it does not merely focus on the generation of knowledge, but that it is also concerned with supporting practical development through a cyclical process of observing, reflecting, planning and acting. A crucial precondition is to avoid a directive role as a researcher: direction with regard to the course of action should be collective. Within the task force for SC, the authors had a facilitating position.

Another precondition for action research is to maintain methodological rigour and a clear research scope (O'Leary 2010). For that purpose, two pilot applications of the Sustainability Check were analysed in-depth in order to explore its application (shown in Figure 2): the N309 project (an infrastructure project with predominantly local spatial implications) and the A1-Zone programme (an infrastructure programme with a more regional scope). These cases were selected as they were among the first practical applications of the Sustainability Check. As such, they could be followed for a longer period, up to and including eventual decision-making. The cases differ in relevant aspects: the level of scale (local and regional level) and principal proponent (provincial and national government). This contextual diversity makes it possible to obtain broad insights the merit and limitations of this instrument in different contexts. Regarding these cases, we base our analysis on interviews with project managers and the coordinators who were

Figure 2. Case study locations in the Netherlands.

responsible for these pilot applications of SC. We also use additional sources (policy documents, media coverage).

In addition to studying the pilot applications, this study also builds on three additional information sources. First, we include the experiences that were obtained during eight task force meetings. These meetings were organized for fine-tuning the Sustainability Check. To verify the experiences from these meetings in an organized research setting, additional expert interviews were held. The interviewed persons were involved in the general development of the instrument (two expert interviews) and in its pilot applications (five expert interviews). Secondly, an expert workshop was organized, which focused specifically on the application and purpose of the Sustainability Check. The workshop brought together practitioners with ample experience in planning at the infrastructure-land use interface and in the application of the Sustainability Check. Finally, the case studies are also complemented with the results of a later, general evaluation study (RHDHV 2015). This evaluation puts the findings from the pilot application in a broader context.

To gain insight into the systemic interaction between the Sustainability Check and conventional planning instruments for assessing the need and purpose of infrastructure projects, we involve Cost Benefit Analysis (Social CBA [SCBA] as applied in the Dutch road infrastructure planning process) in our investigations. Our insights with regard to SCBA are based on a desk study of academic literature and policy documents. This study was complemented with an interview with an SCBA-expert. The interview covered the application of SCBA in area-oriented projects.

4. Empirical results: pilot applications of the Sustainability Check

This section presents the results from the case studies. After outlining the issue, we explore the motivations for applying the Sustainability Check. Subsequently, we present the effects of the instrument on the different functions of DSS: the collection of intelligence, the

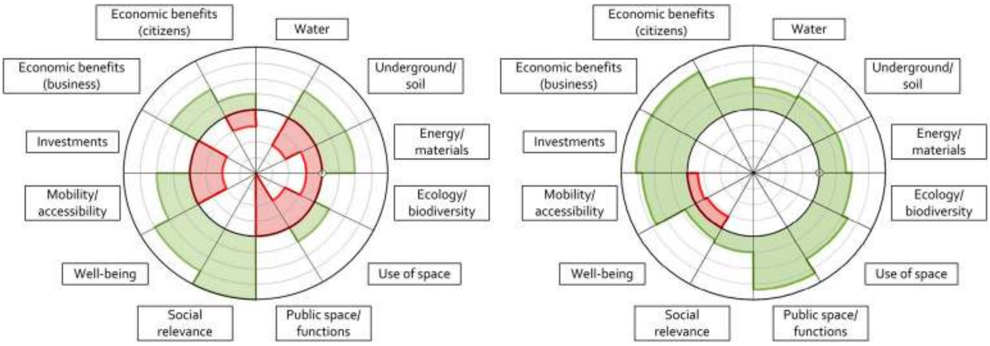

Figure 3. Completed 'synergy wheels' for the N309 project (left) and the A1-Zone project (right). Source: RWS (2012).

Note: Green shading above the horizontal line indicates a positive effect for a tested alternative on a specific theme and red shading below the line indicates that negative effects are to be expected. Since the scoring mechanism allows both positive and negative effects to be shown for each theme, a nuanced discussion of the expected effects of an alternative is facilitated.

generation of alternatives, and choice. The findings from the case studies are followed by general observations that were obtained during the pilot phase (section 4.3). Figure 3 contains the completed synergy wheels for the N309 and A1-Zone pilot applications.

4.1. N309

The N309 is a main road in a regional network under provincial management. At the town of 't Harde, the road experienced congestion problems (see Figure 4). The project manager explains the project as follows:

> A ring road to replace the existing connection that supposedly suffered from congestion had been discussed for ten years. However, the actual problems had not been properly analysed. To me, it was highly questionable whether the construction of a ring road would be the appropriate way to go. At least, it would be hard to defend the purposefulness of this solution in court.

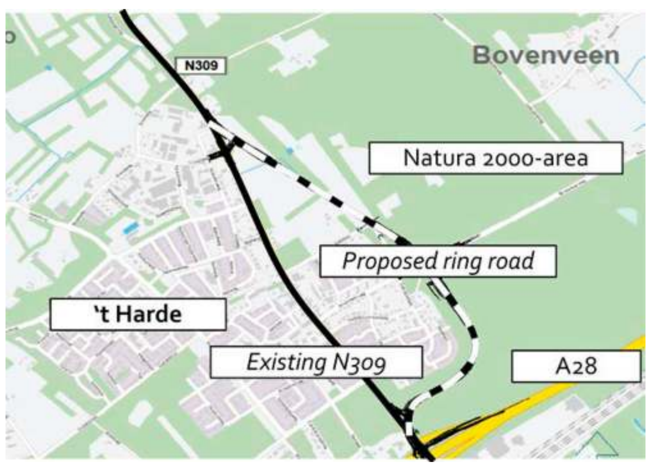

Figure 4. The N309 at 't Harde, including alternative ring road (adapted from Gelderland 2012).

The Sustainability Check was applied to enhance insights into the consequences of the proposed construction of a ring road at the expense of a surrounding forest (Natura 2000 area). As a reference, reconstruction of the existing road through the town was included in the analysis (see Figure 3 and RWS 2012). Municipal authorities considered the current road unsafe and an 'impeding barrier' in the town, and were thus strong proponents of a ring road (De Stentor 2012a). The province approached the issue more open-mindedly and urged more serious consideration of alternative solutions (De Stentor 2012b).

4.1.1. Collection and communication of spatial intelligence

The N309 project manager explained that one of the roles of the Sustainability Check in the project was to offer '*an additional means to communicate information on the effects of the ring road alternative, next to more conventional means such as EIA procedures and a socio-economic survey*'. The instrument gave the primary and co-costs and -benefits an equal position in the planning process. Inclusion of ancillary effects elucidated the differences between the effects of the proposed ring road and the effects of reconstructing the existing ring road. Next to the transport effect, important ancillary topics were traffic safety, nuisance and issues concerning economic vitality and liveability in the town centre area. '*It became apparent that the problem was not restricted to an accessibility issue, but also comprised other spatial interests*', the project manager stated.

The instrument revealed that the benefits of constructing a ring road were rather low in comparison to the negative ecological effects (i.e. loss of Natura 2000). Also, a new ring road would attract additional traffic, which would cause considerable noise issues. Moreover, under the expected circumstances of low economic and demographic growth, socio-economic effects for the town were assessed to be negative. The town's medium and small businesses are largely dependent on the traffic that passes through town. Therefore, reconstruction of the current road would be the preferred alternative from a socio-economic perspective (see Figure 3, RWS 2012; Sjauw En Wa 2015; Duurzaam GWW n.d.).

In conclusion, the application of SC expanded the scope of discussion from traffic-oriented to a more inclusive focus on the area. The analysis brought forward strong arguments for considering other alternatives as well.

4.1.2. Generation of alternatives

The application of SC influenced the plan-making process for the N309. Eventually, SC's assessment led to improved outcomes. The N309 project manager described that the Sustainability Check played a part in the project's co-production process: '*The Sustainability Check was a tool to collectively map out the underlying issues of* [*the N309-project*]'. Based on these discussions, the option to reconstruct the existing road presented itself as a promising alternative solution for which further exploration was justifiable (RWS 2012; Gelderland 2013; Duurzaam GWW n.d.).

The project manager explains the interactive role of the instrument in this process of generating an additional project alternative. First, the application of the instrument '*helped to create a collective base of knowledge about different aspects of the plan within a group of planners who all speak their own languages*'. Second, the project manager confirms that an important purpose of the instrument is '*a means to facilitate a conversation between planners that need to be involved, but all have different backgrounds and interests*'. It appears that, together with the information provided by the Sustainability Check, the insights developed by participants during the collaborative application of the instrument have facilitated dealing with different referential frames.

The visualization of effects in a wheel is perceived as helpful in communicating relevant spatial information in clear and transparent terms. '*The simple visualization in a wheel supports this collective effort as it makes more of a lasting impression than many words*', the project manager noted.

4.1.3. Selection of most viable alternative

In contrast to its role in the functions above, the Sustainability Check had a lesser role in preparing for decision-making in the N309 case. As the project manager explained how the qualitative outcomes enriched decision-making (see also Duurzaam GWW n.d.):

> I did not use the wheel itself in communicating back to our political representatives. Nevertheless, the trade-offs that were made during the application process helped in clearly informing decision-makers about the opportunities for the realization of a solution that was more attractive to the local community. This perspective offered the political representative the opportunity to reconsider the initially preferred [ring road] solution and select the reconstruction alternative as preferable.

Reconstruction of the existing N309 started in 2015.

4.2. A1-Zone

The A1-Zone is a regional programme that intends to enlarge the capacity of one of the major motorways in the Netherlands (A1) along a 70-kilometer stretch in the eastern part of the country (I&M 2013), shown in Figure 5. During strategic explorations, the addition of extra lanes in the middle road verge was considered preferable to adding lanes on the outer verge. The programme combines the capacity enlargement between the cities of Apeldoorn and Almelo with numerous opportunities for regional development. A much-used expression among interviewees is '*transforming the A1-Zone into an*

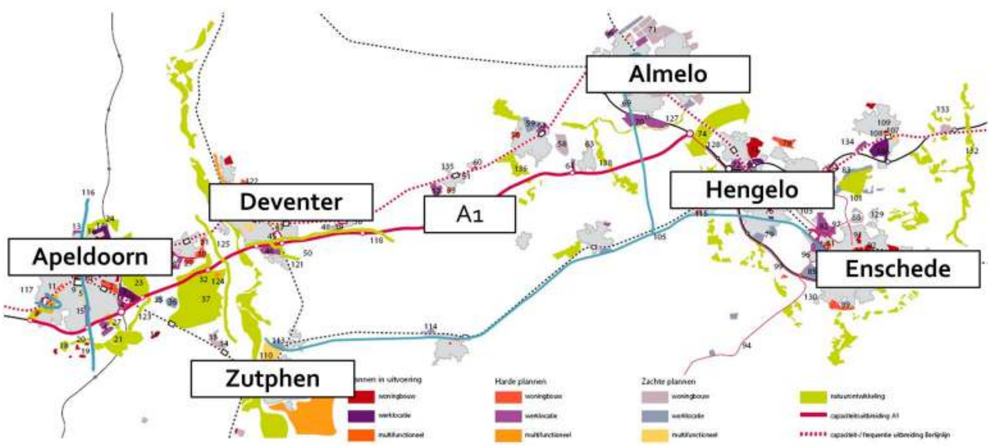

Figure 5. The A1-Zone programme: a multiplicity of interlinked development opportunities, nested on a national, regional or local spatial scale around the A1 capacity enlargement (adapted from Overijssel 2014).

"advert" for the region' (i.e. an appealing and recognizable primary introduction to the region; see also I&M 2012b). This aim calls for integration of national, regional and local interests. Integration of these interests brings together urban traffic arteries, other road-crossing structures, service areas, road layout and landscape design in a multidisciplinary vision (RWS 2012, Figure 3). Consequently, a wide range of stakeholders were involved in the programme. The programme is a collaboration between national, regional and local planners.

The purpose of the Sustainability Check in the A1-Zone programme was primarily to check for consistency between the ambitions that emerged during early strategic explorations and the later operationalization of these ambitions. Additionally, the sustainability value – of the choices made during the strategic explorations and of the ambitions established – was inventoried by means of the Sustainability Check. It must be noted that in the period after the application of the Sustainability Check (but unrelated to this), the A1-Zone programme was delayed by the Dutch transport minister due to budget cuts (De Stentor 2013).

4.2.1. Collection and communication of spatial intelligence

In the A1-Zone programme, the instrument was applied shortly after the determination of a preferred solution. The instrument was applied to enhance functional integration during these steps. Applying the Sustainability Check opened up relevant information for determining the substantive scope of subsequent steps. A policy officer explains:

> I urged that the instrument would be used to "kick off" an integrated process, to open doors and to show that this programme is not limited to road infrastructure. To show that we had to deal with ancillary effects [i.e. co-benefits and –costs]. It has forced us to consider the interrelatedness of land uses in the programme's region.

The coordinator of the instrument elaborates on this by highlighting two issues. First,

> the instrument was applied to look back at the two alternatives: extra capacity on the inside or on the outside verge. Earlier, the inside had been selected as the preferred solution to the capacity issues. SC confirmed this choice to be the more favourable, due to lower landscape impact.

Second, application of SC highlighted severe inconsistencies in the scope of the programme.

> We compared the scope of the preferred solution with the scope of the ongoing studies. The instrument showed that many elements of the preferred solution were omitted in these studies. Especially, the topics related to becoming "an advert for the region" […] had all disappeared, the policy officer explained.

4.2.2. Generation of alternatives

The conclusion that some of the initial ambitions were insufficiently incorporated into the programme's later studies was a wake-up call. The project manager went on to state: '*The Sustainability Check revealed that for several ambitions of the programme, no responsible actor was appointed in the later stages, posing a serious planning risk*' for the detailed development of the A1-Zone plans (see also RWS 2012). An interviewed policy officer explained that the scope of the programme was adjusted after discussion of the findings:

> On the basis of the application of this instrument, we concluded that we must take into account interrelatedness on several issues, such as how we can turn the road and surrounding area into a "prime introduction to the region", or how to deal with service areas.

This conclusion opened a discussion among stakeholders to identify responsible actors for further co-production of the plans. The project manager explained that in that discussion, '*application of the instrument facilitated the communication of individual and collaborative ambitions and the underlying motivations*'. In this regional programme

> the instrument was a useful tool in structuring the programme's assignment. The instrument proved to be an easy means to communicate scores on relevant sustainability themes. […] Especially the use of a wheel helped us to quickly highlight effects and differences between alternatives, the project manager concluded. (see also Figure 3)

Eventually, the outcomes of the application of SC proved to be an incentive to reconsider the scope of the programme's approach in order to make sure it covered all elements of the goal of the programme. '*The instrument* [*thus*] *was an aid to facilitate the interaction between the disciplines*', as the coordinator of the instrument referred to the merit of the instrument reconsidering the roles of the various stakeholders within the programme.

4.2.3. Selection of most viable alternative

Interviewees indicated that the insights resulting from the application of the Sustainability Check in the A1-Zone programme have been informative. However, although the application of the instruments induced a discussion about the scope of the programme and consequent reconsideration of the roles of the programme's stakeholders, the obtained insights have not influenced political decision-making in this case due to the budget cuts that delayed the programme.

4.3. Evaluation of SC's pilot process

SC's pilot phase was broader than the discussed pilot applications (see also section 3.2). In addition to regular meetings of SC's tasks force, a workshop about the purpose and application of the instrument was organized. Also, an evaluation study was carried out (RHDHV 2015).

First, observations from these sources confirmed the pilot application's experience that the instrument facilitates identification of opportunities and threats outside the primary scope of infrastructure planning. A workshop discussion among project managers and planners led to the following conclusion:

> In the initial phases of infrastructure planning, light but comprehensive approaches to handling information feed the planning process, support the exploration of potential directions and facilitate a sense of urgency regarding the importance of an integrated view on the issues.

An evaluation of SC's application (RHDHV 2015) seems to confirm that SC may be applied to identify dilemmas, to make all themes debatable and to draft potential solutions.

Secondly, the application of SC is seen as a tool that facilitates interaction among groups of planners with fragmented referential frames. An evaluation of the instrument states that it facilitates discussion about ambitions and interests throughout the planning process (RHDHV 2015). In the workshop mentioned earlier, participants concluded that interaction sprouting from collectively applying the Sustainability Check leads to a better understanding of the planners' perspectives on spatial issues and their mutual referential frameworks: '*People get to know each other, get to know their mutual "languages" and create an understanding of how people in a particular sector* [*i.e. infrastructure, water, nature, urban development*] *see spatial development*'. SC is experienced to feed the cross-disciplinary communication needed for the smart design of alternative plans at the infrastructure-land use interface in an area.

Finally, one of the interviewed policy officers involved in development of the instrument confirms that eventual selection of a preferred alternative is not the main function of the instrument: '*The instrument is unsuitable to substantiate choice quantitatively.* […] *Its main purpose is to make different options debatable and it provides a view on the possible consequences of decisions*'. In a workshop, participants came to a similar conclusion about SC's role in decision-making. The comprehensive insights provided by the Sustainability Check enrich decision-making by '*sketching "real world" impacts and giving a sense about the implications of a proposed intervention to decision-makers, next to the detailed, but narrow and absolute perspectives provided by conventional instruments (such as CBA or EIA)*'.

5. Comparison of SC and CBA

In this section, we compare SC and a well-known conventional instrument for decision support – Cost-Benefit Analysis (CBA) – in order to explore the interaction between the instruments. Concerning conventional decision support, much effort seems to have been devoted to the improvement of substantive measurements in order to strengthen the applicability of assessment instruments. For example, considerable attention has been paid to incorporating a broader array of themes, in order to enhance the applicability of instruments and their capacity to deal with the interrelatedness of relevant land uses. Much attention has been paid to incorporating 'soft' values such as nature or environmental quality (cf. Koetse and Rietveld 2010; Sijtsma, Van der Heide, and Van Hinsberg 2011; Mouter 2014). The measurements used for estimating effects have also been improved to enhance the instrument's reliability and applicability (cf. Koetse and Rietveld 2010; Bakker 2012).

Examples of these efforts can be found in the Netherlands, where CBA has regained a prominent position in infrastructure planning and decision-making (De Jong and Geerlings 2003). In the Netherlands, the instrument has experienced a remarkable return to prominence (De Jong and Geerlings 2003). Over the years, the use of CBA had been much criticized as being too strongly focused on monetizing decision-making. However, the need for objective decision-making and the desire of project financiers for rational allocation of public funds encouraged a new interest in the method during the 1990s. This interest resulted in a new, formalized guideline for CBA in the Dutch road infrastructure planning process focused on Social Cost-Benefit Analysis (SCBA: Eijgenraam et al. 2000; De Jong 2013). More recently, a guideline has been prepared for the application of SCBA in integrated projects (I&M 2012a). In this section, we compare SCBA and SC.

5.1. Collection and communication of spatial intelligence

With regard to the collection of intelligence, SCBA and the Sustainability Check have different purposes. The Sustainability Check opens up information on primary and ancillary costs and benefits of alternatives by means of a standardized list of questions. From the early stages onwards, this instrument includes local (N309) as well as regional effects (A1-zone) regarding a broad range of social, environmental and economic themes. The instrument's synergy wheel subsequently visualizes these effects in a mutually comparable way. To a large extent, the instrument serves the needs of area-oriented planning regarding collection and communication of planning information (see Table 1). However, in these outcomes the interrelatedness of land uses is not explicitly present. Interrelatedness is only present in the discussion about the outcomes. Potential synergies between land uses remain an implicit element of SC's application process.

The intention of SCBA is also to take interrelatedness into account. For that purpose, it switches between sectoral and comprehensive analysis and includes as many relevant additional effects as possible in its analysis (presenting non-quantifiable effects on other scales [e.g. +\−] or as 'pro-memoria' effects [PM-values]: Sijtsma, Van der Heide, and Van Hinsberg 2011; Bakker 2012). As such, SCBA could be useful in uncovering systemic synergies: '*SCBA's main purpose is to collect and open up welfare-economic impacts of proposed developments targeted at the selection of the most viable alternatives*', as an interviewed SCBA expert explained (cf. Eijgenraam et al. 2000; Sijtsma, Van der Heide, and Van Hinsberg 2013). SCBA applies a large (national) geographical scope in its analyses (Eijgenraam et al. 2000; Beria, Maltese, and Mariotti 2012). However, an interviewed SCBA expert nuanced this by indicating: '*A selection of effects on the regional or local scale is usually made to enhance workability and relevance*'.

Compared to the Sustainability Check, SCBA can be considered a 'heavy' instrument with regard to intelligence collection. It requires much technical expertise and produces intelligence, which may be difficult for planners to interpret (it is often referred to as a 'black box': Beukers, Bertolini, and Te Brömmelstroet 2012; Næss, Nicolaisen, and Strand 2012; Mouter 2014). Moreover, SCBA is a reactive instrument; the information it needs does not usually become available until rather late in the process. Moreover, SCBA relies on input from models (De Jong 2013). The impact of these models and their underlying assumptions on the outcomes of SCBA is strong (Næss 2006; Næss, Nicolaisen, and Strand 2012).

Compared to SCBA, the main contribution of the Sustainability Check seems to be its capacity to collect and communicate multidisciplinary spatial information that can be easily understood by a fragmented range of actors. Moreover, the information that the instrument communicates can be used from the front-end of the planning processes onwards. An advantage is that potential threats and opportunities can be recognized at a moment when the scope of a project is still fluid. A lack of detailed, quantitative information should not be seen as a drawback at the stage of discussing concepts and development directions. It may even be an advantage, since detailed information becomes outdated quickly and directs the emphasis to an unwanted level of detail (Williams and Samset 2010).

5.2. Generation of alternatives

Direct interaction and discussion among fragmented stakeholders to facilitate the generation of alternatives is an explicit priority of the Sustainability Check. The pilot applications illustrate that the instrument's use of transparent, instantly accessible information allows for learning and adjustment of fragmented referential frames. The visualization of the outcomes in a wheel is considered a powerful means of communication that further enhances this process. In the N309 pilot study, this promoted learning and reframing among stakeholders and, ultimately, the generation of an alternative intervention. These capacities facilitate the co-production of integrated project alternatives. A drawback of the Sustainability Check seems to be that it currently still lacks an explicit process architecture. Thus, careful interaction between fragmented stakeholders' issues is not guaranteed. In the pilot applications, interaction followed implicitly from joint sessions where participants collectively filled out the synergy wheels.

With regard to SCBA, the instrument's '*focus is on testing project alternatives; it is not concerned with the collaborative generation of alternatives*', as an interviewed SCBA-expert emphasized. A study by Beukers, Bertolini, and Te Brömmelstroet (2012) revealed that SCBA is often perceived as a 'final test' of project alternatives, rather than as a tool for mutual learning. Also, to some extent SCBA seems to lack the transparency required to appropriately facilitate interaction between fragmented stakeholders. SCBA requires more detailed data and deeper analysis compared to, for example, the Sustainability Check. Therefore, outcomes do not normally become available until the later stages of the decision-making process (Mouter 2014). Nevertheless, it must be noted that process-related aspects of SCBA are currently also receiving more attention. Research by Beukers, Bertolini, and Te Brömmelstroet (2014), for example, discussed several interventions in the SCBA process that may strengthen the function of SCBA as a learning tool in meetings and discussion. Another example is a study by Arts et al. (2009), who emphasize that integrated plans consist of several 'building blocks' (i.e. sectoral elements such as infrastructure, water, housing etc.). They advocate separate SCBAs on the basis of global information for each of these building blocks. On the basis of this information the most attractive elements from different plans may be combined in a new vision. This application of SCBA may become an early stage aid in the generation of optimized of plans and designs.

5.3. Selection of the most viable alternative

In both pilot studies, the Sustainability Check, with the broadly scoped information that it provides, proved highly suitable for comparing alternatives on specific themes. However, the ranking of project alternatives is explicitly not a function of the instrument (RWS 2012).

SCBA, in contrast, is strongly focused on final decision-making. The instrument provides a definitive ranking of alternatives based on the net present value (Sijtsma, Van der Heide, and Van Hinsberg 2013). Although SCBA has the intention to include all socio-economic effects of analysed alternatives, one of the drawbacks of the instrument with respect to integrated planning is the instrument's inability to include these effects equally. As mentioned, non-monetizable effects are expressed on a +/− scale or as 'pro-memoria' effects. However, in practice it appears that the monetized net present value often attracts the most attention. Mouter (2014) found that planning professionals greatly disagree on whether this is appropriate and desirable or not. Moreover, the value of monetizable effects is also cumbersome. According to Næss, Nicolaisen, and

Table 2. Contrasts between innovative and conventional instruments.

	Sustainability check		SCBA	
	Strengths	Weaknesses	Strengths	Weaknesses
Collection and communication of intelligence	Inclusion of primary effects and co-effects to facilitate integrated perspectives at the local and regional scale, available from early stages onwards.	Mutual relationships and potential synergies between themes are only implicit.	Broad socio-economic welfare perspective at the scale of national transport networks. Methodologically strong.	Heavy in application: technical knowledge, 'black box', expensive. Reactive application.
Generation of alternatives	Learning and frame adjustment facilitate co-production of alternatives	No process architecture for application available as yet. Stakeholder interaction is only implicit.	Generation of alternatives is usually not an explicit function of SCBA[a].	
Choice between alternatives	Provides a valuable contextual interpretation of hard quantitative indications.	Does not provide quantified indications.	Quantified net present value for alternatives. Allows for ranking of alternatives. Ranking etc.	Tendency to focus on the monetized final net outcome. 'Pro-memorie' indications for themes that cannot be quantified are easily overlooked.

[a]Although SCBA is generally not used for the generation of alternatives, it must be noted that the process-related aspects of CBA are currently also receiving more attention. Research by Arts et al. (2009) and Beukers, Bertolini, and Te Brömmelstroet (2014), for example, revealed several interventions in the CBA process that may strengthen the function of CBA as a tool for learning tool in meetings and discussion and for optimization of alternatives.

Strand 2012 monetization is often based on debatable assumptions about the value of time and people's willingness to pay. Therefore, equal treatment of primary and ancillary costs and benefits is difficult for the instrument. This reduces SCBA's potential to outline the required nuanced integrated perspectives (Sijtsma, Van der Heide, and Van Hinsberg 2011).

De Jong and Geerlings (2003) argue that SCBA functions best as a 'bullshit detector', for filtering out unfavourable interventions. The main contribution of SC in decision-making seems to be the wider contextual perspective that it adds. Through these perspectives, the instrument provides decision-makers with a necessary context-specific interpretation of the 'hard' SCBA outcomes (Mouter 2014).

Table 2 illustrates the strengths and weaknesses of both instruments.

6. Discussion

The instruments explored here – SC and SCBA – represent two different types of assessment. The preceding analysis has showed that both types have their merit for area-oriented infrastructure planning (see Table 2). This section discusses the strengths and weaknesses of the new group of early-stage sustainability assessment tools in relation to the challenges of area-oriented planning (i.e. meaningful expansion of the scope within an institutionally fragmented context).

6.1. Tools for early stage sustainability assessment

The exploration of SC illustrates the merit of early-stage sustainability assessment tools in area-oriented infrastructure planning approaches. Early-stage sustainability assessment tools may offer several decision support functions that are needed in area-oriented infrastructure planning approaches. For that purpose, such instruments ideally focus on dealing simultaneously with both functional interrelatedness and on addressing fragmentation of actors. These tools may therefore ben coined 'hybrid instruments' (Kok and Van Delden 2009; Runhaar, Driessen, and Soer 2009). Regarding the content of planning, this study teaches that such tools may distinguish themselves from conventional instruments by a more inclusive scope and equal treatment of primary and ancillary effects. With regard to the planning process, proactive application, a transparent analytical process, lower assessment costs and strong communicative capacities due to visualization make such early stage sustainability assessment tools well equipped for coping with institutional fragmentation.

A primary strength of instruments with such characteristics is their capacity to include a broad range of themes. The broad qualitative assessment that is presented makes it possible to include primary and ancillary costs and benefits of alternatives in an equal manner. This appears difficult for conventional instruments, whose main strengths often lie in providing detailed and precise information at the network scale. This information is found to be more difficult to use in interactive processes.

Secondly, in early planning stages, where ideas still have to crystallize, it is difficult, or even impossible, to provide 'detailed information' using conventional instruments. This study illustrates that instruments with the above described capacities have the capacity to proactively analyse opportunities and alternatives in a meaningful way. This capacity makes these instruments well-equipped for supporting the generation of alternatives.

A third capacity that must be discussed here is the capacity of such instruments to address institutional and cultural fragmentation of stakeholders. The instruments facilitate open dialogues based on multidimensional, transparent information. In the case studies, the application of the instrument led to a better understanding of mutual referential frames. This enhanced co-production of alternatives.

Fourth, an area-oriented planning approach intends to place improvements to national transport networks within a local area perspective (Arts et al. 2016; Heeres et al. 2017). The involvement of broadly-scoped sustainability assessment tools adds such a perspective to the information that is available for decision-makers. The case studies show that the addition of this contextual perspective at the area level facilitates well-informed decision-making in area-oriented approaches.

The application of these early-stage sustainability assessment tools provides groups of fragmented planners with a hybrid tool for coping with the tensions between functional interrelatedness and institutional fragmentation. These tools facilitate a planning approach that focuses the attention on co-production of integrated alternatives at the infrastructure-land use interface. That way, such instruments help to determine what extent of integration is appropriate (i.e. determination of the scope).

6.2. Complementary capacities

Although early sustainability assessment potentially enriches assessment with several capacities that support area-oriented planning, it must also be noted that these new tools do not fully support all of the area-oriented infrastructure planning's needs with regard to decision support. Section 5 shows that a complete set of tools, serving most of area-oriented planning's decision support needs, emerges when the explored innovations are applied in coherence with conventional instruments for assessing the socio-economic merit of plans and design.

First, the explorations show that the main merit of such tools is in the generation of alternatives. Innovative tools, such as SC, are therefore most effectively applied from the early stages onwards, to determine an appropriate scope and to facilitate learning about mutual referential frames. Additionally, the new tools may also outline a qualitative contextual perspective in decision-making about infrastructure planning alternatives. However, infrastructure planning in the European context involves multi-million (or even multi-billion) euro investments of community funds. Therefore, quantified information about the merit of alternatives remains important in decision-making. Despite the remarks about the quantification of non-monetary effects as made above, planning procedures describe that these investments must be accounted for as detailed as possible. Conventional instruments can provide a more accurate idea of the final worth of alternatives. For that purpose, conventional instruments remain important as solid checks about the efficiency of investments.

Second, planning and decision-making in area-oriented planning ideally take place on the basis of information about the synergies between different issues at the infrastructure-land use interface. This remains a difficult topic. Both types of instruments show limitations in their attempts to make such trade-offs. Hybrid tools such as SC, on the one hand, include a comprehensive range of themes. However, due to the qualitative nature of the assessment it delivers only sectoral analysis of the included topics. Potential synergies between land uses are only implicit to SC's process. On the other hand, the use of quantitative information by conventional instruments does allow for explicit trade-offs between various effects. However, these instruments are often perceived to lack the capacity to equally include all themes in their assessment (use of PM-effects etc.). Moreover, the monetization of certain values is based on hypothetical assumptions. Therefore, the final net outcomes that are presented do not cover the comprehensive range of themes.

Third, the scales served in assessment are complementary also. On the one hand, conventional instruments, such as SCBA, are particularly strong at the scale of the transport network and are capable of exploring the transport value of infrastructure planning alternatives. The main merit of early-stage sustainability assessment tools such as SC, on the other hand, seems to be at the level of areas. These instruments are therefore primarily suitable for analysing the area value of alternatives. In the theoretical section, we argued that it is essential for area-oriented infrastructure planning to include both scales and values in planning and decision-making. Not as a trade-off, but rather as a comprehensive expansion of scope of planning.

Consequently, early and light sustainability assessment tools cannot fully replace conventional assessment instruments. Rather, these types should be seen as complementary decision support styles (Figure 6). Together, they provide a comprehensive set of decision support tools for analysing the merit of area-oriented infrastructure planning alternatives. They employ qualitative information for proactive generation of plans, as well as quantitative information that is useful during the reactive parts of the planning process. This is in line with the findings of Mouter (2014), who argues that conventional instruments such as

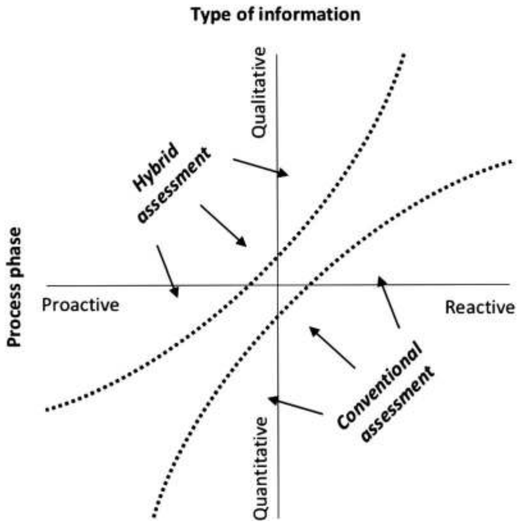

Figure 6. An effective decision support system for area-oriented infrastructure planning combines hybrid and conventional assessment strategies.

Note: The arrows illustrate the ongoing innovation of the instruments: (a) more reactive application possibilities for hybrid instruments, due to improved measurements, and (b) enhanced proactive application of conventional instruments, following from attention to process-related aspects of these instruments.

CBA should remain prominent in decision-making (see also De Jong and Geerlings 2003). The combined substantive and process-oriented character appears to make the new group of sustainability assessment tools a useful addition to DSS for infrastructure projects that struggle with functional interrelatedness and institutional fragmentation.

Hybrid and conventional decision support each have their own particular area of application. This implies that there may be a gap between the use of decision support in the early stages and the final stages of integrated infrastructure planning. Continued innovation is needed in both types of instruments in order to close the gap between the instruments (Figure 6). Examples of such innovation are the improvement of the thematic indicators used by hybrid instruments and a more process-oriented application of conventional tools. These innovations are ongoing (cf. Beukers, Bertolini, and Te Brömmelstroet 2014; Sjauw En Wa and Arts 2016; as well as regular updates of SC).

7. Concluding remarks

This article has explored the role of early-stage sustainability assessment tools in addressing the challenges for decision support that are encountered by an area-oriented road infrastructure planning practice. For that purpose, the application of the Sustainability Check (SC) was explored. SC is a hybrid instrument that focuses on the content as well as the interactive processes of infrastructure planning.

The study has shown that the main capacity of such tools is to support the generation of meaningful, integrated infrastructure planning alternatives. This may be attributed to four capacities: (a) introducing useful intelligence about primary and ancillary costs and benefits of alternatives, (b) facilitating determination of scope and generation of alternatives by proactive use of the information, (c) addressing institutional fragmentation by learning about referential frames, and (d) interpreting the ‘hard’ outcomes of conventional tools by adding a softer, contextual perspective at the area level.

However, the study has also shown that these tools do not support all of the area-oriented planning’s decision support needs. Hence, the use of such tools cannot fully replace the use of conventional assessments about the need and value of infrastructure planning alternatives. Rather, these new instruments must be seen as an addition to infrastructure planning’s toolbox of decision support systems. Especially in the later planning stages, the use of detailed knowledge with regard to welfare effects at the network level remains important.

The main lesson that can be drawn is that area-oriented planning needs the capacities of conventional instruments as well as those of early-stage sustainability assessment tools such as SC. A decision support system for area-oriented infrastructure planning should therefore combine these types of instruments. Both types of instrument require innovations to enhance the instrument’s complementarity and to limit the gap between proactive and reactive assessment.

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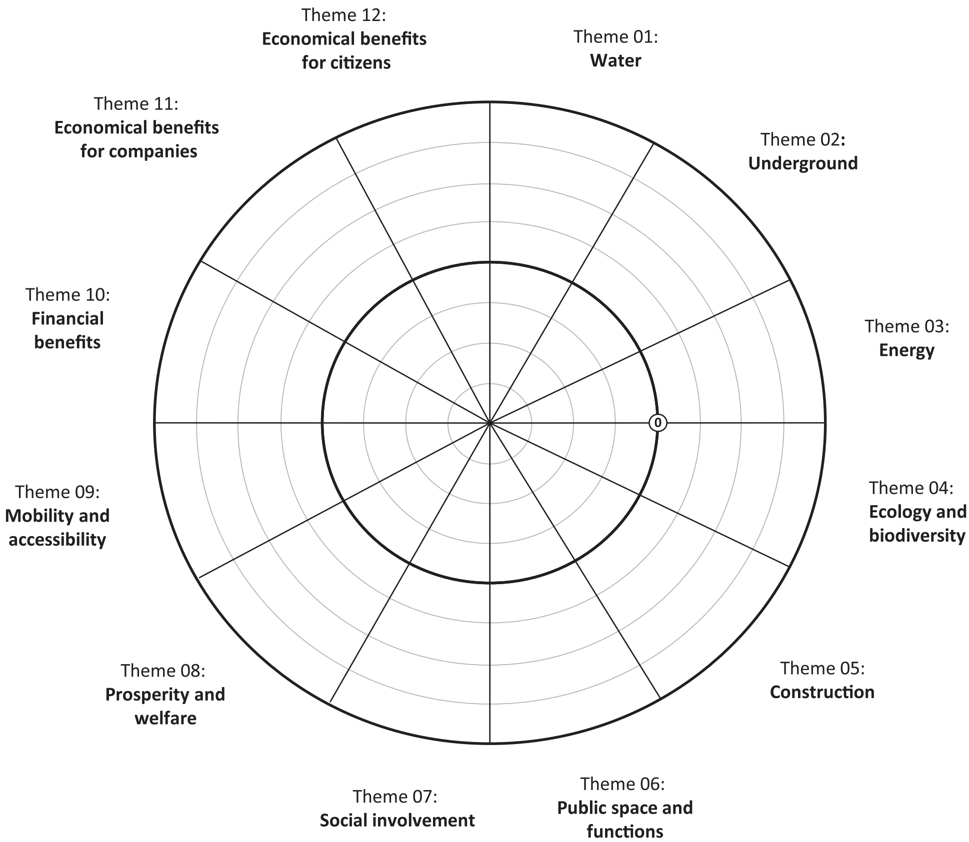
Appendix

The Sustainability Check (SC) instrument (Omgevingswijzer) uses various principles to operationalize the 12 sustainability themes (RWS 2012). The instrument is updated regularly and is publicly accessible at: www.omgevingswijzer.org.

Sustainability theme	Indicators	Relevant principles relate to (e.g.)
Ecology/planet	Water	Water safety/water flooding/water quality/water shortage/climate proofing
	Underground/soil	Soil quality/diversity of soil types/soil biodiversity /archaeology/soil subsidence
	Energy and materials	Reduction of energy consumption/use of renewable energy/use of fossil fuels/consequences of extraction of resources/exchange of energy/robustness of energy networks
	Ecology and biodiversity	Room for flora and fauna/biodiversity/ecological structures
Social/people	Use of space	Linkage with existing regional or other construction needs/restructuring/expansion/multiple land use
	Public space and functions	Spatial quality values: experience, use and future/integrated design
	Social relevance	Social wellbeing/demographical composition and trends/public support/local expertise
	Wellbeing	Health: positive contribution and limitation risks/physical and social safety/prevention of nuisance
Economy/Profit	Mobility and accessibility	Robustness of transport system within/between modalities/efficient infrastructure use/accessibility and connectivity/adaptiveness for mobility policies
	Investments	Cost benefit ratio/area potential/value capturing
	Economic benefits for business	Business climate/economic policy/capacity for innovation and adaptation
	Economic benefits for citizens	Employment/accessibility of job market/development of labour force/available services

The synergy wheel is used to display the scores of assessed alternatives.

The 'synergy wheel' with 12 indicators of sustainability
Source: RWS (2011)


Theme 12:
Economical benefits for citizens
Theme 01:
Water
Theme 02:
Underground
Theme 03:
Energy
Theme 04:
Ecology and biodiversity
Theme 05:
Construction
Theme 06:
Public space and functions
Theme 07:
Social involvement
Theme 08:
Prosperity and welfare
Theme 09:
Mobility and accessibility
Theme 10:
Financial benefits
Theme 11:
Economical benefits for companies
0