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THE SCENE MODEL: GETTING A GRIP ON SUSTAINABLE DEVELOPMENT IN POLICY MAKING*

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Abstract. Sustainable development is a politically and scientifically contested concept. This is partly due to its definition, which contains ambiguous, normative and subjective elements. In addition, sustainable development is a complex concept describing developments at different time-scales, geographical scales and across domains. In this article, we describe the 'SoCial, ENvironmental and Economic (SCENE) model', a conceptual approach towards sustainable development that explicitly addresses these characteristics. The model is based on the structural representation of economic, ecological and social stocks and the interaction between them. The possible applications of the SCENE model include integrated issue description, monitoring of sustainable development, evaluation of complex sustainability-related issues, strategy planning and a framework for quantitative modelling. In addition, the model provides a tool for the communication of these issues. The different applications are described on the basis of case studies. The common goal of all applications is a better understanding of the underlying dynamics of sustainable development and related issues.

Key words: complexity, decision-making, integrated assessment, policy analysis, policy support, regional sustainability.

1. Introduction

The transition towards a sustainable society is one of the major challenges for today's policy-makers. Since the 1992 Earth Summit in Rio de Janeiro a wide range of political, scientific, business-based and individual initiatives have been undertaken in order to achieve sustainable development. An indicator for the increasing role and acceptance of the scientific contribution to sustainable development is the official participation of researchers and scientific organizations during the recent World Summit on Sustainable Development in Johannesburg. A key question in that context is how to handle sustainability-related issues that touch a wide range of disciplines to develop strategies for the sustainable development of regions.

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2. Getting a grip on sustainable development

Since the 1992 Earth Summit in Rio de Janeiro, a range of scientific concepts has been developed in order to capture the many facets of sustainability. Examples are the Indicator for Sustainable Economic Welfare (Daly and Cobb, 1994), the Genuine Progress Indicator (Redefining Progress, 1995) and the Ecological Footprint (Wackernagel and Rees, 1996).

Some approaches are based on the collection of indicators. Without further aggregation these indicators were taken to provide sustainability-related information (e.g. OECD, 1993; UN-DPCSD, 1996). In several studies, the indicators were structured along the lines of forms of capital. For example, UN-DPCSD distinguished social, environmental, economic and institutional capital. The World Bank applied the slightly different structure of social, human, man-made and natural capital (Munasinghe, 1993; World Bank, 1997). Spangenberg and Bonnoit (1998) extended this approach with policy targets for key indicators and interaction between the different domains in order to make 'proactive policy steering' possible. Independently of Spangenberg and Bonnoit, Rotmans et al. (1998) first developed the structure of the SoCial, ENvironmental and Economic (SCENE) model as a support tool for an analysis of regional sustainable development in the Dutch Province of Limburg. Rotmans et al. emphasize the importance of stocks and the interactions between them in long-term sustainability studies. This latter approach has been further developed to the SCENE model as we present it in this paper, based on extensive practical case studies and ongoing research.

2.1. Defining Sustainable Development

Sustainable development has been defined in many different ways. The most widely accepted definition of sustainable development is that of the Brundtland Commission (WCED, 1987):

> Sustainable development is development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.

A common denominator of these definitions is an implied general balance of economic, ecological and social developments.

2.2. Characteristics of Sustainability

The Brundtland definition is a political definition of sustainable development, which contains inevitable problems with respect to a scientific application of the concept, namely normativeness, subjectivity, ambiguity and complexity.

Normativeness implies that something is (i) relating to standards or (ii) tending to create or prescribe standards. The word is derived from the noun 'norm' which the Cambridge International Dictionary of English (CIDE) explains as follows: 'A norm is an accepted standard or a way of behaving or doing things that most people

agree with.' The norm that is set in the above definition of sustainability is intergenerational equity. Future generations should have the same opportunities and/or resources as the current generation. This postulate is widely accepted in politics, but it is nevertheless an arbitrary norm for the weighting of the rights of current and future generations. Therefore the scientific implementation of this norm is contested. For the scientific advisory board of the Dutch government (WRR) the inherent normativeness was sufficient reason to reject the concept of sustainability as a whole (WRR, 1994).

Subjectivity means that something is 'influenced by or based on personal beliefs or feelings, rather than based on facts' (CIDE). In relation to the above definition of sustainable development it is a matter of personal beliefs under which circumstances the needs of the current or future generation are considered to be satisfied. Any benchmark to measure the level of satisfaction against is essentially arbitrary. The same holds for the means that future generations are expected to require fulfilling their needs. In other words, we cannot objectively establish, what is worth to be saved for future generations.

In order to analyse what should be saved for the use of future generations and to what degree, it is necessary to weigh against each other the fundamentally different elements of the social, economic and ecological domains. The Brundtland definition does not give any indication on the relative priorities given to the domains, which makes it ambiguous. A second aspect of ambiguity is implicit in the two contradicting goals of satisfying the needs of current and future generations simultaneously. As there is no obvious benchmark to measure the 'sameness' of abilities to satisfy needs, an ambiguous weighting procedure is needed. The inherent ambiguity has been reason for among others Wolfgang Sachs to reject the concept of sustainability as an oxymoron (Sachs, 1999).

The concept of sustainable development is also complex. The complexity stems from the transgression of time-scales, spatial scale-levels and domains. The processes underlying the concept of sustainable development take place on different time-scales. Where climate change takes decades for its manifestation, water pollution in the case of a flood can be immediate. At the same time, processes take place on spatial scale-levels ranging from local to global. The energy emission of a single household is as much an element of sustainable development as the global loss of biodiversity. Sustainability-related processes also transgress the boundaries between economic, ecological and social aspects. For example, the economic progress of the last century has had an enormous impact on the environment. Complexity means that sustainability-related problems can no longer be addressed from one perspective with respect to time, space or domain, one country, one culture, one ministry or one scientific discipline (Rotmans, 1998).

By any measure, the complexity of our society and thus also the complexity of the applied concept of sustainability seems to be increasing. This can be attributed to different causes. First the element of scale-enlargement: processes at the global and international level more and more interfere with processes at the national and local level. A second important factor is technological development,

which among others leads to time acceleration, causing a shorter rotation time of all sorts of processes, and knowledge increase, in particular about the interactions between social, economic and ecological processes (Rotmans, 1998). These complex dynamics of strongly interacting short- and long-term processes on various scale levels force us to think and act in a more integrative manner.

The characteristics of sustainable development make it not only difficult to analyse sustainability, but also to communicate about it. The inherent subjectivity needs to be mapped out carefully in order to be able to communicate across different perspectives of the circumstances that are considered to be sustainable. The relative values given to social, economic and ecological elements have to be made explicit when communicating on how ambiguity is addressed. The communication about both subjectivity and ambiguity is further exacerbated by complexity. A well-structured and transparent approach to representing the elements of sustainability and their interactions is a necessary precondition for any approach on how to handle sustainability and related issues.

Any approach should, as an end result, not only highlight the driving forces of sustainable development, but also the levers available to influence the system in co-operation with those who handle these levers. Otherwise any approach will remain of academic interest only and not do justice to the concept of sustainability at the interface of science and politics.

3. The structure of the SCENE model

With the SCENE model we continue the traditional distinction of different forms of capital as developed at UN-DPCSD and the World Bank. We distinguish three forms of sustainability-capital: SoCial, ENvironmental and Economic, hence the acronym SCENE. The social capital also includes institutional and cultural aspects. We extended the concept of interaction between the capital domains and the way in which capital stocks are described helping to describe and analyse context and dynamics more accurately. With these additions, the triangle is transformed from a concept for the structuring of sets of indicators for sustainability to a model, that allows the analysis of underlying dynamics and integrated strategy analysis and decision support. Figure 1 is a schematic representation of the 'naked' SCENE model.

3.1. STOCKS

Each capital domain contains a number of stocks. These stocks can be quite generic terms, such as 'quality of life' (social capital), 'environmental quality' (ecological capital) or 'economic vitality' (economic capital). The genericity of the stocks decreases the tendency to favour stocks in the selection, for which quantitative data are readily available. The main criterion for the inclusion of a specific stock must be its relevance for the issue or region under research. Further down, we will explain how to select stocks for a range of applications.

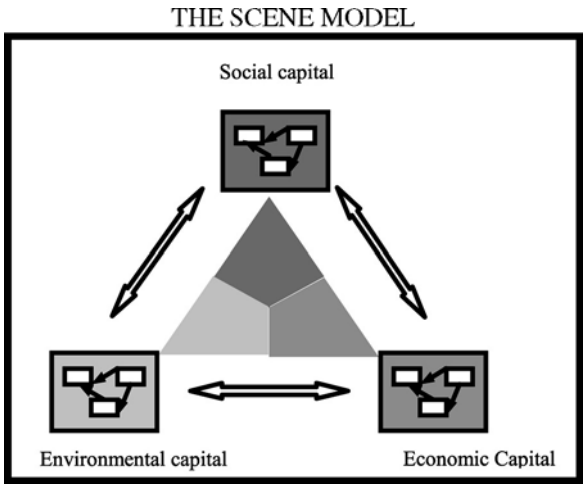

Figure 1. The SCENE model (Rotmans, 1998).

3.2. Characteristics of Stocks

From the legacy of system dynamic modelling, there is a tendency to describe a stock using a single dimension, i.e. quantity. This approach does not do justice to the frequently apparent interaction of different aspects of a single stock. We represent four aspects of a stock, namely its quantity, quality, function and spatial component. Taking 'education' as an example of a stock in a research study on a national level, its quantitative aspects could be described to contain the distribution of education over the population and the number of years in education, the quality could contain the efficiency of the educational system, the function of education could contain how well education prepares for earning a living and taking responsibility, but also the potential for innovation, the spatial aspect could contain the geographic distribution of education and the land surface needed for educational purposes.

It is important to note that a stock can be described using multiple descriptions of the same characteristic. In other words, a stock can be described with an arbitrary (though preferably limited) number of quantitative, qualitative, functional and spatial terms. Only in this way is it possible to capture the wide range of effects that a stock can have in a system. The clustering of these different characteristics of a stock enhances the intuitive understanding of the interaction between the characteristics. The detailed description of the stocks allows the conceptual testing of policy strategies for sustainable development in an integrated way.

3.3. Indicators

Describing the characteristics of a stock is not the same as finding measures or indicators for a stock. It is only in a subsequent step that our focus turns on the

selection of indicators for each of the characteristics. 'Indicators describe complex phenomena in a (quasi-) quantitative way by simplifying them in such a way that communication is possible with specific user groups. The term 'quasi' indicates that, although indicators are mostly quantitative in nature, in principle they can also be qualitative' (Rotmans, 1997). Qualitative indicators may be preferable to quantitative indicators where the underlying quantitative information is not available, or the subject of interest is not inherently quantifiable (Gallopin, 1996).

Each characteristic is assigned one or more indicators or indices from available information-resources. We are aware of the fact that the selection of a measurable indicator for a characteristic with the goal of quantifying or monitoring the development of a certain characteristic often goes together with a loss in descriptive quality. It is for this reason, that we put so much emphasis on the selection of generic terms to describe a system. In this way, the consciousness of what an indicator is meant to measure (and any deviation from that) is best preserved. As we will see in the description of the different applications of the SCENE model further down, selecting indicators is not always necessary, depending on the exact research question.

The selection of indicators completes the variable tree implicit in the SCENE structure. The stem of the tree are the three capital domains, the branches are the stocks within each capital domain, twigs branch off in the form of characteristics, connecting to the leaves, the indicators (see Figure 2).

For an integrated description of an issue it is crucial that all three capital domains are 'filled' with stocks with the same scrutiny. It is of little use to take the three-capital model as a basis for analysis and subsequently neglect one or even two of these capital domains in the analysis.

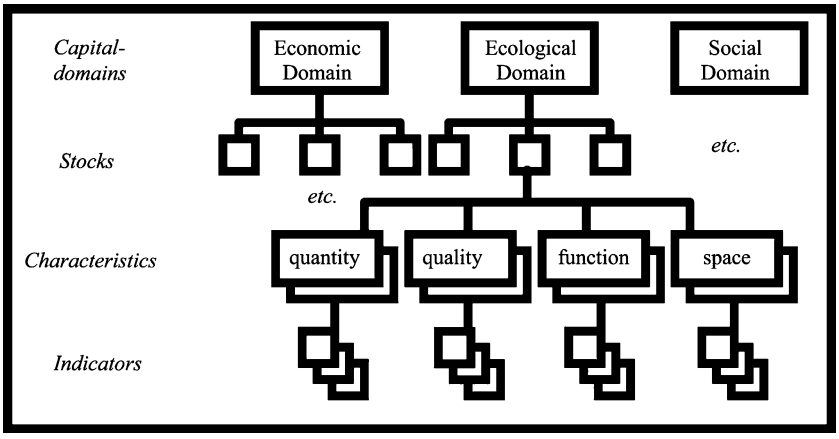

Figure 2. The four layers of the SCENE model.

3.4. FLOWS

In order to complete the structure of the SCENE model it is necessary to define the relationships between the different stocks. We call these relationships 'flows'. Flows are visualized in the triangular SCENE model in the form of arrows.

We distinguish 'intra-flows' and 'inter-flows'. An intra-flow connects two stocks of the same capital domain. Analogously, an inter-flow connects two stocks of different capital domains. Only inter-flows can be carriers of substitution processes, where one form of capital is substituted for another.

In addition to flows between stocks, we define autonomous flows. These describe continuous processes influencing a stock from outside a system. We call these flows 'service' (in-flow) and 'depreciation' (out-flow). Most evident is the example of the stock 'physical infrastructure', where a lack of service leads to a reduction of quality (out-flow in the form of depreciation). By adding service and depreciation, we add to the model explicit policy levers.

Between the characteristics of a single stock, there is a fourth type of flows, describing the close interaction of quantity, quality, function and space.

Depending on the research question, the focus on placing the links can be on links between the generic stocks, between their characteristics or the selected indicators. Later in this article, we will describe this dependency in some detail.

3.5. ADDRESSING COMPLEXITY

The clear structure of the triangular model makes it possible to represent the complexity of sustainability in a way that does justice to the needs of communication and analysis alike. For communication purposes one can choose an appropriate level of detail to provide insights into the developments and context of sustainability-related issues. For analysis the derivation of key issues and stocks using participatory methods is a useful way to reduce the complexity with a minimal loss of information. By postponing the translation of the conceptual model into the black-box of a quantitative model, we enable participants to support maximally the process of defining the details of the stocks and flows. The effect of this is, that the complexity is reduced in such a way, that the policy relevance of the model is optimized.

3.6. SURFACE

The surface of the triangle can be used as an additional way of storing and communicating information. The size of each corner of the triangle is a visual indicator for the strength (or capital value) of that domain. We distinguish three possible developments of the surface of the triangle as a whole: weakening, substitution and strengthening. Weakening implies that there are losses in the capital of all three domains. Strategies that have the effect of weakening can be considered

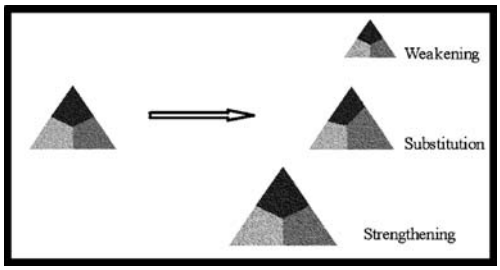

Figure 3. Possible capital developments of the SCENE model.

as the least sustainable option as on all three domains the ability of future generation to satisfy their needs is compromised. The notion of substitution can be used to describe the concept of weak sustainability with all its advantages and disadvantages. With substitution, one domain grows at the expense of another. A widely discussed example is the growth of economic capital at the expense of natural capital in the western world, especially in the 1960s and 1970s. But it is important to note, that comparable links can be described between the economic and social domains, and the ecological and social domains as well. Also, these relationships are not necessarily uni-directional. The economic costs for protecting the environment and for repairing damage done in the past are an example where ecological capital grows at the expense of the economic capital. Strengthening is the third general form of development of the triangle. This process is related to the notion of strong sustainability. By the improvement of all three capital domains, the future ability to satisfy needs is improved. An example would be the successful creation of a natural reserve that is also exploited for recreation. The ecological domain benefits from the extension of natural area, in the economic domain employment and income are created and in the social domain new recreational facilities are added. The processes of weakening, substitution and strengthening are visualized in Figure 3.

4. Completing the SCENE model

In the previous section, we presented the structure of the SCENE model with its four layers ranging from the three capital domains to the selected indicators. In order to be of any use in a practical application, this 'naked' structure needs to be filled in with information. In general, there are two ways in which this can be done. One can either use the insight of one or more experts in a given field or one can rely on participatory methods. Which method to use depends for one thing on the research question at hand and for another on the available resources.

4.1. Expert Insights

The most extreme form of completing the SCENE model using expert insight is a desk-study, where a single scientist selects the relevant stocks, characteristics and flows based on his or her knowledge of the research question at hand. The SCENE model in this case functions as a structuring framework for complex research issues. For contested research questions, a researcher can develop different plausible sets of stocks, characteristics and flows. In several case studies, we use 'perspectives' to arrive at a small set of consistent, but inherently different SCENE models. These different models can be used to describe, and in a later stage, to bridge different views on an issue.

The concept of perspectives is derived from Cultural Theory (Thompson et al., 1990). 'Perspectives may be considered as aggregations of the different points of view humans have, and can be defined as consistent, hybrid descriptions of how the world functions and how decision-makers should act' (Rotmans and Vries, 1997, p. 211). For a more extensive description of the use of perspectives in the field of Integrated Assessment, see van Asselt and Rotmans (1997) and van Asselt (2000).

4.2. Addressing Ambiguity

The ambiguity of the concept of sustainable development is inherent and cannot be reduced. However, by mapping out the differences between perspectives and by analysing trade-offs between different strategies and their effects, it is possible to make the inherent ambiguities visible and thus offering an opportunity for a transparent choice. In the case of highly contested issues with little scientific proof available, taking a decision on the path to choose between the ambiguous options should not be a role for scientists, but for democratic decision-making. Playing a facilitating role during the discussion that leads to the choice is a role for scientists.

Usually, the knowledge of one researcher alone is too limited and/or too entrenched to arrive at a consistent and generally accepted set of stocks, characteristics and flows. Therefore, it is advisable to always allow for feedback from other researchers. For contested issues, a development process involving other experts and stakeholders is advisable. Methods to do so are discussed in the following section.

4.3. Participatory Methods

Participatory methods play a crucial role in the application of the conceptual SCENE model as they help to address the inherent subjectivity and normativeness of the concept and at the same time structure the communication process between the modellers, other scientists, stakeholders and users. Participatory methods involve a plethora of process methods, varying from expert panels, to gaming,

policy exercises and focus groups. The input of non-scientific and practical knowledge and expertize, valuation and preferences through the involvement of actors by means of participatory methods enriches modelling exercises.

The participatory methods we use for the modelling input depend on the characteristics of the problem for which the model is developed and on the type of participants we can expect to participate. In general, different forms of focus groups are applied together with interviews and open feedback sessions. For a detailed discussion of participatory methods in Integrated Assessment, see van Asselt et al. (2001) and van Asselt and Rijkens-Klomp (2002).

Participatory methods can be applied for two distinct purposes, namely to map out diversity or to reach consensus. When the goal of the research process is the description of differences in perspective between different actors, it is most helpful to map out the diversity of their views. If one strives for concerted action of all stakeholders, it is most helpful to apply consensus-building methods. In an optimal case, both methods are combined: First, the diversity of opinions and possible strategies are mapped out. Differences in view are explained and discussed. Subsequently consensus-building methods are applied to arrive at an efficient and effective strategy for action.

With respect to policy making and sustainable development Van Asselt distinguishes five categories of potential participants related to public policy issues, the so-called actors: government, citizens, interest groups, such as non-governmental organizations, business and scientific experts. It is neither feasible nor necessary to employ all actors for every sustainability study. The strategic selection and the recruitment of committed stakeholders is often one of the more challenging steps in the process.

However, we found that developing a policy relevant model for the sustainability of a given region is hardly possible without a structural interaction with stakeholders. The stakeholders map out the relevant factors and their context. In addition, they provide the lines along which complexity must be reduced in order to keep the policy relevant information of the model. In this way, the structure of the model and the dynamics it describes are tailor-made for the users of the model, maximizing its policy relevance. This support in the simplification of the model is vital to the later acceptance of the model. The acceptance is further enhanced by the active participation of those, who will at a later stage work with the outcomes of the model. Developing the model together with the end-users also means that the process of communicating the results will be facilitated. Other than acceptance, structure, policy relevance and communication, there is an inherent benefit of the development in the form of a learning process. In our experience, users who were trained to think in a more integrated fashion were more capable of expanding their frame of thinking that is otherwise restricted by day-to-day pressures.

The use of participatory methods in policy-related research is now widely accepted (see e.g. Jaeger et al., 1997).However, it seems that in some cases participation has become a goal on itself. Without a sharp vision on what the ultimate

goal of a participatory process is, it is unlikely to contribute to any project. A frequently noted disadvantage of using participatory methods is the fact that current topics tend to be over-represented. An example would be a dominance of water-related issues after a flood has taken place. However, not only stakeholders, but also scientists are prone to this tendency. The balancing of participatory input and material derived from desk-studies would level this problem somewhat. Nevertheless it is evident, that it is currently not possible to develop a model for sustainability, that is deemed to be evenly useful and applicable at all times. Certain societal dynamics, and thus certain 'current' issues will have to be represented in redrafted versions of the SCENE model.

4.4. Combining Expert Knowledge and Participatory Methods

In our practical applications of the SCENE model, we mostly combined expert knowledge and participatory methods in order to satisfy the multiple goals of these studies. The participatory research process is then usually limited to the stock level of the SCENE model. On this level, it is possible to derive consistent sets of variables (stocks) and the flows between them in relatively little time. The resulting conceptual framework is then reflected upon by a group of experts, who subsequently complete the more detailed layers of the model. The process of completion goes together with continuous reporting to and feedback from the group of stakeholders. The ongoing interaction is needed in order to avoid dissociation, where the relevant stakeholders do not recognize their own input back in the final version of the model.

4.5. The Role of Participation in Addressing Normativeness and Subjectivity

Spangenberg and Bonnoit (1998, p. 10) have called for the setting of norms or so-called 'performance indicators' in the form of 'quantifiable policy targets' in order to measure the degree to which a policy strategy is successful in achieving sustainability. According to them: 'These targets should be agreed upon by society at large and codified by legislation or other binding means of policy enactment'. In other words, Spangenberg and Bonnoit want to address the normativeness, that is inherent in the concept of sustainability by letting not scientists, but society as a whole set the norms. We find that, lacking norms agreed upon by society at large, norms set by groups of stakeholders are a justifiable compromise. By using participatory methods the way we do, we explicitly address the normativeness of sustainable development.

Analogous reasoning holds for subjectivity. It is an impossibility to develop an objective representation of what is sustainable, let alone an indicator for the degree of sustainability. However, explicitly using the subjective preferences, values and opinions expressed during the participatory process means, that the

resulting model is at least meaningful to those who use it. Simultaneously, the explicit documentation of these preferences, values and opinions provides a basis for discussion. As the model is flexible, alternative sets of subjective criteria can be compared to the existing ones and thus differences in strategies be derived. Which strategy should be applied in the end is once more not for the scientist or the model to decide, but for the democratic process.

5. Ways to apply the SCENE model

The SCENE model can be applied for a wide range of sustainability-related research issues and goals. The SCENE model can serve as a framework for integrated and structured thinking about complex issues, for monitoring sustainable development, for the evaluation of complex sustainability-related issues and for strategy planning. The above functions make the SCENE model a suitable qualitative modelling-framework for quantitative modelling. In addition, the model provides a tool for the communication of these issues. The research goals and how to approach them are described in the following section. Several case studies on different issues serve as illustration.

5.1. Integrated Thinking

A trivial, but highly effective and efficient application of the SCENE model is as a tool for mapping out and structuring complex inter-relations. In this way, the integrated context of stocks can be represented. From this conceptual approach, points of attention and points of discussion can be derived. One example of the SCENE model used as a structuring tool is the NMP4 biodiversity project (Rotmans et al., 2000). This project was an integrated analysis of biodiversity as a support study for the 4th Dutch National Environmental Outlook (NMP4). The SCENE model was used to describe the current state of the stock of biodiversity, in order to establish the driving forces for its development, place biodiversity in its context with developments in other domains, sketch future developments and define policy levers for an improvement of biodiversity. The added value of the SCENE model lay in the clear picture it provided of driving forces, effects and policy options. The structural presentation facilitated the quest for win–win strategies in preserving biodiversity.

When applying the SCENE model as a structuring tool, one can choose to describe the model either on the stock level or on the level of the characteristics, depending on the level of detail requested. With a process of full participation it takes a set of highly dedicated stakeholders to go beyond the stock level. At the same time, a participatory process adds significantly to the content of the model and simultaneously raises the awareness for interactions and the context of their own field among the participants. The importance of this effect should not be underestimated. It has been the most important outcome in many of our governance consulting projects.

One example is the POL project (Provincie Limburg, 2000). The Dutch province of Limburg based its strategic vision on a SCENE model developed for the province in co-operation with participants from a wide range of provincial departments. In this project, the SCENE model has not only mapped out the issue of a sustainable Limburg, but also the necessary paths of communication, to make this ambitious goal come true. The resulting report is now used as an important benchmark for the evaluation of governance strategies.

5.2. MONITORING

The list of indicators derived during the model development process is a useful basis for the monitoring of sustainable development. The advantage of the list is the fact, that the indicators are not loosely selected to represent a range of disciplines or topics, but that they also form a consistent and inter-related set for further analysis and interpretation. It is obvious, that in order to select indicators, it is necessary to complete the SCENE structure to that level of detail for any meaningful results.

Based on an expert process, the Telos Institute has built a monitoring tool for the Dutch province of North-Brabant based on the SCENE model (TELOS, 2001). The state of indicators and their development during the past few years are set against benchmarks. In this way, sustainability-related developments are monitored.

At ICIS, we implemented a participatory process to derive a set of monitoring indicators for the city of Maastricht. The advantage of participation in selecting the indicators lies in the practical applicability of the chosen sets. The user – in this case the civil servants of the city of Maastricht – has in a transparent process laid an explicit link between their daily chores and the more abstract concept of sustainable development (Yang, 2002).

5.3. EVALUATION FRAMEWORK

Choices concerning the inherent trade-offs related to the concept of sustainable development can be explicitly weighed against each other, based on the SCENE model. The inherent ambiguity of the concept can thus be addressed. This application is especially useful in the evaluation of projects where trade-offs between the three domains of sustainability have to be negotiated, for example large infrastructural projects. In order to make the choices between different ambiguous options meaningful, it is helpful to focus on the layer of characteristics. In our experience, this layer best represents the consequences of choices that are made to improve certain key indicators, like economic growth and maps out the hidden consequences in terms of quality, function and space.

In an expert based process, the well-structured overview of economic, ecological and social stocks and characteristics provides a framework for an integrated and balanced evaluation. Any bias towards one or two corners of the triangle becomes

explicit. Generally, the content gains from a participatory approach, where implicit choices made by stakeholders become explicit. The awareness for the existing sets of trade-offs in combination with the perspectives of the stakeholders opens up the space for a well-founded discussion on ambiguous options.

The practical use of the POL report is an example for this application of the SCENE model. The consequences of different policy strategies can be mapped out, including the positive and negative side effects. Based on these options, trade-offs between economic, ecological and social aspects are made explicit, allowing for transparent choices.

Another relevant example in this context is the TOK project. In this project a set of scenarios for the year 2030 was developed for the city of Maastricht (Kockelkorn et al., 1999). The version of the SCENE model used in this project represents the driving forces and effects of policy strategies and offers to the decision-maker well-structured insights into possible future developments.

5.4. Strategy Development

In addition to evaluating strategies, the SCENE model can also serve as a tool for the development of policy strategies. A useful starting point for the development process is the identification of policy-levers, i.e. stocks, characteristics and flows that governance has a direct impact on. Evaluating the consequences of influencing one or more of these policy levers results in strategies that are not influenced by entrenched goals. For example, it is not possible for provincial governance in the Netherlands to directly influence the population size. But population size being a crucial variable in sustainability-related issues, strategies are often still focused on achieving the impossible. Letting that focus go and taking a closer look at feasible interventions has delivered more feasible approaches to sustainability, some of which have the side effect of supporting the preferred development of the population size.

In an ongoing research project about the sustainability of the Netherlands, we are currently systematically analysing policy options for several layers of government and other actors using the described approach. In this process, continued interaction with stakeholders is vital in order to continuously check the assumptions underlying the basic model. In some cases the perceptions of the stakeholders do not overlap with the results of scientific research. The fact, that policy-makers think they are able to influence a certain element, but probably are not (or vice versa) is a point of special attention for the researcher.

5.5. Quantitative Modelling

The structure of the SCENE model, including the derived set of indicators is a transparent framework for the development of quantitative models in the tradition of system dynamics. Generally, the development of each given indicator in the model can be expressed as a differential equation. The set of explanatory variables

consists of all indicators that have a link towards the given indicator, i.e. influence that indicator.

In some cases the complexity of the conceptual model is preventing the straightforward implementation in system dynamic form while still providing any useful results. In these cases, the conceptual model is simplified by selecting a set of key indicators that are especially important for the development of a system. The criteria for this selection procedure depend on the question at hand. During the selection process it is crucial to check, whether the main dynamics of the systems as the expert and/or participants understand it are still represented within the system.

Even in a simplified system, it would be exceptional if all links between indicators in that system were thoroughly researched with widely accepted and reasonably certain results. It is important to explicitly address the less researched links either based on a participatory process or based on a set of scenarios, that represent the range of scientific dissent.

In co-operation with the Technical University Delft (TUDelft) we have used the SCENE model as a framework for quantitative modelling in our ongoing consultancy activities for the city of Maastricht (Yang, 2002). An important lesson from this exercise was the limited ability of decision-makers to commit to the tedious process of discussing the underlying assumptions of the conceptual model at the level of indicators combined with an urgent request to provide quantitative indicators as measures of progress towards a more sustainable city.

TABLE I. The applications of the SCENE model, their goals and the relevant focus levels.

Application	Expert		Participation	
	Main advantages	Focus level	Main advantages	Focus level
Integrated thinking	Structured framework for integrated analysis	Stock/ characteristic	Structured framework for integrated analysis; Raising awareness for complexity	Stock
Monitoring	Framework for relevant indicator selection	Indicator	Selection of indicators with broad acceptance and practical applicability	Indicator
Evaluation	Balancing economics, ecology and social aspects	Characteristic	Making context and trade-offs explicit	Characteristic
Strategy development	Policy levers and consequences	Characteristic	Policy levers and consequences	Characteristic
Modelling	Conceptual structure	Indicator	Conceptual understanding	Characteristic/ indicator
Communication	Complex issue communication	Depending on audience	Basis for reporting and discussion	Depending on audience

5.6. COMMUNICATION

The clarity with which complex sustainability-related issues can be represented in the SCENE model makes it a useful tool for communicating with participants or third parties the process and the results of any of the previous applications. Complex problems can be represented with relatively little loss of information. This also increases the acceptance of the conceptual as well as the analytical model. Decision-makers are not confronted with a black-box tool that provides them with ready-made strategies, but their own input is digested and structured. As the political decisions are to a large extent not taken within the model itself, but left to the policy circuit, decision-makers are more likely to accept the tool and use it intelligently.

Table I provides a summary of the different applications of the SCENE model, their main advantages and the focus level.

6. Future research and conclusion

The full quantification of the SCENE model for a given region is currently in progress. During this process, some major challenges have to be solved. The two major challenges are the representation of uncertainty related to the relationships between different indicators and the development of an interface that allows policy-makers to enter the information they have in such a way, that it is feasible for the modeller to process this information in a coherent and consistent manner.

The SCENE model is a versatile tool for scientists and policy-makers to get a grip on the complexity, ambiguity, subjectivity and normativeness of sustainable development. The model has proven its capabilities as a tool for analysis and communication in a set of case studies. The major problems of the scientific implementation of the concept of sustainable development have been addressed. Further development is necessary, especially in bridging the conceptual applications and the quantitative applications.

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