THE USEFULNESS OF ANALYTICAL TOOLS FOR SUSTAINABLE FUTURES

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Abstract

The aim of this study is to assess the usefulness of analytical tools for policy evaluation. The study focuses on a multi-method integrated toolkit, the so-called SMILE toolkit. The DECOIN/SMILE toolkit consist of the integration of three evaluation frameworks developed within an EU-funded consortium called Development and Comparison of Sustainability (DECOIN) and further applied within the consortium Synergies in Multi-Scale Inter-Linkages of Eco-social systems (SMILE). This toolkit is developed to provide reporting features that are required for monitoring policy-making. The sustainable development perspective is rather difficult to attempt due to its dynamism and its multi-dimensionality. Therefore, in this study, we aim to assess the usefulness of the SMILE toolkit to sustainable development issues on the basis of the critical factors of sustainable development. In other words, here, we will prove the usefulness of the toolkit to help policymakers to think about and work on sustainable developments in the future.

1 INTRODUCTION

Sustainability is the ability to maintain the newly obtained dynamism and to seek to remain viable in perpetuity. Therefore, sustainable development is the development with which the continuity of settlements and environments is maintained while increasing the well-being of inhabitants and offering desirable milieu for economic activities. Sustainable futures are the desired outcomes of many policy evaluations and strategic planning processes. These futures can be achieved only by communication, implementation and monitoring of these policies in a systemic, orchestrated and disciplined manner (Eppler and Platts, 2009). A way to cope with this challenge is the visualization and graphic representations of the current situations and future trends.

As sustainable development and policies are complex in nature, a systemic approach may offer a practical frame of reference. In general, a systems approach aims at portraying the processes and relationships in a complex system that encompass various components which are linked together by means of functional, technical, institutional or behavioural linkages (Harvey, 1969). Although this systemic approach helps to present the current situation and trends, not every stakeholder is capable of understanding the complex outcomes of such solutions as they are often no experts or researchers, but rather decision-makers or the action groups. Therefore, an understandable presentation is very important if researches want their outcomes to be used in the real world.

In this case, the outcomes of the tools used for the evaluation play an important role to explain to come up with relevant policies and solutions. In the literature, among the strength of visual outputs, facilitating the synthesis (Vessey, 1991), enabling new perspective (De Bono, 1973) and better comparisons (Lurie and Mason, 2007), integrating different perspectives (DiMicco et al., 2004) and

creating involvement and engagement (Buzan, 1995 and Huff, 1990) is often stressed (see for more Eppler and Platts, 2009).

Therefore, in this study we focus on the earlier mentioned reporting andvisualization tool with the aim of assessing its usefulness. The so called DECOIN/SMILE toolkit is basically a multi-method integrated toolkit. It consists of the integration of three evaluation frameworks, viz. Advanced Sustainability Analysis (ASA), Sustainability Multi-criteria Multi-scale Assessment (SUMMA), Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MSIASEM). It is developed within an EU-funded consortium called Development and Comparison of Sustainability (DECOIN) and applied within the consortium Synergies in Multi-Scale Inter-Linkages of Eco-social systems (SMILE). The toolkit is developed to provide reporting features that are required for monitoring policy-making with the analysis of the different dimensions of sustainability and further the analysis of the trade-offs and synergies between different aspects of sustainable development. The sustainable development perspective is rather difficult to attempt due to its dynamism and its multi-dimensionality. Therefore, we will investigate the usefulness of this toolkit in helping to better observe the dynamism/new trends in relation with different dimensions of sustainability. To reach our aim, we present a usefulness method that uses critical factors of sustainable development when determining the toolkit to be processed by an outranking method. It is basically an impact structure matrix which reflects the impacts of policy measures (Nijkamp, 1983). During our evaluation, we employ the success and failure factors of the toolkit and the sustainability factors defined in a previous study (Akgün et al., 2011).

Therefore, here, we introduced the importance and usefulness of reporting and visualization tools for policy evaluation. In the following section, we present the tool that we are interested in this study to assess the usefulness of reporting tools. In Section 3, to assess this usefulness we offer the results of our findings by using the impact matrix. The study concludes by discussing what are the most important factors to increase the usefulness of the analytical tools.

2   CRITICAL FACTORS OF SUSTAINABLE DEVELOPMENT

Sustainability has been the subject of intensive discourse at a conceptual level, but unfortunately it has not been treated so often in operational contexts. Here, we offer a systemic operational contribution through the use of case studies, in which the pentagon model is used as a methodological vehicle.

The pentagon concept has been developed and used in systems thinking/evaluation of a multidimensional complexity (Nijkamp, 2008). In the literature, there are several applications of the pentagon model which have demonstrated its methodological power and empirical validity in various studies. The pentagon approach has been applied in several policy studies during recent decades, in order to assess the critical success/ failure factors of a policy (see, e.g. Nijkamp et al., 1994; Nijkamp and Pepping, 1998; Capello et al., 1999; Nijkamp and Yim, 2001; Nijkamp, 2008). Intrinsically, this model aims to map out, in a structured manner, the various forces that represent the critical factors that are essential contributors to the performance of a given policy (Nijkamp and Pepping, 1998). What this rather stylized approach does is to enable some of the key issues of the

policies under research to be discussed in a systemic way. It highlights key dimensions in decision making and also enables us to look at those areas where policy initiatives can influence the way in which sustainable development is enhanced (Button, 1998). It is a systematic evaluation to determine the (most) critical success factors and sub-factors in sustainable development policies.

Success conditions refer to the necessary – though not sufficient – conditions that are to be fulfilled to meet a priori given objectives concerning sustainable development, such as economic performance, social cohesion, and ecological quality. The failure conditions are to be interpreted in a different way. They refer to those factors that drive the performance of a system towards levels that are unacceptable from the perspective of a priori specified objectives. By determining the critical factors, the pentagon model is formed by a pentagon prism which represents the cyclical relations between the necessary – though not yet sufficient – conditions for successful policies (see Figure 1). The original pentagon model, as it was when first developed more than a decade ago, distinguishes five key factors, viz. software (e.g. knowledge), hardware (e.g. research facilities), finware (e.g. financial support), ecoware (e.g. environmental amenities) and orgware (e.g. institutional support systems). These pentagon factors can be applied to both the supply side and the demand side of economic-ecological-technological systems.
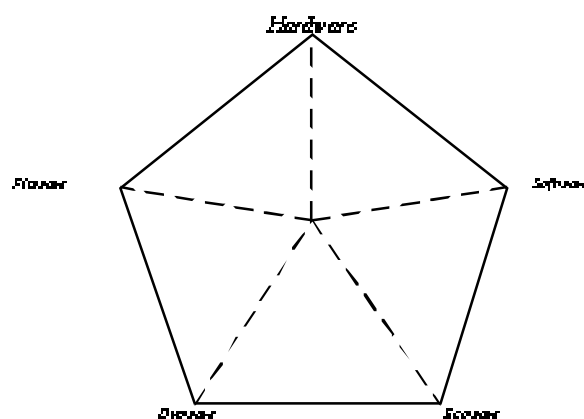

Figure 1. The original pentagon prism comprising necessary conditions for a successful policy

The pentagon approach offers a flexible methodology and has been used in various studies, viz. the evaluation of energy policies (Nijkamp and Pepping, 1998; Capello et al., 1999); the quality of the urban economy (Nijkamp, 2008); sustainable rural development (Gülümser, 2009). Each pentagon model is generated from the original stylized pentagon model so that critical factors of different systems are developed on the basis of necessary conditions. In addition, researchers have adapted the original model to fit any new topic under investigation. For instance, Capello and her colleagues in 1999 and Nijkamp and Pepping in 1998 used the original pentagon factors, but Nijkamp in 2008 adjusted these factors to assess the highest possible quality of an urban economy, where the pentagon factors used were: economic capital; ecological resources; technological systems; geographical infrastructure; and social suprastructure. In addition, the most recent example of the model published by Gülümser in 2009 to underpin sustainable rural development is based on the necessary conditions defined for sustainable development in the Brundtland Report in 1987, and

used systems thinking with regard to the physical system, social system, economic system, locality system, and creative system.

In conclusion, pentagon models applied in various studies show the validity of the model for systems thinking. In other words, such a model offers a valid framework for analysing different problems of an overall system by identifying drivers of the whole system through the identification and analysis of its critical components. The pentagon model is formulated as the result of the in-depth questionnaires carried out among the stakeholders from different case-studies included in the SMILE project.

The original pentagon conceptual framework can be seen as the basis, or starting point, for the development of our basic model. In developing specific stakeholder-based models, we start our systemic approach on the basis of five critical drivers of a system. First, with the help of a literature review for the case concerned and the expertise of researchers with specific knowledge about the case studies, a basic SMILE pentagon model has been formulated (Figure 2). In a second step, the model is validated and improved by (local) stakeholders or experts. This is done by extensive interviews and sometimes by additional questionnaires.
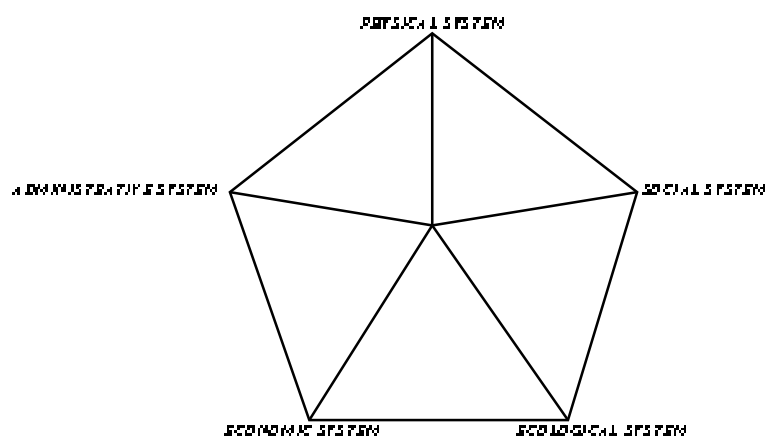

Figure 2. The pentagon model of sustainable development

The final stakeholder specific pentagon model comprising five key forces is as follows:

- The Physical system represents the quality of the human-made environment through which well-being and living standards of people can be determined. It includes aspects like quality of the built environment, infrastructure, accessibility, and the basic level of technology and innovation. Its sub-factors are:
  - o Built environment: This is related to the human-made physical surroundings that are necessary for the execution of all normal human activities (living, working, etc.);
  - o Technology: This refers to (additional) technological systems and development in the related sector(s);
  - o Infrastructure: This indicator refers to the technical infrastructure, e.g. roads, sewage, water, electricity, etc. In addition, it also refers to Internet and telecommunication infrastructure;
  - o Accessibility: This is related to the availability and costs of different modes of transportation.

- The <u>Social system</u> is related to the quality of social networks in the case-study area. This consists of the basic level of education and training, but also of coherence, interaction, and the openness of society to new things. The sub-factors are:
  - o <u>Social capital</u>: This indicator deals with the basic quality of the social system, e.g. the level of education and skills, but also the gender, age and ethnic distribution;
  - o <u>Openness</u>: This is the level of tolerance/interest of inhabitants with regard to new suggestions and concepts in relation to sustainable development;
  - o <u>Participation</u>: This refers to the level of involvement of inhabitants in decision-making processes. It is related to the social dialogue both inside and outside the community with experts and planners;
  - o <u>Awareness</u>: This sub-factor refers to the awareness and understanding of society about sustainability and the particular policy in the case study.

- The <u>Economic system</u> refers to the economic activities and their characteristics inside the case-study area. It deals with the level of diversity of sectors, the level of uncertainty in relation to prices or profits, as well as the structure of economic activities by means of the size of the economic activity and its proprietorship.
  - o <u>Economic diversity</u>: This concerns the number of different economic activities in the case-study area. Even though the case-study area can be focussed on one single sector, other sectors will also be evaluated in relation to economic diversity;
  - o <u>Uncertainty</u>: This factor refers to the possible impacts of unexpected economic shifts, e.g. economic crisis, price changes;

- The <u>Ecological system</u> is related to both the quality and the quantity of natural environments/ ecosystems of the case-study area, as well as the effect of environmental impacts addressed in the case studies. The sub-factors are:
  - o <u>Ecological environment</u>: This sub-factor reflects the quality and quantity (the state) of flora and fauna of the case-study area. Depending on the case study, it may also include parts of the ecological environment which are of interest, e.g. forestry or agriculture;
  - o <u>Environmental impact</u>s: This includes factors that enhance or mitigate environmental impacts. Different indicators are possible to assess the environmental impact, e.g. energy consumption, etc.

- The <u>Institutional system</u> represents the quality of administrative and management issues related to the case studies, including quality of political decisions and policy implementation. The sub-factors consist of:
  - o <u>Governance structures</u>: This refers to the basic quality of governance structures, related to the interaction between different governmental and institutional stakeholders who influence decisions, the efficiency of the decision-making processes, and also influence how well these decisions are implemented and managed in the case-study area;
  - o <u>Integration</u>: This refers to the degree of connectivity and coordination between different policies in one spatial area of policies (and policy makers);
  - o <u>Continuity</u>: This refers to the continuity of policies, policy measures and governments;

In the following section, we offer a brief summary of the evaluation of analytical tools while focusing on the SMILE toolkit. In addition, we also propose the critical factors to assess the usefulness of analytical tools for sustainable futures.

3 ANALYTICAL TOOLS FOR SUSTAINABLE FUTURES: SMILE TOOLKIT AND ITS USEFULLNESS FACTORS

Investigating a system performance is by itself a very difficult task, due to the complexity of the problems that are always involved. Adoption of a simplified model is certainly a way to address part of the problem, but leaving very often unsolved another part of it. Nevertheless, many investigators run the risk of neglecting the complexity of the problem and take their model as reality. As a consequence, they assign a value to a process product according to the results of their simplified investigation. The outcome of this evaluation process is then used in other subsequent evaluations and translated into economic and policy actions. In so doing, the complexity is lost: reality does not fit the model and the planned policy fails or is inadequate. For this reason, policies must take indirect effects into account. It is therefore of paramount importance that a multi-method and multi-scale approach is used when investigating complex systems. Quantifying direct and indirect flows provides a way to measure progresses and trends as well as to evaluate if and to what extent a given policy action is successful for increased sustainability. Understanding how a given behaviour or policy is likely to affect surrounding territories and ecosystems may provide a way to mitigate, prevent or compensate adverse effects on supporting environment.

The ultimate goal of any investigation about a process is to generate a clear picture of the crucial steps as well as crucial input and output flows, i.e. those steps and those flows that affect more heavily the process performance. It is possible to focus on these steps and flows, to understand how important they are in the global economy of the investigate process and to suggest changes capable of leading an improved performance. Some steps may be replaced by alternative patterns, some flows may be decreased by means of more efficient machinery or sub-processes, and finally some flows may simply be avoided without any important consequence for the final product. Indicators are the result of a calculation procedure where the inventory data are multiplied by intensity factors specific of each given method (e.g. oil equivalent factors, transformity, global warming potential, etc). Therefore, when a performance indicator (e.g., the Acidification Potential) is not satisfactory, the analyst goes back to the calculation procedure in order to identify the input items that are responsible for the largest contributions to that impact category and may suggest to decrease their amount by applying more accurate use patterns and technological improvement to the process that delivers a given input (e.g., more efficient production of chemical fertilizers by chemical industry or electricity by power plants). After the suggested changes have been implemented (or their adoption has been simulated) in the process, the analyst will recalculate the indicator under consideration and will assess the extent of the performance improvement. Nonetheless, it is very likely that the suggested change affects other impact categories and, due to the reliance on the same set of input data, the improvement in one category might translate into a worse performance in another category (e.g. fuel de-sulphurization – while improving the emissions - requires an additional technological process and increased energy input and generates additional waste to dispose of).

Quantifying direct and indirect flows of matter and energy to and from a system permits the construction of a detailed picture of the process itself as well as of its relationship with the surrounding environment. Processing these data in order to calculate performance indicators and material and energetic intensities makes it possible to compare the process output to other products

of competing processes. Results may differ depending on the goal, the boundaries, the time scale and the technology and may suggest different optimization procedures. If the analyst is able to provide comprehensive results as well as to explain divergences at the appropriate scales of the investigation, a process can be more easily understood. Conclusions are also reinforced and are more likely to be acceptable for research, application and policy strategies.

Assessing a process performance on different scales offers an effective way to refine the analysis and improve the process. Results from the simultaneous application of a multiple set of methods yield consistent and comparable performance indicators and call for a two-fold optimization pattern:

1. Upstream: trying to decrease the use of or replace those input flows which more heavily affect the material, energy and environmental support demands;
2. Downstream: trying to decrease the use or avoid misuse of the investigated product, in order to negatively affect the input demand by controlling the end of the life cycle chain.

Performance indicators are the final result of a calculation procedure where the inventory data are multiplied by intensity factors specific for each given method (e.g. oil equivalent factors, transformity, global warming potential, etc).

In particular:

- Several quantitative inputs are affected by significant uncertainty;
- Other factors (e.g. the assessment of Intensity factors) may change over time as a consequence of production choices or technological improvement;
- Many flows and results may be correlated to each other, implying the risk of non-linearity and feedback effects, which can significantly alter the results of the quantitative assessment.

On the basis of the above concerns about investigating a systemic process like sustainable development, a toolkit, so-called SMILE toolkit is developed within the finished DECOIN project, and is further implemented within our SMILE project. The toolkit is designed to generate effective multipurpose grammars to be used to represent and study "sustainability issues" in an integrated manner, across different dimensions and scales of analysis. The toolkit has to be adapted, case by case, to the peculiar characteristics of the sustainability problem to be tackled. It is obvious that not just a single protocol (one size fits all) can be used. The application of the toolkit (which type of approach to use and for which purpose) has to be tailored both on: (i) the specific goal of each case study; and (ii) the specific characteristics of the investigated system.

SMILE toolkit aims at helping the EU and its Member States to better observe trends in relation to different dimensions of sustainability. Within the SMILE project the toolkit is applied to a selection of case-studies that are human dominated complex systems (environmental, agricultural, industrial, whole economies) in order to test the potential of the toolkit for a multidimensional assessment of a system's dynamics and sustainability (see Table 1 for the summary of case-studies).

The case-studies subject to our research are very diverse in terms of their sustainability issues, aims, stakeholders and scales. This is summarized in Table 1 to show better the complexity and diversity of our sample.

Table 1 Summary of the case-studies

Case	Aim	Scale	Sustainability Aspects		
			Social	**Ecological**	**Economical**
Finland	Forest ecosystem	National	No stakeholder involvement	Quality and well-being of ecosystems	To increase productivity and labour intensity of the forest sector
Italy	Agriculture sector	Local; Regional; National	Three farms; Inclusion of stakeholders at different scales	Analysis of the amount and the quality of resources; Environmental impact; Analysis of decomposition equations for CO_2 emissions and the non-renewable emergency fraction;	To enable policy makers to provide some incentives; To be able to collaborate with the local market operators
Romania	Energy sector	National	The topic-related ministries; Household; Action groups; Local authorities; Companies	The environmental impact of different energy consumptions.	To reveal the gaps between the Romanian economy and the economy of other EU Member states.
Scotland	National Park	Regional	CNP Authority; National stakeholders; Regional stakeholders; Local stakeholders	Landscape, Built and Historic Environment; Biodiversity; Geodiversity; Sustainable Use of Resources; Energy; Water; and Air	Making tourism and businesses more sustainable, Making housing more affordable and sustainable.
Spain	Toolkit		No sustainability aspect can be provided		

The case-studies in our sample have several similarities and the main similarity is that their general approach is sustainability oriented. The sustainability issues are mainly based on ecological and economical aspect of sustainability. Except the Spanish case-study, all case-studies are sector focused. The Spanish case-study is the most distinctive one among the case-studies. It deals with the toolkit itself and not with a specific aspect of sustainability. Instead, it is very useful in providing the relation of the output of the toolkit with sustainability issues. The case-studies have several scales. Some deal with the national scale while there are case-studies focusing on local or regional scales. Within the Spanish and Finnish case-studies, stakeholders are not involved in the analysis process while the output of both cases is useful for many stakeholders.

The key element in the toolkit is the integration of three evaluation frameworks into one multi-criteria, multi-scale and versatile prototype framework for the assessment of complex systems. The Advanced Sustainability Analysis (ASA), the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MUSIASEM) and the Sustainability Multi-method Multi-scale Assessment (SUMMA) approaches are integrated into a tool, which is easy to use and provides reporting features that are required for monitoring and policy making. The separate tools are described below.

SUMMA[1]: A comprehensive evaluation method (SUMMA – Sustainability Multimethod Multiscale Assessment, [1]) is used in the study in support to decision-making. In SUMMA the different (upstream and downstream) perspectives are not forced to combine, but retain their full wealth of information, on the basis of which wise decisions can be made, also taking into account important external factors such as social and economic welfare. SUMMA is based on a selection of upstream and downstream methods, which offer complementary points of view on the complex issue of environmental impact and performance assessment.

ASA[2]: Advanced Sustainability Analysis (ASA) is a mathematical information system developed by Finland Futures Research Centre (see e.g. Malaska et al 1999; Kaivo-oja et al 2001a; 2001b; Vehmas et al 2003; Luukkanen et al 2005; Vehmas 2009). It can be used to analyze sustainable development from different points of view. ASA analysis can provide quantitative information on the changes and reasons for change of quantitative sustainability indicators from various dimensions of sustainability. What is required is quantitative time-series data on the explained sustainability indicator and other related indicators that form the factors into which the changes in explained sustainability indicator can be divided, or decomposed. In turn this requires some understanding of the explained sustainability indicator and forces relevant to its change. If the quantified data is available, ASA analysis is very flexible and can quantify the contributions of factors of change in sustainability indicators in all the fields (Physical, Social, Economic, Ecological, and Institutional). Obviously the challenge is, firstly, the availability of quantitative time-series data on the sustainability indicators and the relevant other variables forming the contributing factors, and secondly, forming the ASA decomposition equation with sensible interpretations from the available indicator data. In order to improve the usability and value of the toolkit, a lot of attention should be put on the quality of the time-series selected.

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[1] This is retrieved from Smile deliverables D4
[2] Ibid.

MUSIASEM[3]: The MuSIASEM approach [originally proposed as MSIASM by Giampietro and Mayumi, 2000a; 2000b; Giampietro 2003a] has been developed in relation to the emerging field of science for governance. In particular it can be seen as an attempt to generate a methodological approach capable of providing a quality control on quantitative analyses applied to the issue of sustainability. It is based on the seminal idea of "bioeconomics" put forward by Georgescu-Roegen (Mayumi, 2001) and on the conceptual tool of multi-purpose grammar proposed within complex systems theory as a key ingredient for the possibility of getting informed autocatalytic loop (autopiesis) by Kauffman, (1993). MuSIASEM can be used to check the robustness and the relevance of models, datasets, and forecasting. It achieves this result by verifying the congruence of the chosen integrated representation of parts and the whole across scales in relation to the set of constraints implied by the different dimensions of analysis (referred to as the Sudoku effect). That is, it can integrate biophysical, economic, social, demographic and land-use analyses across different hierarchical levels and scales. This integration makes it possible to check the coherence of quantitative characterizations of scenarios across non-equivalent descriptive domains.

Since SUMMA (as LCA in general) is based on a single common inventory (LCI) of all the system's inputs and outputs, a systematic sensitivity analysis can be been simultaneously performed on all calculated data and indicators. In the present study we created in our spreadsheet-based calculation procedure a set of variable cells to which it is possible to assign percentage variations to all input quantities as well as to the values of associated characterization coefficients (intensity factors). Such a procedure is very valuable in order to estimate the actual reliability of the impact assessment itself, accounting for the inevitable uncertainties and variability in the input data and/or intensity factors, as well as to single out the most critical key points of the analyzed process, in the light of different assessment methods. One of the potential uses of the sensitivity analysis applied to the LCA/SUMMA approach is to provide suggestions for governance (to policy makers, managers, institutions) by highlighting different scenarios of the investigated systems as a consequence of policy actions. Changes calculated or foreseen for performance indicators only say what would happen to performances if input flows change for any reason. They do not say anything about the economic and social constraint in which the system operates, nor they systematically assess the reasons, the drivers of the occurred or foreseen performance drop or improvement. The time series related to the system's behaviour in the past or the series constructed based on assumptions (e.g. assuming that fuel efficiency improves by 2% every year) are then processed by the MUSIASEM approach (second step of the toolkit) in order to detect the social and economic constraints (e.g. how a given solution affects the individual income or the fraction of working population); then, time series of input flows and performance indicators are also processed by ASA, in order to decompose the performance into decomposition ratios, each indicating a driver of the change (e.g. labor intensity, energy productivity, etc). In so doing, after calculating past and future performances indicators according to a number of biophysical criteria and methods, the feasibility of solutions from an economic and social point of view is assessed (MUSIASEM) and the main drivers identified (namely, what these drivers were in the past and how should they be characterized in order to reach the planned performance in the future.

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[3] This is retrieved from the SMILE deliverables D3.

As a consequence of the sequential application of SUMMA, MUSIASEM and ASA (the DECOIN toolkit), policy making is provided with a series of performance indicators, their evolution over time, their improvement potential based on higher individual or technological efficiency, socio-economic constraints to planned actions and finally drivers of change based on decomposition analysis, interlinkages and synergies.

The DECOIN toolkit was designed and formulated to test and highlight the pros and cons of an innovative procedure capable of generating multi-scale indicators (embracing the three approaches of the toolkit). This procedure, when fully developed, should later on be used to tailor the representation of the sustainability predicament "a la carte" on the issue definition given by social actors.

In our consortium, one of our partners: UAB has generated for its case-study a questionnaire to gather the input of scientific stakeholders (people interested in the problem of how to generate sustainability analysis). This questionnaire had two objectives. The first objective was to gather the opinion of stakeholders on whether the outcome of the DECOIN Toolkit that contains the three methodologies ASA, SUMMA and MUSIASEM, represents a useful and interesting input for a discussion among stakeholders and social actors within the area of policy making. The second objective was to gather the opinion of stakeholders about the applicability, drawbacks and advantages of using the integrated assessment techniques such as that DECOIN toolkit to develop innovative analytical models within sustainability analysis. Although the results of the data and information retrieved from this questionnaire were based on the Catalonian case-study, which focuses on the energy security in Catalonia, the results are also very useful for our evaluation of the usefulness of the DECOIN toolkit in relation with the sustainability indicators.

The results are many but here we will summarize the ones related to the usefulness of the toolkit. Stakeholders participated in the questionnaires, underlined the importance of including scientific knowledge to the policy/decision-making processes in a comprehensive manner but without oversimplification and reductionism that ignores complex system functions. In other words, the output of the scientific knowledge must be understood by different stakeholders but the output must also include all the knowledge without missing one single outcome. This result highlights the essentiality of conducting integrated assessment and multi-criteria evaluations. The stakeholders have noted that to account for complexity and the interaction between different elements one has to take into account all different dimensions ranging from the political, to the economic and environmental. However, it is clear that multidisciplinary is challenging since at times it can miss in-depth analysis and result in erroneous decision making. Yet, it is also mentioned that choosing only one set of indicators within one discipline will also lead to an ill-representation of complex systems. It has been acknowledged that the use of integrated analyses can be seen as a tool to help support decision making. Specifically for the issue of energy, in Catalonia the importance of analyzing and planning the evolution of energy use has been highlighted especially for considering the perspectives and the implications of other variables such as demography, the weight of different economic sectors, and obviously lifestyles at the household level. Such an analysis is crucial to base energetic trends grounded in reality. Regarding the different spheres of analysis the economical dimension is seen as very important as it can result in budget restrictions (faced especially with the Crisis).

However, environmental policies are also important and should be in line with the social contexts as well, in order to be successful.

In conclusion, the result of the research of the Catalonian case-study suggest that the adoption of new tools capable of generating an integrated characterization across different levels and dimensions can provide an effective complementation to the conventional use of standard development indicators. The feed-back received indicates that the ability to develop quantitative characterization of performance (problem structuring and choice of indicators) is of particular importance. for the social actors that will be affected by the decision.

The application of the data has both positive and negative consequences. The toolkit requires quite extensive and qualitative precise databases. Most of the consequences are in relation with this characteristic of the toolkit. Above we count down some of the consequences of the application of the toolkit by our consortium.

Due to the main characteristics of the toolkit, the production of the first output - the draft of a relevant diagram- requires both expertise and time. This can be seen as one of the negative consequences. In addition, once the system diagrams were finalised, much of the data desired was not available and it had to be transformed, estimated or even generated artificially. The time spent on statistics compilation exceeded expectations. This shows that one of the most important factors about the usefulness of the toolkit must be definitely data related issues.

The results of the toolkit are as good as the quality of the input data. As mathematical calculation models they are most sensitive to shortcomings and misinterpretations of data. Because of the data dependency, the models are unable to discover new unsustainable trends. They are only able to identify trends within existing database. This must be kept in mind when assessing the usefulness of the models for stakeholders. On the basis of the cited negative consequence about the last output of the toolkit, the output and also the perception and expectation of the toolkit are very important to assess its usefulness.

In addition, apart from expertise to use these models also the translation of results needs deep expertise and background understanding of the sector you are analysing. Thus the toolkit is still very much a tool of environmental experts. Therefore, the knowledge of the users is again another important factor for our assessment.

Of course, the toolkit and its outputs do not have only negative consequences, there exist also positive ones. For instance, within the data constraints, the possibilities to analyse functioning and sustainability of human-economic activities with these models are numerous. Also, the results give interesting new insights to reasons behind unsustainable trends to stakeholders. These findings could be obtained also by deep expertise, but the toolkit eases and speeds the analysis greatly and thus it redeems expectations. Therefore, expectations and demand of the users are also among the important factors.

Besides the given factors to assess the usefulness of the toolkit, there are many others. We explain all of them within a toolkit pentagon model in the sub-section 6.3. But before this explanation, we first offer our approach and methodology in the following sub-section.

4   LINKING THE USEFULNESS OF THE TOOLS TO SUSTAINABLE FUTURES

4.1   Approach and Methodology

We will investigate the usefulness of the SMILE toolkit. To reach our aim, we present a 'usefulness method' that uses critical factors of sustainable development when determining the usefulness of the toolkit using an outranking method. It is basically an impact structure matrix, which reflects the impacts of policy measures (Nijkamp, 1983). During our evaluation, we employ the success and failure factors of the toolkit and the sustainability pentagon factors.

In general terms, our consortium SMILE addresses the interfaces between scientific achievements in sustainability analysis and the various user categories and interest groups that are either involved in sustainable development or that are interested or involved in the development of SMILE toolkit. To assess the usefulness of the toolkit, we conducted interviews among experts who somehow experienced the SMILE toolkit (see Appendix A.2 for the interview). Therefore, 11 experts from different case-studies participated in our research in March 2010. The collected data is processed in four steps by the use of the impact matrix methodology. These four steps are:

Step 1 - Definition: During this step, the critical factors of sustainable development and the critical factors related to the use of the toolkit are defined. These factors are used as the criteria to formulate the impact matrix.

Step 2 - Ranking: secondly we calculate the ranking of factors of sustainability and of the toolkit separately and ranked them without taking into account any causal relations.

Step 3 – Matrix: The third step is related to the formulation of the impact matrix. During this step, first we define the consistent relations between the factors of sustainable development and of the toolkit. Later, we score these relations and calculate their weights.

Step 4 - Assessment: The fourth and the last step is to evaluate our findings and to assess the usefulness of our toolkit.

4.2   Critical Factors of Analytical Tools

The critical factors of the sustainable development are given in the previous sections in details. Therefore, in this sub-section we will provide only the critical factors of the toolkit. In order to assess the usefulness of the toolkit, the five success and failure factors and their sub-factors are:
- Data Requirements: This factor refers to the data and resources needed for the application of the SMILE toolkit in order to obtain reliable assessments of the scientific output.
    - Reliability: The reliability of the data
    - Availability: The availability of reliable data
    - Access: Access to reliable data by the researchers/users
    - Generation: Possibilities for data generation when information is missing
    - Hidden data: The hidden data related to the informal economy etc.
- Output: This relates to the output provided as the result of the methods of the toolkit. Its sub-factors are:

- o Visual: This reflects to the visual output such as tables, graphs, diagrams, histograms and figures, etc.
        - o Numerical: This reflects to the output, such as scores, percentages, rankings etc.
- Support System: This factor refers to the contribution of administrative units to help and assist direct and indirect users of the toolkit and to increase their understanding of the toolkit.
        - o Perception: This refers to the perception of the supporting administrative units and their (initial) positive or negative thoughts about the toolkit.
        - o Experience: This refers to the contribution of administrative units to assist the users to experience the toolkit.
        - o Collaboration: This means the contribution of administrative units to ease the access to their data and to apply the results.
- Users: This factor refers to the direct and indirect users and their attitude towards the toolkit. Therefore, its decomposition is:
        - o Awareness: This refers to the awareness of possible users about the toolkit and the usefulness/benefits of the toolkit, the knowledge of possible users and their understanding of the toolkit.
        - o Demand: This refers to the existence of demand for the output/results of the toolkit by the users.
        - o Expectations: This deals with the expectations of users from the toolkit.
        - o Willingness: This is the willingness of users to understand and use the toolkit.
        - o Networks: This means the networks of users which will help to the spread of the toolkit.
- Technology: This factor refers to the technology of the toolkit itself and also to technologies required to use the toolkit. Its decomposition is:
        - o Software language: The language of the toolkit is very important to use the toolkit. The possible users may prefer to use the toolkit in their maternal language. Therefore, the language of the toolkit can have a critical role.
        - o Specifications: This refers to the technological needs and infrastructure required for the use of the toolkit.

In the following sub-section, we rank the critical factors of the toolkit and sustainable development while weightening each critical factor.

4.3   Application of the Impact Matrix

The impact matrix to assess the usefulness of the toolkit consists of critical factors as defined above. But, before constructing the impact matrix, first we calculate the ranking and scores of the factors of sustainable development and the toolkit separately from the perspective of scientific users of the toolkit. This calculation is the second step of our evaluation.

The results of the scoring and ranking process show that experts rank the sustainability systems as: ecological system, institutional system, social system, physical system and economic system respectively (Table 2).In addition, the ranking of the toolkit is output, data, users, support and technology respectively (Table 2). The scores change between 0 and 5 as we have collected data and they are calculated as the average of the total scores of all stakeholders.

Table 2 Scores and ranking of critical factors

Sustainability	Score	Weight	Ranking EW	W	Toolkit	Score	Weight	Ranking EW	W
Physical system	3.6	0.18	4	4	Data	4.0	0.38	2	2
Social system	3.6	0.18	3	3	Support	3.3	0.20	4	4
Economic system	3.2	0.07	5	5	Output	4.3	0.40	1	1
Ecological system	4.5	0.65	1	1	Users	3.5	0.20	3	3
Institutional system	3.9	0.20	2	2	Technology	3.0	0.10	5	5

In addition, we calculate an equally-weighted (EW) and weighted (W) scale based on the interviews. The critical nature of a factor depends on the criticality of its decomposition. This means the weights are the clarification of the criticality of factors compared with each other (Akgün et al., 2010). Therefore, the two types of weights allow us to better understand whether the defined factors are seen as robustly critical from the point of view of different experts. The results show that the rankings are very robust as both types of ranking are the same.

An impact matrix is a summary of the impacts of issues on each other in a tabular form. In our case, the columns represent the factors of the toolkit while the rows represent the sustainable development factors (Table 3). While constructing the impact matrix, we have two types of scores and weights. The first type of scores and weights is obtained from the interviews and is the one of the consistent causal relations between some of the sustainability and toolkit factors. These causal relations are shown with highlighted scores in In Table 14.

Table 3 The impact matrix of toolkit factors by sustainability factors

	Score				
	Data	Support	Output	Users	Technology
Physical system	3.55	3.40	3.90	2.95	2.90
Social system	3.70	3.75	3.95	3.75	3.20
Economic system	2.95	3.25	3.75	3.05	3.10
Ecological system	4.00	3.85	4.35	3.75	3.75
Institutional system	3.55	3.40	4.05	3.35	3.45
	Weight				
Physical system	0.13	0.19	0.29	0.02	0.05
Social system	0.15	0.10	0.29	0.16	0.10
Economic system	0.05	0.14	0.24	0.04	0.09
Ecological system	0.25	0.43	0.53	0.10	0.38
Institutional system	0.05	0.06	0.30	0.05	0.15

The causal relations are identified in relation to the toolkit and its requirements. Even, there are 272 cells for the potential causal relations between sustainability and toolkit sub-factors. Therefore, the consistent causal relations are only 55 of them. The meaningful causal relations are shown in Table

16. As can be seen from the table, not each sustainability sub-factors and toolkit sub-factors are represented in the consistent causal relations.

Table 4 The causal relations of sustainability and toolkit sub-factors

Sustainability	*Toolkit sub-factors*
Physical System	
Built-Environment	Reliability (Data); Demand(Users)
Technology	Reliability (Data); Demand(Users); Willingness(Users); Networks(Users); Software Language (Technology)
Infrastructure	Reliability (Data); Demand(Users); Willingness(Users); Networks(Users); Software Language (Technology)
Accessibility	Reliability (Data)
Social System	
Social Capital	Reliability (Data); Perception (Support); Awareness (Users); Demand(Users); Willingness(Users); Networks(Users); Software Language (Technology)
Openness	Reliability (Data); Perception (Support); Awareness (Users); Demand(Users); Willingness(Users); Networks(Users); Software Language (Technology)
Participation	Reliability (Data); Demand(Users); Willingness(Users); Networks(Users)
Awareness	Reliability (Data); Demand(Users)
Economic system	
Economic Diversity	Willingness(Users)
Uncertainty	Reliability (Data); Demand(Users); Willingness(Users); Networks(Users)
Ecological system	
Ecoquantity	Reliability (Data); Demand(Users)
Ecoimpact	Reliability (Data); Demand(Users)
Institutional system	
Governance	Reliability (Data); Perception (Support); Experience(Support); Collaboration(Support); Demand(Users)
Integration	Perception (Support); Experience(Support); Collaboration(Support); Demand(Users)
Continuity	Reliability (Data); Perception (Support); Experience(Support); Collaboration(Support)

The second type of scores and weights are calculated as the average of the crossed relation in the impact matrix (Table 3). At a first glance, even though we cannot show a consistent causal relation, our toolkit is very effective for sustainable development. As mentioned earlier, our toolkit is valid and very useful for environmental experts so we see this also in our assessment that the highest contribution in terms of data reliability and the user demand of the toolkit is to the ecological systems.

Therefore, we can state that the SMILE toolkit has an indirect positive effect on sustainable development. Below we offer the assessment of the usefulness of our toolkit for sustainable development. To understand better the assessment of the impact matrix and the impact of the toolkit on the sustainable development, we have drawn two types of figures for the equally weighted and weighted scores. The first type of figures (a) shows any relation in the impact matrix and the second type (b) shows only the consistent causal relations.

According to the equally weighted scores shown in Figure 18, we can easily see that the causal relations are very effective for each component of the sustainable development. All toolkit factors

have an impact on first the ecological system. The main contribution and usefulness of the toolkit is to the ecological systems. The changes in ecological systems are difficult to investigate and to predict. In addition, among the toolkit factors, users and data contribute to the economic system. However, the contribution of the toolkit to the economic system is smaller than its contribution to the other sustainability factors.
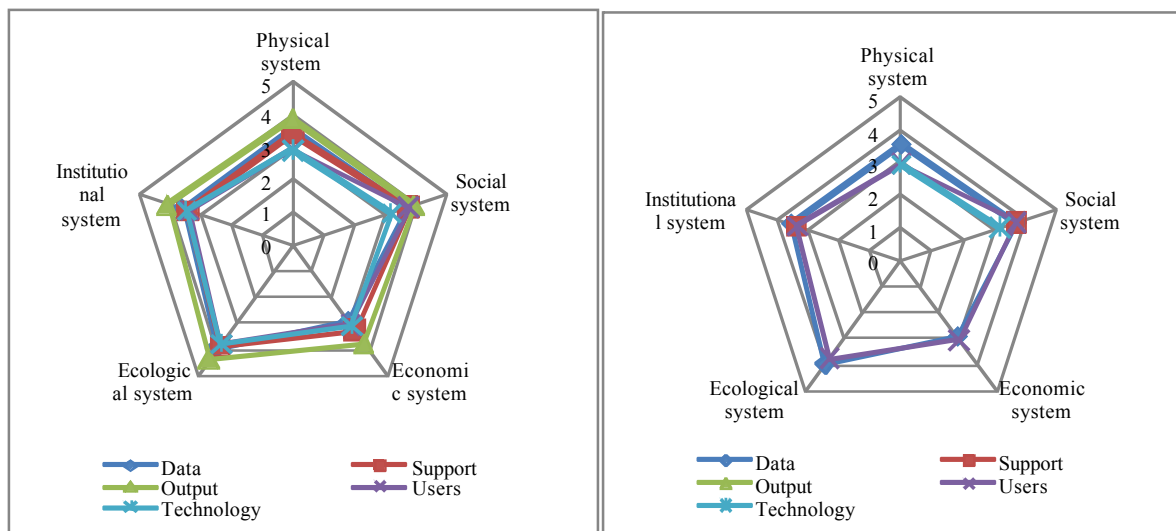

Figure 1 Assessment of the impact matrix - Equally weighted scores a) all relations; b) consistent relations

In order to test the robustness of our impact matrix, we also evaluated the impact matrix with the weighted factors (Figure 19 a, b). The results of the impact matrix by weighted scores show that our analysis is robust as the ranking of the sustainability factors by the toolkit remains the same in terms of consistent causal relations. In other words, the main contribution of the toolkit is on the ecological system which is followed by social systems. In addition, our analysis is sensitive in terms of its contribution to the economic system. The causal relation of economic system with support which is not a consistent relation and the relation of economic system with users which is a consistent relation is not anymore the least impact but take a higher position.
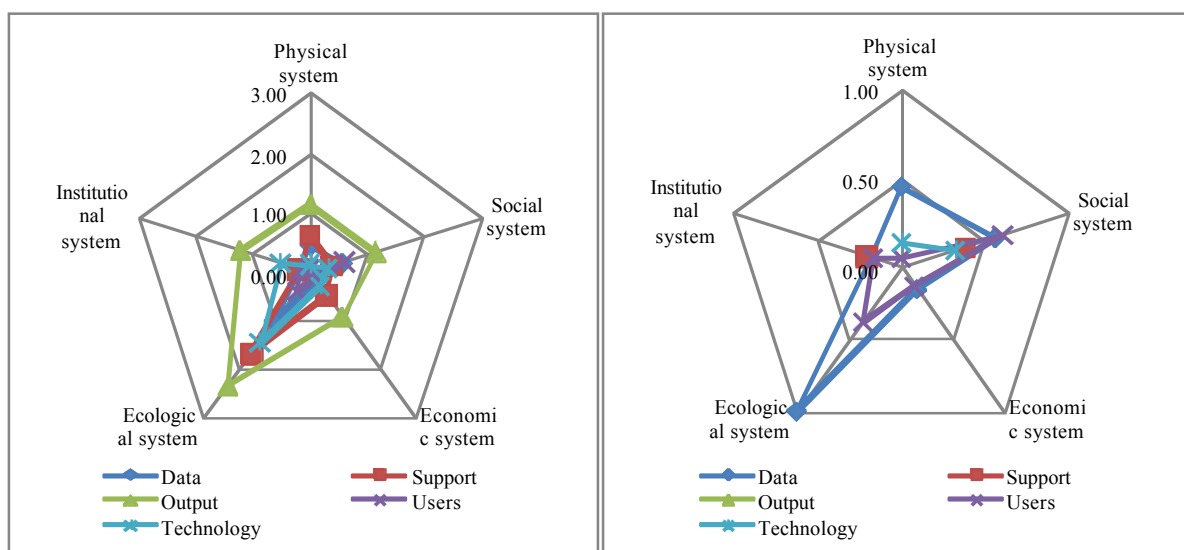

Figure 2 Assessment of the impact matrix – Weighted scores a) all relations; b) consistent relations

The results show that the contribution of the toolkit to insights in sustainable development and policy implications is obviously important in terms of non-economic issues. Moreover, the results also demonstrate that the impact of the toolkit on the economic system depends on the users and the way to use the toolkit.

Both the toolkit and the results of the toolkit impact matrix have proved the usefulness of the toolkit to obtain insights for sustainable development. Although the toolkit is successful, According to our results, more improvement is needed to spread the usage of the toolkit to a wider group of users.

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