18th World IMACS / MODSIM Congress, Cairns, Australia 13-17 July 2009
http://mssanz.org.au/modsim09

# The requirements analysis for the Meta-Model Sustainability Impact Assessment Tools (SIAT) to ensure a high use and acceptability among policy decision makers – A critical review

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**Abstract:** This paper conducts in the frame of the model development Sustainability Impact Assessment Tool (SIAT) a critical analysis at science-policy interface. The analysis emphasises the methods and the process of end-user involvement that aimed at surveying model requirements. We reveal potential problems of institutional embedding of the decision support system SIAT and give recommendations to avoid shortcomings while developing the model design.

The meta-model SIAT is the central tool of the European research project SENSOR, which has been developed in the period from 2005 to 2009. First, we illustrate the methodology of the SIAT that is tailored to simulate land use policies. SIAT allows conducting ex-ante sustainability impact assessment towards the target year 2025 at the level of 570 European regions.

Then, the critical analysis at the policy-science interface discusses the procedure of the SIAT development process and reveals the mean of prototyping as basis for the requirement analysis. We summarise the major problems we faced at intuitional level that influenced the quality of the requirement analysis. Finally we conclude on the institutional reasons for asymmetric information that the discontinuous and inhomogeneous environment of our target institution (i) hinders efficient stakeholder involvement and (ii) causes shortcoming to mirror precise end-user requirements in the architectural model design. Quantifying end-user utilities on realistic needs is not precisely applicable due to (a) high opportunity costs to survey and harmonise individual requirements, (b) uncertain forecasts on costs estimates, (c) asymmetric information related to high transactions costs for communication and strategic behaviour of policy makers, researcher and IT developer, (d) requested but unfeasible technical implementation possibilities, (e) predefined and thus limited ‘room of manoeuvre’ and constraints laid down in research proposals and resulting contracts.

We conclude on experience-based potential shortcoming in the project design and during the model development process and give final recommendations on a potential strategy to avoid them.

## 1 Introduction

The European Union funded Integrated Project SENSOR develops ex-ante Sustainability Impact Assessment Tools (SIAT) to support decision making on policies related to multifunctional land use in European regions (Helming et al. 2008). The meta-modelling approach SIAT is the central product of the SENSOR project, which innovates sustainability impact assessment towards an integrated perspective of region-explicit economic, environmental and social trade-off impact analysis.

There is a need for methods and tools aligned to user needs and therefore the links at the science-policy interface are sensitive (McIntosh et al., 2008, Norse and Tschirley, 2000). To ensure acceptability and usability among decision makers, the development of the model design is fundamental process to incorporate user requirements (McIntosh et al., 2005). Gaps between the user requirements and the utility of integrated modelling tools are usually apparent and hinder the acceptability of decision makers (McCown, 2002, Reeve and Petch, 1999). Numerous interactions with potential users, researcher, as well as software engineers evolved the design of the SIAT according to *functional requirement analyses* (Stellman and Greene, 2005).

The objective of the paper is to (a) present briefly the analytical focus of SIAT, to (b) summarise the procedures and applied methods of the SIAT development process, and to (c) conduct a critical analysis at the science-policy interface in the context of its institutional implications. We focus on prototyping as a mean to survey end-use requirements in group discussions. For this purpose, we define in chapter 2 the terminology and the approach of the SIAT meta-model. Chapter 3 describes in a critical analysis specific linkages between IT developers and potential end-users. Institutional implications on the model design and the procedure of the development process as well as the applied requirement analysis will be outlined. We conclude in chapter 4 on the institutional implications for designing the SIAT.

## 2 Terminology and Model Definition of SIAT

The core concept of the Sustainability Impact Assessment Tools (SIAT) is the use of meta-modelling techniques. In this regard we first define the terminology to classify the model with regard to the analytical scope of SIAT. Subsequent the major model features will be summarised.

*Impact assessment (IA)* helps to structure the process of policy making that identifies the main options for achieving the objective and analyses most likely impacts, values the options and reveal potential synergies and trade-offs (EC 2002b). *Integrated impact assessment (IIA)* often focus on predicting policies to measure either the impacts of direct policies or the effects of pressures or states (e.g. effects of pollution) by means of a more holistic, overarching approach. As defined in the EU policy context, it identifies social, environmental and economic impacts (EC 2002a). IIA is often used in the context of the obligatory process to conduct IA at EU-level before implementing intended policies (Thiel 2009, in press), which is laid down in the Communication COM 2002/276 on Impact Assessment (EC 2002b).

*Integrated modelling* is often defined as either linking models towards an generic integrated framework to allow flexible (re-)use and linkage of components (Van Ittersum et al. 2008) or an integrated (external) model framework that generate results on specific policy cases (e.g. Common Agricultural Reform). These processed results can be implemented in a component-based meta-model to conduct sustainability impact assessments (Helming et al. 2008, Sieber et al. 2008). Furthermore, *integrated modelling approaches* are also often utilised in terms of integrating interdisciplinary thematic scopes (Wei et al. 2009).

In very general terms, *metadata modelling* supports the analysis and construction of models applicable. A meta-model provides a framework that can be seen as a model of model results (OECD 2004). In literature the simple *meta-modelling* in the field of environment and agriculture often concerns specific issues and uses targeted model applications, e.g. on topics of nitrogen or watershed management (for example Piñeros Garcet 2006, Barton et al. 2008). Definitions of metadata often describe them as data about other data, which are used in modelling frames (LCNS 2003).

Under the above three described dimensions, the SIAT uses techniques of *integrated meta-modelling* in the field of *sustainability* that combines economic, environmental and social dimensions. SIAT has been built for *integrated impact assessments (IA)*, which strongly focus on impacts of *land-use policies* with special focus on trade-offs at cross-sectoral level between the sustainability dimensions (Sieber et al. 2008). IA by SIAT is tailored to provide its services at EU decision making level in a broader view of ‘quick scan analysis’; at the level of Directives General (DG), Joint Researcher Centres (JRC) and related research fields of consultancies and national institutes as EU-contractors.

SIAT focuses on simulating land use policies ex-ante to the year 2025 at a regional scale of 570 NUTS2/3 regions (European administrative boundaries). Its approximately 100 indicators implicitly synthesise the agriculture sector and from it related sectors of forestry, tourism, nature conservation, energy and transport (Sieber et al. 2008). The purpose of SIAT targets regionalised trade-off analysis between the sustainability indicators, the valuation by critical limits to build sustainability decision choice spaces. These can be applied at single indicator level or as (aggregated) indicator indices. Latter we call Land Use Functions (LUF) to indicate the provision of ‘good and services’ at regional level (Perez-Soba et al. 2008).

By means of the Graphical User Interface (GUI) end-users are able to preselect free combinations of policy variables (e.g. subsidy) and to choose policy intensities (e.g. Million Euro) to be simulated by using pre-calculated response functions from a model framework (Jansson et al. 2008). The GUI allows to simulate a policy scenario in the following way: Step (1) computes the macroeconomic reference scenario values of the impact indicators for the target year. Variations of the reference scenario are expressed in 'business as usual', 'high-growth' and 'low-growth'. They vary in terms of no change, positive and negative anticipated trends of the incorporated land use drivers: Oil Price, Expenditures for Research and Development, Labor Force, Demographic Changes and World Economic Demand. Step (2) identifies the policy case (thematic area) to be simulated. Each policy case contains sets of policy instruments (variables). Within each case the user can select, combine and change different policy instruments as well as its intensities. Step (3) illustrates the computed scenario results of impact indicators as consequence of the policy settings. Results are presented in interactive maps, tables and graphs. Photorealistic visualizations support impressions on changes within landscape views at a scale of 5x5 km. Map layer (Google data) superimpose additional geographical information for specific analysis. Step (4) evaluates impacts according to sustainability criteria that are expressed in critical limits (thresholds, targets). This valuation defines an allowable sustainability choice space, which is based on region-specific tolerance limits per indicator. Step (5) aggregates groups of indicators to Land Use Functions (LUF) that indicate as indices the level of goods and services at regional level. Nine LUFs have been defined: 'Provision of work', 'Human health and recreation', 'Cultural landscape identity', 'Residential and non-land based industries and services', 'Land based production and Infrastructure', 'Provision of abiotic resources', 'Support and provision of habitat' and 'Maintenance of ecosystem processes' (Perez-Soba et al. 2008).

Table 1 summarises the major characteristics of SIAT according to the simulation sequence of methodological components (a) policy cases, (b) impact analysis and (c) sustainability valuation.

| | **Policy cases** | **Impacts** | **Sustainability Valuation** |
|---|---|---|---|
| **Scope of Impact Assessment** | Land use policies related to the Common Agricultural Policy incl. biodiversity aspects and Bioenergy policies (extendable) | Multifunctional agriculture on land use and 45 social, economic and environmental indicators with 55 class sub-divisions | Sustainability valuation on 9 Land Use Functions (LUF) as indication on Goods & Services at spatial-explicit level of rural regions |
| **Level of comparison** | Effects of *current, EU-wide evenly applied policies* and emerging future proposals | *Ex-ante scenario assessment* on single indicators against the 'reference run' | *Ex-ante valuation* on nine Land Use Functions (LUF), e.g. provision work etc. |
| **Time scale** | Base year in a range of 2004-2006 | Comparative static, target year 2025 | Comparative static, target year of 2025 |
| **Spatial scale(s)** | Generally EU-wide applied policies | NUTSX (2/3), NUTS 1, NUTS 0 | NUTSX (2/3) |
| **Sector coverage** | Policies at mostly sector level (e.g. CAP) with additional macroeconomic extensions (e.g. R&D for technical progress) | 6 sectors agriculture, forestry, tourism, energy, transport and nature conservation within macroeconomic frame | Accumulated normalised sector contributions of all sectors within macroeconomic consistency frame |
| **Transparency, Traceability** | Interface fact sheets with policy definitions | Back-tracing function on calculations (application) | Back-tracing functions on calculations (application) |
| **Level Institutional embedment** | Stakeholder involvements: *qualitative interviews* and *group discussions* | Institutional involvement only to minor extent *Expert knowledge* of indicator experts | *No: Expert knowledge* (researcher) of LUF experts |
| **Technical performance** | Graphical User Interface, pre-calculations triggered though policy settings | Calculation: *Short model response time* through response protocols | Calculation: *Short model response time* (indicator aggregation and weighing) |

Table 1: The scope of analysis and the model features of SIAT (Sieber 2009)

## 3 Critical Analysis at the Policy-Science Interface

In the previous chapter we defined the terminology used in the context of IA and then we described the SIAT meta-modelling approach. The institutional implications at the policy-science interface influence the process between model design and use (McIntosh et al. 2008, Thiel 2009, in press, Gerlach and Kuo 1991, Sanders and Courtney 1985). Considering institutional structures seem to be indispensable requisite to successfully conduct requirement analysis (Santhanam et al. 2000). The institutional implications should be carefully taken into account, when requirement analysis for model design is conducted. Among numerous proposed techniques for requirement analysis in literature 'stakeholder involvement' and model evolvement by 'prototyping' are suggested in manifold variations (Young 2001, Sommerville 2006, Wiegers 2003, Guida et al. 1999). The methods we have applied to survey end-user requirements will be discussed with regard to our institutional environment at EC level. In this chapter, we finally try to conclude on the problems we faced during the SIAT development process.

## 3.1 Procedure of the Requirement Analysis

From the experience with SIAT a number of guidelines can be drawn as highly relevant for the project process of meeting a required model design. The SIAT design process considered the following steps and actions during the development, which we considered as actual undertaken measures.

(1) *Reviewing and benchmarking gathered knowledge of similar projects*: Based on the existing in-house knowledge a critical review and benchmark of existing model approaches is essential. With regard to similar projects existing knowledge could be used with regard to the conceptual model design. There might exist in-house synergies to be used at the level of software architecture and components. Re-using of existing model components is most effective to avoid redundancies as costs of software development are often underestimated. In this regard simulation procedures, calculation techniques, visualization components as well as already established relations to sub-contractors in tendency capacities shared among projects. The overall effect of these measures to reduce costs can be considerable to levelling the problem of underestimated costs in project proposals.

(2) *Adjustment of basic requirements:* Based on the Documentation of Work (DOW) basic requirements with reference to analytical objectives and technical specifications have been surveyed. The DOW description was unspecific enough to have a certain degree of freedom for 'own' specifications in terms of designing the model SIAT, but the analytical objective was clearly defined. Further surveys at the level of the contracting body (EU Commission) created a common project understanding and priority setting of objectives. Thus, indispensable is a close contact to the responsible commissioner's view. Once, basic requirements and a priority setting were available, both have to be translated into a first prototype.

(3) *Develop a simplistic Prototype:* Initial problems to communicate the analytical scope and features of the model approach was the reason to develop a first prototype. Based on both previous processes above, the modelling group met for a one-week hands-on exercise on prototyping. The group was composed of researcher with different background from software engineers, landscape planners to agricultural engineers. Subcontracted graphic artists delivered on-demand design elements. The result was a fully functional, but simplistic SIAT prototype that contained (a) a user interface, (b) a topic-structure for content management (c) a model application for one exemplary policy simulation and (d) visualization mapping component. This SIAT version was evident key for an improved communication on the model design and functionality. The gathered feedback by structured user involvements in group discussions served as input for prototype II.

(4) *Group discussions with end users:* Group discussions based on SIAT prototype I aimed at gathering end user requirements in a structured way. Preferably a mixed group of software engineers, researcher and policy experts as potential end users have been involved. The workshops showed the importance of establishing key contacts with potential end users. The modelling group faced the major problem to establish a continuous group over time that allows iterative feedbacks. Main reasons for this were strategic behaviour, expressed shortage of time and a high fluctuation of positions among key stakeholders within institutions. Deliberate discussion guidelines intended to focus on general expectations on the functionality ("What should the model perform to make it useful?") and specific requirements to cover a preferable broad thematic area of application among all potential end users ("What do you need additionally for your specific scope of work?"). Our experience was at policy level a rather mutual general learning on IA processes than receiving detailed requests on model features.

(5) *Targeted input of experts:* Along with group discussions, single interviews with end users and specific experts (e.g. interaction model design) steered the fine tuning of the SIAT design. This additional technique is a valuable technique, since sincere options and expert judgments are only

expressed in bilateral discussions. In contrast group discussion may lead to strategic behaviour on expressed end user requirements. A specific group within SENSOR conducted end-user analysis and surveyed expectations in bilateral interviews. Apart from numerous internal expert interviews external surveys are being conducted and results will be expected by midyear 2008. Major problem is the availability and preparedness of policy maker that result often in interviews with researcher at the science-policy interface.

(6) *Final negotiation with regard to given capacities:* Given specifications and definite further requirements based on demonstrated prototypes need final decisions on ultimate changes. This last step included negotiation with regard to given capacities, cost estimations on realistic possibilities. Approaching the final project deadline means often discarding open unachievable tasks.

To reveal the difficulties the model developers faced, we would like to concentrate on the number (4) of group discussions. Central focus in group discussions was the developed prototype of SIAT (see number 3), which was the mean to survey the end-use requirements. The problem of approaching adequate end-users can be defined by mainly two characteristics of user groups. The first group is composed of scientists, who work at the science-policy interface, but are not directly involved in policy decision processes. They might be helpful as catalysers, if they have direct contacts to policy makers. The second group are decision makers, who tend be involved in day-to-day policy making, have very limited time capacities for model-related stakeholder involvements. Both groups have been involved in the group discussions, but the groups were generally composed with higher shares of researcher.

In all 33 interactions with user-groups have been conducted. The group size differed in average from 5 to maximal 30 people. SIAT presentations at scientific conferences, cross-institutional workshops were organised at the following levels:

(a) DG Research / EU Commission 2005 [kick-off meeting on expectations],

(b) IES / Joint Research Institute 2006 [stakeholder meeting on conceptual design],

(c) Directorates- General & EU Parliament 2006 [Stakeholder meeting with SEAMLESS FP6-project]

(d) SENSOR / Research institutes 2006-2008 [various internal discussion on conceptual design]

(e) SENSOR Peer-group meeting 2008 [feedback and advice on SIAT prototype]

(f) IPTS / Joint Research Institute 2008 [scientific discussion and feedback]

(g) DG Research (EU Commission).

Based on our experience in the above mentioned group discussions we can draw following conclusions in terms of stakeholder involvements of policy decision makers as potential end-users at institutional level:

- We faced the major problem that the institutional environment and related end-user groups were at the beginning of the project widely unknown. In tendency, the needed time to approach, convince and establish end-user (groups) have been underestimated.
- The transaction costs to analyse the target institution were at the level of IT-development not included. This resulted in capacity shifts on cost of the budget for software development.
- Due to these hidden costs the involvement of preferable representative potential end-user groups is a major weakness to successfully embed models in institutions for actual decision making.
- The usefulness of the type of potential end-users differs. Often researcher at the science-policy level has been gained. They can be key for success for institutional embedding, provided that they are well positioned in the direct environment of policy decision making (e.g. Joint Research Institutes of the European Commission). Contrary, scientists gave often complementary support with regard to academic research questions.

## 4 Conclusions

SIAT allows for simulating land-use policies to conduct Sustainability Impact Assessments. SIAT was developed by means of the applied methods of 'software prototyping' to survey end-user requirements in group discussions. A number of lessons learnt with regard to difficulties to establish end-user groups and to survey necessary information can be summarised as follows:

*Uncertainties and asymmetric information*

The model design should ideally mirror reasonable end user requirements. Discrepancies between surveyed requirements, model design and use of models for integrated impact assessments imply different fields of uncertainties that hinder applying model requirement analyses in practice:

The organisational structure of institutions is often complex and not visible for researcher. The structure influences information needs and the role of the interviewed person imply a high risk and often do not reflect representative institutional thinking. This leads to the conclusion to work at the level of established *representative* end-user groups. Quantifying utility level on realistic needs is not precisely applicable due to (a) high opportunity costs to survey and harmonise individual requirements, (b) uncertain forecasts on costs estimates, (c) asymmetric information related to high transactions costs for communication and strategic behaviour of policy makers, researcher and IT developer, (d) requested but unfeasible technical implementation possibilities, (e) predefined and thus limited 'room of manoeuvre' and constraints laid down in research proposals and resulting contracts. The reality always differs from theoretical optimum, although actual decisions on model design should follow ideal principles as much as the information is available.

*Recommendations*

Conducting user involvements in the institutional context should at least minimise the risks for non-realistic end-user requirements. For this, we recommend to shift capacities towards endeavours to establish few *representative* end users-groups earliest possible. The personal and close contact to policy decision makers seems to be key for success; especially for convincing on the usefulness of the model approach. Scientific officers close to the policy-science interface should be additionally involved, as they can establish contacts in the field of policy decision making. Continuity of the iterative process development and offering applications for direct use seems to be equal important. Special attention should be given to the responsibility assignments within the IT developer group in terms of the organisational group structure. Potentials for efficiency enhancement on reduction of transactions costs and transparency endeavours to make hidden costs transparent should be used from earliest possible.

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