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Empirical guidelines for forest management decision support systems based on the past experiences of the expert's community

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Abstract

Aim of the study: Decision support systems for forest management (FMDSS) have been developed world wide to account for a broad range of forest ecosystems, management goals and organizational frameworks (*e.g.* the wiki page of the FORSYS project reports 62 existing FMDSSs from 23 countries). The need to enhance the collaboration among this diverse community of developers and users fostered the rise of new group communication processes that could capture useful knowledge from past experiences in order to efficiently provide it to new FMDSS development efforts.

Material and methods: This paper presents and tests an exploratory process aiming to identify the empirical guidelines assisting developers and users of FMDSS. This process encompasses a Delphi survey built upon the consolidation of the lessons-learned statements that summarize the past experiences of the experts involved in the FORSYS project. The experts come from 34 countries and have diverse interests, ranging from forest planners, IT developers, social scientists studying participatory planning, and researchers with interests in knowledge management and in quantitative models for forest planning.

Main results: The proposed 37 empirical guidelines that group 102 lessons-learned cover a broad range of issues including the DSS development cycle, involvement of the stakeholders, methods, models and knowledge-based techniques in use.

Research highlights: These results may be used for improving new FMDSS development processes, teaching and training and further suggest new features of FMDSS and future research topics. Furthermore, the guidelines may constitute a knowledge repository that may be continuously improved by a community of practice.

Key words: forest management; guidelines; guidelines definition process; lessons learned; decision support systems; system architecture; knowledge management; participatory planning; Delphi.

Introduction

Forests serve a multitude of functions, including the provision of timber and non-timber forest products, clean water, carbon storage, recreation, and biodiversity. Major European policy initiatives, such as the Ministerial Conference on the Protection of Forests in Europe (http://www.foresteurope.org) and EU Strategic Research Agenda for the Forest-Based Sector (EU 2010) are being implemented to support multifunctional forest management. Addressing these diverse goals to satisfy the needs of forest owners, the forest industry, and society poses a considerable challenge

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for forest managers. A number of computer-based systems that help analyse and display forest data have been developed to help managers with the complexity of forest planning (*e.g.* Reynolds *et al.,* 2008). Yet, the need for coordination in the development and application of the forest management decision support systems (FMDSS) motivated the establishment of the European network for forest decision support (FORSYS) as a project of EU-COST. The researchers and users of the FORSYS community focus on organizing and sharing the knowledge on FMDSS in Europe. For that purpose, a FORSYS Semantic Wiki Web was built and currently describes 62 existing FMDSSs from 23 countries. The emphasis is on the architecture of these systems, the models & methods used to support decision-making, the knowledge management tools and participatory processes adopted by the stakeholders engaged on forest management. The FORSYS community further aims at defining guidelines for future work on FMDSS. The FORSYS guidelines are statements or other indications of policy or procedure, aiming to assist developers and users on appropriate courses of action for the successful development of FMDSS.

This article reports the initial efforts towards the development of guidelines for FMDSS. The definition and use of guidelines are uncommon in the field of natural resource management. Nevertheless, guidelines have been successfully used to assist practitioners in information systems design, medicine and health care services. The Programming Style Guidelines firstly proposed by Kernighan and Plauger (1978) and the Human Interface Guidelines (*e.g.* GNOME, 2012; Android, 2012) are examples of recommendations or best-practices used by systems developers to enhance the intuitiveness, consistency and maintainability of the source code and the application interfaces, respectively. The practice guidelines aim to assist the practitioners and patients decisions on a wide variety of topics (*e.g.* health promotion, screening, diagnosis) and may further play an important role in health policy formation (Grilli e*t al.,* 2000; Woolf *et al.,* 1999).

The guidelines and the instructions about guidelines utilization are often freely available at dedicated web portals (*e.g.* G-I-N, 2012; SIGN, 2012). However, the process used to define the guidelines is often undocumented, loosely structured and specific of each working domain. It may rely on consensus among experts during periodic meetings that take place in the course of large-scale collaborative projects (often in information systems). Or, guidelines may be the outcome of individual initiatives from a large number of experts that combine the literature review with their working experience (often in medicine and health care). In the latter, appropriate rating methods are implemented and used by a broader community of experts that are asked to assess the validity and reliability of the proposed practice guidelines. The AGREE II (Agree, 2009) is an example of such on-line rating tools in use to assess the quality of the practice guidelines.

Newly group communication processes for defining guidelines may be key for assuring the consistency and validity of the arising empirical guidelines. These processes may rely on techniques for capturing tacit knowledge and past experiences of a community of experts as the basis for the guidelines identification.

The most common approaches used in the field of forest management to structure and share knowledge based on experience include case studies, literature reviews and surveys. In particular, case studies are widely used for synthesizing past experiences in the field of information systems. The term does not refer to a single process or method, but rather the application of a variety of methods (personal experience, interviews, document research, etc.) to one or more particular instances of a phenomenon, such as an organization, event, or initiative (Yin, 2003). In relation to FMDSS, the case is typically the use of a system to address specific forest planning problems. Most of the FMDSS literature focuses on the system architecture and/or novel models and methods developed for a forest management problem and often include hypothetical cases designed to illustrate functionality (*e.g.* Pretzsch *et al.,* 2006). Few real-world situations have been reported. Such case studies have the advantage of enabling detailed understanding of both the tools and the context in which they are applied. On the other hand, this focus tends to make case studies idiosyncratic. The definition of broader case studies (*e.g.* Bailey, 1986; Barber and Rodman, 1990; Cortner and Schweitzer, 1983; Iverson and Alston, 1986; Johnson, 1987; Kent *et al.,* 1991) or the comparison among multiple case studies (Gordon, 2006; Johnson *et al*., 2007) may provide valuable information for establishing common architecture features and general development processes for FMDSS adequate to specific forest planning problems. Yet, this method often fails to capture the tacit knowledge of the experts engaged in the development processes as well as their experiences in unsuccessful developments.

The few literature reviews in this field of study include single journal articles (Mendoza and Vanclay, 2008), chapters in larger works addressing DSS in general (Reynolds *et al.*, 2008) and ecosystem management in particular (Oliver and Twery, 2000; Rauscher, 1999; Reynolds *et al.*, 2000). More recent themes around which reviews have been structured include sustainable forestry (Rauscher *et al.*, 2006; Reynolds, 2005; Shao and Reynolds, 2006), simulation models (Landsberg, 2003; Mäkelä *et al.*, 2000; Muys *et al.*, 2010; Pretzsch *et al.*, 2008) and the use of multi-criteria decision analysis approaches (Díaz-Balteiro and Romero, 2008). These reviews provide easy information access and have a broad coverage of a topic area. They may compare existing FMDSS, discuss common features and highlight gaps between existing systems and theoretical user needs. However, this method relies exclusively on formal literature. This is a disadvantage especially in an applied field such as FMDSS, where much of the experience may not be documented in this academic fashion. Additionally, in this synthesized form, it can be difficult to tell source and quality of the information in the individual studies included. The uncoordinated nature of included studies means coverage of subtopics and their consistency are likely to be uneven. In all of the above-mentioned reviews, except one (Díaz-Balteiro and Romero, 2008), the selection process is undocumented (assumed to be the personal knowledge of the authors). These reviews also vary in terms of attention to identifying specific guidelines for future FMDSS developments *versus* simply summarizing existing research.

The surveys published in this field mainly focus on the inventory of the existing FMDSS (Johnson *et al.*, 2007; Lee *et al.*, 2003; Mowrer, 1997; Schuster *et al.*, 1993). These studies have drawn their lessons from a comparison of the capabilities of existing systems to a synthesis of needs based on theoretical definitions of the problem from the literature. They fail to capture tacit knowledge from the experts' community.

Fürst *et al.* (2010) is the only example of a survey-type approach with emphasis on the capturing tacit requirements from the potential users. In two workshops, they used a mind-mapping technique and a Delphi survey to attain future application areas for forest management support tools and users' requirements or desirable system properties, respectively. Nonetheless, no guidelines were drawn from this process.

Other exploratory studies have been using the Delphi survey technique to capture tacit knowledge and attain consensus from a group of experts when limited evidence exists on the specific topic in question (*e.g.* Okoli and Pawlowski, 2004). Nevo and Chan (2007) provide a recent example with similar objectives to our own; they synthesized success factors in the design and application of knowledge management systems. Jaana *et al.* (2011) also used the Delphi technique to develop a consensual list of key information and technology issues faced by the directors of public hospitals.

These studies suggest that the Delphi survey approaches may be adequate to capture unpublished experiences that would be omitted in a literature review and to cover these experiences in a broader, more synthesized fashion than possible with case studies.

This article extends the work of Fürst *et al.* (2010) and applies a new modified Delphi survey to approach the lessons-learned by the FORSYS community from both successful and failure practices.

Material and methods

The process of guidelines definition was based on a new modified Delphi survey that captured empirical evidence of the FORSYS experts. In general terms, the Delphi technique relies on repeated responses of questionnaires and controlled feedback to obtain consensus from a group of experts. It generally involves relatively small groups of experts asked to anonymously provide written answers to a set of questions over two or more rounds, with the opportunity to revise their answers based on the input of others. It is assumed that Delphi technique takes advantage of the power of groups to make better decisions than individuals on average (Okoli and Pawlowski, 2004).

There are a lot of variations of the original Delphi technique (Brown, 1968), but in general the variations of Delphi methods can be summarised as requiring (Okoli and Pawlowski, 2004): a) some feedback of individual contributions of information and knowledge; b) some assessment of the group judgment or views; c) some opportunity for individuals to revise views and; d) some degree of anonymity for the individual responses. This research extended one of the earliest definitions of expertness in the Delphi studies (Brown, 1968), which addressed the status among the peers, number of years of professional experience, or the combination of objective indicators of expertness and a priori judgement factors. This study further considered the nature of experts' knowledge and its complexity, defining the expert as someone who has either explicit or tacit knowledge about a specific domain of FMDSS development or use. As a consequence, the empirical guidelines evolved from the experience-based knowledge of panellists, who communicated their lessons-learned within the Delphi framework rather than separated their normative knowledge from the tacit knowledge. In addition, the developer perspective was not separated from the user perspective.

As the Delphi method relies on group dynamics for arriving at consensus rather than statistical power, a panel of 10-18 experts has been seen as sufficient number of respondents (Okoli and Pawlowski, 2004).

The proposed process for guidelines definition encompassed two rounds (Fig. 1).

The first exploratory round aimed to capture the experts' past experiences synthesized as lessons-learned, while the second aimed to rank and cluster them into the empirical guidelines. Both rounds were coordinated by the guideline development group, composed by the experts that represented the several FORSYS Work Groups, including DSS Architecture (WG1), Models and Methods (WG2), Knowledge Management (WG3) and Participatory Processes (WG4). The panellists were further classified into 4 main profiles. The academics primarily focused on lecturing, the researchers within a university framework, the developers engaged in DSS developments for commercial purposes and the government scientists working on governmental institutions.

First round of the Delphi survey

The first round of the Delphi survey involved the international panel of experts participating in the FORSYS workshop held in Thessaloniki in the 6th of May 2011. The panel consisted of 29 experts from 18 nationalities and various domains of FMDSS application and types of organizations (Table 1). The percentage of panellists interested on Methods and Models and Knowledge Management techniques resembled the percentage of members of the WG2 and WG3 (around 35% and 20% respectively). Yet, the percentage of panellists interested on DSS Architecture and Design was bigger than the percentage of members of WG1 (31% against 18%). The percentage of panellists from the Participatory Planning working group (WG4) was lower than the percentage of members of WG4 (around 10% against 20%).

This first round of the Delphi survey had 3 main phases (Fig. 1). During the first phase, the panellists were asked to brainstorm on their personal experiences with the development and use of FMDSS. For this purpose, the panellists were firstly asked to frame both their successful and failure practices into five major domains of DSS Development and Use, namely DSS

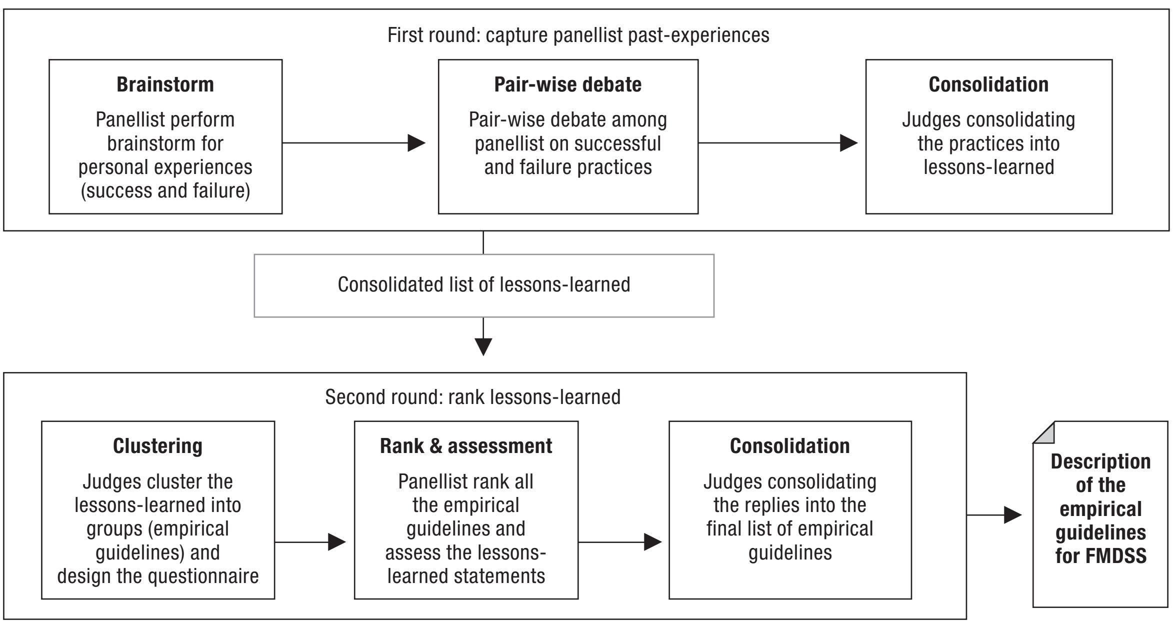

Figure 1. Empirical guidelines definition process, based on a modification of the Delphi survey technique.

Table 1. Panellists' domains, affiliations and nationalities for Delphi rounds 1 and 2 (codes for the representation of names of countries in the parenthesis are taken from ISO 3166 standard)

Panellists' domain	Academics		Researchers		Developers		Government scientists		Total	
	1st round	2nd round	1st round	2nd round	1st round	2nd round	1st round	2nd round	1st round	2nd round
DSS Architecture & Design	1 (BR), 1 (GR), 1 (MA), 1 (BE), 1 (IE), 1 (PT), 1 (SE)	1 (GR), 1 (IE), 1 (CH)	1 (FI)	1 (GR), 1 (PT)	1 (FI)	1 (FI), 1 (BR)*		1 (NZ)*	9	8
Methods & Models of the Model Base	3 (PT), 1 (ES), 1 (NO)	1 (SE), 1 (FI)*	1 (FR), 2 (RU)	1 (RU), 1 (SE), 1 (PT), 1 (GR), 1 (LV)*, 1 (FI)*	1 (ES)	1 (LV)*	1 (UK), 1 (IE)	1 (RU)	11	10
Knowledge Management	1 (AT), 1 (SI), 1 (SK)	1 (AT), 1 (SI), 1 (FI)*	1 (FI), 2 (IT)	2 (IT)		1 (UA)*, 2 (SE)*, 1 (IT)*		1 (SI), 1 (US)*	6	11
Participatory Processes	1 (FI), 1 (NL)						1 (UK)	1 (UK)	3	1
Total	16	8	7	14	2	3	3	5	29	30

* Panellists that did not participate in the first round of Delphi survey.

Project Organisation; DSS Development; Models and Methods; Knowledge Management Techniques; and Stakeholders Engagement, their Role, and Adoption on Real Life Situation. The evaluation of DSS development was further specified for individual phases, including architecture & specification, coding & testing, maintenance & user support, documentation & training, dissemination & commercialization. Then, they presented their practices in a form of answers to an open-ended questionnaire. The panellists could present up to three items per domain and highlight the most important one. In addition, the participants were encouraged to suggest any other domain.

In the second phase of this round, the guideline development group encouraged pair-wise group communication to consolidate the individual past experiences into common successful and failure practices in FMDSS development and use. Most of the Delphi studies (*e.g.* Nevo and Chan, 2007; Jaana *et al.*, 2011) did not address failure practices nor included the pair-wise debate. The consolidation phase conducted by the panellists may speed the process of attaining consensus among the panellists and further facilitate the work of the guideline development group. For this purpose, the individuals were grouped in pairs and the pairs reached decisions through a process of informal consensus; each individual in the pair was able to communicate his practices, and the consolidated evaluation was recorded on the open-ended questionnaire and submitted to the guideline development group. The practices were transcribed word by word into the database.

Two initial phases of the first round of Delphi method took a total of 40 min (20 min for individual brainstorm and 20 min for pair-wise discussion).

During the last phase of this round, three members of guideline development group acted as judges and consolidated the items reported by the panellists. One of the members took the lead on grouping identical items and counted the frequency of the repetitions (or votes) of items across the questionnaires. The members agreed upon few naming and wording conventions. As examples, the original wording of the panellists was preserved whenever possible. Judges combined messages in an objective way (ellipsis of words like "lack of", "good", etc.). When several identical replies were found, the item took a new generic name given by the judges.

The initial consolidated list of items displayed the successful and failure practices in two separate columns and ordered according to the total number of votes.

Two initial phases of the first round of Delphi method took a total of 40 min (20 min for individual brainstorm and 20 min for pair-wise discussion).

The consolidation work pursued with the definition of the lessons-learned statements. The items in success practices were directly transformed into lessons-learned statements while those in failure practices were transformed into their positive opposite. For example: "Poor IT skills within the team" become "Good IT skills within the team".

For triangulation purposes, two other members of the guideline development group repeated the entire consolidation work. Finally, the agreement between the judges was checked and the disagreements were discussed until a common view was found (*cf.* Nevo and Chan, 2007).

Second round of the Delphi survey

The second round of the Delphi survey was completed in three major phases. The first phase aimed to reduce the scope of items to be assessed by the panellists during the second round. In most studies (*e.g.* Nevo and Chan, 2007; Jaana *et al*., 2011) it consisted of a narrowing down phase where the least important items were dropped out. Contrarily, this study clustered the lessons learned into functional resembling groups called the empirical guidelines. This clustering analysis established a two-level hierarchy of items (*i.e.* empirical guidelines and lessons-learned). The clustering phase was firstly conducted by a member of the guidelines development group that was instructed to use a maximum of 10 clusters per domain of DSS development and use, for the purpose of questionnaire simplification. This member proposed the name of the cluster (*i.e.* the empirical guideline) and further identified the lessons-learned statements included in each cluster. The lesson-learned was grouped in exactly one empirical guideline. The clustering analysis was repeated by 2 other members for the purpose of triangulation and the discrepancies were further discussed until a common consensus was found.

In the second phase, the panellists were asked to rank each empirical guideline in a digital questionnaire according to their perception of its relative importance, into 4 categories: very important, important, meaningful, not relevant. They were advised to classify a maximum of 5 empirical guidelines as very important, and 5 other as not relevant. The remaining empirical guidelines should be classified as important or meaningful. The final ranking of the guidelines was then calculated by giving 4 points to each "Very Important" answer, 3 points to "Important", 2 points to "meaningful" and 1 point to each "Not relevant".

The panellists were further asked to assess the lessons-learned statements proposed for the empirical guidelines. They were encouraged to provide suggestions, especially when they express their disagreement on the content.

The second round of the Delphi method involved 18 panellists from 11 countries replying either to on-line questionnaire launched on April 17th 2012 or submitting the paper copy filled out during the FORSYS workshop in Zvolen on May 10th 2012 (Table 2). The percentage of replies from panellists interested in DSS Architecture & Design and Methods & Models of the Model Base remained as in the first round. Yet, the percentage of replies from the knowledge management interested panellists increased about 7% and the percentage of participatory processes-interested panellists decreased about 5%. 67% of the respondents used the digital questionnaire, and the remaining replied with the printed version during the FORSYS workshop conducted approximately a year after the first round. In the second round, 12 new panellists were involved (2 panellists interested on DSS Architecture & Design, 4 in Methods & Models, 6 in Knowledge Management). The total number of countries represented rose to 23. The results from these panellists were considered separately in order to keep the accuracy of the Delphi survey.

In the last phase of the second round the agreement between the panellists were analysed using the Kendall's tau and Spearman's rank correlation. An aggregated ranking was produced and compared to the original rank based on the votes. Then, the guidelines development group completed the description of the empirical guidelines, incorporating the improvements suggested by the panellists.

Results

The 22 pair-wise questionnaires submitted after the pair-wise discussion in the first round provided a total of 354 items, including those repeated over the questionnaires. The panellists reported significantly more

Table 2. Number of items reported by the panellists related with successful and failure practices, per domain of DSS development and use after 1st Delphi round. Includes the total Number of pair-wise questionnaires that addressed each domain

Domains of DSS development and use	Total N. of items related with successful practices	Total N. of items related with failure practices	Total N. pair-wise questionnaires that addressed the domain
DSS Project Organisation	22	26	17
DSS Development			
DSS Arch. & Specification	45	22	18
Coding & Testing	29	23	18
Maintenance & User Support	20	7	15
Documentation & Training	20	9	18
Dissem. & Commercialization	10	13	13
Models & Methods Applied	26	12	17
KM Techniques	17	6	10
Stakeholders Engagement	27	20	18
Total	216	138	22

successful practices than failure practices (216 against 138 respectively) (Table 2). Each domain of DSS development and use had an average of 21.3 and 14.5 items for successful and failure practices, respectively. The domain DSS Architecture & Specification recorded the maximum number of items (45 and 22 for successful and failure practices, respectively), while the Dissemination & Commercialization recorded the minimum (10 and 13 for successful and failure practices, respectively). The Knowledge Management domain was the less covered; it was addressed only by 10 of the pair-wise questionnaires.

Furthermore, 18 of the pair-wise questionnaires provided items for at least one of the subjects of the DSS Development domain. Particularly the domains of DSS Architecture & Specification, Coding & Testing, Documentation & Training, and Stakeholders Engagement were addressed by 82% of the panellists.

The consolidation work of the guidelines development group at the end of the first round grouped the items repeated across the questionnaires. For example, the "role of different actors well defined" and the "shallow organization (clear responsibilities)" appearing in the list of successful practices on project management were aggregated under "clearly define the responsibilities among the team members". Similar aggregation was done for other domains of DSS development and use. The consolidation work further aggregated items that were addressed in distinct pair-wise questionnaires within complementary successful and failure practices. For example, the item "involve stakeholders and users in all phases of DSS development", included the successful practices "future owner of the DSS involved", "early involvement of decision makers" and "users as project owners" and the failure practices "not involving stakeholders or users representatives", "wrong people involved" and "future owner of DSS not known" that were reported on 3 distinct questionnaires. Some items were moved across domains and grouped to other items considered semantically identical. In particular the items related with costs, team composition and team involvement that were presented across the phases of DSS development were all grouped into the DSS project organization. For example "no budget for training" reported on Documentation & Training was grouped to other identical items, like "small development budget", and "foreseen enough time and budget" into the final statement of lessons-learned "make sure that adequate budget for the entire DSS development phases is granted". This consolidation work lead to the reduction of the total number of practices to 191. After the failure practices were transformed into their positive opposites, the final number of statements, i.e. lessons-learned, was reduced to 102.

The clustering phase grouped the 102 lessons-learned into 37 empirical guidelines (Appendix 1). The most important guidelines in the first round were "Adequate team composition, size and motivation" (G20) and "User documentation" (G01), both with 24 votes (Fig. 2). Also "DSS development framework" (G09), "Stakeholders and users involvement across the entire DSS development phases" (G26) and "Models and Methods within DSS" (G30) were among the top

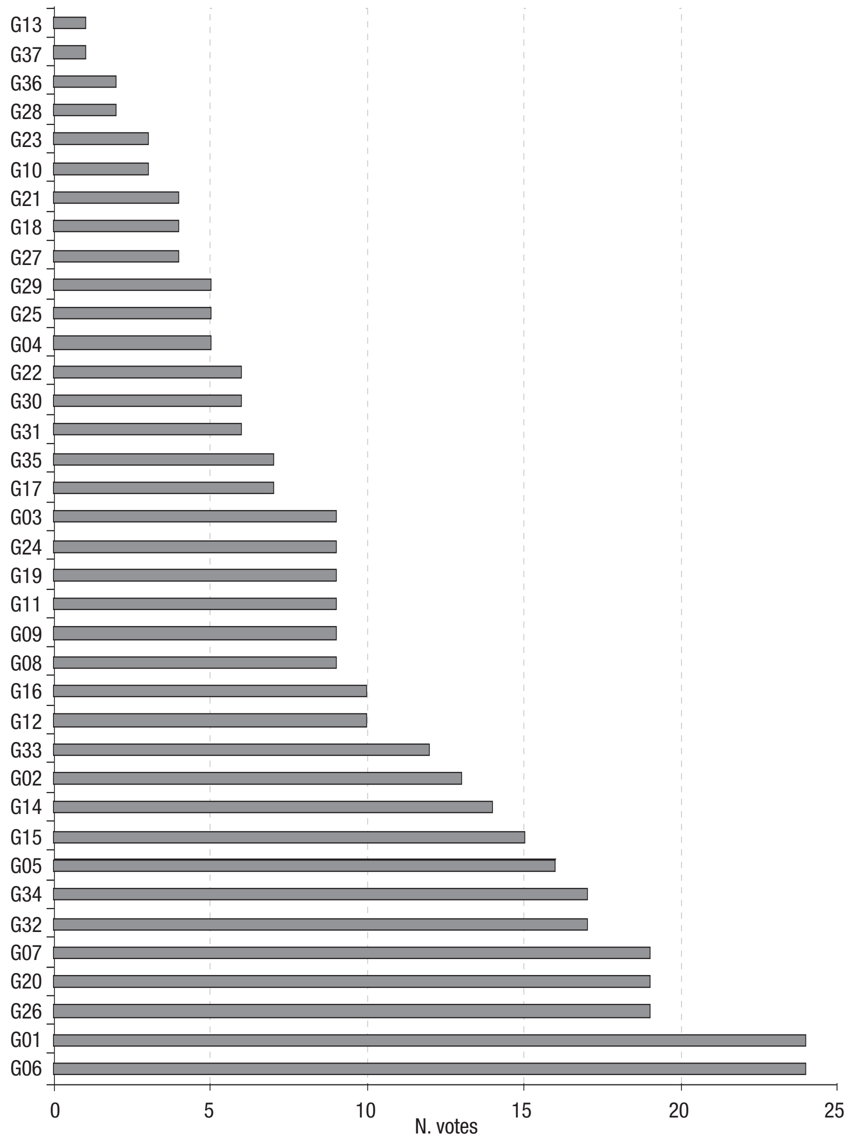

Figure 2. Number of votes in each empirical guideline after 1st round.

five, all with 19 votes. Among the 10 most voted guidelines, 6 were in the DSS development domain and 2 were in the domain Models & Methods, including G30 and "Select the best fitting M&M to the problem and the user's needs" (G32). The remaining domains had only one guideline in the top 10 ("KM tools within DSS" (G34) for the domain of Knowledge Management techniques and G26 for the domain Stakeholders engagement, their role and adaptation to real life situation).

The least voted guidelines in the first round were "M&M easy to understand and interpret" (G33) (1 vote), "Development tests" (G13) (1 vote), "M&M well documented and scientifically sound" (G31) (2 votes), "KM tools suitable for a specific need are implemented" (G37) (2 votes), "KM tools familiar and easy to use" (G36) (3 votes) and "Stakeholders and users motivation towards DSS utilization" (G28) (3 votes) (Fig. 2).

After the second round, the "DSS architecture and specification methodologies" (G06) became the most voted with 10 votes as "very important" (and 61 points in the total ranking), while it had rank 6 after the first round (Fig. 2, Fig. 3). The guidelines "adequate team composition size and motivation" (G01), "stakeholders and users involved across the entire DSS development phases" (G26) and "user documentation" (G20) were the most voted in both rounds. The score in the total ranking was 63 points, 57 points and 61 points respectively.

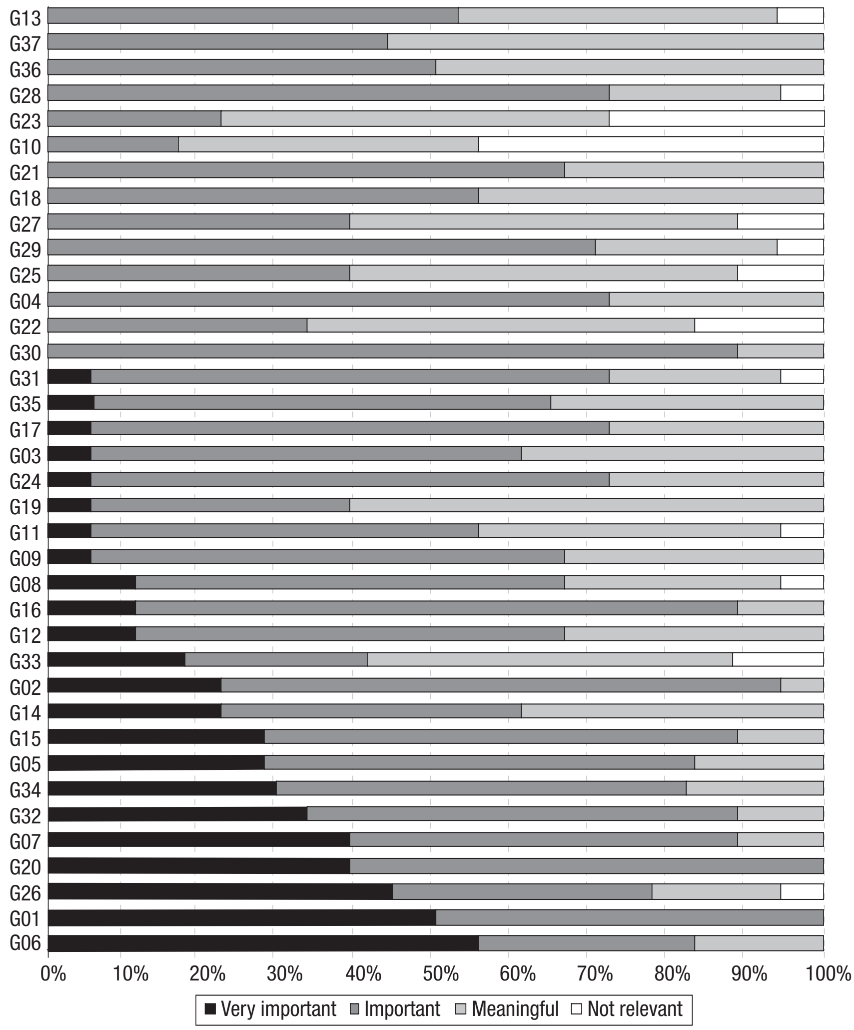

Figure 3. Percent frequency of replies per empirical guideline after 2nd round.

When only the very important answers are looked at, the "user-oriented interfaces" (G07) rose to the rank 5, while previously being in the 13th position. The G09 "DSS development framework" and G30 "Models and Methods within DSS" that were initially in the top five, dropped to the 16th and 24th position after the second round. The least votes were given to guidelines concerning the development cycle (G10), price policy (G23) and commercialization structure (G22). They also got most "Not relevant" answers during the 2nd round. The score in the total ranking was 31 points, 35 points and 39 respectively.

The analysis of the panellists that were involved in Zvolen, but not in Thessaloniki (12 people), shows a similar ranking of the guidelines when considering only the very important answers. The second to sixth first ranked guidelines after the second round are within the fifth first ranking positions of these panellists. Only G06 "DSS architecture and specification methodologies" dropped from first to 10th place. The biggest change in position occurred with G28 "Stakeholders and users motivation towards DSS utilization", which rose from rank 35 to rank 7, as well as with G21 "User training", which rose from rank 32 to rank 9. These huge differences could be explained by the fact that a presentation focussed on stakeholders was presented just before the exercise.

The rank correlations between the 1st and 2nd round were 0.69 for Spearman's correlation and 0.50 for Kendal's tau, which shows that the relative importance of the guidelines changed after the second round. The second round emphasised the user's perspective while the first round emphasised the developer's perspective. However, if we compare the ranking between the 4 profiles of the panellists *(i.e.* academics, developers, government scientists and researchers) (Table 3), 3 of them ranked the guidelines G06, G20 and G26 as the most important, even the developers. G06, G20 and G26 were considered very important also by the panellists from 3 FORSYS work groups.

Panellists reached moderate consensus also on the importance of "Adequate team composition, size, motivation" (G01), "Modular developments" (G05), and "User-oriented interfaces" (G07) that were regarded as very important by 2 of the profiles. When the results were analysed per panellists' main Work Group of Interest, "User Tests" (G15) were added to "Adequate team composition size and motivation" (G01) as very important guideline by 2 work group of interest. In fact, 8 of the guidelines were among the top 5 voted as very important when the results were analysed by panellists' profile and main FORSYS work group of interest (G01, G02, G05, G06, G07, G15, G20, G26). None of these rankings displayed guideline under the domain of Knowledge Management among the 5 most important.

From the Fig. 4 it can be seen that the second round has enabled the differentiation between the guidelines that had ties in the first round. For instance, a couple of guidelines had 9 votes in the first round, but after the second round their votes varied from 41 to 57. This also indicates that the importance of some items rose after the first round.

Discussion

The results showed that the group communication process relying on the Delphi-survey is a quick way to capture tacit knowledge and to reach consensus on the guidelines identification and their relative importance under different perspectives of large number of experts. Another advantage of this process is that it could be applied for guidelines development in any field of research.

When applying this method, the size and composition of the expert panel and the guidelines definition group are of importance. The participants' expertise should cover the range on domains in study, in a proportion representative of the interests of the entire experts community (in this case the participants of the FORSYS project).

The guidelines definition group should have at least 3 members involved in the consolidation phase after the first round. Discussion and informal consensus was needed to tackle few dubious situations, although their effect on the final results was proved to be minor. This was the case of clustering some of the lessons-learned that could have belonged to more than one guideline. For example, "system embedded in the business of the organization" could be assigned to G09 or alternatively to G17, which is related to FMDSS maintenance. Moreover, some guidelines could be in more than one domain. For instance, "Involvement of users and stakeholders on project management" can belong to domain DSS Project Organization or to Stakeholders Engagement. Another issue that emerged during the Delphi survey was that some lessons-learned could be considered themselves as an empirical guidelines, or could be grouped into a more general guideline. For example, the "development tests", "performance tests" and "user tests" were initially grouped into a single guideline related with DSS tests. However, after discussion, the guidelines definition group decided to make separate guidelines in order to raise the importance of the user tests perceived by the panellists.

One reason for the change on the relative importance of the guidelines in the second round may lie in the way the questionnaires were formulated. The questions of "what went well" and "what went bad" in the first round may have led the experts to thinking in terms of the development process in the purest sense, while the compiled list of empirical guidelines in the second round could have reminded the experts about the more general topics of DSS development. It is evident that the second round has increased the value of the empirical guidelines by encouraging the panellists to give more thought to the items.

The outcome of the process may provide valuable insights for future FMDSS developments. The guidelines may contribute to more efficient DSS development processes through relevant recommendations particularly in the domains of DSS project organization and DSS development.

In respect to the domain of Models and Methods, the lessons-learned do not intent to provide much information concerning which specific methods or models should be included in the DSS. On the other hand, this may indicate that the possibility to select the type of growth model is not a main concern, or since growth and yield models are already implemented and represent the core of forest DSS, they do not need to be mentioned.

Likewise, the experts think it is important to have some knowledge management tools within a DSS, but

Table 3. Top 5 of the empirical guidelines most voted as very important per each panellist's profile and main FORSYS Work Group of interest

DSS Domain and empirical guidelines	Profile				Main WG of interest			
	A	D	R	G	WG1	WG2	WG3	WG4
DSS Project Organization								
G01. Adequate team composition, size, motivation		×	×		×	×		
G02. Efficient communication and coordination among the team members	×				×			
G03. Clear definition of the responsibilities and ownership of the DSS								×
DSS Developmen								
G05. Modular developments			×	×		×		
G06. DSS architecture and specification methodologies	×	×	×		×	×	×	
G07. User-oriented interfaces	×			×	×		×	×
G14. Performance tests			×					
G15. User Tests	×						×	×
G17. Tools for maintenance and support		×						
G20. User documentation		×	×	×		×	×	×
Stakeholders Engagement								
G26. Stakeholders and users involvement across the entire DSS development phases	×	×		×	×		×	×
Models and Methods								
G32. Select the best fitting M&M to the problem and the user's needs						×		
G33. M&M easy to understand and interpret				×				

A: academics. D: developers. R: researcher. G: government scientists. WG1: DSS architecture. WG2: Models and Methods. WG3: KM techniques. WG4: Participatory planning. ×: Empirical Guidelines most voted as very important, according to the profile and main WG of interest.

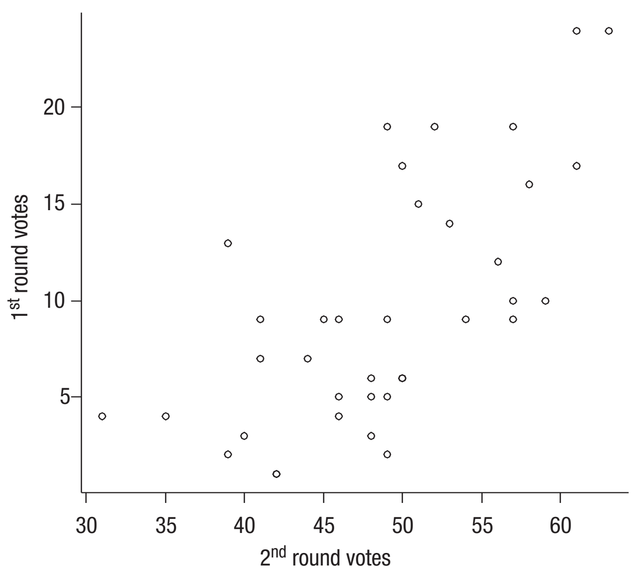

Figure 4. The relationship between the first round number of votes and the second round votes calculated using a Borda-Count style.

only 10 questionnaires provided successful or failure practices in respect to the Knowledge Management techniques, which may evidence that there is low experience of the FORSYS community about this domain. No information concerning the specific tools was detected. For instance, having a GIS and a database is probably seen as prerequisites for using a FMDSS, and as such self-evident, while other KM methods seem to be too poorly known among the forestry experts to give any proper guidelines as to their use. Furthermore, the panellists clearly perceived the importance of the stakeholder engagement. They gave some recommendations of the composition of stakeholders and users group but without reporting specific participatory methods applied to enhance their involvement.

The failure practices reported during the first round were also an important outcome of the process; they generally reflect some aspects affecting the success of the developers' project, but may still be neglected or need significant improvement. In particular, the panellists expressed the need to improve "DSS project organization in respect to the team composition, size and motivation" (G01) as well as "Project planning and budgeting, foreseeing the continuity after DSS development" (G04). They reported deficiencies in the dissemination and commercialization structures (G22 to G24), which fail to bring the DSS close to attention of the potential users. These growing concerns of the developers may be a consequence of evolving, in some cases, from prototyping done by a small team under the framework of research and academic projects, to fully integrated DSSs developed by larger teams often for commercial purposes. Fürst *et al.* (2010) reported that altough computerized-tools are clearly prefered to support planning and decision processes, the use of subjectively "home-made" combinations of fragmented solutions (spreadsheets for calculation, mailing for comunication, GIS for visualization and spatial analysis) still prevails. This suggests that the challenge is to develop more integrated and robust solutions.

The panellists further reported inefficiencies on the DSS development process, related with long DSS development cycles and "black-box" development frameworks that may be due to the use on inappropriate specification methodologies (G06), lack of code documentation (G12), or lack of standards and code reutilization (G09).

The failure practices further provided evidences about other aspects of the DSS development that may impact its usability to the final users. They highlighted the need to focus on the users, meaning that the DSS should address the users' requirements, favouring simple interfaces easily apprehended by the users rather than research-oriented interfaces (G07). Previous work on the users' requirements in respect to tools to support forest management (Fürst *et al.*, 2010) also suggested that self-explanatory user interfaces are a precondition for broad acceptance and use. They further emphasized the importance of broad and instant accessibility to users, *i.e.* provision of an on-line service or on-line support. In our research, the aspects related with web applications were grouped in the guideline "DSS development framework" (G09) that had 1 vote as "very important" (corresponding to the 13th position on the ranking) but 11 votes as "important". Fürst *et al.* (2010) stated that three most important features of DSS from the user perspective are the possibility to integrate iteratively experience from case studies, from regional experts as well as future scientific results into a knowledge management tool (*i.e.* learning system). The empirical guideline "KM tools within DSS" (G34) expressed this concern but this aspect was considered very important only by 5 of the panellists.

In order to improve the FMDSS usuability, the panellists suggested that the stakeholders and users should be involved in all DSS development phases. Particular attention should be given to users' training and the DSS user tests, preferably with real data (G21, G15). The development team should provide user documentation (G20) and user support, forward periodic DSS updates and also commit to a affordable price policy (G23).

Conclusions

This article presented a group communication process for the definition of guidelines for Forest Management Decision Support Systems development and use.

The process is replicable and further assures the consistency and validity of the arising guidelines. It relies on a Delphi-survey approach to capture past experiences. It proved to be adequate to capture tacit knowledge from a group of experts. Consequently, it may be used complementary to other methods used to synthesize past experiences, such as case studies, reviews and other types of surveys.

This research was the first known initiative to establish guidelines in the field of natural resource management. It involved a total of 30 experts from 23 countries in the FORSYS EU-COST project. It led to the identification of 37 empirical guidelines that group 102 lessons-learned. The guidelines cover several domains, including DSS Project Organisation, DSS Development, Models and Methods, Knowledge Management Techniques, and Stakeholders Engagement, their Role, and Adoption on Real Life Situations. They address both the developers and the user's perspectives.

This research showed that the empirical guidelines driven from the past experiences may be valuable for future FMDSS developments. In future, the development of FMDSS should be seen as a communicative process between the multidisciplinary development team and stakeholders and users, which should be involved throughout the entire FMDSS development. DSS architecture and specification methodologies are still likely to play one of the key roles in successful functioning of the DSS, but the developers should put more efforts in initial problem definition and problem structuring, and they should favour methodologies that would be able to adapt to future users' requirements and would also meet changing policy and market requirements. Such adaptive communicative process should finally result also in adequate user documentation and more user-oriented interfaces and thus hopefully satisfy the end-users.

The empirical guidelines definition process will proceed with the establishement of a knowledge repository built on a wiki web-based platform (http://fp0804.emu.ee/wiki/). Future work will focus on the content maintenance of this web page. The guidelines will be freely available and the forestry community world-wide may consult them and therefore improve their descriptions. New lessons-learned and/or guidelines may be suggested and added to the wiki after discussion among the guidelines definition group.

The community may also be asked to assess the quality and relevance of the empirical guidelines by rating several evaluation criteria displayed in a on-line rating tool embedded on the wiki. This future tool may be inspired on other appraisal tools in use to assess practice guidelines (*e.g.* the AGREE II tool, 2009).

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Appendix 1. List of empirical guidelines and their underlying lessons-learned. Includes the number of votes in each lesson-learned at the end of each Delphi round. The votes of 1st round represent the number of items reported on the pair-wise questionaires that were then included it the empirical guideline. The votes of the 2nd round were calculated by giving 4 points to each "Very Important" answer, 3 points to "Important", 2 points to "meaningful" and 1 point to each "Not relevant"

Id.	Empirical guidelines	Lesson-learned	1st round	2nd round
DSS Project Organisation				
G01	Adequate team composition, size, and motivation	— Establish a multidisciplinary development team with: a) Adequate size (more than 2 members) b) Experienced and motivated members with forestry and IT skills c) Researchers (but not only PHD students) d) Professional IT developers — Maintain stable team without personnel changes during the DSS development process — Select a project manager with adequate skills and experiences — Include steering group members with appropriate business skills	24	63
G02	Efficient communication and coordination among the team members	— Establish good communication mechanisms between the team members — Foster activities that increase cooperation among the team members — Organize initial training on the DSS development methodology	9	57
G03	Clear definition of the responsibilities and ownership of the DSS	— Clearly define the ownership of the DSS — Clearly define the responsibilities: a) Among the team members b) Among the parties involved in DSS delivery, implementation and promotion — Reach agreement on DSS usage and commercialization	6	48
G04	Adequate project planning, budgeting, implementation, and support	— Elaborate an overall plan for the entire DSS development process: a) Account for testing, documentation, training b) Foresee the continuity of the DSS after the end of the project c) Plan for support services — Revise the DSS development plan frequently to account for delays — Ensure that adequate budget for the entire DSS development phases is available	9	49
DSS Developmen-Architecture & Specification				
G05	Modular development	— Use plug-in architecture, supported by modules that: a) Can be easily integrated into more complex systems b) Can be combined into a flexible DSS appropriate for the intended application c) Enhance the DSS re-utilization in new problems and cases — Foresee DSS scalability to larger problem instances and new problem types	12	56
G06	DSS architecture and specification methodologies	— Use brainstorming for thorough problem description before starting the design and programming — Favour the DSS design and architecture methodology which:	17	61

Appendix 1 (cont.). List of empirical guidelines and their underlying lessons-learned. Includes the number of votes in each lesson-learned at the end of each Delphi round. The votes of 1st round represent the number of items reported on the pair-wise questionaires that were then included it the empirical guideline. The votes of the 2nd round were calculated by giving 4 points to each "Very Important" answer, 3 points to "Important", 2 points to "meaningful" and 1 point to each "Not relevant"

Id.	Empirical guidelines	Lesson-learned	1st round	2nd round
		a) Enhances the involvement of stakeholders and users b) Is based on process identification and in the problem description c) Is adequate for both current and future development d) Can guide the entire DSS development process — Provide detailed but efficient specifications that: a) Rely on graphical and interactive techniques (*e.g.* use cases, E-R models) b) Meet policy and market requirements		
G07	User-oriented interfaces	— Use graphical user interfaces for reporting that are simple, user-oriented; with a user-friendly design (distinct from research-oriented interfaces)	10	59
		— Visualize results in geographical information systems (GIS)	5	49
G08	Integration of DSS with existing systems	— Review existing systems related to the DSS under development — Enhance the DSS integration with other existing DSS by using Web-services		
G09	DSS development framework	— Encourage the development of Web applications — Encourage object-oriented developments — Use high performance databases — Use open-source/open framework — Adopt international standards for concepts, processes, data models) — Favour state-of-the-art information technologies	19	49
G10	Short development cycle	— Start with prototyping and short development cycles, aiming at early release	4	31
DSS Development-Coding & Testing				
G11	Adequate programming environment and programming tools	— Use flexible and rapid development tools — Limit module development to a few fast programming languages — Use multi-language platforms that enable code reutilization	9	46
G12	Code management	— Use practices that ease the maintenance of the code, fostering: a) Coding according to good practices b) Code reutilization c) Automatic code backup and versioning — Provide thorough code documentation within the code itself — Use pseudo-code to pass models/methods to the developers — Use adequate data structures	17	50
G13	Development tests	— Assess the code quality with systematic development tests that are: a) Planned in advance b) Embedded on the code and included on code documentation c) Automatically performed	1	42
G14	Performance tests	— Assess the models and methods quality with systematic performance tests using a test protocol based on the problem description	15	51

Appendix 1 (cont.). List of empirical guidelines and their underlying lessons-learned. Includes the number of votes in each lesson-learned at the end of each Delphi round. The votes of 1st round represent the number of items reported on the pair-wise questionaires that were then included it the empirical guideline. The votes of the 2nd round were calculated by giving 4 points to each "Very Important" answer, 3 points to "Important", 2 points to "meaningful" and 1 point to each "Not relevant"

Id.	Empirical guidelines	Lesson-learned	1st round	2nd round
		— Have an adequate data set at disposal for performance tests: a) First use a simple case where the results are known b) Then repeat tests with at least one complete data set c) Include both real and historical data, preferably provided by the stakeholders d) Include exceptional cases in the tests — Ensure having experts for performing the tests and/or evaluating the results		
G15	User Tests	— Let the users conduct tests to assure the compliance with their requirements: a) Involve multiple independent users with different profiles b) Conduct the test using the stakeholders' data c) Avoid user tests done by researchers involved on the project d) Plan mechanisms to motivate users to conduct the tests	10	57
DSS Development-Maintenance & User Support				
G16	Team for maintenance and support	— Establish a maintenance and support team with members devoted to improvement of the tool; representatives from the DSS development team; and the contact person clearly indicated	9	54
G17	Tools for maintenance and support	— Use specific tools for reporting problems and supporting requests — Provide on-line support	6	50
G18	DSS releases and updates	— Provide periodic releases based on continuous requirements collection and system updates	5	46
G19	Support Users community	— Promote networking and foster a users' community — Set up a web page devoted to the DSS and update it with the information for the users' community — Promote "User days" bringing together the users community and the DSS developers	7	44
DSS Development-Documentation & Training				
G20	User documentation	— Provide user's manual that is short, searchable, and preferably on-line; Built with examples and case descriptions; Uses language easily understood by the users; Suitable for different user profiles; Developed with the help of users (users to users) — Add help buttons on the dialog boxes & wizards — Provide a demo version with sample data — Ensure that the DSS is published in scientific articles	24	61
G21	Users training	— Organize interactive training with follow-up — Support training on-the-job — Enable self-learning	5	48
DSS Development-Dissemination & Commercialization				
G22	Commercialization structure	— Establish a commercialization network (national and international partners and customers) — Use simple and appealing DSS interfaces to motivate interested users	13	39

Appendix 1 (cont.). List of empirical guidelines and their underlying lessons-learned. Includes the number of votes in each lesson-learned at the end of each Delphi round. The votes of 1st round represent the number of items reported on the pair-wise questionaires that were then included it the empirical guideline. The votes of the 2nd round were calculated by giving 4 points to each "Very Important" answer, 3 points to "Important", 2 points to "meaningful" and 1 point to each "Not relevant"

Id.	Empirical guidelines	Lesson-learned	1st round	2nd round
		— Conduct system demos that meet the future customer demands, avoid showing research oriented interfaces — Enhance academic/policy/economic vector interface — Rely on professional support for client prospecting and contacts		
G23	Price policy	— Have affordable prices and a flexible price policy for the DSS and for the services it offers — Produce low cost DSS but not completely free	4	35
G24	DSS dissemination	— Plan a dissemination strategy for the DSS — Enable free downloading of trial versions — Use "champions"/"opinion-makers" to promote the DSS — Provide demos on how the DSS can be used to support decision-making in real life situations	6	50
Stakeholder Engagement, Roles, and Adaptation to Real Life Situations				
G25	Stakeholders and users involvement in project management	— Foster active involvement of users and stakeholders in project management decisions — Require clear definition of the DSS objectives and IT environment from the users	9	41
G26	Stakeholders and users involvement throughout the entire DSS development	— Involve stakeholders and users in all phases of DSS development: a) Avoid including them only in kick-off, DSS design & specification and problem definition meetings. b) Foster their involvement during development and testing c) Assign clear responsibilities to stakeholders and users for defining the input data for DSS and validating intermediate results d) Inform users of DSS updates — Rely on participatory techniques, meetings and surveys to enhance the stakeholders involvement in the DSS development — Use group decision-making processes	19	57
G27	Stakeholder and user selection	— Involve motivated stakeholders and users with adequate expertise and experience — Look for representativeness of the stakeholders and users — Promote ambassadors to promote the DSS development in the organization — Use a stable group of stakeholders and users with minimal changes throughout the DSS development process	7	41
G28	Stakeholders and users motivation towards DSS utilization	— Avoid language not clearly understandable by the stakeholders — Start by motivating users to use simple models first — Manage the users' resistance towards the use of DSS in real life situations	3	48
G29	Manage expectations of all parties involved	— Clearly define what the DSS can and cannot do — Foster trust and transparency in the DSS development and use	9	45

Appendix 1 (cont.). List of empirical guidelines and their underlying lessons-learned. Includes the number of votes in each lesson-learned at the end of each Delphi round. The votes of 1st round represent the number of items reported on the pair-wise questionaires that were then included it the empirical guideline. The votes of the 2nd round were calculated by giving 4 points to each "Very Important" answer, 3 points to "Important", 2 points to "meaningful" and 1 point to each "Not relevant"

Id.	Empirical guidelines	Lesson-learned	1st round	2nd round
		— Foster the cooperation between the stakeholders and the researchers — Foster political will and commitment		
Models and Methods (M&M)				
G30	M&M within DSS	— Use the M&M most common to DSS, including: a) Classical statistics b) Knowledge based M&M c) Indicator- based modelling d) Process modelling e) Optimization f) Monte-Carlo methods g) Growth & yield models h) Dynamic modelling i) Decision analysis j) Data mining k) Simulation m) Multiciteria decision analysis j) Cellular automata	19	52
G31	M&M well documented and scientifically sound	— Use M&M well described in the scientific literature, avoid using "black-box" models	2	49
G32	Select the best fitting M&M to the problem and the user's needs	— Combine several interoperable M&M within the same DSS — Favour the use of robust M&M that are adequate for several problems and cases — Select M&M appropriate for a specific problem — If the DSS relies on a separate commercial component (*e.g.* a linear programming solver), try to make the DSS adaptable to multiple vendor solutions — Incorporate M&M that handle multi-criteria decisions — Incorporate M&M that handle spatial data and spatial constraints — Use IT infrastructure that enhances the M&M performance even for complex problems — Take into consideration the quality of the information available for the M&M	16	58
G33	M&M easy to understand	— Produce output of the M&M that is easily interpretable and interpret by the users	1	42
Knowledge Management (KM) Techniques				
G34	KM tools within DSS	— Use KM tools within DSS (or DSS development), including: a) Delphi techniques b) Data bases c) Geographical information systems d) Expert systems e) Cognitive maps f) Communities of practice g) Best practices h) On-line journal	14	53

Appendix 1 (cont.). List of empirical guidelines and their underlying lessons-learned. Includes the number of votes in each lesson-learned at the end of each Delphi round. The votes of 1st round represent the number of items reported on the pair-wise questionaires that were then included it the empirical guideline. The votes of the 2nd round were calculated by giving 4 points to each "Very Important" answer, 3 points to "Important", 2 points to "meaningful" and 1 point to each "Not relevant"

Id.	Empirical guidelines	Lesson-learned	1st round	2nd round
		i) Lessons-learned		
		— Integrate KM in the DSS development		
G35	KM tools well documented and used in all phases of DSS development	— Use KM tools in all phases of DSS development, including knowledge identification, knowledge storage, knowledge transfer and knowledge application	4	46
G36	KM tools familiar and easy to use	— Assess the applied KM tools from the user perspective — Use KM tools the user is familiar with	3	40
G37	KM tools suitable for a specific need are implemented	— Enable integration of expert judgment	2	39