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TOWARD DECISION THEATER DESIGN FOR COMMUNITY FOREST MANAGEMENT & PLANNING: THE CASE OF QUÉBEC

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ABSTRACT: *A generic framework for designing decision theaters (DTs) is proposed. The implementation of this framework is illustrated on community forest management in the province of Québec. In particular, we develop the conceptual design of an integrated Forest Community Decision Support System (FC-DSS). FC-DSS aims at supporting complex forest management planning that involves governmental planners and multiple forest users.*

KEYWORDS: *Decision Theater, stakeholders, participatory planning, group decision making, forest management.*

1 INTRODUCTION

To prevent conflicts that may arise among forest users and promote social acceptance of forest management plans, governments and forest companies have implemented different public consultation and participatory mechanisms. This is observed in Canada, where about 350 million hectares are covered by forests, of which more than 90% are publicly owned (NRCAN, 2016). Canadian forests offer rich biodiversity and various ecosystem services (carbon sequestration, water filtration, wildlife habitat, etc.). They provide recreation activities (hunting, fishing, hiking, camping, etc.) and vital material and spiritual needs for First Nations. They also largely contribute to the economy, provide employment and support hundreds of forest dependent communities. These benefits have attracted many forest users (forest companies, First Nations, outfitters, trapping permit owners, etc.) who coexist in the same forest territory. As a consequence, disagreements might arise among forest users, leading furthermore to severe disputes.

To mitigate forest users' conflicts and harmonize the uses, the province of Québec has recently introduced a new forest regime (1st April 2013) and implemented participatory mechanisms across all forest regions of the province. One of these mechanisms is called "*Local Integrated Land & Resource Management Panel*" (hereinafter referred to as *Local Panel*). Local Panels aim at enabling forest users to express their concerns and take part to forest management planning, which falls under the responsibility of the Ministère des Forêts, Faune et Parcs of Québec (Ministry of forests, wildlife and parks, hereinafter referred to as MFFP). However, these panels met a limited success. In a previous work (Boukherroub *et al.*, 2016), we presented decision theaters (DTs) as a promising approach for dealing with complex decision making involving multiple decision makers and stakeholders, and we discussed the potential benefits of such an approach for participatory planning in the forest sector in Québec. This paper proposes a generic framework for designing DTs. We show how this framework can be implemented to support forestry community planning in the province of Québec. To this end, we develop the conceptual design of a DSS (Decision Support System) called Forest Community DSS (FC-DSS). FC-DSS support different forest users (experts and non-experts) at different phases of the decision making process while respecting their needs. The reminder of the article is organized as follows: the next section presents the forest planning processes and participatory mechanisms introduced by the new regime in Québec. Section 3 presents the concept of DTs. In section 4, we present the proposed framework followed by the FC-DSS. Finally, we conclude in section 5 and present our future work.

2 FORESTRY PLANNING IN QUEBEC

2.1 Planning levels and participatory mechanisms

In the province of Québec, more than 90% of the forests are publicly owned. These public forests are managed by the MFFP. Under the new regime, two plans are prepared by MFFP in collaboration with forest users (through participatory mechanisms): the *tactical integrated plan* and the *operational integrated plan*. The tactical plan aims at defining the management strategy to implement at the Forest Management Unit (FMU) level[1]. It specifies the sustainable forest management goals for an FMU (or a group of FMUs) and includes decisions related to areas of intensified fiber production, conservation areas, location of forest roads and infrastructures to develop, silviculture treatments, and the annual allowable cuts (AAC) in the FMU. The tactical plan is prepared for a horizon of five years.

The tactical plan is tightly linked to the strategic management plan prepared by the Bureau du Forestier en Chef (Forest Chief Office, hereinafter referred to as BFEC) in collaboration with MFFP planners. BFEC is

[1] An FMU is a geographic forest area, which supplies mills holding timber supply licences in the FMU's territory.

an independent organism responsible for determining the AAC in all FMUs of the province of Québec. The strategic forest management plan is a 150 years-horizon plan, prepared for each FMU (or group of FMUs). It determines silvicultural treatments per strata over time and the volumes of timber that can be harvested annually (AAC) while ensuring a non-declining (sustainable) volume yield (BFEC, 2013). This long-term plan includes 30 periods of five years each. The decisions of the first five years period (silvicultural treatments, conservation areas, etc.) are inputs for the tactical plan while the sustainable forest management goals of the tactical plan are inputs for the strategic plan. In fact, the two plans are prepared through an iterative process involving MFFP planners, BFEC planners and the forest users (Local Panels).

The operational plan includes decisions related to harvest area selection (MFFP responsibility) and allocation to mills and to the Timber Auction Office (Bureau de Mise en Marché du Bois)[2], and forest road and infrastructure planning (forest companies' responsibility). Operational plans are prepared for a planning horizon of 1-3 years. Tactical and operational plans should be coherent with the goals and orientations defined at the provincial and regional levels. More specifically, the tactical plan should respect the goals and orientations of the sustainable forest management strategy (SFMS) (provincial level), the orientations of the public land use plan (provincial level), and the regional plan for integrated development of natural resources and the territory (regional level). The SFMS is the basis for all governmental policies and actions in terms of forest management, and all users of the territory must respect SFMS orientations and goals.

The operational and tactical plans are prepared by the MFFP in collaboration with the Local Panels (introduced in section 1) and Operational Panels. These two panels together with public and First Nations consultations are the main participatory mechanisms introduced by the new regime. The aim of the Operational Panels is to align the requirements of forest companies (license owners) which require a forest certification with the forest management strategy and optimize wood procurement plans. The public and First Nations consultations allow the broad public and First Nations (respectively) to express their concerns regarding the operational and tactical plans.

A Local Panel is established by the regional authorities for each FMU (or a group of FMUs) or a municipality (or a group of municipalities) in a given forest region. The main goal is to ensure that interests of the forest users are taken into account during the planning process (MFFP, 2013). The Local Panels are formed by representatives of timber license owners, harvesting permit owners, First Nations band council, environmental institutions, outfitters, hunting permit owners, etc. The number of forest users' representatives at the Local Panel varies from one region to another, depending on the forest area size, the number of forest users in the region and the type of activities they perform or services they provide (timber harvesting, outfitting, hunting, etc.), the presence of First Nations in the region, etc. MFFP planners, experts and representatives of the regional authorities as well as invited researchers, consultants, etc. can also participate to the Local Panel meetings. Coordinators are identified by the regional authorities responsible of the Local Panels for organizing and animating the meetings. Around five meetings are organized during the year. Usually, working comities formed by members of the Local Panels also organize meetings to work on specific topics. The results of these working comities are presented to the Local Panel members. The decision making process for preparing the tactical plan takes two to three years. However, the Local Panel members deal also with decisions related to the operational plan, which is prepared each year.

Decisions made by the Local Panel members are based on consensus. In case no consensus can be reached, dispute settlement mechanisms are used to find solutions. In fact, the functioning rules of the local Panels are defined at the early phases of Local Panel implementation, and all Local Panels' members must agree on these rules. In this study, we focus on Local Panels and the tactical planning process. More details on Local Panel members' activities during the tactical planning process are provided in section 4.2.

2.2 Results of implementing Local Panels in Québec

A previous study (Gharbi, 2014) reported that implementing the planning process introduced by the new regime in real-life was complex, long, and costly. Lack of reactivity and late feedback of MFFP planners, lack of information (lack of data and capacity to analyse it), lack of coordination among forest users, and delays due to verification, validation, consultation, and harmonization processes are mentioned as the main issues. These findings are based on a number of interviews conducted by researchers of Université Laval with forest companies between 2012 and 2013 in different regions of Québec; Lanaudière, Hautes-Laurentides, Saguenay, Lac-Saint-Jean, Chaudières-Appalaches. It was also reported that the participatory mechanisms were not efficient in addressing forest users' issues and solving conflictual situations (Gharbi, 2014).

These observations are confirmed in the region of Bas-Saint-Laurent where a survey has been conducted by a regional development agency in 2013 (Robert, 2013). The evaluation was based on 19 meetings between 2010 and 2013. A questionnaire was distributed to 84 participants. 27 responses were returned. Although, the respondents recognize that the Local Panels helped them

[2] Under the new regime, 25% of the allowable cuts are sold through the auction market (BMMB). The remainder is allocated to mills holding timber supply licences.

understanding the concerns of participants from other areas of interest, many issues were pointed out. It was reported that the progress was long and traditional conflictual positions still exist. In fact, the majority of respondents mentioned that their concerns were not effectively taken into account by MFFP planers. Many respondents also indicated the absence of real consensus concerning some topics. The lack of impact analysis and information availability at the right time, and contradictions among information were identified as the main issues.

We conducted additional interviews in the region of Mauricie between December 2015 and April 2016 with three experts who played an active role in implementing and operating the Local Panels in the region: two experts are from the MFFP and the third one is the coordinator of the Local Panels implemented in the region. The three experts reported that real consensuses were extremely difficult to achieve. The main reasons mentioned were that confidential agreements were in some cases committed between participants outside the Panels; some participants were not willing to participate to the discussions and had the tendency to hide their opinions (e.g., participants who don't feel confident with their "low" knowledge level); some participants had to align with the views of persons or organization they represent regardless of their own views and willingness to collaborate; and, in some cases, two sub-groups having differing views were formed inside the Panel, and this resulted in extreme inconsistency among goals and the impossibility to find compromises.

In this regard, the experts mentioned that some economic objectives such as maximizing timber harvesting were not even consistent with the ecological constraints defined by the SFMS. The most conflicting issues were related to forest road planning, wildlife habitat, and the landscapes. It was also reported that many participants did not trust the scientific knowledge and information presented to them, but relied solely on their perceptions. Finally, as in Bas-Saint-Laurent, the lack of information and impact analyses was identified as an issue.

These studies show that in many regions of Québec, implementing the Local Panels met a limited success. However the MFFP, the regional authorities and forest users recognize the complexity of making plans while involving many actors having different interests, values, and goals. The MFFP and the regional authorities are seeking for improving this situation. We propose to use DTs as a decision making approach for addressing these issues.

3 DECISION THEATERS

DTs can be viewed as meeting rooms characterized by specific input/display technologies and seating arrangement that allow a group of people to interact with each other and with the data in order to contextualize a decision-making situation, evaluate the impacts of decisions, and find a common solution. An example of a DT configuration is shown in figure 1. Due to recent advances in communication technologies, DTs can also be extended to virtual meeting rooms, and accommodates remote participants.

Figure 1: A decision theater built at Arizona State University (Decision Theater Network (ASU, 2016))

The term "decision theater" was used in the 70s to designate a new teaching approach in marketing decision-making (Tolle, 1971). A laboratory called "Decision Theatre" was built at Our Lady of the Lake University of San Antonio. It was used as a learning facility for management students and as a research tool in decision-making and organizational research (Roach, 1986). More recently, Arizona State University has built a DT in Tempe, Arizona (2005) (figure 1). Another DT has been built by the McCain Institute for International Leadership in Washington D.C. (2013). These two DTs together form the Decision Theater Network (ASU, 2016). Other universities such as University of British Columbia, Huazhong University of Science and Technology (China) and Tecnológico de Monterrey (Mexico) have all built DTs. These DTs are often referred to as semi-immersive environments due to their specific configuration and display technologies (e.g., panoramic wall displays) that allow catching participants' attention (immersion), for instance through real-scale 3D image displays.

Preparing a plan for disease outbreaks; assist policy makers and stakeholders in understanding the socio-economic implications of different energy extraction investment options; explore how the effects of climate change on natural resources could contribute to political instability are some examples of research projects conducted within the Decision Theater Network (ASU, 2016). However, the scientific literature does not provide sufficient information on how the DT is being used to conduct these projects: Edsall & Larson (2006) and Larson & Edsall (2010) described a study in which the effects of visual information technology on public understanding of groundwater management in the desert metropolis of Phoenix (Arizona) were evaluated. The study compared a 3D demonstration in the DT to a parallel 2D Power Point presentation in a standard classroom. Based on a water management model called WaterSim, which was presented in the DT of Arizona to a group of decision makers and stakeholders, White *et al.* (2015) studied the perception and understanding of participants of uncertainty. In a similar study, White *et al.* (2010) investigated the decision makers' perceptions of the credibility, salience, and legitimacy of WaterSim.

Research conducted in the Landscape Immersion Laboratory (LIL) at University of British Columbia aims at investigating, in community planning context, the effects of visualization technologies and semi-immersive environments on the public ability to understand and evaluate alternative forest management plans and landscape planning scenarios. Regarding forest management, a visualization system linking together forestry modelling programs and a 3D rendering engine was developed and implemented at LIL (Cavens, 2002; Meitner *et al.*, 2005). This visualization system allows orchestrating the flow of large amount of data needed for creating accurate portrayals of forest landscapes based on high-level policy decisions (Cavens, 2002). Meitner *et al.* (2005) reported that this visualization system enabled researchers to see forestry modelling outputs in new ways and helped them to detect errors and evaluate the models limitations and assumptions.

The visualization system was used in public forums in the context of interdisciplinary research projects in sustainable forest management. It was found that the visualization aspect was helpful, as it tends to make the modeling outputs more relevant to the average attendee. Sheppard & Meitner (2005) described a pilot study conducted in southeastern British Columbia, where one of the research questions was whether spatial models and visualization technologies were effective in participatory planning, and what impact do these tools have on the results. Two alternative forest harvesting plans were prepared and evaluated in three different ways. First, experts were asked to evaluate the two plans against a set of sustainability criteria. Then, different groups of stakeholder were asked to provide their preferences for the same set of criteria. The stakeholders' preferences were used to weight the evaluations of the experts. Finally, the direct preferences of the stakeholders were obtained by using realistic landscape visualization supporting scenario descriptions. Although similar results were obtained for all three evaluation methods, it was reported that over 90% of participants found the visualization helpful (Sheppard & Meitner, 2005).

Concerning landscape planning, Salter *et al.* (2009) explored the abilities of LIL's immersive display environment and CommunityViz; a GIS based decision support system that includes a semi-realistic and interactive landscape visualization capabilities, to improve participant understanding of residential density policies. The authors described two workshops held at LIL facility where three land use alternative plans were presented to the participants. It was reported that the ability to dynamically explore the visualizations of the plans and see real-time changes in indicator metrics were considered by the participants particularly informative, and appeared to increase participants' understanding of the plans. In particular, the visualizations allowed the participants with less knowledge to better understand the residential density policies and to contribute to the discussion (Salter *et al.*, 2009).

Other concepts found in the domains of military, politics, media, and business such as war room, situation room, command and control center, operations center, management cockpit war room can also be linked to the concept of DT. Interested readers can refer to Boukherroub *et al.* (2016). We can conclude that the literature does not provide enough information for implementing a "DT approach" as the decision process can hardly be reproduced. In particular, it is not clear how decision makers and other participants in the DT interact with data, with decision supports tools and with each other, and how each actor contributes to the process of problem definition, analysis, and solving given his/her background knowledge, perceptions, values, etc. The next section presents our methodology for designing DTs. It also presents FC-DSS (forest community-DSS) designed for enabling the implementation of DTs in the context of forestry planning in Québec.

4 METHODOLOGY

4.1 Decision theater design

We propose a generic framework to support the design of DTs (figure 2). We were inspired by the descriptions of DTs provided in the literature and ASU website (see section 3) as well as the concept of Group Decision Support System (GDSS). The term GDSS appeared in the literature in the 1980's. It refers to "an interactive computer-based system which facilitates solution of unstructured problems by a set of decision makers working together as a group" (DeSanctis & Gallupe, 1985). Four components are attributed to a GDSS; *hardware* (input/output devices, common viewing screens or individual monitors displaying information to the group, etc.), *software* (data bases, model bases, user interfaces, etc.), *people* (decision makers, facilitators, etc.), and *procedures* (e.g., verbal discussions, flow of events, etc.) (Huber, 1984; DeSanctis & Gallupe, 1985). These components are arranged to support a group of people in the context of a decision-related meeting (Huber, 1984).

The framework we propose (figure 2) encompasses five main components (or systems): *decision entities*, *decision support component*, *organizational system*, *decision theater layout*, and *technologies*.

- **Decision entities**

We distinguish decision makers and stakeholders. The stakeholders considered are those who are directly affected by the decisions and who share decision-making power. They are referred in the literature as active stakeholders (Grimble & Wellard, 1997; Martins & Borges, 2007). Other participants can attend the meeting (*passive* stakeholders, observers, experts, etc.), but they cannot participate to the decision making process.

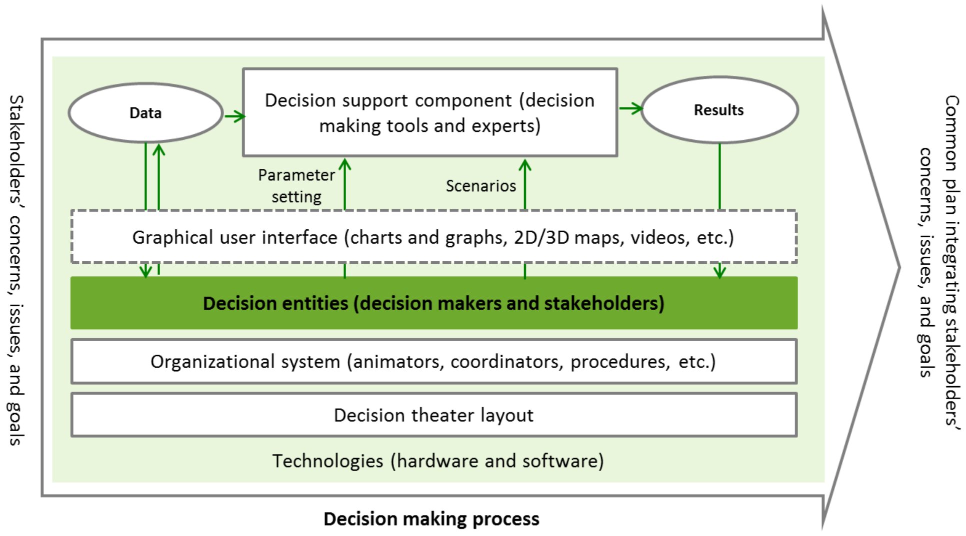

Figure 2: Generic framework for designing decision theaters

- **Decision support component**

We consider decision support tools (qualitative or quantitative) as well as experts. In complex decision making situations, for which DTs are aimed, decision makers and stakeholders need decision support tools to represent (model) the relations between their goals and the variables (actions or decisions) that might impact these goals, and to predict the outcomes. An expert might be a scientist who can provide the decision makers and the stakeholders with specific knowledge regarding a complex issue or the effect of an action in the long term. He/she could also be a decision support specialist responsible for running the decision support tools. He/she must be very responsive to be able to translate the decision makers and stakeholders' questions into models and to provide the answers in a timely fashion. He/she must also be able to explain the models and data sources, to help decision makers and stakeholders to define the confidence zones of the models' outputs, and to support output interpretation.

- **Organizational system**

We consider the support staff such as coordinators, animators, and technicians (facilitators) as well as procedures. For instance, the coordinator organizes the meetings; he/she produces meeting reports, and he/she shares documents with the participants. The animator animates the discussions; he/she explains the procedures, he/she makes sure that all participants express their ideas, etc. IT technicians are required for managing the hardware and network connections. The procedures specify the functioning of the participatory mechanism put in place such as the role of each participant, how decisions are made, how conflicts are solved, etc.

- **Decision theater layout**

The layout represents the physical configuration of the DT such as the shape of the meeting room, the size and shape of display screens, the arrangement of tables and seating chairs, etc. As an example, the DT in Tempe, Arizona (figure 1) has a core physical component called the "Drum", which is a round room with seven screens arrayed across 260 degrees (White *et al.*, 2010). Brehmer (2007) argues that seating arrangement facilitates interactions and communication among participants.

- **Technologies**

Technologies support all other DT's components. Technologies concern the hardware and the software. The hardware encompasses physical devices used to input, store, extract, and visualize data such as computers, common displaying screens, individual screens, boards as well as communication and recording devices (cameras, microphones, etc.). The software concerns data bases, model bases, graphical user interfaces, communication protocols, and other application programs to be used by the participants. The graphical user interface, in particular, plays an important role in DTs. It allows displaying tables, lists, charts, videos, maps, etc. that can be visualized on screens by the participants.

The decision making process in the DT is supported by all five components as shown in figure 2. As suggested by former studies (e.g. Sheppard & Meitner, 2005; Martins & Borges, 2007; Vacik *et al.*, 2014), we consider three phases in the decision making process:

- ***problem identification***, which involves the acquisition and analysis of information to understand and define the decision problem(s), by identifying concerns, issues, and goals, alternative options, conflicts and interactions, etc.;
- ***problem modelling***, which involves building a model to represent relations between alternative options and outcomes of decision makers and stakeholders;
- ***problem solving***, which involves the selection of the final plan(s), by prioritizing alternative options.

At these different phases, the decision makers and the stakeholders, directly or through facilitators, enter data (concerns, issues, goals, preferences, etc.), extract data (e.g. description of alternative options), set parameters, define scenarios, and visualize the data and the results (geographical area of interest, impact of alternative options, aggregated results of the group, etc.). These tasks call for a system integrating data, information, models, and methods. DSSs facilitate this integration. In this study, we adopt the definition of DSS given by Fischer *et al.* (1996), Leung (1997), and Rauscher (1999); a computer based tool which provides support to solve ill-structured decision problems by integrating database management systems with analytical and operational research models, graphic display, tabular reporting capabilities, and the expert knowledge of scientists, managers, and decision makers to assist in specific decision making activities. Therefore, a DSS combines different components of the DT; the decision support component, decision entities, and technologies. In the next section, we present our FC-DSS to be implemented in a DT for dealing with participatory planning in forestry in the province of Québec. We focus on the Local Panels and the tactical planning level.

4.2 Conceptual design of Forest Community DSS

To collect data and design FC-DSS, we relied on a qualitative approach combining interviews, documentation, and observations. The interviews were conducted with MFFP experts involved in preparing the forest planning manual (version 5.1) and other MFFP experts and coordinators involved in implementing and operating the Local Panels in different regions of the province of Québec (Lanaudière, Capitale-Nationale, and Mauricie). The forest planning manual is produced by MFFP. It describes how the tactical and operational planning processes should be implemented under the new regime (MFFP, 2013). This manual and the manual for determining the allowable cuts (2013-2018 period) produced by BFEC (BFEC, 2013) are among the key documents on which we relied. We also consulted the guide for implementing the Local Panels (Desrosiers *et al.*, 2010) and different reports on Local Panels meetings (Mauricie and Lanaudière regions). Finally, we attended two meetings of two distinct Local Panels in the regions of Lanaudière and Mauricie as observer.

We can distinguish three phases in developing the conceptual design of FC-DSS. In the ***first phase***, we used the data collected to map the tactical planning process from a macroscopic point of view. The objective was to identify the actors involved (*decision entities*), the main activities, interactions among the actors (information flow) and intensity of these interactions as well as the decision support tools used and the tasks of experts involved (*decision support component*). We also identified the main visualization elements provided by the decision support tools and other application programs and tools (e.g., GIS) (*technologies*). This first mapping was essential for representing the "big picture" of the whole process, and for determining how the tools being used could be re-organized for designing the FC-DSS. It also helped us to communicate with our MFFP partners, who validated our understanding of the process, through an iterative process. In the ***second phase***, we mapped in more details the activities of the tactical planning process by using IDEF0, a well-known technique for modelling complex processes (Aguilar-Savén, 2004). Finally, in the ***third phase***, based on previous mappings and inspired by the DSS SADfLOR v m 1.0 described in (Garcia-Gonzalo *et al.,* 2015), we developed the conceptual design of FC-DSS. The next paragraphs present in more details each one of the three phases.

4.2.1 Phase 1: Macroscopic mapping of the planning process

Figure 3 illustrates the mapping of the main activities of the decision entities, the tools/experts supporting these activities, the elements visualized by the actors (visualization system in figure 3), and the interactions among the actors and tools/experts, from a macroscopic view. Clearly the visualization elements are the "interfaces" between the actors and the tools/experts supporting their activities. The numbers on the narrows in the figure indicate the sequence of information exchanged between the actors. The representation provided in figure 3 is common to most regions in the province of Québec. However, some differences can be observed from one region to another. Among the decision entities, we distinguish the Local Panel members who might be representatives of forest users (persons or organizations), regional authorities, or MFFP representatives (experts and planners/decision makers). MFFP experts may or may not make decisions depending on the task assigned to them, which is to provide knowledge and expertise solely or to provide both knowledge/expertise and participate to decision making. Outside the Local Panel meetings, we distinguish MFFP planners and BFEC planners. Activities described in figure 3 occur after the Local Panel members have identified the areas of intensified production of fiber and parts of existing forest roads to develop in the long term.

First, MFFP experts present the ecological issues identified in the SFMS (e.g. forest age structure, spatial organization in the forest, forest composition, etc.) to integrate into the tactical plan, on mandatory basis. The other participants present their concerns and issues related to forest management (e.g., landscape alteration, disturbance of wildlife habitat, etc.). Some issues are also related to forest certification requirements. Issues related to forest certification are presented by industrials having or requiring a forest certification. Next, most relevant issues are endorsed by the Local Panel members, and potential solutions are proposed (mainly by experts) for addressing these issues. A potential solution can be a specific silvicultural treatment such as *partial cutting*, area conservation, revolution extension, etc. These solutions can also be found in forest certification standards or in regulations. Tables presenting the endorsed issues, the objectives, indicators and their targets known as VOIC cards are prepared for some (quantifiable) issues.

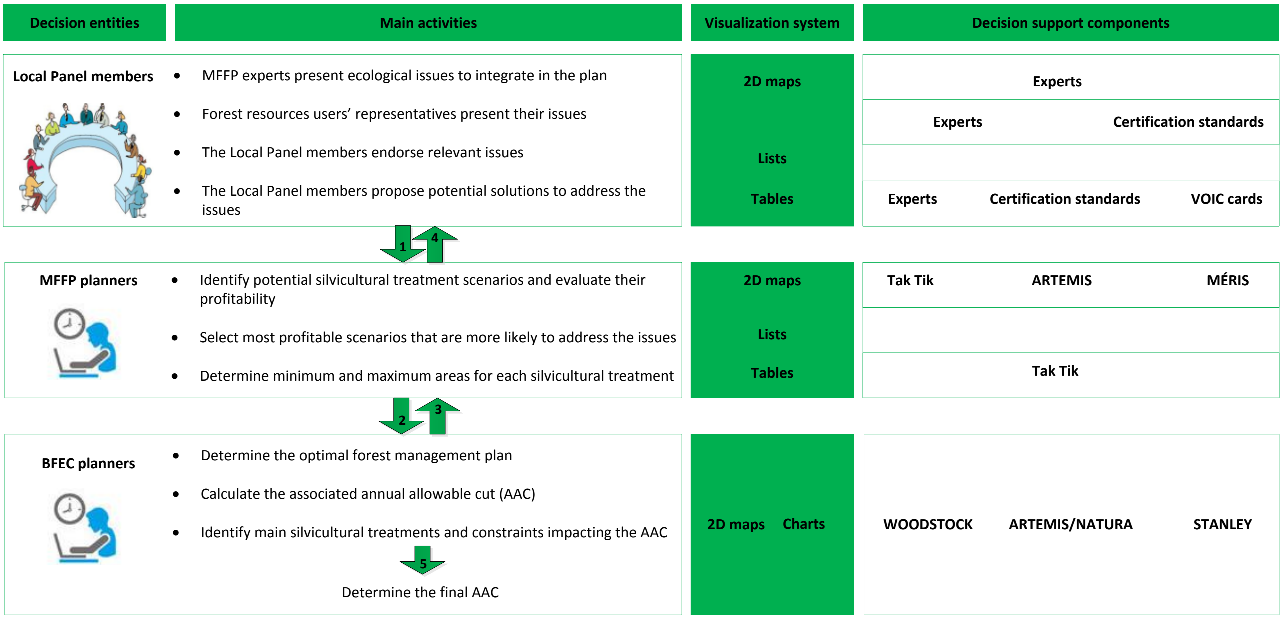

Figure 3: Macroscopic mapping of forest tactical planning process in the province of Québec

VOIC cards are used as a tool to monitor the implementation of the proposed solutions. The Local Panel members use mainly 2D maps (provided by ArcGIS software) to geographically visualize elements of interests (conservation areas, wildlife reserves, forest road network and other infrastructures, lakes, etc.) as well as tables (e.g. VOIC tables) and lists (e.g. list of issues). The proposed solutions are further refined by MFFP planners (outside the Local Panel meetings) who identify more precisely the silvicultural treatments and scenarios. MFFP planners use a tool called Tak Tik to generate the silvicultural treatments and scenarios. Another tool called MÉRIS is used jointly with forest growth/yield data provided by a tool called ARTEMIS to evaluate the profitability of the silvicultural treatments generated by Tak Tik. Most profitable silvicultural scenarios that are more likely to address the issues are selected by MFFP planners and provided to BFEC planners. Minimum and maximum areas per silvilcutural treatment are also generated by Tak Tik and provided to BFEC planners. MFFP planners might use 2D maps (ArcGIS) to locate major constraints related to harvesting operations, areas of intensified production of fiber, etc. They also use tables and lists to visualize information (e.g. list of silvicultural treatments). BFEC planners produce the strategic management plan based on the orientations provided by MFFP planners (alternative sivicultural scenarios, minimum and maximum areas per silvilcutural treatment) as well as potential solutions provided by the Local Panels. BFEC planners use an optimization-based tool called Woodstock jointly with forest growth/yield tools (ARTEMIS and NATURA) and a spatialization tool called Stanley to produce the strategic management plan and the associated AAC. BFEC planners also perform sensitivity analyses to identify the main variables and constraints impacting the AAC. BFEC planners can visualize the data and results in different ways (2D maps on GIS, charts, tables, lists, etc.). The results produced are provided to MFFP planners who may adjust the silvicultural scenarios and maximum/minimum areas per silvicultural treatment before BFEC planners determine the final AAC. This is in fact an iterative process. Once the process is completed, the information on the VOIC cards is updated to take into account the results produced by MFFP planners and BFEC planners (final solutions and targets).

It is observed that MFFP planners and BFEC planners are in full control of the decision making tools (Tak Tik, MÉRIS, Woodstock, etc.). In fact, MFFP/BFEC planners use these tools in their offices outside the Local Panel meetings. Therefore, it is not surprising that in many regions of Québec, there are transparency issues and lack of trust among forest users. As stated by Antunes *et al.* (2006), the results of decision making processes in which the analysts are in full control of decision support raise equity, trust, and representativeness issues among stakeholders. Moreover, the final solutions (produced by MFFP planners and BFEC planners) might take time before they could be presented to the Local Panel members. Furthermore, due to the long feedback of MFFP planners and BFEC planners, impact analyses are rarely performed. Finally, there is a lack of coordination among the forest users, MFFP planners, and BFEC planners. As a consequence, BFEC planners might produce the strategic management plan and determine the AAC before the Local Panels have provided all their inputs.

4.2.2 Phase 2: Detailed mapping of the planning process

Figure 4 illustrates the representation of an activity by using IDEF0. IDEF0 is derived from the Structured Analysis and Design Technique, and allows representing the input and output data of a given activity, the resources used (actors, decision support tools, etc.) as well as the controls of the activities (e.g. procedures, guidelines, regulations, etc.). Therefore, it is possible to precisely map the information flow within a process, and link the activities to each other. Moreover, IDEF0 allows representing activity diagrams with different detail levels. For example, the activity illustrated in figure 4 (A6.2) is a sub-activity (or child) of the activity A6 (parent). This modelling methodology allowed us to identify precisely the data needed to perform all activities of the tactical planning process, how and where the data is available (e.g. data bases), and which actors/tools use the data. This information was crucial for developing the conceptual design of FC-DSS.

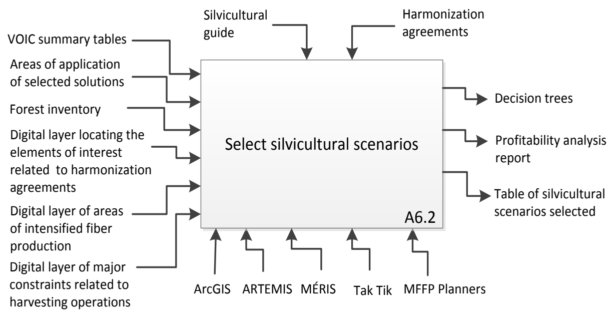

Figure 4: Example of an activity modelled by using IDEF0

4.2.3 Phase 3: FC-DSS design

FC-DSS integrates the tools used by MFFP planners and BFEC planners and provides a shared data management module for all users (Local Panel members, MFFP planners, and BFEC planners). FC-DSS encompasses a *data management module*, two distinct *model base modules (MFFP and BFEC)*, and a *data and results visualization module* (see figure 5). All users can update or enter data into FC-DSS and visualize the data or the results via an Internet browser from their local PCs. As stated by Rammer *et al.* (2014), recent advances in technologies allow the development of web-based decision support tools and improved Internet browsers can run complex web applications. Reduced access barrier (no downloads or installations required), increased interactivity offered by web GIS and social networks, and active participation of large groups are among the advantages of a web-based approach (Rammer *et al*., 2014).

The four components of FC-DSS are independent and encapsulated in graphical user interfaces. We distinguish three distinct graphical interfaces to meet the needs of three categories of users; MFFP planners, BFEC planners, and the Local Panel members (i.e forest users' representatives). Local Panel members could have a customized graphical user interface to address their specific needs in terms of data and results representation and visualization. As mentioned in previous studies (Andrienko *et al.*, 2007; Salter *et al.*, 2009; Rammer *et al.* 2014), stakeholders need an easily understandable presentation of information. Moreover, stakeholders having difficulty in understanding maps and scientific information may need a detailed view of alternative solutions, background information, and customized visualizations. MFFP planners and BFEC planners would have distinct graphical interfaces since they perform distinct tasks: MFFP planners control the model base module *"MFFP"*, which contains Tak Tik and MÉRIS tools used to generate silvicultural treatments and scenarios and to evaluate the profitability of these silvicultural scenarios (respectively). BFEC planners control the model base module *"BFEC"*, which contains forest models generator (*Horizon CPF*), a forest management plan generator (*Woodstock*), and a spatialization tool (*Stanley*). As mentioned previously earlier, MFFP planners are responsible for preparing the tactical and operational plans, while BFEC planners are responsible for generating the strategic management plan and determining the associated AAC.

All users can access the data, but there might be some restrictions for editing the data under the control of MFFP planners or BFEC planners (e.g., territory data, forest inventory, forest growth/yield data, etc.). The main information that can be entered by the forest users into FC-DSS is related to their concerns or issues, the description of these issues, their preferences regarding the issues, potential solutions, and financial data (e.g., operations costs might be provided by industrials). Elements that can be visualized include lists of concerns/issues entered into the system, aggregated results of the group (e.g. aggregated preferences), lists of possible silvicultural treatments and scenarios, VOIC tables (i.e. endorsed issues and associated objectives, indicators, and targets), graphs presenting the allowable cuts per species and per period, texts describing the issues or possible solutions, different digital layers and maps produced by ArcGIS, etc. The forest users may also guide MFFP/BFEC planners in defining alternative solutions and scenarios (e.g. forest management scenarios). Given that the tools used by MFFP planners and BFEC planners require high technical skills, it is not relevant that Local Panel members (other than MFFP planners or experts) handle these tools. These tools, especially Woodstock, which is an optimization-based tool, are complex to handle, and might take significant time to run. Therefore, generating silvicultural treatments/scenarios and alternative strategic management plans in real time may not be efficient. To deal with this issue, MFFP/BFEC planners could run the tools offline. Then, during the Local Panel meetings, demonstrations by MFFP/BFEC planners or other experts, explaining which assumptions have been taken into account, how the parameters have been set, which scenarios have been tested, and what results have been generated could be presented to the Local Panel members. The Local Panel members can discuss the assumptions, propose new scenarios, comment the results, etc., and a new iteration (offline run of the models followed by a presentation during the meetings) can occur. However, when the results are available, all users can any time access to them online.

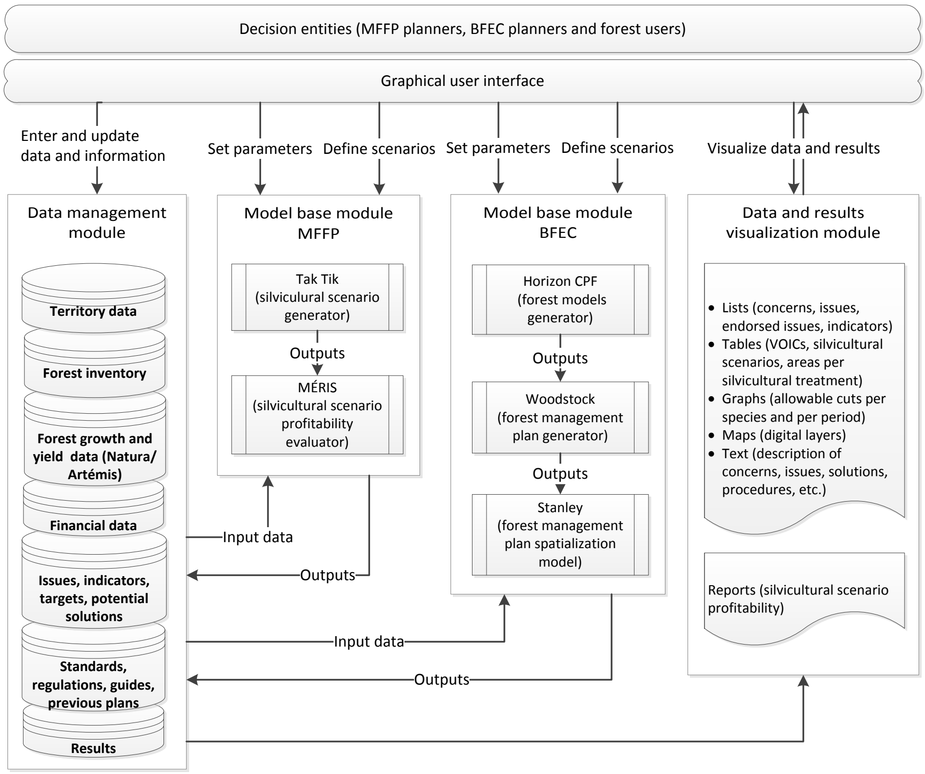

Figure 5: Conceptual design of FC-DSS, inspired by (Garcia-Gonzalo *et al.*, 2015)

4.3 Expected improvements for participatory planning in the forest sector in Québec

DTs appear as a promising approach for dealing with participatory planning issues encountered in the forest sector such as those observed in the province of Québec (see sections 2.2 and section 4.2.1). For instance, information availability was identified as a major issue in many regions. Information located in shared data bases (descriptive data, input data, results, etc.), which can be accessed easily in real-time on the web would substantially improve this situation. This is one of the capabilities of FC-DSS. FC-DSS also supports the forest users in representing and sharing their knowledge, issues, and expectations, by providing the functionality of entering directly into the system, concerns, issues, potential solutions, description of concerns/issues/solutions, etc. In Mauricie region, the interviewed experts indicated that the majority of participants would have appreciated visualizing the results of a given solution. This would have improved impact analysis, which was pointed out as a major issue in other regions. FC-DSS provides a visualization module that offers the possibility to visualize data and results in different ways (maps, lists, tables, videos, charts, etc.). By taking advantage of recent application development, it could also be possible to interact with the data, for example, by exploring a landscape (2D map or a realistic 3D map) from different perspective and observing distances or by challenging the parameter values of the decision support tools. These capabilities combined with DT's specific layout and wall screens provides the possibility to display large amount of data in an "optimized" way, by exploiting the configuration of the wall screens (e.g. in figure 1, the cascading effect of a decision can be displayed from the left screen up to the right screen). This can help to figure out the effect of an assumption or a decision (e.g. a silviculture scenario) on different indicators (e.g., AAC, age structure indicators, etc.), and support trade-off analysis, negotiation, and consensus building. Information input/display, interaction capabilities and experts' support, would also improve the comprehension of forest users regarding forest management modelling and solving. This would furthermore, enhance their confidence in the information presented to them and in the scientific knowledge (trust and transparency issues). This is a critical aspect of the engagement of forest users in the planning process and their willingness to collaborate and mitigate conflicts (Sheppard & Meitner, 2005; Martins & Borges, 2007).

Last, but not least, implementing FC-DSS would reduce the planning process duration. Enhancing comprehension, transparency, trust, willingness to collaborate and to mitigate conflicts would accelerate negotiations and consensus building among the forest users. On the other hand, improved information sharing among MFFP planners, BFEC planners, and forest users would enhance communication and coordination, and mitigate silo working.

5 CONCLUSION

Immersion, interaction with technology, and data visualization offer new opportunities for decision makers, stakeholders and planners to make better decisions in complex situations that traditional decision support tools cannot address alone. DTs are one of the approaches offering these capabilities. In this paper we proposed a generic framework for designing DTs. To show how this framework could be implemented in real-life, we developed the conceptual design of a DSS called Forest Community DSS (FC-DSS) for dealing with a participatory planning in the forest sector observed in the province of Québec. We are currently at the phase of validation of this conceptual design with our partners from MFFP. In our future work, we intend to map the decision making processes (tactical panning) implemented in different regions of Québec, and identify best practices in order to propose a well-structured decision making process to implement in the DT. We will also investigate at which phases of the decision making process (problem identification, problem modelling, and problem solving) FC-DSS should be used to support the decision makers and stakeholders.

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