

Sustainable forest management using Decision Theaters: Rethinking participatory planning

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ABSTRACT: Involving stakeholders in the decision-making process can be very complex and time consuming. Decision theater (DT), which enables the combination of visualization and decision modeling capabilities together with human capacity of insight and interaction, is proposed for addressing this challenging problem in the forest sector. A generic framework for designing DTs to support participatory planning in the forest sector is proposed. To enable DT implementation and support decision-making in the DT in the province of Québec, Canada, the conceptual design of a decision-support system called Forest Community-DSS (FC-DSS) has been developed. Implementing FC-DSS along with other technologies in a DT environment can contribute to engage the stakeholders in the decision-making process by increasing participation frequency, collecting more inputs from the stakeholders, supporting the development and evaluation of alternative options and the selection of preferred alternatives. A DT-based collaboration approach would contribute to address the multiple issues of the stakeholders involved in participatory planning in Québec. Other Canadian provinces and other countries facing similar issues can benefit from the proposed approach.

KEYWORDS: Decision theater, participatory planning, sustainable forest management, DSS, group decision-making.

1. INTRODUCTION

Integrating sustainability goals in the decision-making process and promoting social acceptability is crucial for successful sustainable planning. This requires inviting the community members to share their concerns and perspectives and participate in the decision-making process. Examples are found in environmental management (Antunes et al., 2006), waste management (Hornsby et al., 2016), urban planning (Salter et al., 2009), and natural resources management (Langsdale et al., 2013). However, involving stakeholders in the decision-making process can be very complex and time consuming. Often the stakeholders have different backgrounds, different personal values and interests, and their perceptions might be as important as facts (Bishop et al., 2008). As a result, conflicts may arise, leading to situations where it is impossible to find compromises. All these issues are observed in the process of forestry planning in Canada.

About 350 million hectares in Canada are covered by forests, of which more than 90% are publicly owned (NRCAN, 2016). As such, public requirements on how forests should be managed must be rigorously taken into account. Many benefits are expected from the forest, ranging from employment opportunities, tourism, local economic development, ancestral practices, to ecosystem services. Moreover, a wide range of forest users having rights or agreements with government co-exist in the same forest territory, which inevitably leads to disagreements and conflicts. To address these issues, the government in the province of Québec adopted a new forest regime in 2013 that promotes sustainable forest management (SFM). SFM focuses on conservation of biodiversity, soil, water, ecosystems, and productivity as well as social issues, which is an identified open problem in forestry (Rönnqvist et al.,

2015). The new regime introduced a participatory mechanism called “*Local Integrated Land & Resource Management Panel*” (hereinafter referred to as Local Panel). The aim is to enable the stakeholders to express their concerns and take part in forest management planning. Despite the social acceptance of the Local Panels as a participatory mechanism, many issues have been identified, revealing their limits. Lack of information at the right time, inconsistency of data, lack of impact analyses, lack of transparency and trust, and difficulty in finding compromises and reaching consensus are some of those issues. In fact, the stakeholders may expect to be offered the possibility to evaluate alternative options from the perspective of their interests, knowledge, and value-driven criteria, and may wish to contribute to problem definition, problem analysis and solution generation (Antunes *et al.*, 2006; Andrienko *et al.*, 2007). To this end, the stakeholders need an easily understandable presentation of information and easily usable interaction facilities (Andrienko *et al.*, 2007; Salter *et al.*, 2009; Rammer *et al.*, 2014). The Local Panels currently do not address all these aspects.

In forest participatory planning literature, methods such as multi-criteria techniques, goal programming, multi-agent systems (MAS) combined with interactive and visualization tools have been developed. However, these methods alone are not sufficient. They need to be integrated and become a part of a participatory mechanism acceptable to the stakeholders as a means for making decisions. As stated by Phillips and Bana e Costa (2007), unless models are included in a social process that becomes an accepted way of doing things, institutionalized within an organization’s culture, they will not survive when their champions leave the organization. DTs are one of these processes. DTs enable the combination of visualization and decision-modeling capabilities together with human capacity of insight and interaction. They offer easily usable interaction facilities and easily understandable visualization of information to the stakeholders. Thus, DTs combined with forest participatory mechanisms already implemented in Québec, offer a promising approach for dealing with forest planning in Québec. However, current studies do not provide comprehensive information and methods on how to design and implement DTs, notably in the context of participatory planning in the forest sector. The main contributions of this paper are a generic framework for the design of DTs to support participatory planning in the forest sector and a proposal of a conceptual design of a decision support system (DSS) called Forest Community-DSS (FC-DSS), aimed at facilitating decision-making in the DT and implementing the proposed framework in the province of Québec. The remainder of the article is as follows: next section provides an overview of the main forest participatory planning approaches using interactive and visual tools, a description of DTs, and recent contributions in the field. Section 3 describes current public-owned forest planning in Québec and presents a regional case study and Local Panels’ main issues. Section 4 presents the proposal. In Section 5, the proposal is discussed. Finally, the conclusions are presented in Section 6.

2. LITERATURE REVIEW

This section first presents the main forest participatory planning approaches using interactive and visual tools. Second, it describes DTs and the main contributions in the literature.

2.1 Forest participatory planning approaches

In 2011, the European Commission reaffirmed the importance of Corporate Social Responsibility (CSR) in creating opportunities for innovation and growth and offering values “on which to build a cohesive society and on which to base the transition to a sustainable economic system” (EC, 2011). One of the principles of CSR relies on the management of organizations’ interaction with their stakeholders (EC, 2011; GRI, 2013; Panda and Modak, 2016). This requires inviting the community members to share their concerns and perspectives and participate in the decision-making process. Involving the stakeholders in the decision-making

process is an important problem in forest resources management. Proposed approaches focus on stakeholder election, acquisition of information to understand the problem, modeling the relations between alternative options and outcomes of decision-makers and stakeholders, and selecting an option (Martins and Borges, 2007). Approaches used for selecting the stakeholders could be informal based on criteria such as history with planning processes (Grimble and Wellard, 1997; Khadka and Vacik, 2012) or formal, based on matrices representing the influence and the importance of the stakeholders (Sheppard and Meitner, 2005). For information acquisition such as goals, management alternatives, and conflicts, participatory methods such as interviews, Delphi method, brainstorming, and the nominal group technique are commonly used. Maps and visualization tools are used to complement these methods, which might require significant cognitive effort from the stakeholders. In a Swedish case study, Nordsröm *et al.* (2010) reported that during interviews aimed at collecting the stakeholders' views on forest management, the stakeholders were given maps to mark the areas of interest to them and explain how they should be managed to benefit their interests. For problem modeling and problem solving, four main approaches are used; optimization methods, multi-criteria techniques, SoftOR, and multi-agent systems (MAS). These approaches can also be used for information acquisition (Martins and Borges, 2007).

Multi-criteria methods are used to structure the problem, weight the criteria, and evaluate the alternative options against the criteria in order to choose an option. The weighting process can be facilitated by a general approach or through software. As an example, Ananda (2007) used AHP (Analytic Hierarchy Process) and Expert Choice software to obtain the stakeholders' preferences regarding three alternative forest management plans in a regional case study in Australia. Mendoza and Dalton (2005) implemented AHP in a web-based software for multi-stakeholder assessment of forest sustainability in Ontario, Canada. The use of AHP is frequently used and reported from other countries such as Finland (Kangas, 1994), Sweden (Nordsröm *et al.*, 2010; Lundström *et al.*, 2016), Nepal (Khadka and Vacik, 2012) and Spain (Rico and Gonzalez, 2015). Other multi-criteria techniques used include, among other, multi-criteria approval voting (Lukkanen *et al.*, 2002), Multi-Attribute Utility Theory (Ananda and Herath, 2003), PROMETHEE II, ELECTRE III (Kangas *et al.*, 2003), and the Analytic Network Process (ANP) (Groselj *et al.*, 2015). One limitation of multi-criteria techniques is that they do not support the stakeholders in generating alternative plans. Regarding optimization methods, goal Programming is the most used technique to consider the multiple objectives of the stakeholders. Garcia-Gonzalo *et al.* (2015) described SADfLOR DSS, which implements goal programming. SADfLOR provides interactive decision maps that illustrate in a graphical form possible trade-offs between the objectives (Borges *et al.*, 2017). The Monsu software developed in Finland implements goal programming and utility theory formulation (Pukkala, 2004). Monsu includes a visual interface to interactive optimization, which shows how changes in the importance of objectives affect the solution, and a landscape visualizer allowing the user to visualize the current forest or its future states. Virtual Reality Modeling Language (VRML) files can also be used to generate visualizations allowing the user to move in a virtual forest (Pukkala, 2004). In the same vein, Falcao *et al.* (2006) developed a real-time forest landscape 3D-visualization tool for very large areas in Portugal. A visualization system linking forestry modeling programs and a 3D rendering engine that creates portrayals of forest landscapes was also developed in British-Columbia, Canada (Meitner *et al.*, 2005). The impact of such forest landscape portrayals on the stakeholders was investigated in a pilot study (Sheppard and Meitner, 2005).

SoftOR includes different methods known as problem structuring methods (Rosenhead, 1989). Some methods such as the Strategic Option Development and Analysis (SODA) involve the use of a software. Within SODA methodology, a facilitator interviews group members and models the perceptions of each member in a cognitive map - a network of concepts

(nodes) linked to form chains of argumentation (Hjortsø, 2004). The individual maps are merged by the facilitator to establish, for example, a comprehensive definition of the problem, showing multiple explanations and consequences, multiple options, and anticipated effects of options (Eden and Ackermann, 1998). Hjortsø (2004) applied SODA to a Danish case study to support public participation in strategic forest management planning. Decision Explorer software was used to facilitate the cognitive mapping aimed to support eliciting stakeholder knowledge and perceptions and presenting the aggregated result in a useful form for negotiation (Hjortsø, 2004). One limitation of cognitive mapping is that it is not possible to convey the geographical location of forest activities. Thus, the information produced by its solution might be of little value to understand the management problem and to efficiently support decision-making (Borges *et al.*, 2002). MAS approach was adopted by Bousquet *et al.* (1998) to develop a simulation environment called CORMAS, aimed for renewable resource management. Projections of outcomes of individual management plans are defined with role-playing games and can be visualized with a Geographic Information System (GIS). In fact, GIS is used in many studies as a tool for organizing the data in a consistent way and providing user-friendly displays (Martins and Borges, 2007). Ligtenberg *et al.* (2004) also explored MAS to simulate spatial planning scenarios based on modeling a multi-actor decision-making process.

All above methods, while presenting certain limitations, undeniably play an important role in forest participatory planning processes. DSSs in particular have proven to be suitable platforms for complex and strategic large-scale planning problems (Martins and Borges, 2007). However, these methods alone are not sufficient and need to be integrated in a decision-making framework for participatory planning. Phillips and Bana e Costa (2007) proposed using decision conferencing. This is a process where the key players who wish to resolve important issues facing their organization gather. They are assisted by an impartial facilitator, who is a specialist in decision analysis, using a model of relevant data and judgements created on-the-spot to assist the group in thinking more clearly about the issues (Schein, 1999). However, within decision conferencing framework, in-live development of complex forest planning models is not realistic.

2.2 Decision theaters

The term decision theater was used in the 70s to designate a new teaching approach in marketing (Tolle, 1971). A laboratory called “Decision Theatre”, which combines the features of a drama theater, an observer’s gallery, and a behavioral laboratory, was built at Our Lady of the Lake University of San Antonio (Roach, 1986). It was used as a learning facility in management and a research tool in decision-making. More recently, Arizona State University (ASU) 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 DT Network (ASU, 2016). Other universities such as University of Alaska (UA), University of British Columbia (UBC) (Figure 2), Huazhong University of Science and Technology (China) and Tecnológico de Monterrey (Mexico) have also built DTs. The core physical component of the DT in Tempe is called the “Drum” (Figure 1), which is a round room with seven screens arrayed across 260 degrees that can display models, panoramic computer graphics or 3D video content (White *et al.*, 2010). It includes capacity for audio and video recording as well as tools for collecting data from participants (White *et al.*, 2010). Larson and Edsall (2010) studied the effects of visual information technology on public understanding of groundwater management. Based on a water management model called WaterSim, which was presented in the DT to a group of decision-makers, 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’ perception of the credibility, salience, and legitimacy of WaterSim. The Landscape Immersion Laboratory (LIL) at UBC is a three

projector, front-projected theater environment facility with enough room for 10 -15 people (Figure 2) (Salter *et al.*, 2009). Research conducted at LIL aims at investigating the effects of visualization and semi-immersive environments on public ability to understand and evaluate alternative plans. Salter *et al.* (2009) explored the abilities of LIL's immersive display environment and CommunityViz; a GIS based DSS that includes a semi-realistic and interactive landscape visualization capabilities, to improve participant understanding of residential density policies in landscape planning context.



Figure 1. A decision theatre designed and built at Arizona State University (ASU, 2016)

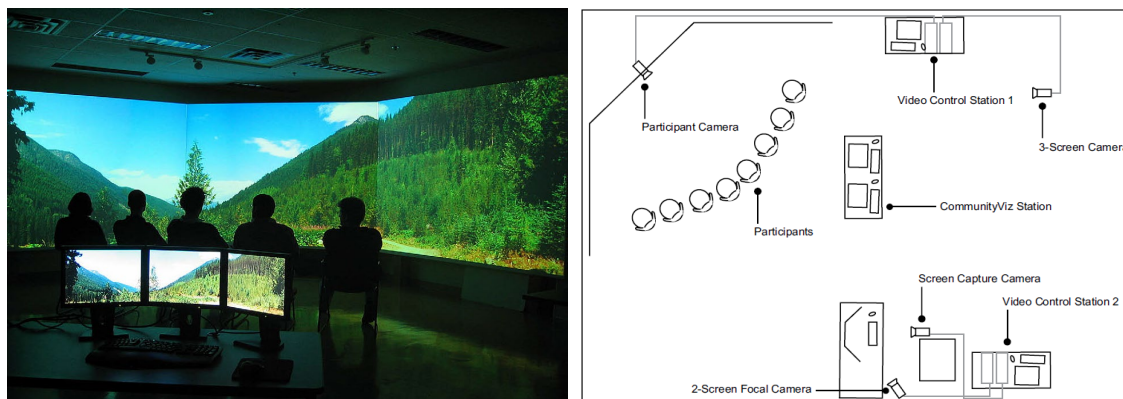


Figure 2. Landscape Immersion Laboratory built at UBC and example of a possible layout (Salter *et al.*, 2009)

Other concepts such as GDSS (Group Decision Support System), war room, operations center, situation room can also be linked to DT. In the 90s, Public Storage used a war room to keep alert for new locations for storage facilities, track the competitors in a particular location, and link potential investors with storage facility opportunities (Shaker and Rice, 1995; Shaker, 2002). The management cockpit war room (Daum, 2006) uses information technologies and ergonomic room design to improve the productivity of a management team. The four walls display information related to the company's resources, the extent to which the objectives are reached, the obstacles, and the decisions that should be made (respectively). Information is structured following the Balanced Scorecard and the Tableau de Board principles with a particular focus on visualization. GDSS is "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). GDSS encompasses four components arranged to support a group in a decision-related meeting: hardware (e.g. input and output devices, common viewing screens), software (e.g. model bases, user interfaces), people (e.g. decision-makers, facilitators), and procedures (e.g. verbal discussions) (DeSanctis and Gallupe, 1985; Huber, 1984). In the military, operations centers are used to collect real-time data and improve situation awareness in time-sensitive operations in order to make quick decisions (Granlund *et al.*, 2001; Brehmer, 2007). Research projects grouped under the

name “command center of the future” have been launched in the 90s in different countries with the aim of designing new arrangements for command & control by taking advantage of new technology development (Brehmer, 2007).

The Future Operations Centre Analysis Laboratory (FOCAL) at Australia’s Defence Science and Technology Organisation is based around an SGI Reality Center and provides a large virtual reality display environment (Wark *et al.*, 2005). It implements a multi-agent architecture to enable interaction, information retrieval and processing, information synthesis, and display. The user interface supports “natural” interaction between users and virtual geospatial displays. FOCAL provides virtual adviser that dialogs with the users and briefs them on a developing situation, point out significant events, and suggest alternative options (Wark *et al.*, 2005). ROLF 2010 project is conducted at the Swedish National Defence College (SwNDC). ROLF 2010 environment is characterized by a small staff, a seating arrangement around a table, and different information technologies (Brehmer, 2007). The seating arrangement is inspired from campfire configuration. A 3D display system called Visioscope™, which is integrated to the table allows staff members to communicate while maintaining eye contact. Large screens mounted onto the walls (Visionarium™) display additional information and offer a different visualization perspective. Individual work stations behind the staff members allow them to communicate with their subordinate commanders and support staff and access to their personal DSSs. Finally, a critiquing system embedded in Visioscope™ (avatar) listens to the plans developed by staff and points out significant aspects (Brehmer, 2007). A micro-world called C3Fire has been developed at SwNDC to test some hypotheses. C3Fire generates a task environment allowing staff members seated around Visioscope™ that displays a shared map, to cooperate with firefighting unit chiefs in order to extinguish a forest fire (Johansson *et al.*, 2003).

While war rooms and operations centers focus on situation awareness improvement and real-time/short term decision-making in a teamwork context, DTs focus more on long-term decision-making in participatory planning contexts. DTs, while having common features with decision conferences, by using recent technology development, provide advanced capabilities for modeling, visualizing, data exploration and analyze, and making decisions in a new way. This makes DTs a suitable approach for handling complex problems inherent to forest participatory planning. However, there are only few studies in the literature reporting on the use of DTs and there is a lack of comprehensive methods on how DTs are designed and implemented to support participatory planning in the forest sector. Some studies are too specific to small instances (e.g. Salter *et al.*, 2009) while others are too general (e.g. ASU’s DT Network).

3 FOREST PLANNING IN QUÉBEC AND CASE STUDY

First, the planning process and participatory mechanisms implemented in Québec are described. Next, a regional case study is presented along with the Local Panels’ issues.

3.1 Forestry planning and participatory mechanisms in Québec

In Québec, more than 90% of the forests are publicly owned. Public forest management falls under the responsibility of the *Ministère des Forêts, de la Faune et des Parcs of Québec* (Ministry of Forests, Wildlife and Parks, hereinafter referred to as MFFP). The new regime introduced integrated planning and new participatory mechanisms (Figure 3) to enable the forest stakeholders to participate in forestry planning (MFFP, 2013).

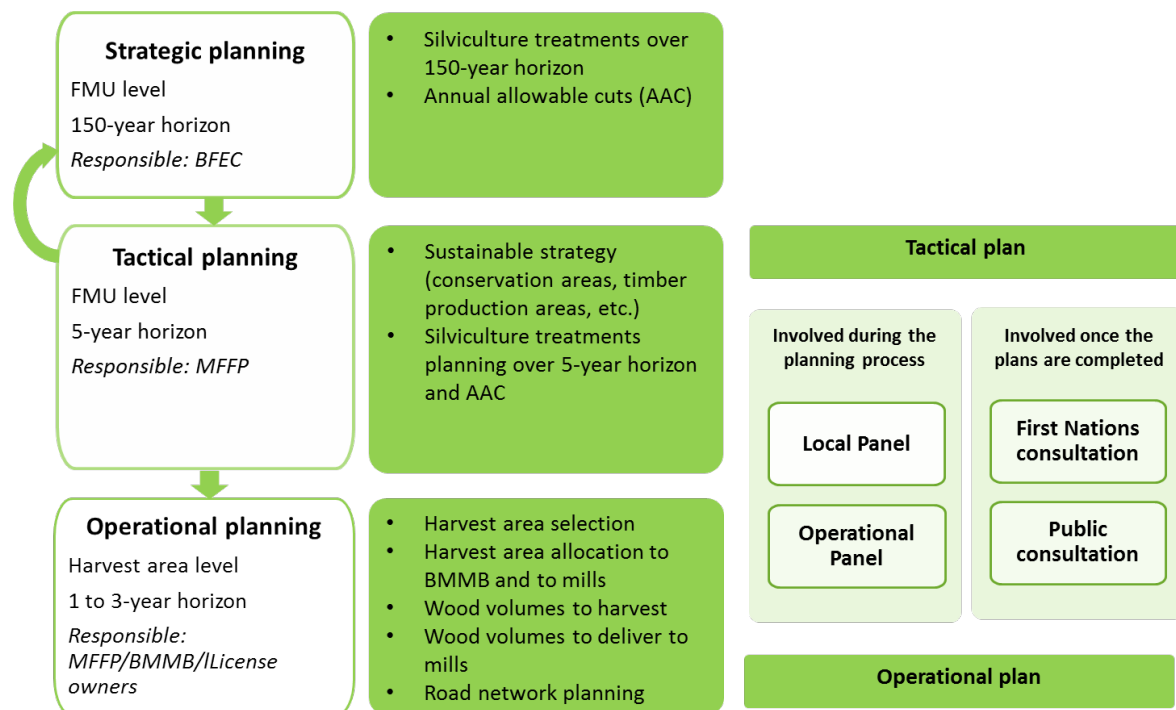


Figure 3. Description of public-owned forest planning in Québec

Three planning levels can be distinguished; strategic, tactical and operational. The plans must be coherent with the provincial and regional orientations. The forest management strategy is the basis for the strategic and tactical plans. In the Québec context, the strategy is determined at the tactical level by MFFP planners in collaboration with the Local Panels. It specifies forest resource allocation (e.g. conservation areas, timber production areas), forest roads and other infrastructures to develop as well as the sustainability goals for a (group of) forest management unit (FMUs¹) for the next five years (MFFP 2013; 2015). The strategy guides the strategic plan, which determines management activities (e.g. silviculture treatments) and the volumes of timber to be harvested annually while ensuring a non-declining yield (i.e. Annual Allowable Cuts, referred to as AAC) over a 150-year horizon (BFEC, 2013). The strategic plan is prepared by the *Bureau du Forestier en Chef* (Forest Chief Office, hereinafter referred to as BFEC²) in collaboration with MFFP for all 71 Forest FMUs of the 13 forest regions of Québec (BFEC, 2013). The strategic plan includes 30 periods of five years each. The decisions of the first period are inputs for the tactical plan. Thus, the tactical plan includes the forest management strategy as well as the management activities and AAC for the upcoming five years. Finally, the operational plan is prepared for a of 1-3-year horizon by MFFP planners in collaboration with the Operational Panels and the Local Panels. This plan uses the outputs of the tactical plan as constraints. Decisions considered include harvest area selection, harvest area allocation to mills and to BMMB, wood volumes to harvest from each harvest area, wood volumes to deliver to each mill, and forest road planning (MFFP, 2013; 2015).

The participatory mechanisms introduced by the new regime are: Local Panels, Operational Panels, First Nations and public consultations. Local and Operational Panels are involved during the planning processes while public and First Nations are consulted once the plans are validated by the Local Panels (Figure 3). These consultation mechanisms allow the broad

¹ An FMU is a forest area, which supplies mills having supply agreements in the FMU's territory.

² BFEC is an independent entity from MFFP.

public and First Nations to express their concerns regarding the forest plans. An Operational Panel is established for an FMU or a group of FMUs subject to a harvesting agreement. Operational Panels are formed of representatives of license owners (i.e. supply guarantee/harvest permit holders), MFFP and BMMB³. The aim of the Operational Panels is to align the requirements of license owners who require forest certification with the forest management strategy and prepare the operational plans. A Local Panel is established by the regional authorities or a regional organization for each FMU (or a group of FMUs) in a given region. However, in the same region, the number of Operational Panels might not be the same as the number of Local Panels. For instance, in a forest territory including two FMUs subject to a harvesting agreement, a Local Panel can be established for each FMU but only one Operational Panel can be established for both FMUs. The category of stakeholders which must be represented at the Local Panels is determined by the law (e.g. First Nations, municipalities, license owners, controlled zone operators, and outfitting permit holders, among others). The aim of the Local Panels is to enable the stakeholders to express their concerns and take part in forest planning.

This study focuses on the contributions of the Local Panels at the strategic and tactical levels. Operational planning and Operational Panels' contributions are beyond the scope of this research. Interested reader can refer to (Gharbi *et al.*, 2014).

3.2 Mauricie region case study and Local Panels' issues

The Mauricie region has a surface area of 40,000 km², of which 85% is covered by forests, mostly publicly owned. The forest industry is an important contributor to the regional economy, with 7,600 created jobs and \$2.4 billions of economic benefits⁴ (2011 estimations, CRÉ, 2011). Over a large part of the territory, more than 7,000 rights and statues have been allocated. This led to the co-existence of multiple users in the territory. There are five FMUs in the region, of which four are FSC (Forest Stewardship Council) certified. The Local Panels have been implemented in Mauricie since 2010. In the beginning, five Local Panels were established for the five FMUs. Later, two Local Panels merged, and at the end of 2015, all four Local Panels merged into one regional Panel. This new Panel focuses on regional issues (common to all FMUs), while local working committees are put in place to address each FMU's specific issues. The regional Panel's participants include the representatives of the following interest groups (MFFP, 2015): First Nations (five representatives), municipalities (three), license owners (three), controlled operation zone (one), wildlife reserves (one), outfitting permit holders (one), maple syrup permit holders (one), tenants of land for agricultural purposes (one), trappers (one), and regional environment council (one). MFFP representatives also participate in the regional Panel's meetings as planners or experts in wildlife habitat, old forests, and legislation aspects, among others. A facilitator ensures coordination with all representatives and animates the meetings. Decision-making is based on consensus. A quorum is required for any meeting or for making any decision. The quorum is 50% + 1 of all categories represented at the regional Panel and 50% + 1 of representatives having a voting right. MFFP representatives and the facilitator do not participate in decision-making and are not included in the quorum. The detailed planning process is described in Section 4.

The aim of merging the four Local Panels into one regional Panel was to eliminate redundancy and improve Local Panels' efficiency. In fact, the four Local Panels met with only limited success. Interviews were conducted by the research team in December 2015 and April 2016 with the coordinator of the four Local Panels and two MFFP representatives. It was reported

³ Timber is obtained from public forests based on supply agreements (supply guarantees for mill owners and harvest permits for non-owners) or via a public auction market, under the responsibility of the Timber Auction Office (Bureau de Mise en Marché des Bois, referred to BMMB).

⁴ Canadian dollars.

that some participants were not willing to participate in the discussions or clearly express their opinions (e.g. participants who do not feel confident with their knowledge) while other participants did not trust the scientific knowledge and information presented to them, but relied solely on their perceptions. It was also mentioned that real consensus was extremely difficult to achieve. In some cases, two sub-groups having differing views were formed inside the Panels, and this resulted in extreme inconsistency among goals and the impossibility of finding compromises. In this regard, some economic objectives (e.g. maximizing the AAC) were not even consistent with the ecological objectives defined by the SFM. The most conflicting issues were related to forest road network planning, wildlife habitat, and the landscapes. Finally, the lack of information and impact analyses was pointed out as a major issue.

Despite the implementation of one regional Panel in Mauricie to improve the participatory mechanism, the aforementioned issues have still not been addressed. In fact, these issues are common to many regions in Québec (Robert, 2013; Althot, 2014; Fortier and Wyatt, 2015). The main issues identified in Maurice region and in other regions of Québec are presented in Table 1.

Table 1. Main issues of the Local Panels in the province of Québec

<ul style="list-style-type: none"> • Fuzzy, complex, and long planning process (2-3 years) • Lack of information at the right time/delays/lack of reactivity and long feedback of MFFP • Lack of coordination • Lack of trust and transparency, and unwillingness to collaborate • Difficulty in understanding information and lack of trust in scientific knowledge 	<ul style="list-style-type: none"> • Regional particularities are not sufficiently considered • Forest resources users' concerns are not taken into account • Lack of impact analyses • Information inconsistency • Divergent goals, absence of compromises, conflicts and absence of consensus • Inefficient plans
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Currently, the government, regional authorities and the stakeholders are seeking to address these issues.

4 PROPOSED APPROACH AND METHODOLOGY

A generic framework for the design of DTs to support forest participatory planning is proposed. In order to implement DTs in Québec to support the Local Panels, the research team relied on a qualitative approach combining interviews, documentation, and field observations, to map the forest planning process and capture the participatory planning features. This allowed the research team to identify existing components and additional elements required for implementing DTs in Québec. One of these components is an integrated DSS, required for supporting decision-making in the DT. Therefore, the conceptual design of a DSS is proposed (i.e. FC-DSS). First, the generic framework is presented. Second, the implementation of the framework in the Québec case is described.

4.1 A framework for decision theater design for forest participatory planning

The proposed framework (Figure 4) is based on information provided in the literature (Salter *et al.*, 2009; White *et al.*, 2010), ASU website, and GDSS concept (Huber, 1984; DeSanctis & Gallupe, 1985) (see Section 2) as well as the experience of the authors in forest collaborative planning. The principles and best practices of participatory planning using models (collaborative modeling) in natural resources management were also considered (Martin and Borges, 2007; Langsdale *et al.*, 2013).

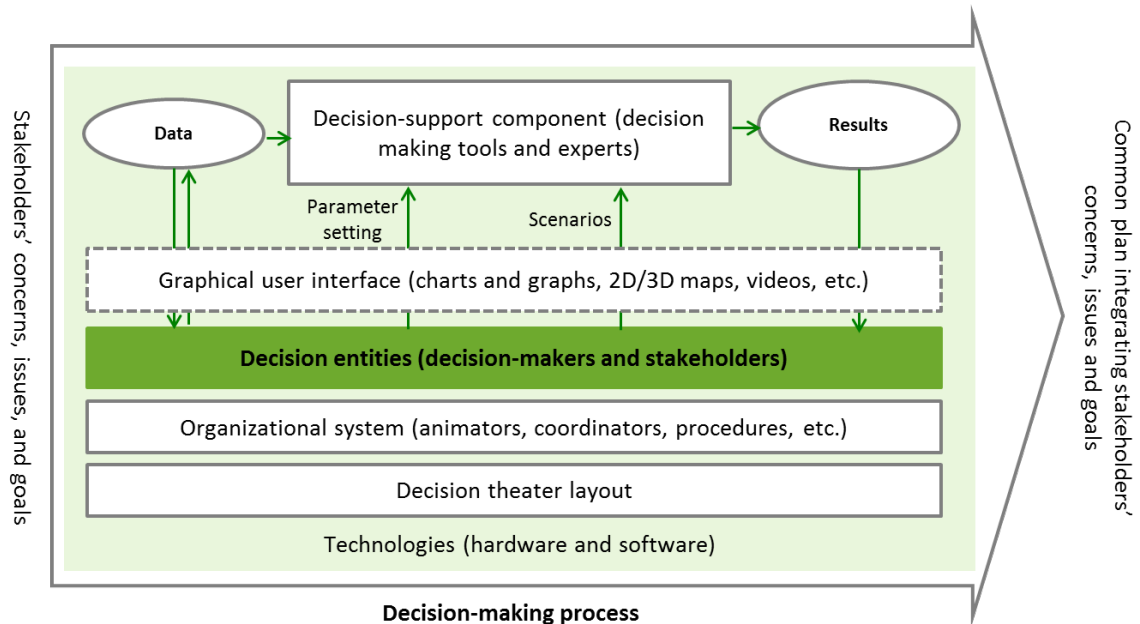


Figure 4. Conceptual framework for the design of a decision theatre

The proposed DT design is aimed at supporting participatory planning. Therefore, as shown in Figure 4, the stakeholders' concerns, issues, and goals should be considered in the decision-making process, which ultimately produces a common plan integrating those concerns, issues, and goals. The DT encompasses five components: *decision entities*, *decision support component*, *organizational system*, *technologies*, and *decision theater layout*, which all support the decision-making process.

a. Decision entities

The decision-makers and the stakeholders are the decision entities. The identification of stakeholder and the selection of their representatives should ensure an adequate representation of all organizations or persons directly or indirectly affected by the decision-making outcomes. The elected stakeholders should share decision-making power and be involved in all planning steps (Martins and Borges, 2007). Other participants such as facilitators and experts might be involved and have an impact on the decisions, however, they do not participate in the decision-making.

b. Decision-support component

The decision-support component refers to the decision-support tools and experts. Decision-makers and stakeholders need tools for example, to represent their issues and goals, express their preferences, evaluate potential solutions, and prioritize the options. These tools range from simple qualitative tools to more advanced planning tools such optimization techniques. Experts might be scientists who can provide the decision-makers and the stakeholders with specific knowledge. Experts might also be decision-support specialists (or modelers) responsible for running the decision-support tools. The modeler must be able to listen, understand stakeholders' expectations, adjust models to reflect what is relevant to the stakeholders, and provide answers in a timely fashion (Langsdale *et al.*, 2013).

c. Organizational system

This component includes facilitators, coordinators, technicians, and procedures. In some cases, the facilitator and the modeler can be the same person (Langsdale *et al.*, 2013). The facilitators provide context information and guidance through the decision-making process (Rammer *et al.*, 2014). They must be sufficiently informed to translate between different

disciplines, ensure that discussion remains relevant, and synthesize what participants are saying (Langsdale *et al.*, 2013). Neutral facilitators are essential for ensuring full participation of the stakeholders (Desrosiers *et al.*, 2010). The coordinators organize the meetings, communicate with the participants, and produce meeting reports, among others, while technicians manage the hardware and network connections and assist decision-makers and stakeholders in the use of their computers. The procedures specify the functioning rules of the participatory mechanism (e.g. participants' election process).

d. DT layout

The layout represents the physical configuration of the DT such as the size and shape of the meeting room, the size and shape of display screens, and the arrangement of tables and seating chairs. Different configurations can be designed. For instance, the DT in Tempe (Figure 1) has a round room with seven screens arrayed across 260 degrees, and which allows for conference room or theater-style seating (White *et al.*, 2010). Within ROLF environment, staff members sit around a table to allow for eye contact and facilitate interactions (Brehmer, 2007). Another example is the three projector, front-projected theater environment of the Landscape Immersion Laboratory (Salter *et al.*, 2009) (Figure 2).

e. Technologies

Technologies are at the heart of DTs and support all other DT components. They encompass the hardware and the software. The hardware includes physical devices used to input, store, extract, and visualize data such as computers, tablet PCs, common and individual displaying screens, electronic boards as well as communication and recording devices. The software concerns databases, model bases, graphical user interfaces, communication protocols (e.g. Internet and Wi-Fi), and other application programs. Graphical user interfaces play an important role in visualizing and interacting with data. They allow the participants to display and visualize different content including tables, lists, charts, videos, and 2D/3D maps.

In the implementation phase, it is important to consider the particularities of the planning process and participatory mechanism put in place. The next section presents the proposed implementation of the framework in public-owned forest management in Québec.

4.2 Implementing the proposed framework in Québec case

First, the planning process mapping is presented. Second, the DT components required to for Québec case are identified. Finally, the conceptual design of FC-DSS is described.

4.2.1 Mapping of the participatory planning process in Québec

The research team relied on interviews, documentation, and field observations. The interviews were conducted during the December 2015-August 2016 period, with three MFFP experts involved in elaborating the forest planning process (documented in the manual of forestry planning), and five other experts involved in implementing and operating Local Panels in three regions. The manual of forestry planning, which is produced by MFFP describes the planning process. This manual, the manual for determining the AAC (BFEC, 2013), and the documents describing tactical plans in Mauricie and Lanaudière regions (2013-2018 period) are the key documents used. The guide for implementing Local Panels (Desrosiers *et al.*, 2010) and different reports of Local Panels meetings were also consulted. Finally, the research team attended two meetings of two distinct Local Panels in Lanaudière and Mauricie regions (April and May 2016, respectively). The macroscopic mapping of the planning process is illustrated in Figure 5. Figure 5 is complemented by Figure 6, which shows more precisely the steps of the process, from the stakeholders' representatives election up to the production of the tactical and strategic plans. Figure 7 provides a more detailed view of the process (information exchange and data processing by the decision-support tools).

• **Macroscopic mapping of the planning process**

As shown in Figure 5, the actors involved in the decision-making process are the Local Panel members, MFFP planners, and BFEC analysts (non-members of the Local Panel). The members of the Local Panels might be representatives of the stakeholders or the MFFP. MFFP representatives act as the ultimate decision-makers, planners or experts. Researchers, consultants, and observers can also be invited to the Local Panel meetings. Coordinators and facilitators are identified by the organization responsible for the Local Panels for organizing and conducting the meetings. MFFP planners and BFEC analysts use the outputs of the Local Panels to prepare/adjust the strategic and tactical plans and provide the results to the Local Panels. While, the Local Panel members meet four to five times during the year, working committees (formed by members of the Local Panels and experts) work continuously on specific topics (e.g. proposing potential solutions for addressing stakeholders' issues). The results of the working committees are presented to the Local Panel members during their meetings (Figure 6). The planning process duration is two to three years. The main activity of MFFP, the information acquisition stage, is to present ecological issues identified in the SFM strategy and other provincial/regional issues or those considered in previous plans. Issues defined in the SFM strategy range from age structure, vegetal composition, forest configuration, wildlife species and habitat, to water and soil protection. The stakeholders' representatives also present their issues (e.g. visual landscape quality, timber production, and forest certification requirements). Most relevant issues are endorsed and classified as operational or tactical (Figure 6).

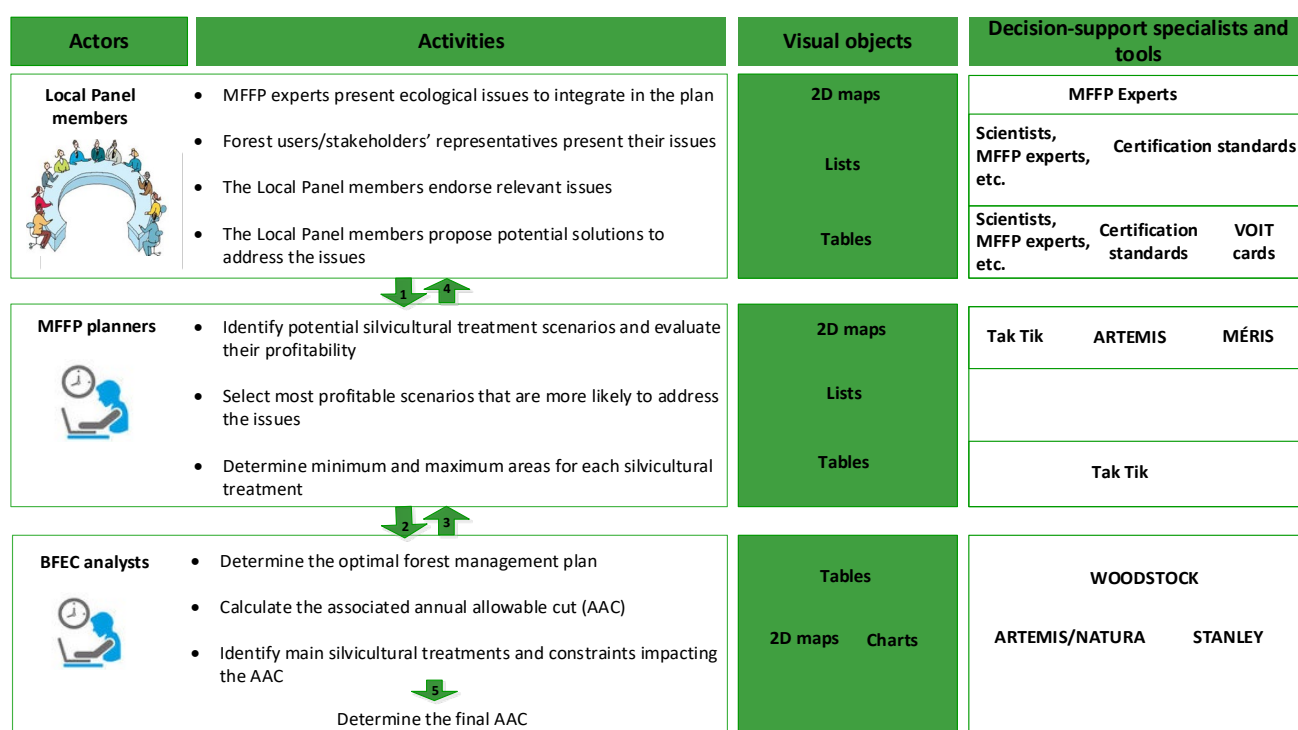


Figure 5. Macroscopic mapping of the planning process

Operational and tactical issues are dealt with at the operational and tactical level, respectively. Endorsing the issues allows the Local Panel members to determine the goals of the forest strategy of the FMU(s). Potential solutions are then proposed (Figure 6). A potential solution can be a specific silviculture treatment such as partial cutting, area conservation, and extending stand revolution. Tables presenting endorsed issues, the objectives, indicators and their targets, known as VOIT cards (Value, Objective, Indicator, Target), and a synthesis table of these VOITs, are prepared. VOIT cards are used to synthesize information, and to

monitor the implementation of proposed solutions. For more on VOIT, the reader can refer to CSA-Z809-08 (CSA, 2008). Other decisions such as identifying intensified fiber production areas and prioritizing forest roads to develop are also discussed by the Local Panel members.

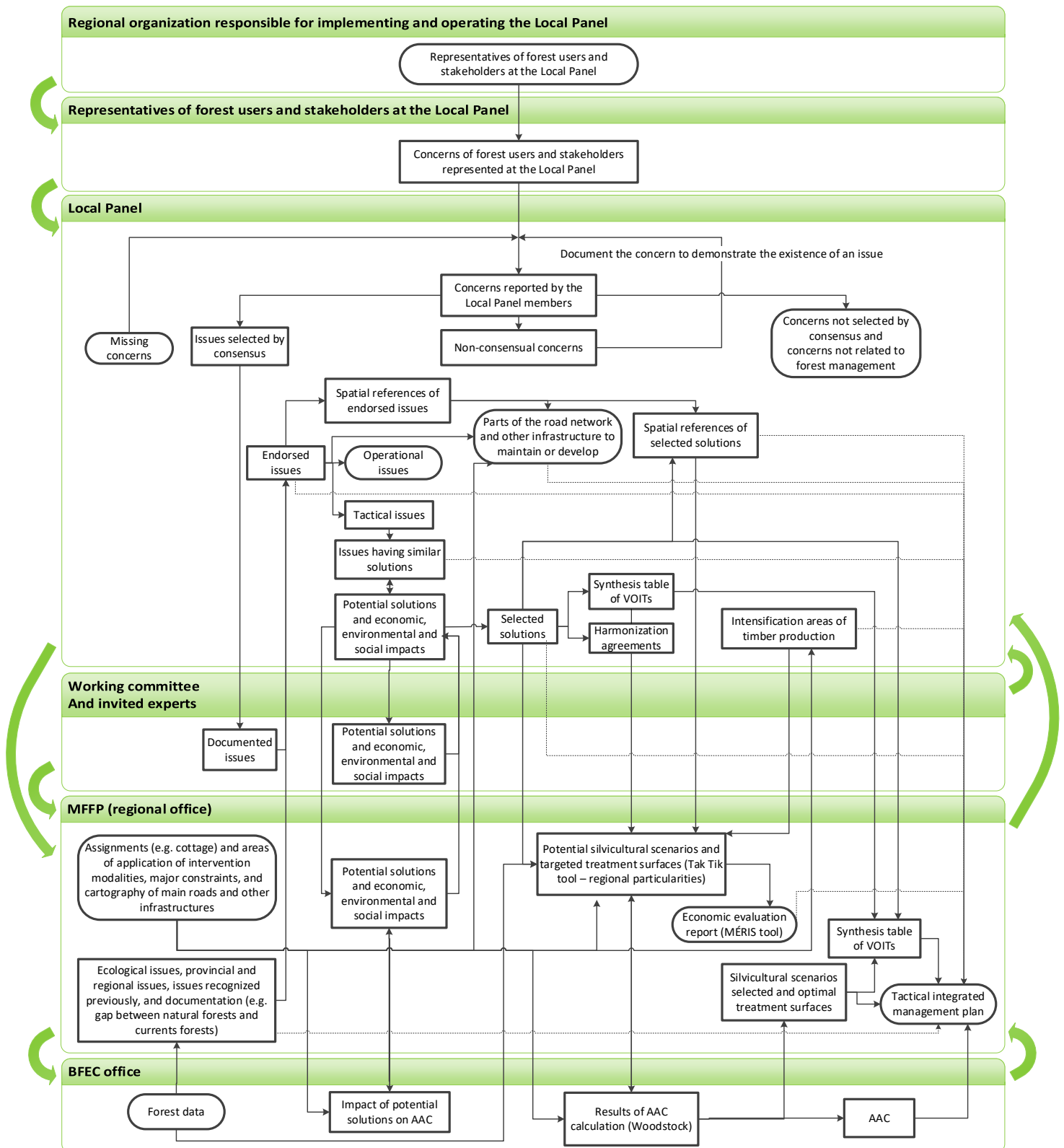
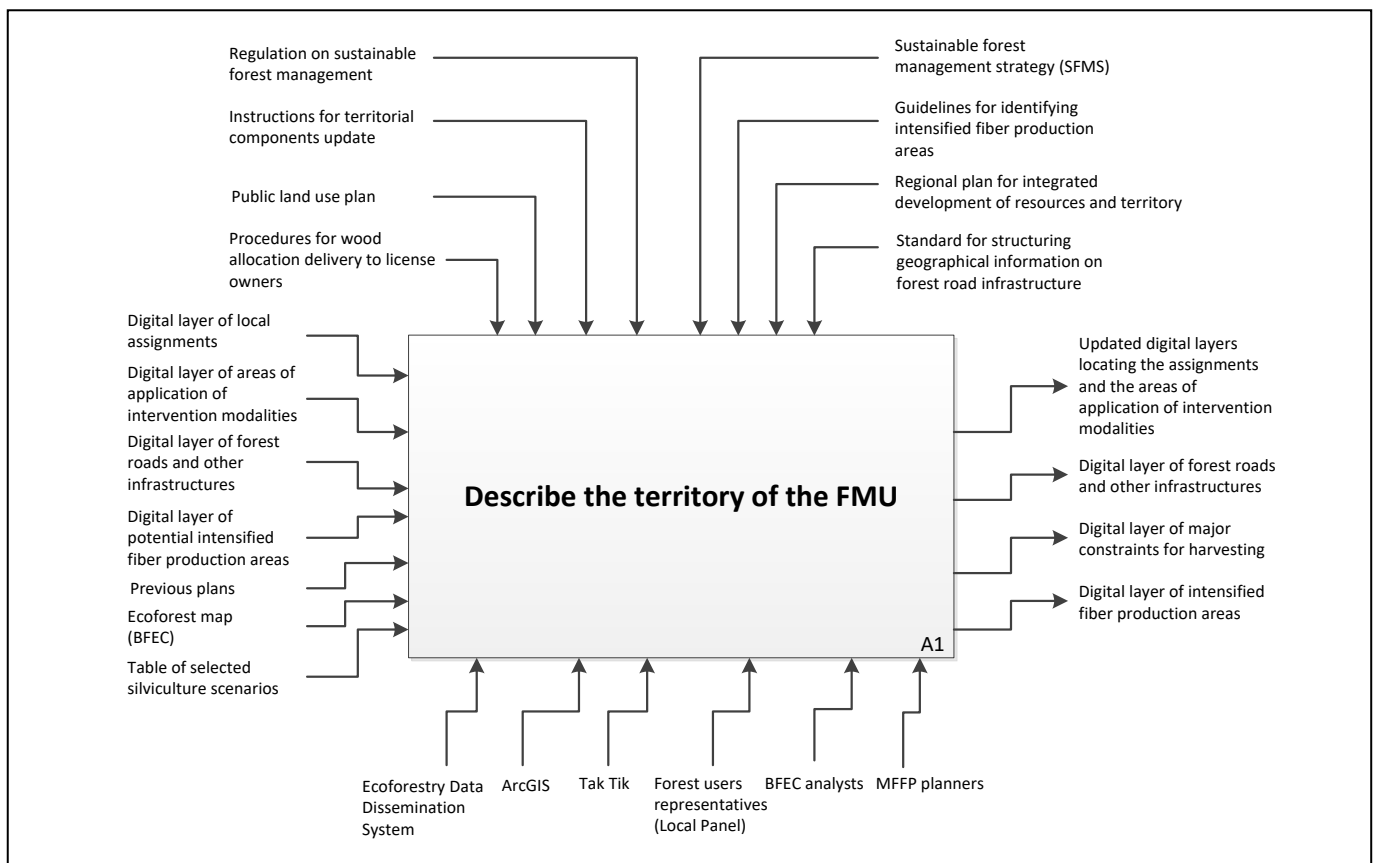


Figure 6. Main steps of the planning process

The proposed solutions are further refined by MFFP planners, who determine more precisely the silviculture actions and silviculture scenarios, by using Tak Tik tool, which also provides the minimum and maximum area surfaces for each silviculture treatment. Another tool (MÉRIS) is used jointly with forest growth/yield data (ARTEMIS) to evaluate the profitability of the silviculture treatments. Most profitable silviculture scenarios that are more likely to address the issues are selected and provided to BFEC analysts, who produce the strategic management plan. BFEC analysts use the optimization-based tool Woodstock jointly with forest growth/yield tools (ARTEMIS and NATURA) and a spatialization tool called Stanley to generate the optimal strategic plan and AAC. The results are provided to MFFP planners who may adjust the silviculture scenarios and maximum/minimum area surfaces before BFEC analysts determine the final AAC. Finally, information on the VOIT cards is updated to include the final results of MFFP planners and BFEC analysts.

• **Detailed mapping of the planning process**

IDEFO methodology (Icam DEfinition for Function Modeling) was used to map the detailed planning process and show information exchange and how the data is processed by the decision-support/visualization tools (Figure 7). IDEFO is appropriate for modeling complex processes (Aguilar-Savén, 2004). It has been successfully used in forestry studies (Haapaniemi, 2011; Erlandsson, 2013). The activity represented in Figure 7 is the description of the FMU's territory. The activity is further decomposed into four sub-activities A1.1, A1.2, A1.3, and A1.4. The aim is to precisely describe which input data are required by which activity, which outputs are produced from the inputs, which controls are required (i.e., arrows entering the top of the box which specify conditions required to produce correct outputs), who is performing the activity and which tools are used (arrows entering from the bottom of the box) while keeping the link between sub-activities. By using IDEFO, the data needed to perform all planning process's activities, in which form and where the data is available (e.g. databases), and which actors/tools use the data, were identified.



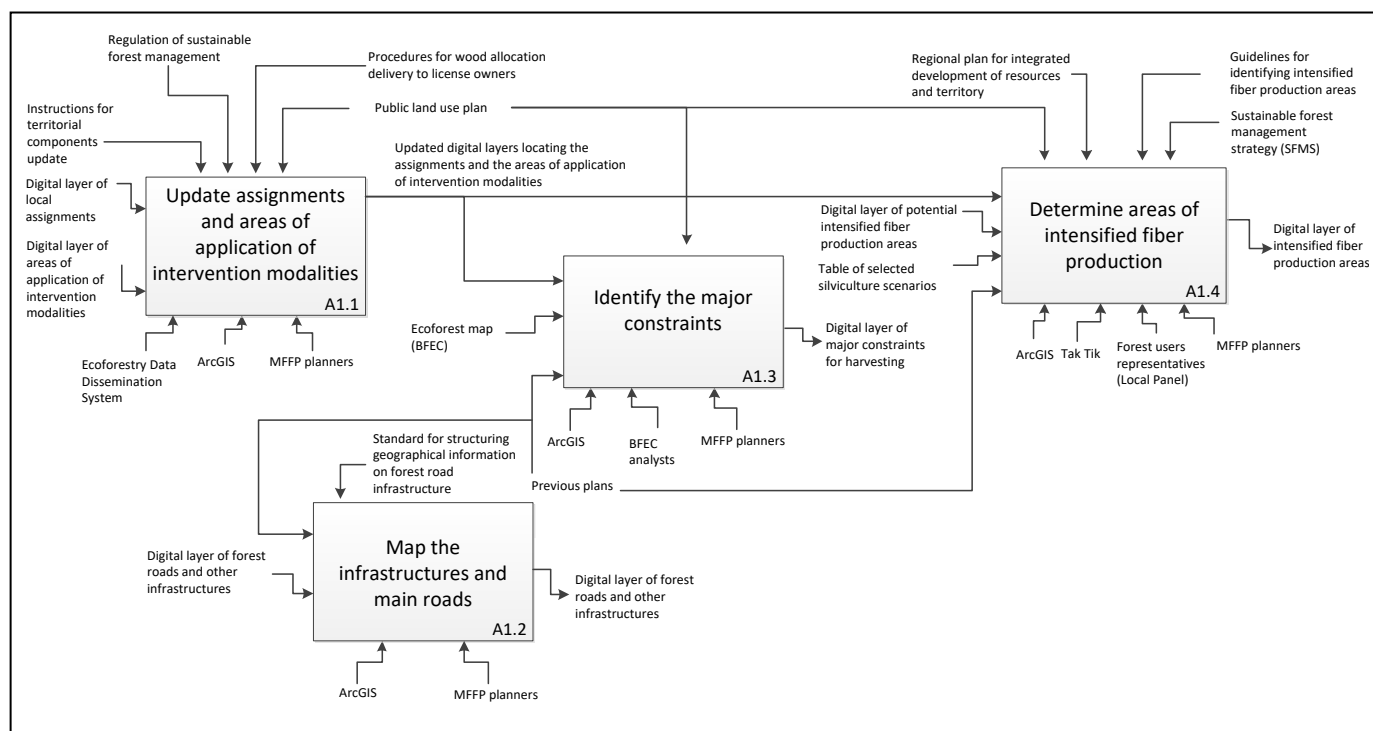


Figure 7. Activity breakdown into sub-activities by using IDEF0

4.2.2 Designing the DT components for Québec case

The planning process mapping identify which elements of the current participatory planning process could be integrated as components of the DT and the additional elements required to implement DTS in Québec (Table 2). In particular, the conceptual design of the decision-support component (called FC-DSS) and a possible DT layout are proposed.

Table 2. Additional elements required for implementing DTs in Québec

Components	Existing elements	Elements required
a. Decision entities	<ul style="list-style-type: none"> Decision-makers: MFFP representatives Representatives of the stakeholders 	<ul style="list-style-type: none"> Representatives of BFEC (stakeholder)
b. Decision-support component	<ul style="list-style-type: none"> MFFP experts and scientists VOIT cards and certification standards GIS Generator of silviculture actions and scenarios (Tak Tik) Silviculture profitability analysis tool (MÉRIS) Forest growth/yield simulators (ARTEMIS and NATURA) Forest management plan optimization tool (Woodstock) Forest management spatialization tool (Stanley) 	<ul style="list-style-type: none"> BFEC experts Integrated DSS: FC-DSS (Figure 9)

c. Organizational system	<ul style="list-style-type: none"> Facilitators and coordinators MFFP planners (modelers) Procedures (e.g. Local Panel members' election, decision endorsement, and conflict resolution) 	<ul style="list-style-type: none"> Specialists in Tak Tik and MÉRIS Specialists in forest growth/yield simulators Specialists of Woodstock and Stanley tools Procedures for using FC-DSS
d. DT layout	<ul style="list-style-type: none"> "U" configuration of the tables (Figure 8) One front projected screen 	<ul style="list-style-type: none"> Minimum of three arrayed (and mobile) screens Reconfigurable tables Mobile chairs
e. Technologies	<ul style="list-style-type: none"> Hardware: computers, projector, tablet PCs, paper board Software: GIS database, model bases (Tak Tik and MÉRIS, Woodstock, among others) 	<ul style="list-style-type: none"> Large screens (three to five) Common database Personalized graphical user interfaces Remote communication technologies (e.g. visio-conferencing) Wi-Fi and Internet access Recording devices and cameras

- DT layout (component d)**

The DT layout proposed (Figure 8) is inspired from ASU DT layout (Figure 1) and the current configuration of the meeting rooms used by the Local Panel members (observed in Mauricie and Lanaudière regions).

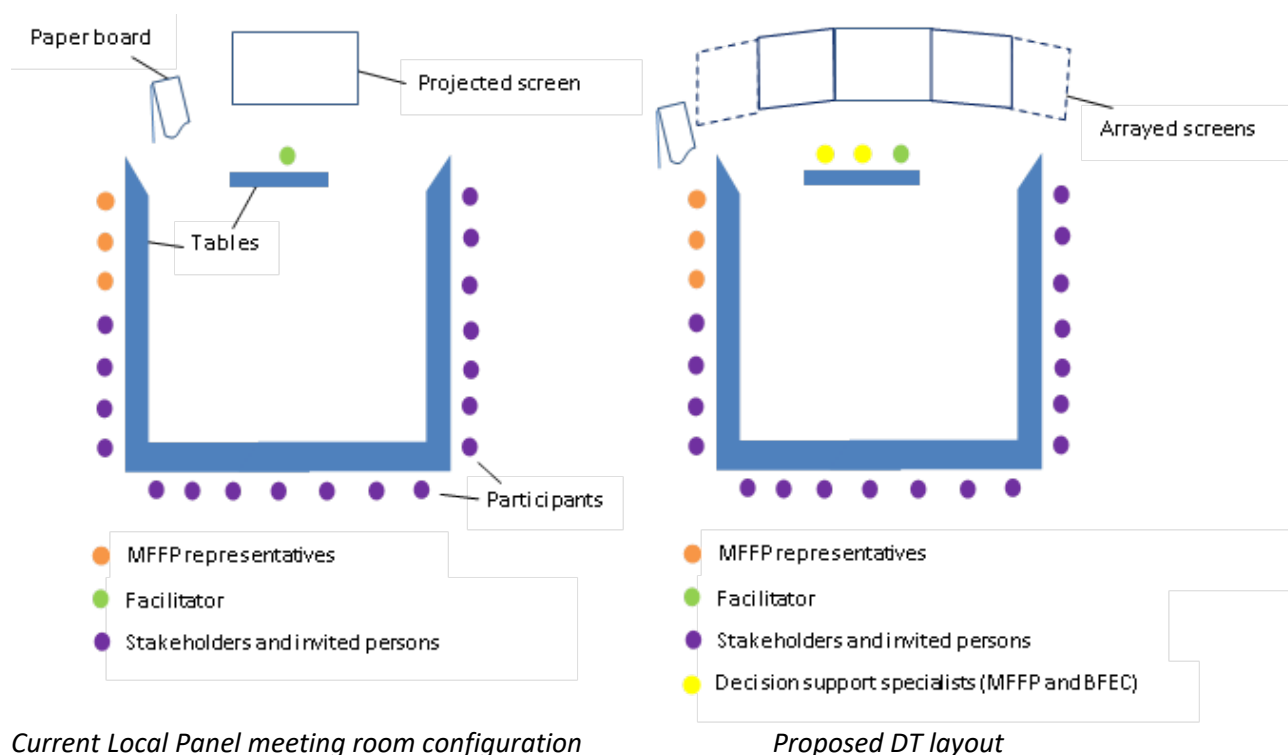


Figure 8. A possible DT layout for the Québec case

- Decision-support component FC-DSS (component b)**

Inside the DT, the stakeholders with the assistance of the facilitators/experts/decision-support specialists, express their issues and goals, display background information, propose

solutions, define management scenarios, and visualize the results. These tasks call for a system integrating data, information, models (e.g. silviculture scenario generator, forest growth simulator, and forest management optimization tool, among others), methods (e.g. VOIT cards), graphical displays, and expert knowledge of stakeholders, and decision support specialists. To facilitate this integration, the research team proposes to develop FC-DSS, which enables combining three components of the DT: the decision-support component, decision entities, and technologies. Thus, FC-DSS development is essential for efficiently implementing a DT.

The development of FC-DSS is based on the decision-support tools and databases currently used for strategic and tactical planning. The design of FC-DSS is inspired from SADfLOR (Garcia-Gonzalo et al., 2015). FC-DSS provides a shared data management module for the Local Panel members, two distinct model base modules, and a data and results visualization module (Figure 9). It is also web-based. All users can update or enter their inputs into FC-DSS via Internet browsers from local PCs. Some data such as forest inventory and forest growth/yield data can only be modified by MFFP planners and BFEC analysts. However, this data can be visualized by all users via their graphical user interfaces. Information that can be entered by the stakeholders into FC-DSS is related to their issues, the description of these issues, potential solutions, and preferred solutions. The four components of FC-DSS are independent and encapsulated in the graphical user interfaces. The stakeholders have a customized graphical user interface to address their specific needs in terms of data and results representation and visualization. Elements that can be visualized include lists of concerns/issues, possible silviculture treatments and scenarios, VOIT tables, graphs presenting AACs, texts describing the issues or possible solutions, and different digital layers and maps. While a GIS is currently being used by MFFP planners and BFEC analysts, additional tools offering rich visualization capabilities need to be integrated to FC-DSS. MFFP planners and BFEC analysts have distinct graphical user interfaces since they perform two distinct tasks requiring specific skills: MFFP planners control the model base module “MFFP”, which contains Tak Tik and MÉRIS. BFEC analysts control the model base module “BFEC”, which contains forest models generator (Horizon CPF), Woodstock and Stanley. During the Local Panel meetings, the stakeholders’ representatives will have the possibility to guide the decision-support specialists (i.e. MFFP and BFEC) in setting parameters and defining alternative scenarios. The models’ results can be discussed and further analyses performed. All scenarios tested, results generated and background information can be accessed via Internet at any time by the stakeholders.

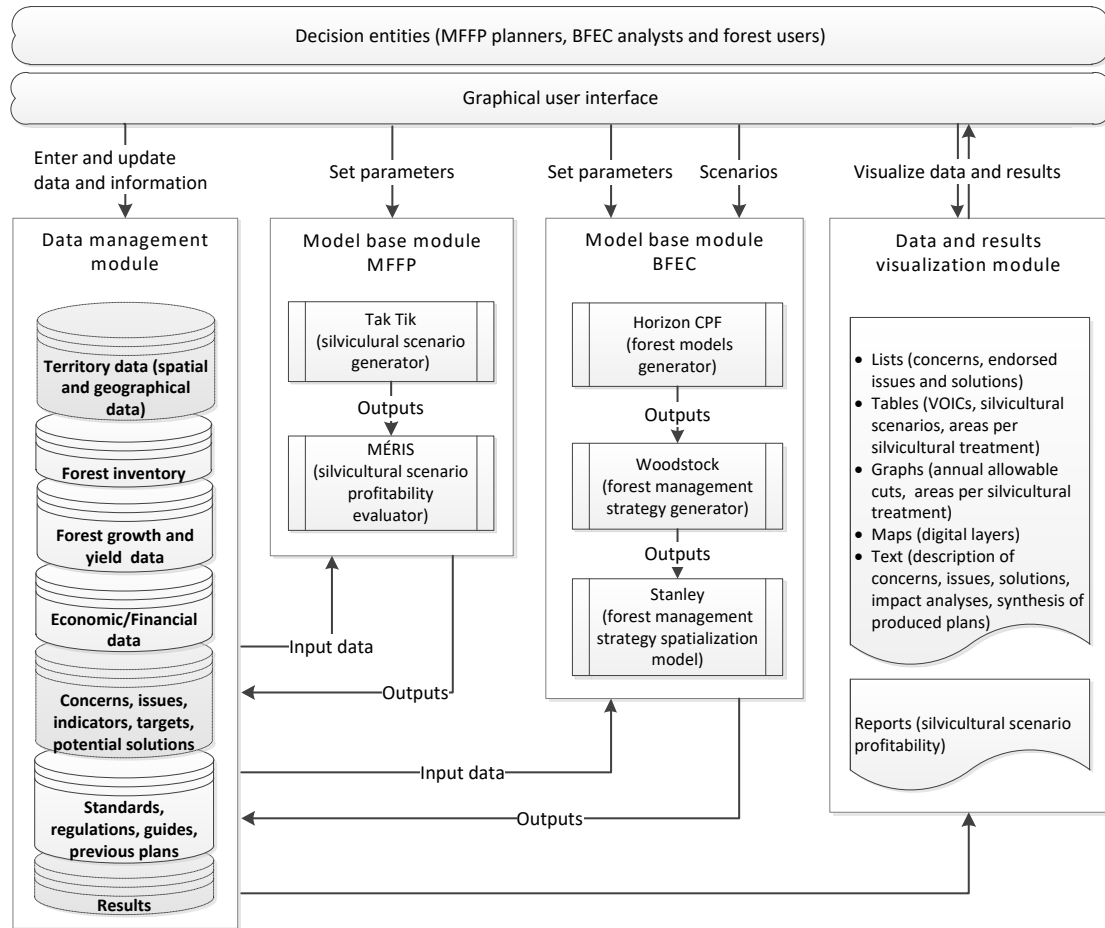


Figure 9. Conceptual design of FC-DSS, inspired by (Garcia-Gonzalo et al., 2015)

5 DISCUSSION OF THE QUÉBEC CASE

MFFP planners and BFEC analysts handle large and complex data sets. They use different (non-integrated) databases and decision-support tools. Handling these aspects requires advanced technical skills and knowledge in various domains (e.g. forestry, biology, environment, analytics, Big Data, and optimization). There are also multiple iterative sub-processes and feedback loops in the planning process. These aspects may explain why it is difficult for the stakeholders to understand and trust the information and why the planning process is perceived as complex and fuzzy. It is not surprising that we observe lack of information at the right time, lack of reactivity and coordination, long feedback, delays, and long planning process. FC-DSS enables integrating experts' knowledge, decision-support tools, databases, visualization tools, and other methods in one automated system. For a DSS to be operational, the available information has to be compiled in a structured and clearly arranged way (Menzel *et al.*, 2012). Therefore, FC-DSS will enable the stakeholders to access well-structured information. The customized user interfaces will enable presenting this information in more simple and familiar ways, which would lead to rapid comprehension, to more confidence and willingness to collaborate. For instance, it was reported in Mauricie region that some stakeholders were not willing to participate in the discussions because they did not feel confident with their knowledge (see Section 3). Using Internet will allow the stakeholders to explore information in detail during a longer period of time. This would support the learning process of stakeholders needing more time to process new knowledge. As an example, in Outaouais and Abitibi regions, the stakeholders expressed the need for more time to interact with the information and to investigate the proposals (Leclerc and Andrew, 2013). The possibility for "shy and silent" members (Kangas and Store, 2003) to express their

opinions in a fair and equal way is another advantage of FC-DSS. In Mauricie region, it was reported that shy stakeholders had the tendency to hide their opinions. In addition, offering an equal opportunity for the stakeholders to express their opinions increases transparency (Kangas and Store, 2003). Transparency also means that at any point in time, the users can access the background information, the procedure followed to produce the outcome, and the numbers generated (Menzel *et al.*, 2012). FC-DSS allows the stakeholders to access all this information. Using FC-DSS would also enhance communication among MFFP planners and BFEC analysts. In a multidisciplinary group, DSSs can support creating a common language (Menzel *et al.*, 2012; De Meo *et al.*, 2013). FC-DSS would thus contribute to addressing the issues of long feedback and lack of coordination. Due to all the above improvements, the complexity of the decision-making process and the time and resources needed, would be significantly reduced.

FC-DSS is essential for the implementation of DTs for efficiently supporting the Local Panels. The other components of the DT expand FC-DSS capabilities by offering additional means for interaction, visualization, and negotiation. First, the technological environment of DTs is attractive, and could contribute to engage the stakeholders in the decision-making process. Absenteeism was reported in many regions. Early and frequent participation of the stakeholders helps in receiving their inputs, developing and evaluating alternatives, and selecting the preferred alternative (Langsdale *et al.*, 2013). Second, DTs can display different information on adjacent wall screens (Figures 1 and 2). This enables, for example, simultaneously visualizing different indicators associated to a given management plan (e.g. volume of timber to harvest, age dispersion, species composition, and the number of sites of high quality). The management plan's effects on these indicators can be analyzed and trade-offs can be identified, which could foster the negotiations and support consensus building. Currently, the Local Panels are not efficient in finding compromises as reported for instance in Mauricie region. The stakeholders have to commit much effort and time to reach consensus and conflicts still exist in many regions. DT immersion capabilities can help the stakeholders to express their concerns and also understand the concerns of participants from other areas of interest. For example, video projections of harvest areas, old forests, and conservation areas on the wall screens can be used to highlight regional particularities, issues, and the results of previous management actions. By using more sophisticated techniques such as nature rendering engines (i.e. coupled with FC-DSS), 3D forest portrayals resulting from different alternative plans could be visualized from different perspectives. For instance, in Mauricie region, it was mentioned that the stakeholders would have appreciated visualizing the results of a given solution. Meitner *et al.* (2005) stated: "simply creating a picture of a proposed management alternative causes people to question and think about these proposals in ways that they might typically not do otherwise." Finally the physical layout of the DT can significantly improve interactions among the stakeholders. Using Internet complements face-to-face meetings by offering an alternative to participants less familiar with discussions in public meetings to express their opinions.

An important aspect to consider before building DTs in Québec is how many are required. Considering that the forest regions in Québec are remote, one centralized DT is not realistic. On the other hand, building a DT in each one of the 13 regions might be very expensive. One possibility could be to use mobile technologies that are easily transportable by truck and configurable. To this end, good coordination is required to ensure the availability of the technologies when they are needed by the Local Panels.

6 CONCLUSIONS

Due to recent technology development in the forest sector, tools supporting forest management planning which enable data visualization and impact analyses from different perspectives are becoming widespread (Têtu, 2014). In this study, a generic framework for the design of DTs to support forest participatory planning was proposed. To show how the framework can be implemented in the Québec case, the planning process was mapped and the DT components required to support this process were identified. The conceptual design of the decision-support component, called FC DSS, which considers the current decision-support tools used in Québec was developed. To show the value of implementing FC-DSS and DTs in Québec, a regional case study was used to illustrate how the Local Panels' issues could be efficiently addressed.

Implementing DTs in Québec would support sustainable forest management planning. Many of the Local Panels' issues could be addressed and the participatory planning would be substantially improved. Furthermore, other participatory mechanisms such as Operational Panels and public and First Nations consultations could benefit from the facilities and the technologies of these DTs. To this end, the DSSs supporting decision-making in these different participatory planning contexts should be easily exchangeable. Applying the proposed framework in other participatory planning contexts requires to carefully consider their specific particularities such as the planning process, the decision-support tools used, the participatory mechanisms put in place, governance modes, and regulations.

In the second phase of this research, a pilot project in collaboration with our partner, the Ministry of Forests, Wildlife and Parks of Québec (MFFP) and the FORAC Research Consortium will be conducted in a regional case study in Québec. The following is a statement by our collaborators from MFFP: "We believe that the theoretical concept of decision theaters presented by the research team is a very interesting approach for improving the work of Local (and Operational) Panels. We are very interested in a second phase of the project, which would take the form of a pilot project in a regional case study, with the aim of operationalizing the concept of decision theaters, through the implementation of decision-support tools. In our view, one of the biggest challenges of this second phase of the project would be the development of a decision-support tool that gives operational answers (impact assessment) very quickly so that decisions can be made".

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