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Sustainable Forest Management using Decision Theaters: Rethinking Participatory Planning

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Abstract. Integrating sustainability goals into forestry planning and promoting social acceptability is crucial for a successful sustainable forest management. However, involving stakeholders in the decision-making process can be very complex and time consuming. Traditional decision support tools are not sufficient for dealing alone with these issues. We propose to use decision theaters (DTs), which enable the combination of visualization and decision modeling capabilities together with human capacity of insight and interaction, for addressing this challenging problem. A generic framework for designing DTs is developed. The proposed framework encompasses five main components: decision entities, decision support component, organizational system, decision theater layout, and technologies. To show how a DT could be implemented for forestry planning in the province of Québec, Canada, we develop the conceptual design of a decision support system (DSS) called Forest Community DSS (FC-DSS). FC-DSS includes a data management module, two distinct model base modules, and a data and results visualization module, which are encapsulated in graphical user interfaces aimed at supporting the needs of planners, analysts, and stakeholders. Finally, the benefits of implementing a DT and FC-DSS for supporting forestry planning are discussed.

Keywords. Decision theater, stakeholders, participatory planning, collaboration, sustainable forest management, forestry planning, natural resource management, DSS.

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1 INTRODUCTION

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, 2001; 2011; ISO 2010; GRI, 2013; Panda and Modak, 2016). This requires inviting the community members who have a stake in the issue to share their concerns and perspectives and participate in the decision-making process. Examples are found in environmental management (Gregory, 2000; Siebenhüner and Barth, 2005; Antunes *et al.*, 2006; Díez *et al.,* 2015), waste management (Hornsby *et al.*, 2016), urban planning (Salter *et al.*, 2009), and natural resources management (Meitner *et al.*, 2005; Saarikoski *et al.*, 2010; Langsdale *et al.*, 2013; Mountjoy *et al.*, 2013; White *et al.*, 2015). However, involving the stakeholders in the decision-making process can be very complex and time consuming. Often stakeholders have different backgrounds, and therefore are likely to have different personal values and interests (Andrienko *et al.*, 2007). Moreover, the stakeholders often have heterogeneous and different levels of knowledge, and their perceptions might be as important as facts (Bishop *et al.*, 2008). As a result, conflicts may arise among the stakeholders, leading to situations where it is impossible to build consensus or find compromises.

All the above issues are observed in the process of forest planning in Canada. In order to prevent forest users’ conflicts and promote social acceptance of forest management plans, the Canadian government and forest companies have implemented different public consultation and participatory mechanisms across the country. 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 by government and forest companies must be rigorously taken into account. Many benefits are expected from the forest, ranging from employment opportunities, tourism, local economic development, spiritual and ancestral practices, to diversified ecosystem services (wildlife habitat, carbon sequestration, water filtration, etc.) (Rönnqvist *et al.*, 2015; Boukherroub *et al.*, 2017). At the same time, a wide range of forest users having rights or agreements with government (timber harvesting rights, hunting/fishing permits, outfitting leases, etc.) co-exist in the same forest territory, which inevitably leads to disagreements and conflicts. Therefore, integrating sustainability goals into forestry planning and promoting social acceptability is crucial for government. This is the case in the province of Québec, which recently adopted a new forest regime (April 1, 2013) aimed at promoting sustainable forest management (SFM). SFM is a strategic issue that permits forestry with increased emphasis on ecosystem management (Gunn, 2007). SFM focuses on conservation of biodiversity, soil, water, ecosystems, and productivity as well as social issues (Rönnqvist *et al.*, 2015).

The new regime introduced a participatory mechanism called “Local Integrated Land & Resource Management Panel” (hereinafter referred to as Local Panel). These Panels have been implemented across all forest regions of the province since 2010. The aim is to enable forest users and other stakeholders to express their concerns and take part in forest management planning (Desrosiers *et al.*, 2010), which 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) (MFFP, 2013). However, recent studies have shown that implementing Local Panels only had a limited success in many regions (Robert, 2013; Gharbi, 2014; Têtu, 2014; Fortier and Wyatt, 2014; Althot, 2015, Boukherroub *et al.*, 2016a). Lack of information at the right time, inconsistency of data, lack of impact analyses, complex and long planning process, incapacity to find compromises and build consensus, and lack of transparency and trust have been identified as major issues. However, MFFP, regional authorities and forest users recognize the complexity of making plans while involving many stakeholders having different interests, values, and goals. Currently, MFFP and the regional authorities are seeking to improve this situation.

Traditional decision support tools such as simulation, optimization models, and multi-criteria decision-making techniques are not sufficient for dealing alone with these complex situations. It is argued in the literature that equity, trust and representativeness issues result from decision processes relying merely on formal assessment techniques and in which the analysts are in full control of decision support (Antunes *et al.*, 2006). In fact, stakeholders may expect to be offered the possibility to evaluate alternative options from the perspective of their interests, knowledge, preferences, and value-driven criteria, and may also wish to contribute to problem analysis and solution generation (Andrienko *et al.*, 2007), or even to problem definition (Gregory, 2000; Antunes *et al.*, 2006; Martins and Borges, 2007). To this end, the stakeholders need an easily understandable presentation of information and easily usable interaction facilities (Andrienko *et al.*, 2007). Moreover, stakeholders that have difficulty in understanding maps and scientific information may need a detailed view of alternative solutions, background information, and customized visualizations (Andrienko *et al.*, 2007; Salter *et al.*, 2009; Rammer *et al.*, 2014). Therefore, there is a need for new approaches enabling the combination of visualization and decision modeling capabilities together with human capacity of insight and interaction. Decision Theaters (DTs) are one of these approaches. The aim is to take advantage of recent technology development to support complex decision-making problems such as those involving multiple decision makers and stakeholders or dealing with massive data. 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 impact of decisions on stakeholders and decision makers' outcomes, and find a common solution. Figure 1 provides an example of a DT built at Arizona State University (ASU, 2016).

Figure 1. A decision theater built at Arizona State University (ASU, 2016)

Other concepts such as war room, operations center, situation room can also be linked to DTs. Applications are found in the domains of the military, business, management science, and natural resources management. 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 and informed decisions (Granlund *et al.*, 2001; Brehmer, 2007; Scott *et al.*, 2007). War rooms in business context are used for gathering information on competitors, customers, and policy in order to forecast the market dynamics and make decisions accordingly (Shaker and Rice, 1995; Shaker, 2002), for tracking and monitoring company's performance (Daum, 2006), or for organizing complex programs and visualizing massive data (Shaker and Rice, 1995). In natural resources management, the literature focuses mainly on the effect of visual information and interactive tools on public understanding of complex topics (e.g. groundwater management (Larson and Edsall, 2010) and land use policies (Salter *et al.*, 2009)), public choices of alternative options (e.g. forest management plans (Sheppard and Meitner, 2005)), and decision makers perception of uncertainty, credibility, salience, and legitimacy of natural resources management models (White *et al*., 2010; White *et al*., 2015). However, current research on DT concept does not provide enough information, clear guidelines, or a systematic approach for designing and implementing a DT-based approach for decision-making support. This is true for decision-making problems involving multiple and heterogonous actors with different interests and objectives and having different backgrounds and levels of knowledge. Yet, this is a recurrent problem in natural resources management (Gregory, 2000; Antunes *et al*., 2006; Andrienko *et al.*, 2007, Martins and Borges, 2007; Rammer *et al.*, 2014; Garcia-Gonzalo *et al.*, 2015) as observed in forestry planning in the province of Québec.

We propose a generic framework for the design of DTs and present a pathway toward the implementation of DTs in the forest sector in Québec. The proposed framework encompasses five main components: *decision entities, decision support component, organizational system, decision theater layout,* and *technologies*, which support the decision-making process in the DT. During the decision process, the decision makers and the stakeholders, directly or aided by facilitators, enter data, extract data, challenge the models' parameters, define scenarios, and visualize the results in different forms. These tasks call for a system integrating data, information, models, and methods. To facilitate this integration, the development of a DSS (Decision Support System), which combines different components of the DT (decision entities, decision support component, and technologies), is required. For the case of forestry planning in Québec, the conceptual design of a DSS called Forest Community DSS (FC-DSS) is proposed. The remainder of the article is organized as follows: next section provides a description of forestry planning and participatory mechanisms introduced by the new regime in Québec and identifies issues related to current planning process. Section 3 explores DT concept and presents its application in different domains. Section 4 presents the proposed framework and the conceptual design of FC-DSS. The expected results of implementing a DT and FC-DSS for supporting forestry planning in the province of Québec and addressing efficiently the identified issues are analyzed in Section 5. Our conclusions are presented in Section 6.

2 PROBLEM DESCRIPTION

Forest products supply chains can be seen as large networks through which wood fiber is gradually transformed into consumer products such as pulp and paper, lumber, engineered wood products and biofuels (D'Amours *et al.*, 2008). Decisions related to forest products supply chains range from land-use, regeneration, road building, harvesting, transportation, to production at saw-, pulp-, paper-mills and heating plants (Rönnqvist *et al.*, 2015). Two main research topics can be distinguished in the literature (D'Amours *et al.*, 2008). The first category, referred to as forestry, focuses on forest management, harvesting and transportation (Gunn, 2007; Paradis *et al.*, 2013; Handler *et al.*, 2014). The second focuses on supply chain planning for the manufactured products and sale markets (Vila *et al.*, 2006; Ouhimmou *et al.*, 2008; Cambero *et al.*, 2016; Taskhiri *et al.*, 2016). The problem described in this paper falls into the first category. This section is divided into two parts. First, current forestry planning process and participatory mechanisms implemented in Québec are described. Second, the main shortcomings and issues of the planning process and the *Local Panel* participatory mechanism are presented.

2.1 Forestry planning and participatory mechanisms implemented in Québec

In Québec, more than 90% of the forests are publicly owned. Under the new regime, timber can be obtained from public forests based on supply agreements (75% of the available wood volumes) or via a public auction market (25% of the available wood volumes). A supply agreement authorizes a saw-, pulp-, paper-mill owner, and, in some cases, non-owners to annually harvest from a specific region, a specific volume of timber of a given species and quality (Boukherroub *et al.*, 2017). These annual volumes are known as supply guarantees (mill owners) or harvest permits (non-owners). The remainder of the available wood volumes is sold by the Timber Auction Office (Bureau de Mise en Marché des Bois, hereinafter referred to as BMMB), an entity that belongs to MFFP, through organizing sealed-bid one-winner auctions (Farnia *et al.*, 2015; Weraikat *et al.*, 2016). Public auctions aim at creating market opportunities for new players, to allow for the development of new business models, to favour greater efficiency, and promote the emergence of innovative products and services beneficial to the economy, the society, and the environment. Under the new regime, MFFP has extended responsibilities regarding forestry planning. In particular, harvest planning and postharvest activities which were under the responsibility of forest companies, are now under the responsibility of the MFFP. The new regime introduced integrated planning and new participatory mechanisms (*Local Panels* and *Operational Panels*) to enable forest users (forest companies, First Nations, outfitters, agricultural land owners, etc.) and other stakeholders (local communities, environmental organizations, etc.) to participate in forestry planning and express their concerns (Desrosiers *et al.*, 2010; MFFP, 2013). Figure 2 illustrates forestry planning levels and decisions as well as participatory mechanisms under the new regime. As described by D'Amours *et al.* (2008), forestry planning decisions range from strategic to operational. This study focuses on the strategic and tactical planning levels and the contributions of Local Panels, which are involved mainly at these two planning levels. Next paragraphs describe the three planning levels and participatory mechanisms.

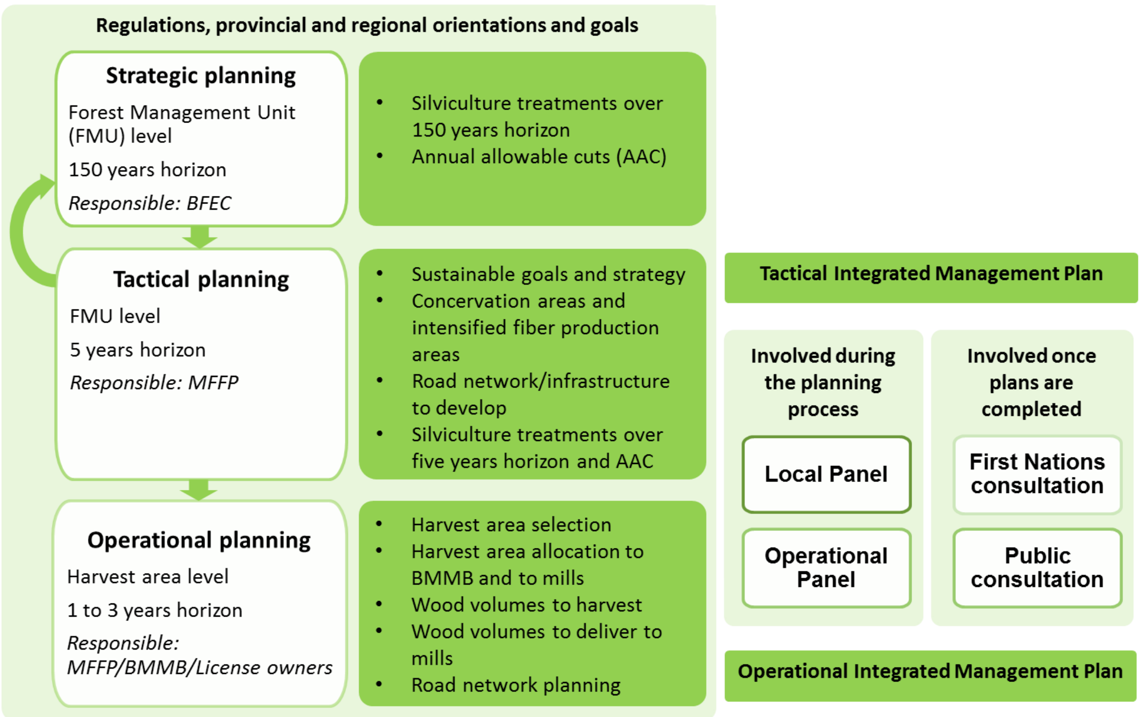

Figure 2. Forestry planning under the new regime in the province of Québec

In public forests context, responsibility for planning activities is distributed across government and forest companies (Paradis *et al.*, 2013). In Québec case, the government (i.e. MFFP) is involved at all planning levels, but has a greater responsibility at the tactical and operational levels (Figure 2). At the strategic level, the Bureau du Forestier en Chef (Forest Chief Office, hereinafter referred to as BFEC) in close collaboration with MFFP prepares the strategic management plan. BFEC is an independent entity responsible for determining the annual allowable cuts (AAC) for all Forest Management Units (FMUs) in the province of Québec (BFEC, 2013). An FMU is a forest area which supplies a number of mills having timber supply agreements in the FMU's territory. FMUs are the basis for AAC calculation and forest planning. The number of FMUs in the province of Québec is 71, and the area surface ranges from 150 km2 to 24,500 km2, approximately. The strategic management plan is a 150 year horizon (BFEC, 2013). It determines management activities (e.g. silviculture treatments) over space and time, and the volumes of timber that can be harvested annually while ensuring a non-declining yield (i.e. AAC) (BFEC, 2013; Bouchard *et al.*, 2016). AAC calculation is based on complex simulations of forest growth and projected management activities over a long-term planning horizon (Paradis *et al.*, 2013). The strategic plan includes 30 periods of five years each (BFEC, 2013). The decisions of the first period are inputs for the tactical integrated management plan, hereinafter referred to as the tactical plan. The tactical plan is prepared for a five-year horizon at the FMU level. It aims at determining the sustainability forest management goals for the FMU (or a group of FMUs) and the strategy to implement in order to achieve these goals (MFFP 2013; 2015). The forest management strategy specifies forest resource allocation (e.g. conservation areas, timber production areas, and intensified fiber production areas) and forest roads and other infrastructures to maintain or develop. The management strategy should not be confused with the forest management plan. "Strategy is something management does and not the result of running a computer model" (Gunn, 2007), which is the case of the strategic management plan. Moreover, in Québec case, the forest management plan is long term (150 years) while the strategy is mid-term (five years). As stated by Gunn (2007), "not all strategies are long term". The forest management strategy guides the strategic plan while the strategic plan assists decision makers in validating the strategy and determining silviculture treatments and AAC for the upcoming five years. Therefore, the strategic and tactical plans are prepared through an iterative process involving BFEC analysts and MFFP planners (BFEC, 2013; MFFP, 2013; 2015).

The operational integrated management plan (referred to the operational plan) uses the outputs of the tactical plan as constraints. It is prepared for a planning horizon of 1-3 years at the FMU level. 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 and other infrastructure planning (MFFP, 2013; 2015). MFFP is responsible for the first four decisions, BMMB is involved in selecting harvest areas to be sold through public auctions, while the license owners (refers to those holding a timber supply guarantee or a harvest permit) are responsible for forest road/infrastructure planning. From the industrial perspective, these decisions are rather tactical or even strategic (Epstein *et al.*, 2007; D'Amours *et al.*, 2008). Based on the operational plan, license owners prepare an annual harvesting plan known as the "annual program". Harvest areas selected for the next 1-3 years are added to a pool of harvest areas previously allocated to the license owners. From the new set of harvest areas, the license owners select a sub-set to harvest in the upcoming year and adjust the wood volumes to harvest and to deliver to mills while respecting supply guarantees and other constraints dictated by the operational and tactical plans (e.g. transportation distances, supply guarantees, species and timber qualities, geographical dispersion, conservation targets, etc.) The objective is to allow license owners to consider additional requirements, constraints and preferences into the annual harvesting plan. However, the license owners must find a common agreement on the annual program (MFFP, 2013; 2015). The annual program requires MFFP's validation before its execution. Consulting First Nations might also be required (MFFP, 2013).

The strategic, tactical and operational plans must be coherent with the goals and orientations defined at the provincial and regional levels. More specifically, the strategic and tactical plans should respect the goals and orientations of the SFM strategy (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 SFM strategy is the basis for all governmental policies and actions in terms of forest management, and all users of the territory must respect SFM strategy's orientations and goals (MFFP, 2015). The public land use plan is prepared by the Ministry of Energy and Natural Resources (MENR). It defines the main governmental guidelines related to public territory use (development, protection, etc.). Finally, the regional plan for integrated development of resources and territory is prepared by a regional panel (formed by representatives of the forest industry, water and environment, energy and mining, citizens, regional authorities, First Nations, etc.), which defines the regional orientations and priorities in terms of natural resources development (MFFP, 2015).

The *Local Panels* and *Operational Panels* together with public and First Nations consultations constitute the participatory mechanisms introduced by the new regime (MFFP, 2013). Local Panels and Operational Panels are involved during the planning processes while public and First Nations are consulted once the plans are completed and validated by the Local Panels (Figure 2). The aim of the Operational Panels is to align the requirements of license owners who require forest certification (e.g. FSC, FSI, CSA) with the forest management strategy and optimize wood procurement plans (e.g. annual program planning). An Operational Panel is established for each forest territory subject to a harvesting agreement. Operational Panels are formed by license owners as well as MFFP and BMMB representatives. The public and First Nations consultations allow the broad public and First Nations (respectively) to express their concerns regarding the operational and tactical plans. MFFP jointly with forest companies are responsible for conducting First Nations consultations while the regional authorities jointly with MFFP are responsible for conducting public consultations (MFFP, 2013).

A Local Panel is established by the regional authorities or a regional organization for each FMU (or a group of FMUs) or a municipality (or a group of municipalities) in a given region. The main goal is to ensure that interests and concerns of the forest users and other stakeholders are taken into account in the planning process (Desrosiers *et al.*, 2010; MFFP, 2013; 2015). The organization responsible for a given Local Panel determines the forest users and stakeholders who will be represented at the Local Panels based mainly on legislation requirements. The different categories of forest users/stakeholders which must be represented at the Local Panels include First Nations, regional municipalities including metropolitan communities, timber supply grantees, persons or organizations managing controlled zones, persons or organizations allowed to organize activities, provide services or operate a business in a wildlife reserve, outfitting permit holders, harvesting permit owners, lessees of land for agricultural purpose, etc. These forest users and stakeholders must designate the persons who will represent them at the Local Panels. Other interested forest users and stakeholders not mentioned in the legislation might also be represented (MFFP approval is required). The number of representatives at a given Local Panel varies from one region to another, depending on the number and categories of forest users and stakeholders (e.g. presence of First Nations in the region). MFFP is also actively engaged within the Local Panels acting as the ultimate decision maker, planners or experts. Researchers, consultants, and observers can also participate in the Local Panel meetings as invited persons. Coordinators and facilitators are identified by the organization responsible for the Local Panels for organizing and conducting the meetings. Four to five meetings are generally organized during the 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. Currently, the planning process duration is two to three years. However, the Local Panels also deal with issues related to operational planning and ongoing forest operations.

2.2 Shortcomings of forestry planning and Local Panel mechanism

The implementation of the new forestry planning and Local Panels in the province of Québec occurred in 2010. The changes introduced raised many concerns in the forestry community. Interviews conducted with the Québec Federation of Forestry Cooperatives[1] between 2012 and 2013 revealed that the participants found the new planning process fuzzy and doubted the efficient execution of the operational plans since they were under the responsibility of MFFP (Gharbi, 2014). The participants deplored the lack of consideration of regional particularities by MFFP (timber dispersion, number and categories of forest users, presence of First Nations in the territory, etc.) They were also expecting high operational costs and low profitability due to the auction market mechanism (timber price, road network development costs, etc.) and to the change of responsibility in regard to harvesting planning and postharvest activities (under-utilization of industrial resources dedicated to planning, MFFP planners' inexperience in operational planning, etc.). Têtu (2014) reported that some forest representatives found the tactical planning for the period 2013-2018 deficient and attributed this situation mainly to responsibility transfer from the industry to government. This issue and lack of consideration of regional particularities were also reported in the region of Côte-Nord, where interviews have been conducted with nine representatives of the forest industry, government, regional authorities, and First Nations in 2015 (Althot, 2015). Other interviews within the period 2012-2013 with forest companies in five other regions; Lanaudière, Hautes-Laurentides, Saguenay, Lac-Saint-Jean, Chaudières-Appalaches (Gharbi, 2014; Gharbi *et al.*, 2014), revealed that implementing the planning process was complex, long, and costly. Lack of reactivity and late feedback of MFFP planners, lack of information, lack of coordination among forest users, and delays due to verification, validation, consultation, and harmonization processes were mentioned as the main issues. As mentioned earlier, currently, two to three years might be required to produce the tactical plans.

Concerning the Local Panels, it was reported that these were not efficient in addressing forest users' issues and solving conflictual situations (Gharbi, 2014). In particular, it was mentioned that sustainability goals were not clear, not easy to measure, and they were not accepted by all forest users and stakeholders. A First Nation representative in the region of Côte-Nord stated that the Local Panels do not enable considering participants' interests and the right issues are not dealt with. Local Panels are rather places where conflicts arise (Althot, 2015). These observations and aforementioned issues are also reported in the region of Bas-Saint-Laurent, where a survey was conducted by a regional development agency in 2013 (Robert, 2013). The evaluation was based on 19 meetings between 2010 and 2013. Although, the respondents recognize that Local Panels helped them understand the concerns of participants from other areas of interest, it was reported that progress was long and traditional conflicts still exist. In fact, the majority of respondents mentioned that their concerns were not effectively taken into account by MFFP. Many respondents also indicated the absence of real consensus concerning some topics. Moreover, it was mentioned that some issues were not fully treated or postponed due to lack of information/proofs, or in order to avoid potential conflicts. Lack of impact analyses, lack of information at the right time, and

[1] http://jc.fqcf.coop

contradictions within information were also identified as major issues. Leclerc and Andrew (2013) who studied two Local Panels in the regions of Outaouais and Abitibi concluded that while the Abitibi case demonstrated a good governance capacity, in the region of Outaouais, consensus was extremely difficult to achieve. The participants had to commit much effort and time to reach real consensus. The authors also mentioned in Outaouais region the Local Panels appear as simple channels for participants to express their opinions and not a place where decisions are made. In the same vein, Fortier and Wyatt (2014) reported that in the regions of Lanaudière and Mauricie, First Nations do not consider the Local Panels as places where territory management is determined nor spaces where rights can be stated. Local Panels are simply places for establishing and maintaining relations with other forest users and places for acquiring information and staying up-to-date (Fortier and Wyatt, 2014).

We conducted additional interviews in the regions of Mauricie and Capitale-Nationale between December 2015 and April 2016 with five experts who played an active role in implementing and operating the Local Panels in the two regions. Four experts are from MFFP and the fifth one is the coordinator of the Local Panels implemented in the region of Mauricie. Of the four MFFP experts, three were involved in Mauricie region, and one in the region of Capitale-Nationale. In Mauricie region, the experts reported that real consensus was extremely difficult to achieve. The experts mentioned that some participants were not willing to participate in the discussions and had a tendency to hide their opinions (e.g. participants who didn't feel confident with their "low" knowledge level or participants who simply didn't want to get involved in the discussions). The experts also mentioned the existence of confidential agreements, which were committed between participants outside the Panels. In some cases, two sub-groups having differing views were formed inside the Panel, which resulted in extreme inconsistency among goals and the impossibility of finding compromises. In particular, the experts mentioned that some economic objectives such as maximizing timber harvesting were not even consistent with the ecological goals defined by the SFM strategy and regulations. The most conflicting issues were related to forest road network, wildlife habitat, and landscapes. It was also reported that many participants did not trust the scientific knowledge and information presented to them, but relied solely on their own perceptions. Finally, lack of information and lack of impact analyses and results visualization were identified as major issues. In Capitale-Nationale region, the interviewed expert explained that 50% of the Local Panels participants had difficulty in understanding information presented to them. To address this issue in the region, MFFP made significant efforts to continuously provide comprehensive explanations. Table 1 summarizes aforementioned issues. The first column presents issues related to the participatory planning process (i.e., involving Local Panels), and the second, issues related to the results of the participatory process.

Table 1. Main issues in forestry planning identified in Québec

Participatory planning process	Participatory planning results
• Fuzzy, complex, costly, and long process • Lack of information at the right time/delays/lack of reactivity and long feedback (MFFP) • Lack of coordination • Lack of trust and transparency, and unwillingness to collaborate • Difficulty in understanding information and lack of trust in scientific knowledge	• 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

As a conclusion, although putting in place a participatory mechanism to enhance contributions of stakeholders to forest planning should be commended, it appears that the implementation of the new forestry planning and the Local Panel mechanism in the province of Québec met with only limited success. However the MFFP, the regional authorities and forest users recognize that making complex plans while involving many participants having different interests, values, and goals, is extremely challenging. Currently, MFFP and the regional authorities are seeking to improve this situation. We propose implementing DTs to address the identified issues (Table 1) and improve the participatory planning process. The concept of DT is presented in the next section.

3 DECISION THEATERS

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). Roach (1986) described this laboratory as a multi-room facility combining the features of a drama theater, an observer's gallery, and a behavioral laboratory. It includes an arena located in the center of the theater, in which participants interact, and support technologies such as interactive computer terminals, audiovisual recording equipment, and display monitors. The furnishings of the arena are changeable; it can be set up as a conference room, an executive office, etc. Display of computer output can be shown on a large monitor mounted onto the walls. Information used by participants is obtained from printed reports hand-carried into the arena or from interactive computer terminals inside the arena. These terminals enable the participants to have access to databases, information and decision support systems. The galleries are used to observe the decision-making process inside the arena. 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 Decision Theater Network (ASU, 2016). Other universities such as University of British Columbia (UBC), 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, display and interactive technologies (e.g. panoramic wall displays) that allow catching participants' attention, for instance through real-scale 3D image displays. Due to the relative newness of these immersive environments, most of research undertaken is ongoing. We provide a description of DTs built in Tempe, Arizona (Figure 1) and UBC's Landscape Immersion Laboratory as well as research projects conducted in these DTs.

The core physical component of the DT in Tempe, Arizona (Figure 1) is called the "Drum". It 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; ASU, 2016). The Drum allows for conference room or theater-style seating, accommodating up to 25 people. It also includes capacity for audio and video recording as well as tools for collecting data from participants (White *et al.*, 2010). Preparing a plan for disease outbreaks, assisting policy makers and stakeholders in understanding the socio-economic implications of various energy extraction investment options, exploring how climate change's effects on natural resources (e.g. water, food, and energy) could contribute to political instability, supporting the education of undergraduate students and assisting graduate and post-graduate research (e.g. create and review large-format content, support discussion and share data around complex topics and ideas) are some examples of the uses of Decision Theater Network (ASU, 2016). However, the scientific literature does not provide sufficient information on how Decision Theater Network is being used: Edsall and Larson (2006) and Larson and 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 (Arizona) to a parallel 2D Power Point presentation in a standard classroom. Based on a water management model called Water-Sim, 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' 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 to comfortably sit in. The chairs are movable, which allows reconfiguring the room in function of the number of users and the dynamics of the situation (Cavens, 2002). Research conducted at LIL aims at investigating, in community planning context, the effects of visualization technologies and semi-immersive environments on public ability to understand and evaluate alternative forest management plans and landscape planning scenarios. Regarding forest management, a visualization system linking together forestry modeling programs and a 3D rendering engine was developed and implemented at LIL (Cavens, 2002; Meitner *et al.*, 2005). This visualization system allows orchestrating large amount of data flow needed for creating accurate portrayals of forest landscapes based on high-level policy decisions (Cavens, 2002). The visualization system was used in public forums in the context of interdisciplinary research projects in sustainable forest management. Sheppard and Meitner (2005) described a pilot study conducted in southeastern BC, where one of the research questions was whether spatial models and visualization technologies were effective in participatory planning, and what impact these tools have on the results. Two timber-harvesting scenarios were prepared and evaluated in three different ways. First, experts were asked to evaluate the two scenarios. Then, different groups of stakeholders were asked to weight experts' evaluations. Finally, 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 and 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 where three land use alternative plans were presented to the participants.

Other concepts found in the domains of military, politics, media, and business such as war room, operations center, and management cockpit war room can also be linked to the concept of DT. In the military, the term war room was introduced during WWII by Churchill's war cabinet, which opened the Cabinet War Rooms in London in 1939, to continue running the government and direct the war (Daum, 2006; Buling, 2007). The Map Room and the Cabinet Room were two key facilities. The Map Room was used as a command and intelligence center, where information was presented and daily meetings were held to discuss the situation. The Cabinet Room was a decision room, used for the war cabinet meetings and Churchill's meetings with his defense committee, bringing together specific ministers, and chief of staffs of the armed forces, when an important decision had to be made (Daum, 2006). More recently, war room can refer to intelligence analysis center (Roberts and Koumpis, 2004), situation room, and operations center, also called command & control center (Buling, 2007). In the military, most research attempts to address the question of how to improve situation awareness in team-working and time-sensitive operations context in order to make quick and efficient decisions. In particular, some studies focus on the design of large wall screens used to display information in order to support shared situation awareness and improve battlespace visualization (Smallmann *et al.*, 2001; Darling and Means, 2005; Scott *et al.*, 2007). According to Barnes (2003), visualization should allow the commander to understand information well enough to see options and predict outcomes. Other research projects grouped under the name "command center of the future" have been launched in the 1990s in different countries (ROLF 2010 in Sweden, Command Center 21 in the UK, FOCAL in Australia, CCOF and CPOF in the US, etc.) with the aim of designing new arrangements for command & control by taking advantage of new information technology development (Brehmer, 2007). We found only a few works in the literature describing these projects. In what follows, we give an overview of FOCAL and ROLF 2010 projects.

The Future Operations Centre Analysis Laboratory (FOCAL) at Australia's Defence Science and Technology Organisation (DSTO) is based around an SGI Reality Center and provides a large virtual reality display environment (Wark *et al.,* 2005; Broughton *et al.*, 2006). It implements a multi-agent architecture to enable interaction, information retrieval and processing, information synthesis, and display. Wark *et al.* (2005) described the development of a user interface used to support "natural" interaction between users and a virtual geospatial display. Broughton *et al.* (2006) presented the conceptual design and prototype development of virtual planning rooms. The virtual geospatial display is a 3D representation of a geographical area of interest (e.g. virtual battlespace), rendered in real time using imagery, maps, terrain, and weather data. It provides an augmented photo-realistic 3D model of the area and allows the dynamic, near real-time display of objects within the environment. FOCAL also provides virtual advisers agents with real-time, photo-realistic embodied animated characters that dialog with the users by using spoken language understanding and speech synthesis. These virtual advisers can brief the command team on a developing situation using text, images, video, and other multimedia; point out significant events for further attention; and suggest alternative courses of action (Wark *et al.*, 2005). Virtual planning-room concept is proposed as a 3D visualization tool for course of action diagrams (similar to decision trees) (Broughton *et al.*, 2006). A decision tree provides the possibility to globally view a plan, but finer details of the decision process at each node are not represented. Virtual planning rooms address this issue by placing additional information inside the nodes. Within a virtual planning room, the user can view and interact with relevant information, and explore different abstraction levels or alternative data sets by navigating to adjoining rooms. The user can focus on particular details while maintaining contextual information in the background (Broughton *et al.*, 2006).

ROLF 2010 project is conducted at the Swedish National Defence College (SwNDC) at the request of the Swedish Armed Forces. Some of the concepts developed rest upon the assumptions that a seating arrangement would facilitate communication among staff members, and the use of data available from different sensors jointly with advanced technologies to present the data would facilitate situation awareness of staff members (Granlund *et al.*, 2001). ROLF 2010 environment is characterized by a small staff, a seating arrangement around a table, and four different information technologies (Brehmer, 2007). The seating arrangement is inspired from campfire configuration: historically, people used to gather in a close circle around the campfire when they had to make important and complex decisions. The first information technology considered in ROLF environment is the VisioscopeTM, a 3D display system integrated into the table to allow staff members to communicate while maintaining eye contact. The second information technology is the VisionariumTM, which is constituted of large screens mounted on the walls. The function of VisionariumTM is to offer a different visualization perspective from looking into VisioscopeTM, and to display additional information. Individual work stations behind the staff members are the third information technology. It allows a staff member to communicate with his/her subordinate commanders and support staff, and access his/her personal decision support system when needed. The fourth information technology is an avatar embedded in VisioscopeTM, which is "the mouthpiece of a critiquing system that listens to the plans developed by staff and critiques them, pointing out aspects that they may have overlooked" (Brehmer, 2007). STRATMASTM (STRATegic MAnagement System) is the integrated decision support system that has been developed for ROLF 2010. It is a simulation model based on agents moving in a substrate of cellular automata. Simulations allow examining the consequences of different assumptions and the extent to which the plans developed by the decision makers are sensitive to those assumptions (Brehmer, 2007). A micro-world (i.e. a small and well-controlled simulation system having the important characteristics of a real system) called C3Fire has been developed at the SwNDC to test some hypotheses before final ROLF environment is built (Granlund *et al.*, 2001). C3Fire was initially used as a research tool, but later, it has also been used as an education tool for military officers. C3Fire generates a task environment allowing a group of decision makers seated around VisioscopeTM that displays a shared map, to cooperate with firefighting unit chiefs in order to obtain an overview of the current situation and extinguish a forest fire (Granlund *et al*., 2001; Johansson *et al*., 2003). The firefighting unit chiefs who control the ground units are responsible for informing the decision makers on the current situation and following their instructions to extinguish the fire. The decision makers try to understand the situation, predict future critical situations, make plans, and transmit their instructions to the firefighting unit chiefs (Granlund *et al*., 2001). To do so, they need to get information from the firefighting unit chiefs. As an example, in an experiment involving 60 military students, Johansson *et al.* (2003) studied two information-sharing mechanisms between the firefighting unit chiefs and the decision-makers to evaluate their impact on the decision makers' performance. The firefighting unit chiefs can submit information directly to the shared map, by placing objects on a similar map on their screen (fast and precise way of providing information). The other mechanism consists in communicating information by e-mail. The information is then input manually by the decision makers into the shared map (slower and less precise way of providing information).

The concept of war room is also used in business as a decision-making tool. Evidence Based Research, Inc. (EBR), Connective Management and N.E.T. Research are some examples of companies developing and implementing war rooms for companies. Shaker and Rice (1995) and Shaker (2002) reported many examples of companies that have used war rooms since the early 1990s. For instance, in an "all-out" concerted effort to sell more Taurus automobiles, Ford set up a war room in the Renaissance Center office tower in Detroit. 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. Extensive demographic data and elaborate maps were used to analyze the socio-economics in a given region. Energy Texas used a war room as the nerve center where computers monitor and display the selling prices of electricity offered by neighboring utilities. When the price was right, the war room researchers alert management who make purchases. Shaker and Rice (1995) and Shaker (2002) described the war room approach as "a very focused, intense effort to organize complex programs, to develop programs and strategic plans, and to visualize and assimilate data and linkages between information that impacts multidimensional plans" (Shaker and Rice, 1995; Shaker, 2002). According to Shaker and Rice (1995), the war room provides a solution to information "glut" and visualization problems. The management cockpit war room is another type of business war room (Daum, 2006). It is based on human intelligence (e.g., information processing capacity by human brain) and management processes principles and uses information technologies and ergonomic room design to improve the productivity of a management team. Meetings are prepared by the chief cockpit officer (usually the head of the department concerned) and the cockpit officer (his/her assistant). Current status of the meeting subject and the status of actions agreed on in previous meeting are first analyzed on a computer placed in the war room (flight deck) and linked to the company's information system. Each one of the four walls in the war room displays information formalized as questions and answers related to the company's resources, the extent to which the objectives are reached, the obstacles the company faces, and the decisions that should be made to achieve the objectives (respectively). This display system also determines the seating arrangement of the participants. For example, the CFO sits toward the wall that gives external information on market, customers, and competitors, which he/she is less exposed to during day-to-day activities. Information is structured following the Balanced Scorecard and the Tableau de Bord principles with a particular focus on visualization and communication aspects.

Another concept related to war rooms and DTs is GDSS (Group Decision Support System) (DeSanctis and Gallupe, 1985; Jelassi and Beaclair, 1987). This term 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 and 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 (databases, model bases, user interfaces, etc.), people (decision makers, facilitators, etc.), and procedures (e.g. verbal discussions, flow of events, etc.) (DeSanctis and Gallupe, 1985; Huber, 1984). These components are arranged to support a group of people, typically in the context of a decision-related meeting (Huber, 1984). Jelassi and Beaclair (1987) described the main contributions in this area in the 80's. More recent works focus on consensus assessment in multi-criteria and group decision-making contexts, by using mathematical models (Xu and Wu, 2011; Pérez *et al.*, 2014). Table 2 presents the concepts related to DT discussed above and a summary of their applications in the domains of military, business, management science, and natural resources management.

Table 2. Applications of DTs and related concepts

Military	Business/Management science	Natural resources management
War room, operations center, command & control center, situation room, intelligence center	*War room, situation room, intelligence center, management cockpit war room, GDSS*	*Decision theater, semi-immersive environment*
• Collect data to stay informed • Collect real-time data to improve situation awareness in time-sensitive operations in order to make quick and informed decisions	• Collect data to stay informed about the market, competitors, regulations, etc. • Organize, standardize, share, and visualize management data to improve interdepartmental team work and better monitor the company • Organize complex programs • Visualize massive data • Learning facilities in management and marketing • Research facilities on decision making	• Orchestrate large data flow for creating forest landscape portrayals • Analyze the effect of landscape visualization on public choices (e.g. alternative forest plans) • Study the effect of visual information and interactive tools on public understanding of complex topics (e.g. groundwater management, land use policies) • Investigate decision makers' perception of uncertainty, credibility, salience, and legitimacy of natural resources management models (WaterSim model)

DT implementation in different domains proves its relevance as a decision-making approach for dealing with various decision problems, ranging from very short to long-term planning. DTs appear particularly relevant for dealing with complex problems characterized by high uncertainty and risk (e.g. military), multiple decision makers and stakeholders (e.g. natural resources management), multiple goals (e.g. sustainability aspects), massive data, etc. However, current research on DT concept does not provide enough information, clear guidelines, or a systematic approach for designing and implementing a DT-based approach for decision-making support, notably in the context of sustainable natural resources management. The next section presents the proposed methodology for addressing this gap.

4 METHODOLOGY

This section is divided into two parts. First, a generic framework for designing DTs is presented. The second part describes the conceptual design of FC-DSS (forest community-decision support system) aimed at implementing DTs for supporting participatory planning in the forest sector in Québec.

4.1 Decision theater design

We propose a generic framework to support the design of DTs (Figure 3). We were inspired by the descriptions of DTs provided in the literature and ASU website (see Section 3). The proposed framework encompasses five main components (or systems): *decision entities*, *decision support component*, *organizational system*, *decision theater layout*, and *technologies*. Without loss of generality, we consider the case of participatory planning.

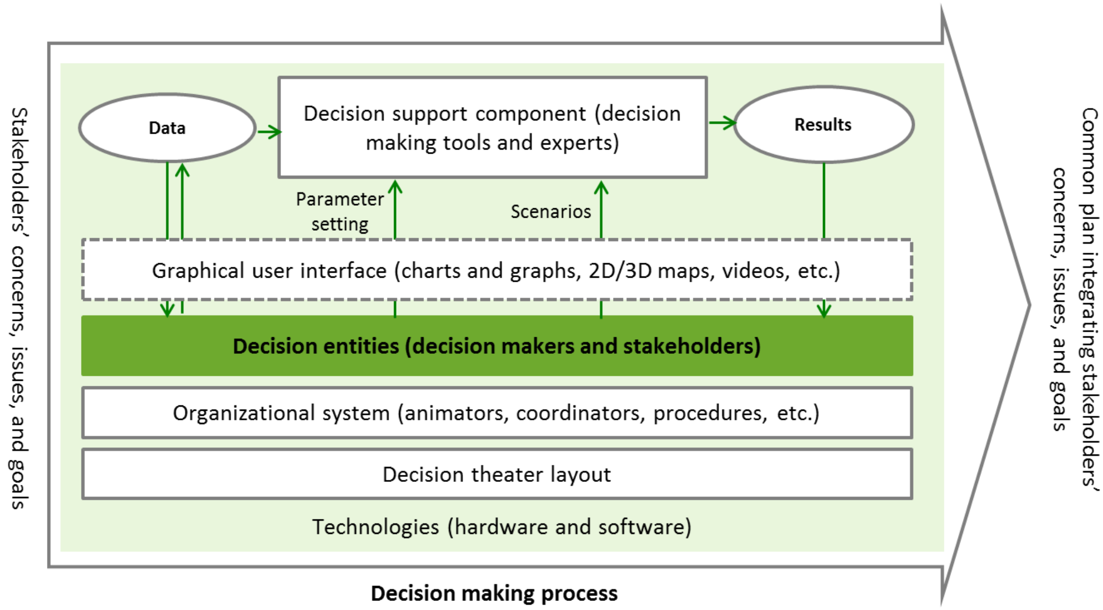

Figure 3. Conceptual framework for the design of DTs (Boukherroub *et al.*, 2016b)

Decision entities

We distinguish decision makers (or policy makers) and the stakeholders. It is important that the identification of stakeholder and the selection of their representatives ensure an adequate representation of all organizations or persons directly or indirectly affected by the decision-making outcomes (Martins and Borges, 2007). This is crucial for guaranteeing fairness and credibility of the decision process (Sheppard and Meitner, 2005). Identification and selection processes can be informal, based on criteria such as property rights, history with planning processes, reputation, importance, and influence (e.g. Grimble and Chan, 1995), or formal, based on matrices representing the influence and the importance of different stakeholders as perceived by others (e.g. Colfer *et al.*, 1999). Harrison and Qureshi (2000) referred to an interactive process, where discussions with pre-identified stakeholders reveal others, previously unknown (e.g. Antunes *et al.*, 2006; Langsdale *et al.*, 2013). Stakeholders, once elected, should share decision-making power and be involved in all planning steps (Martins and Borges, 2007). Other participants such as experts might be involved and have an impact on the decisions, however, they cannot participate in the decision making.

Decision support component

We consider decision support tools (qualitative or quantitative) as well as experts in the decision support component. In complex decision-making situations, at which DTs are aimed, decision makers and stakeholders need decision support tools to understand the problem, represent their issues and goals, express their preferences, identify potential solutions and outcomes, analyze, and prioritize best options, identify sensitive variables, understand their impact on the results, etc. These tools can range from simple qualitative tools such as means-ends network (Gregory, 2000) and SWOT method (Kotler, 1988), to more advanced planning tools such as optimization models, heuristics, and simulation models. Experts might be scientists who can provide the decision makers and the stakeholders with specific knowledge regarding complex issues. Experts might also be decision support specialists responsible for running the decision support tools. These are also referred to as modelers (Langsdale *et al.*, 2013) or model moderators (Siebenhüner and Barth, 2005). Decision support specialist must be able to listen, understand expectations from technical and nontechnical participants, and adjust models (or develop new ones) to reflect what is relevant and what is of interest to decision makers and stakeholders (Langsdale *et al.*, 2013). He/she must also be very responsive to be able to adjust models and to provide answers in a timely fashion. He/she must be able to explain the models and data sources, to help decision makers and stakeholders define the confidence zones of the models' outputs, and to support output interpretation. A decision support specialist can have strong influence on the interaction process by the way models are introduced and handled, and the selection of questions that are posed to the models. This is why choosing decision support specialists with collaborative skills and diverse modeling abilities is considered as a best practice in participatory planning in natural resources management (Langsdale *et al.*, 2013).

Organizational system

This component includes facilitators, also referred to as moderators (e.g. Siebenhüner and Barth, 2005; White *et al.*, 2010), coordinators, and technicians as well as procedures. In some cases, the facilitator and decision support specialist can be the same person (Langsdale *et al.*, 2013). The importance of facilitation in participatory processes is acknowledged in many studies (e.g. Siebenhüner and Barth, 2005; Sheppard and Meitner, 2005; Salter *et al.*, 2009; Desrosiers *et al.*, 2010; Menzel *et al.* 2012; Robert, 2013). The role of the facilitators is to provide context information and guidance through the decision-making process (Rammer *et al.*, 2014). For instance, in the study described by White *et al.* (2015), the facilitator tasks were to describe the assumptions, data sources and analysis, as well as the immersive DT setting with its associated scientific and technical specificities. As decision support specialists, facilitators can exert a strong influence on the direction of the process, the content being discussed, and the transfer of knowledge among the participants (Siebenhüner and Barth, 2005). Facilitators 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 (Selle 2000). Choosing facilitators able to understand and appreciate what modeling can provide was identified as a best practice (Langsdale *et al.*, 2013). In the case where landscape visualizations is used as a major tool, facilitator knowledge of visualization content and procedures is very important (Von Haaren and Warren-Kretzschmar, 2006; Salter *et al.*, 2009). Furthermore, Salter *et al.* (2009) suggest that multiple facilitators are required when interactive scenario modeling tools are used. The coordinators are responsible for organizing the meetings (date of the meeting, preparing and sharing documents needed, etc.), communicating with the participants, producing meeting reports, etc. while technicians are required to manage the hardware and network connections, assist decision makers and stakeholders in the use of their computers (e.g. navigate and drive), etc. Finally, the procedures specify the functioning rules of the participatory mechanism put in place such as participants' election process, 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 size and 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 "Drum", which is a round room with seven screens arrayed across 260 degrees. The Drum allows for conference room or theater-style seating, accommodating up to 25 people (White *et al.*, 2010). Landscape Immersion Laboratory (LIL) at UBC is a three projector, front-projected theater environment facility which can accommodate 10 to 15 people. The chairs are movable which allows reconfiguring the room in function of the number of users and situation dynamics (Cavens, 2002). Within ROLF environment (operations center of the future developed in Sweden, see Section 3), staff members sit around a circular table to allow eye contact, and facilitate interaction and communication (Brehmer, 2007). It is inspired from the fact that, historically, people used to gather in a close circle around the campfire when they had to make important and difficult decisions. A 3D display system (VisioscopeTM) is integrated into the table to allow the staff members to communicate while maintaining eye contact.

Technologies

Technologies are at the heart of DT concept. They support all other DT components. Technologies concern hardware and software. The hardware encompasses 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 (cameras, microphones, etc.). The software concerns databases, model bases, graphical user interfaces, communication protocols (e.g. intranet, internet, wifi, etc.), and other application programs to be used by the participants. In particular, improved internet browsers facilitate running complex web applications which can be accessed easily due to the widespread availability of broadband internet connections (Rammer *et al.*, 2014). On the other hand, interactive telecommunication technologies provide opportunities for the rapid registering of large numbers of opinions directly to computer memory and helps reduce problems resulting from geographical insularity and long distances (Kangas and Store, 2003). Graphical user interfaces play an important role in visualizing and interacting with data (see Figure 3). They allow displaying tables, lists, charts, videos, 2D/3D maps, etc. that can be visualized on screens by the participants (see Figure 3).

The decision-making process in the DT is supported by all five components as shown in Figure 3. As suggested by former studies (e.g. Simon, 1960; Sheppard and Meitner, 2005; Martins and Borges, 2007; Vacik *et al.*, 2014), we consider three main phases in the decision-making process: *problem identification (intelligence), problem modeling (design),* and *problem solving (choice).*

- **Problem identification** involves the acquisition and analysis of information to understand and define a decision problem, by identifying concerns, issues, and goals, alternative options, conflicts, interactions, etc.
- **Problem modeling** involves building a model to represent relations between alternative options and outcomes of decision makers and stakeholders.
- **Problem solving** involves the selection of an option, by prioritizing alternative options.

At these different phases, the decision makers and the stakeholders, directly or with the assistance of experts/facilitators/decision support specialists and by using their knowledge and decision support tools, enter data (e.g. concerns, issues, goals, preferences, etc.), extract data (e.g. description of alternative options), set parameters, define scenarios, and visualize the data and the results (e.g., geographical area of interest, results of alternative options, aggregated results of the group). These tasks call for a system integrating data, information, models, and methods. To facilitate this integration while taking advantage of the technology, the design of a DSS (Decision Support System) is required. 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 three components of the DT: *decision support component, decision entities, and technologies*. The conceptual design of FC-DSS, aimed at supporting DT implementation for dealing with participatory planning in forestry in the province of Québec is presented next.

4.2 Implementation in the forest sector in Québec: the conceptual design of FC-DSS

To collect data and develop the conceptual design of FC-DSS, we relied on a qualitative approach combining 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, which is documented in the forest planning manual, and other MFFP experts and coordinators involved in implementing and operating Local Panels in three different regions in Québec (Lanaudière, Capitale-Nationale, and Mauricie). Some results of these interviews were presented in Section 2.2. The forest planning manual (MFFP, 2013) is produced and updated by MFFP. It describes how the tactical and operational planning processes should be implemented under the new regime (MFFP, 2013). This manual (Version 5.1), the manual for determining the allowable cuts (2013-2018 period) produced by BFEC (BFEC, 2013), the documents describing tactical plans for the 2013-2018 period, produced in Mauricie and Lanaudière regions (e.g. MFFP, 2015), are among the key documents on which we relied. We also consulted the guide for implementing Local Panels (Desrosiers *et al.*, 2010) and different reports of Local Panels meetings (Lanaudière and Capitale-Nationale regions). Finally, we attended two meetings of two distinct Local Panels in the regions of Lanaudière and Mauricie as observer, in April 2016, and May 2016, respectively.

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 and strategic planning processes from a macroscopic view. The objective was threefold: (1) to identify the actors involved (*decision entities*), the main activities and steps, interactions among the actors as well as the decision support tools used and the tasks of experts involved (*decision support component*). We also identified the visualization elements provided by the decision support tools and other application programs (e.g. ArcGIS) (*technologies*). This mapping was essential for representing the "big picture" of the strategic and tactical planning processes, and for determining how the tools being used could be re-organized for designing FC-DSS. (2) The mapping was key in identifying the aspects of the planning process that contribute to the issues described in Section 2.2 (Table 1). (3) The macroscopic mapping was a useful communication tool with our MFFP partners, who validated our understanding of the planning process through an iterative process. In the ***second phase***, we mapped in more detail the activities and information flows of the planning process by using IDEF0, a well-known business process mapping methodology (Aguilar-Savén, 2004). The objective was to refine the planning process mapping, and precisely identify the activities of the process, the input/output data of these activities, the decision support tools, and the databases used, as well as the users of data, decision support tools, etc. 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. Next paragraphs provide more details on the three phases.

4.2.1 Phase 1: Macroscopic mapping of the tactical and strategic planning process

Figure 4 presents the mapping of the main activities, tools/experts supporting these activities, the elements visualized by the actors (visualization system in Figure 4), and actors' interactions with the tools/experts, from a macroscopic view. Visualization elements are highlighted in the figure to show the "interfaces" between the entities and the tools/experts supporting the planning activities. Figure 5 complements Figure 4, by describing all steps of the tactical and strategic planning process from the selection of the representatives of forest users and stakeholders up to the production of the tactical and strategic management plans. The representations provided by the two figures are based on the forest planning manual (V5.1) and our interviews with MFFP experts, who validated the two schemes. The planning activities and processes presented in Figures 4 and 5 are common to all regions 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/stakeholders or MFFP representatives. MFFP representatives may or may not be involved in decision making depending on the task assigned to them, which is to provide knowledge/expertise solely (i.e. planners and experts) or to provide knowledge/expertise and also participate in decision making (i.e. decision makers). Outside the Local Panel meetings, we distinguish MFFP planners and BFEC analysts, who use the outputs of the Local Panels to prepare/adjust the strategic and tactical plans and provide the results to the Local Panel members. Besides the work of the Local Panels, MFFP planners and BFEC analysts, working committees formed by members of the Local Panels continuously work on specific topics such as documenting the issues of forest users/stakeholders, proposing potential solutions for addressing the issues, and assessing economic, environmental and social impacts of the proposed solutions. The results of these working committees are presented and analyzed during the Local Panel meetings (Figure 5).

The numbers on the narrows in Figure 4 indicate the sequence of information exchanged between the different actors. The main activity of MFFP experts in the first stages of the planning process is to present ecological issues defined in the SFM strategy and other provincial and regional issues (e.g. issues identified in regional plans) as well as issues considered in previous tactical plans. Issues defined in the SFM strategy range from age structure, vegetal composition, forest configuration, wildlife species and habitat, to water and soil protection. Considering the issues defined in the SFM strategy in the forest plans is mandatory. On the other hand, the representatives of forest users/stakeholders present their concerns and issues related to forest management (e.g. visual landscape quality, timber production, forest road uses, etc.). Among these issues, we find concerns related to forest certification requirements (e.g. FSC, FSI and CSA). Certification issues are presented by the representatives of forest companies having or requiring a forest certification.

Next, most relevant issues are endorsed and classified as operational or tactical issues by the Local Panel members. Figure 5 describes the steps leading to this classification. Operational issues are dealt with at the operational planning level and tactical issues at the tactical level. Endorsing the issues allows the Local Panel members to determine the goals of the forest management strategy to implement in the concerned FMU(s). Next, potential solutions are proposed for addressing endorsed issues. Figure 5 describes the steps leading to solution identification and selection. A potential solution can be a specific silviculture treatment such as *partial cutting*, area conservation, extending stand revolution, etc. Potential solutions can also be found in forest certification standards or legislation. Tables presenting the endorsed issues, the objectives, indicators and their targets, known as VOIT cards (Value or Issue, Objective, Indicator, Target), as well as a synthesis table of these VOITs, are prepared for most relevant issues. VOIT cards are used as a tool to synthesize information on the issues, and to monitor the implementation of proposed solutions. More details on VOIT can be found in the document CSA-Z809-08 - Sustainable Forest Management (Canadian Standards Association, 2008). Other decisions such as identifying intensified fiber production areas and prioritizing parts of the road network and other infrastructure to maintain or develop are also discussed and endorsed by the Local Panel members (Figure 5). As shown in Figure 4, the Local Panel members use 2D maps, provided by ArcGIS, a geographical information system software, to geographically visualize elements of interests (lakes and rivers, wildlife reserves, forest road network and other infrastructures, etc.), information synthesized in tables (e.g. VOIT tables), lists (e.g. list of issues), etc.

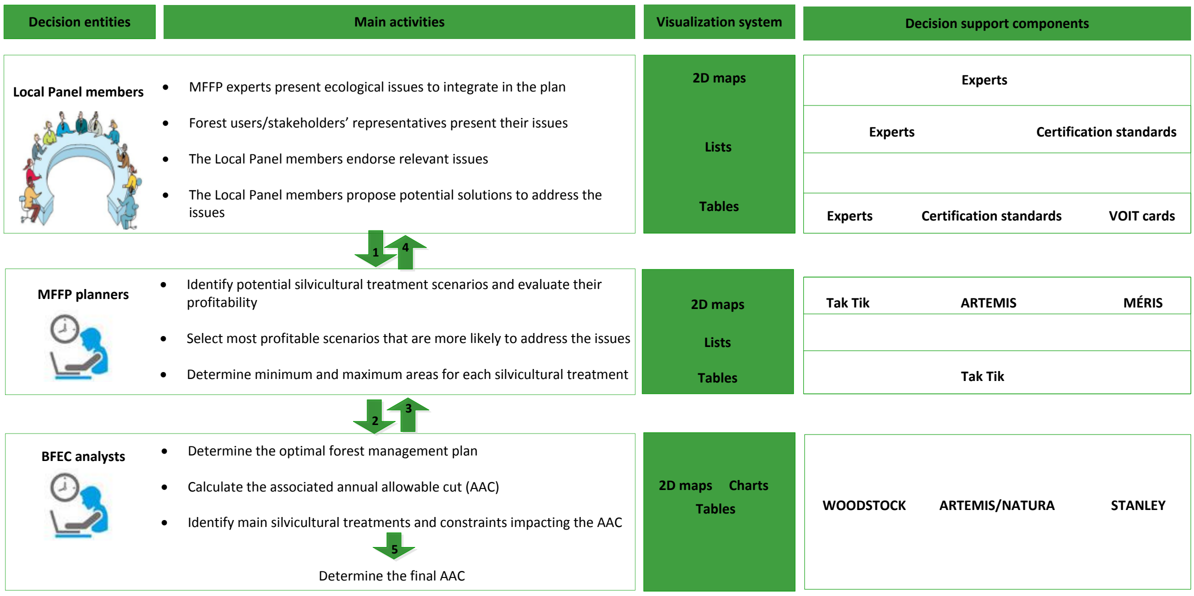

Figure 4. Macroscopic mapping of tactical and strategic planning activities, adapted from (Boukherroub *et al.*, 2016b)

The proposed solutions are further refined by MFFP planners, who determine more precisely the silvicultural treatments and silviculture scenarios, by using a tool called Tak Tik. This tool also provides the minimum and maximum area surfaces for each silviculture treatment. Another tool called MÉRIS is used jointly with forest growth/yield data provided by a tool called ARTEMIS to evaluate the profitability of the silviculture treatments. Most profitable silviculture scenarios that are more likely to address the issues are selected by MFFP planners and provided to BFEC analysts. MFFP planners use 2D maps (ArcGIS) to locate major constraints related to harvesting operations, intensified fiber production areas, etc. They also use tables and lists to visualize information such as the list of silviculture treatments. BFEC analysts produce the strategic management plan based on the orientations provided by MFFP planners (silviculture scenarios, minimum and maximum area surfaces, etc.). BFEC analysts 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 optimal strategic management plan and calculate the associated AAC. BFEC analysts also perform sensitivity analyses to identify main variables (e.g. silviculture treatments) and constraints impacting the AAC. BFEC analysts can visualize the data and results in different ways (2D maps on GIS, charts and tables). The results produced are provided to MFFP planners who may adjust the silviculture scenarios and maximum/minimum area surfaces before BFEC analysts determine the final AAC. Once the process is completed, information on the VOIT cards is updated to take into account the final results produced by MFFP planners and BFEC analysts (i.e. final solutions and targets). As shown in Figure 5, the activities described above are performed continuously (e.g. issue selection, documenting and endorsing the issues) and some of these activities are nested or performed concurrently. For instance, in the same meeting, potential solutions for endorsed issues can be discussed while additional issues (not yet documented or endorsed) can be presented. An example of nested activities is the selection of silviculture treatments and scenarios and determination of the area surfaces (MFFP planners) and AAC calculation (BFEC analysts).

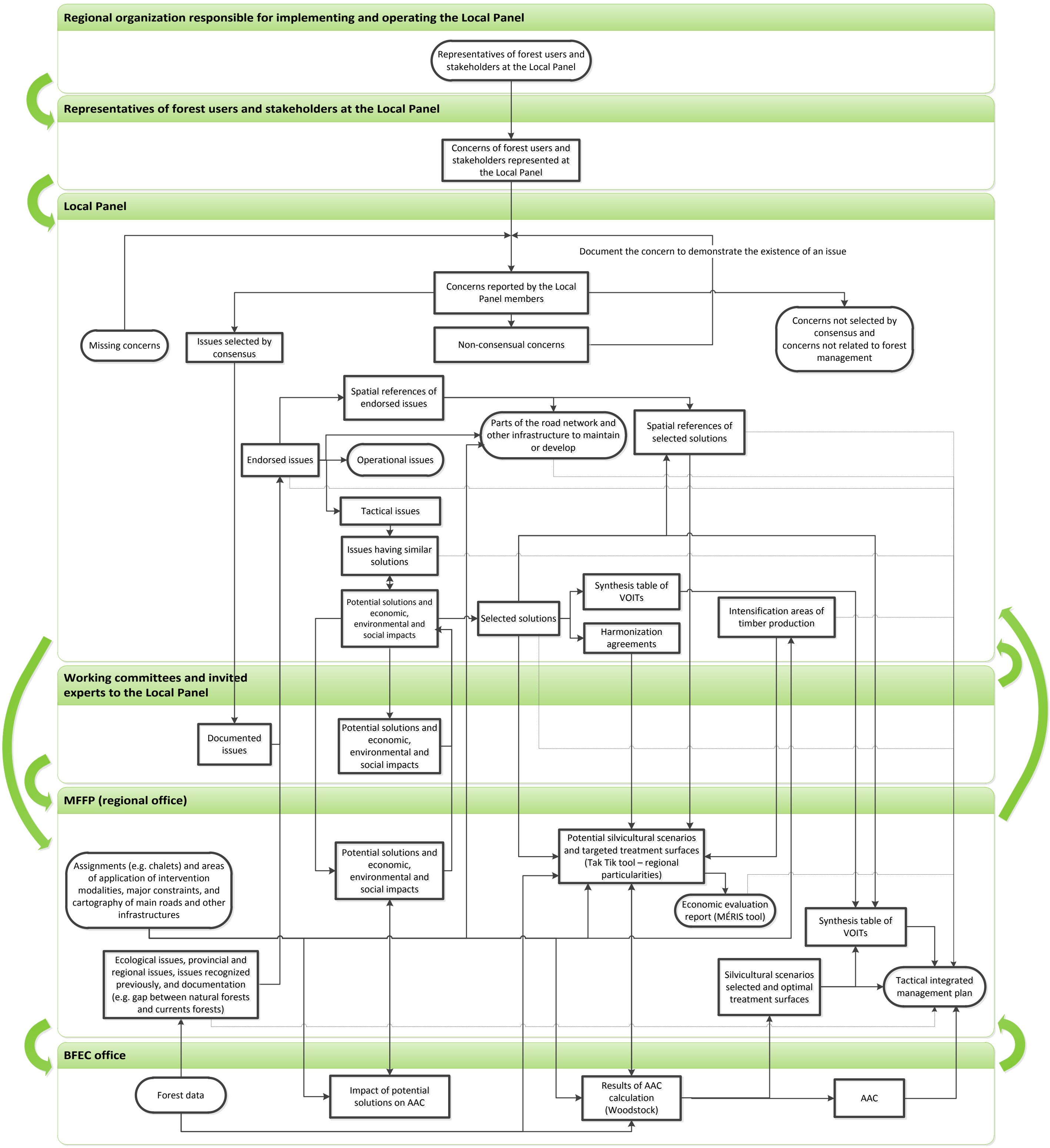

Figure 5. Steps of the participatory planning process in Québec (strategic and tactical levels)

The current tactical and strategic planning processes could explain some of the issues identified previously in Section 2.2 (Table 1). First, although we presented macroscopic and simplified mappings, the planning process might appear complex (Figure 5), notably for forest users and stakeholders who are not used to forestry planning and who might have low knowledge level. MFFP planners and BFEC analysts handle complex tools, large and diverse data, complex concepts, many inputs and outputs, etc. Indeed, information exchanged and decision support tools used are very specific to forestry, and handling these aspects requires highly technical skills and knowledge in various domains (forestry, biology, environment, management, optimization and modeling). This may explain why the planning process is perceived as fuzzy and complex, and why it is difficult for some participants to understand and trust information presented to them. Moreover, MFFP planners and BFEC analysts are in full control of the decision process and decision support tools (Tak Tik, MÉRIS, Woodstock, etc.). Therefore, it is not surprising that we observe lack of trust and transparency and unwillingness to collaborate in many regions. There are also multiple iterative sub-processes and interactions and feedback loops in the planning process. This may explain the lack of information at the right time, the lack of reactivity and coordination, the long feedback and delays, and furthermore, the long duration of the planning process. For example, it is not uncommon that BFEC analysts produce the strategic management plan and determine the AAC before the Local Panels have provided all their inputs (issues, potential solutions, etc.). As a consequence, forest users and stakeholders claim that their concerns are not taken into account and deplore the lack of impact analyses. The development of FC-DSS allows integrating experts' knowledge, decision support tools, visualization tools, and other methods used to support the planning process in one common and automated system. FC-DSS would mitigate aforementioned issues. However, to enable this integration, information presented in Figures 4 and 5 needs to be refined. The next section presents the detailed mapping of the planning process.

4.2.2 Phase 2: Detailed mapping of the planning process

Business process mapping has proven to be a useful tool for the analysis of supply chain processes in the forest sector in different countries, for example for analyzing the impact of different industrial contexts on procurement, management and development of harvesting services in Sweden (Erlandsson, 2013), cost calculation and business process improvement in Finland and Germany (Windisch *et al.*, 2013), and operational planning process mapping in Canada (Gharbi *et al.*, 2014; Gharbi, 2014). In this study, we used IDEF0 methodology (Integration Definition for Function Modeling 0), a well-known standard for modeling complex processes (Aguilar-Savén, 2004). IDEF0 has already been successfully used in other studies in the forest sector (Cascini *et al.*, 2008; Haapaniemi, 2011; Erlandsson, 2013). IDEF0 methodology is considered as exhaustive in terms of capturing information (Colquhoun and Baines, 1991). It offers detailed rules to consistently model functions (or activities) with their hierarchies and interactions and it realistically captures coordination and feedback between and within activities (Windisch *et al.*, 2013). An activity is represented by a box in an IDEF0 model as illustrated in Figure 6. Input data are represented as arrows entering the left side of the activity box, while the outputs are represented by exiting arrows on the right side of the box. Inputs are objects that are transformed by the activity to produce outputs (Erlandsson, 2013). Controls are displayed as arrows entering the top of the box. These objects specify some conditions required for the activity to produce correct outputs (e.g. regulations). Finally, mechanisms are displayed as arrows entering from the bottom of the box. Mechanisms are the means supporting the execution of the activity (e.g. planners and tools). Inside the box is the breakdown of that activity into smaller activities (sub-activities), which together comprise the box at a higher level (Kim and Jang, 2002). For more on IDEF0 methodology, the reader can refer to (Kim and Jang, 2002) and (Aguilar-Savén, 2004).

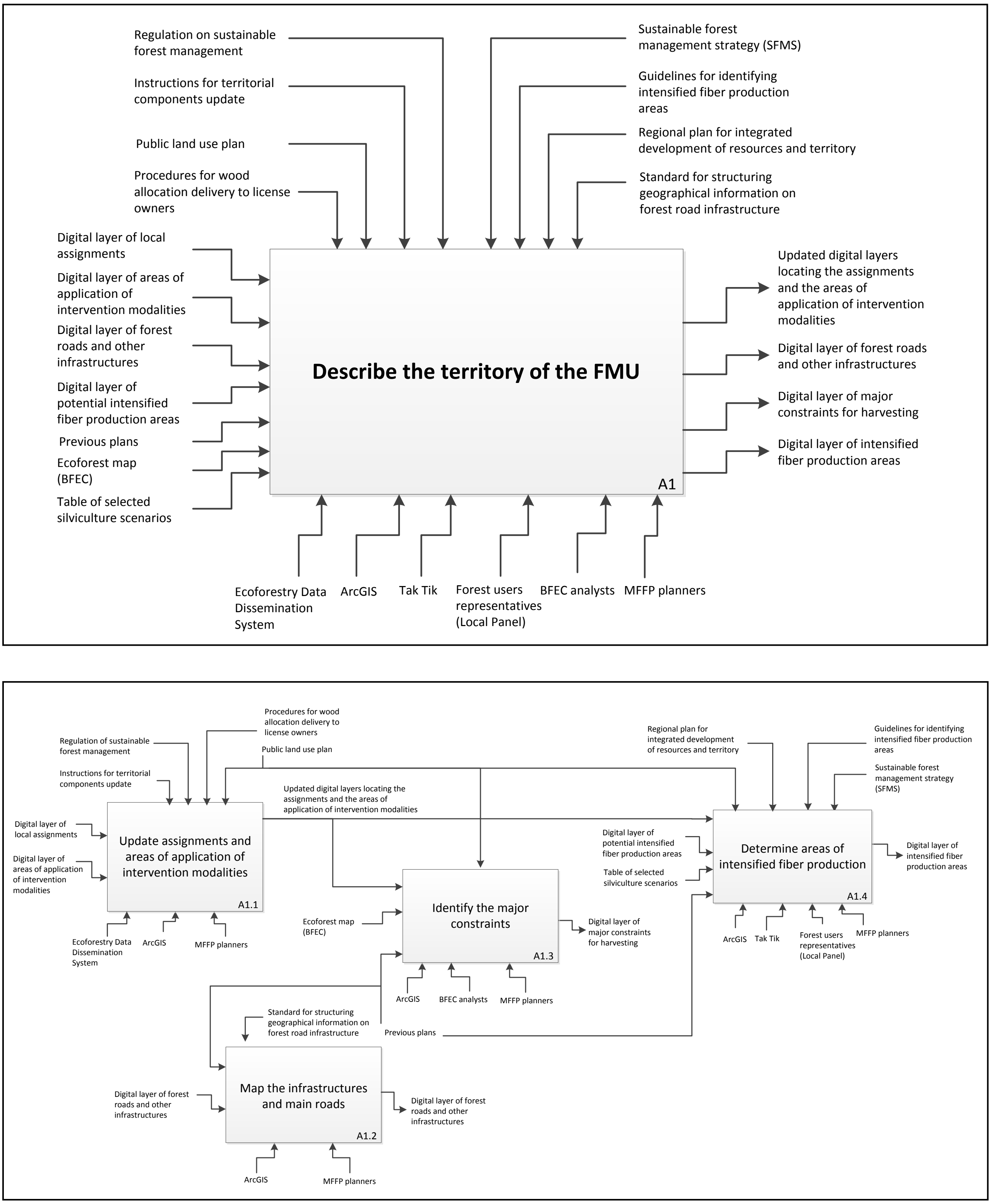

Figure 6. Example of activity breakdown into sub-activities by using IDEF0 methodology

The top-level activity in our case is *Prepare the strategic and tactical plans*. The breakdown of this activity leads to a diagram of activities describing the activities required for preparing the strategic and tactical plans and how these activities are related to each other. Then, each activity is decomposed into a more detailed diagram of activities to describe the sub-activities required for performing that activity. An example is provided in Figure 6. Figure 6 presents the process of describing the FMU territory, one of the activities required in the planning process (problem identification or intelligence phase). Parent activity A1 *Describe the territory of the FMU* is further decomposed into four sub-activities A1.1, A1.2, A1.3, and A1.4 (child activities). The aim is to precisely describe which input data is required by which activity, which outputs are produced from the inputs, which controls are required, who is performing the activity and which tools are used while keeping the link between the sub-activities. By using IDEF0, it was possible to precisely map the information flows of the planning process and link the activities to each other. Therefore, we could precisely identify the data needed to perform all activities of the planning process, in which form and where the data was available (e.g. databases), and which actors/tools use the data. This information was crucial for developing the conceptual design of FC-DSS, which is presented next.

4.2.3 Phase 3: conceptual design of FC-DSS

FC-DSS (Figure 7) integrates the tools used by experts, MFFP planners and BFEC analysts and provides a shared data management module for all users (Local Panel members, MFFP planners, and BFEC analysts). It is inspired by the DSS SADfLOR v m 1.0 described in (Garcia-Gonzalo et al., 2015). FC-DSS encompasses a *data management module*, two distinct *model base modules (MFFP and BFEC)*, and a *data and results visualization module.* FC-DSS is web-based. Recent advances in technologies and improved Internet browsers allow the development of web-based decision support tools (Rammer *et al.*, 2014). Reduced access barrier (no downloads or installations required) and active participation of large groups are among the advantages of web-based approaches (Rammer *et al.*, 2014).

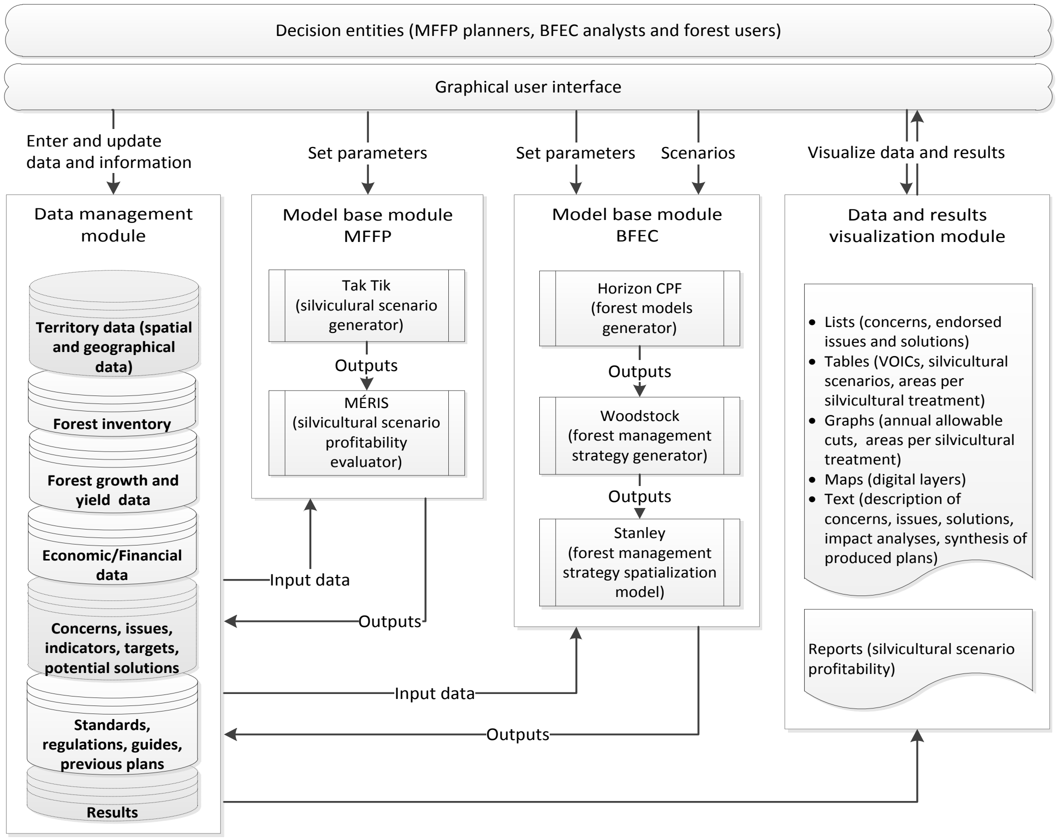

Figure 7. Conceptual design of FC-DSS, inspired by (Garcia-Gonzalo *et al.,* 2015), adapted from Boukherroub *et al.* (2016b)

FC-DSS supports all three decision process phases. All users (forest users and stakeholders and their representatives at the Local Panels, MFFP planners and BFEC analysts) can update or enter their inputs into FC-DSS via Internet browsers from local PCs (during the meeting or outside the meetings). 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 forest users/stakeholders into FC-DSS is related to their concerns and issues, the description of these issues, their preferences regarding the issues, potential solutions (problem identification phase), parameter values (problem modeling phase), and most preferred solutions (problem solving phase). To this end, a Web application for entering data and a specific data base for saving the inputs need to be developed. The four components of FC-DSS are independent and encapsulated in the graphical user interfaces. We distinguish three distinct graphical interfaces to meet the needs of the three categories of users: MFFP planners, BFEC analysts, and forest users/stakeholders. The last category of users will have a customized graphical user interface to address their specific needs in terms of data and results representation and visualization. Currently, such a graphical user interface does not exist. 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 and stakeholders having difficulty in understanding maps and scientific information may need a detailed view of alternative solutions, background information, and customized visualizations. Elements that can be visualized include lists of concerns/issues entered into the system, lists of possible silviculture treatments and scenarios, VOIT 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, etc. While ArcGIS is currently used by MFFP planners and BFEC analysts for displaying digital layers, maps and graphs, additional tools offering rich visualization capabilities need to be integrated to existing tools.

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 tools used to generate silviculture treatments and scenarios and to evaluate their profitability (respectively). BFEC analysts control the model base module *"BFEC"*, which contains forest models generator (*Horizon CPF*), a forest management plan optimizer (*Woodstock*), and a spatialization tool (*Stanley*). We call to mind that MFFP planners are responsible for preparing the tactical and operational plans, while BFEC analysts are responsible for preparing the strategic management plan and determining the AAC. Although MFFP planners and BFEC analysts have access only to their specific modules, communication and coordination is enhanced since they share all data and results generated by their specific planning and analysis tools. During the meetings, the representatives of forest users and stakeholders at the Local Panels will have the possibility to guide MFFP planners or BFEC analysts in setting parameters and defining alternative scenarios (e.g. forest management 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 forest users/stakeholders. Of course, the tools currently used for tactical and strategic planning need to be further developed and simplified to enhance FC-DSS capabilities in terms of interaction with the data, the models and the generated results. The next section presents the expected results of implementing FC-DSS and DTs for participatory planning in the forest sector in Québec.

5 RESULTS OF IMPLEMENTING FC-DSS AND A DT IN THE FOREST SECTOR IN QUÉBEC

First we discuss the aspects related to using FC-DSS in Local Panel context. Next, we discuss the benefits of implementing a DT.

5.1 Results of implementing FC-DSS

One of the advantages of FC-DSS is that it allows all users to access information via Internet and visualize it through customized graphical user interfaces. According to Menzel *et al.* (2012), for a DSS to be operational, the available information has to be compiled in a structured and clearly arranged way, which contributes to improve the quality and selection of information. Thus, using FC-DSS in Local Panel context will contribute to address lack of information issue. Access to quality information was identified as a major success factor of participatory planning according to 15 surveyed forest users, stakeholders and researchers (over 19 respondents) who participated in a pilot project involving a participatory forest management mechanism during the period 2006 – 2009 in Québec (Roy *et al.*, 2010). Access to quality information is considered as one of the criteria ensuring good participatory processes (Menzel *el al.*, 2012; Díez *et al.*, 2015). On the other hand, the customized user interfaces provided by FC-DSS will enable presenting information to forest users and stakeholders in more simple and familiar ways, which will allow rapid comprehension. Roy *et al.* (2010) identified "access to simplified information" as another success factor in the context of the pilot project conducted in Québec. This important feature of

FC-DSS will contribute to address understanding issue and lack of trust in scientific knowledge. Access to information via Internet will enable the users to explore information in detail during a longer period of time, for example before the Local Panel meetings. This will support the learning process of forest users and stakeholders needing more time to understand and acquire new knowledge. As stated by Kangas and Store (2003), people have different learning styles and learning abilities in public meetings. In the context of the pilot project conducted in Québec, some participants identified "access to information before the meetings" as a success factor (Roy *et al*., 2010). The Local Panel members in the regions of Outaouais and Abitibi also expressed the need for more time to investigate and evaluate the proposals and to interact with the information (Leclerc and Andrew, 2013). Learning supports dialogue and enquiry with other participants (Dale and English, 1999). Using FC-DSS will thus contribute to enhance participants' willingness to participate in the discussions and the collaboration process. This implies that the participants will pay more attention to the concerns of participants from other areas of interest (Roy *et al.*, 2010). The participants would furthermore build more respectful and trustful relationships, and would be more willing to find compromises and build consensuses. However, the participants' ability to express their opinions immediately and publicly can vary (Kangas and Store, 2003; Jankowski, 2009). Therefore, the possibility for "shy and silent" group members to express their opinions in a fair and equal way (Kangas and Store, 2003) is another advantage of using FC-DSS.

According to Kangas and Store (2003), offering an equal opportunity for participants to express their opinions increases the transparency of the group work. Transparency means also that at any point in time, the users (participants and outsiders) can have access to and understand the background information, the procedure followed to produce the outcome, and the numbers generated (Dale and English, 1999; Menzel *et al.,* 2012). A DSS can improve transparency. FC-DSS allows the generated results to be accessed by the decision support tools used by MFFP planners or BFEC analysts (e.g. silviculture treatments, forest management scenarios, etc.) as well as the background information supporting the models' results (assumptions, models' parameters, etc.). This will lead to more transparent models for the forest users and stakeholders and enhanced traceability and information consistency. As an example, in a study investigating the usefulness of DSSs in participatory planning in the forest sector in Finland and Italy, it was found that "giving transparency and traceability to the decision-making process" and "supporting communicating to stakeholders the information concerning the various alternatives" were attributed the highest values by the interviewed experts (De Meo *et al.*, 2013). Using FC-DSS will also result in enhanced communication among MFFP planners and BFEC analysts and less feedback loops. It is advanced in the literature that in a multidisciplinary group, DSSs can support creating a common language (Menzel *et al.*, 2012; De Meo *et al.*, 2013), which enhances communication. FC-DSS will thus contribute to address the issue of long feedback as well as coordination and silo working issues. Finally, due to enhanced communication, better inclusion of forest users and stakeholders, improved comprehension, more transparency, trust, and willingness to collaborate, the complexity of the decision-making process and the time and resources needed, will be significantly reduced.

5.2 Results of implementing a DT

The aim of developing FC-DSS is to enable implementing a DT for supporting the work of Local Panels in Québec. The other components of the DT (i.e. physical layout, organizational system, and additional technologies) complement FC-DSS by offering additional means for interaction, visualization, negotiation, and deliberation. Therefore, implementing a DT will provide additional benefits for participatory planning that complement the benefits of FC-DSS we discussed earlier. First, the technological environment of DTs is attractive, and could thus contribute to engage forest users and stakeholders in the decision-making process. Langsdale *et al.* (2013) argue that early and frequent participation of the stakeholders helps in receiving their inputs, develop and evaluate alternatives, and select the preferred alternative. Second, DTs offer the possibility to display different information on adjacent large wall screens. This enables for example, visualizing at the same time different indicators associated to a given management plan (i.e. generated by FC-DSS) such as the volume of harvested timber (AAC), the age dispersion, the species composition, the number of sites of high quality, etc. The impact of different management plans on a specific indicator could also be visualized on the adjacent screens (i.e. one management plan per screen). In the former example, the management plan's effects on the different indicators can be analyzed and compared, compromises and trade-offs can be identified which could further foster the negotiations and support consensus building. DT immersion capabilities can also be useful in the problem identification phase. For example, video projections of harvesting areas, old forests, conservation areas, natural parks, etc. on the wall screens can be used by the forest users/stakeholders or experts/facilitators to highlight regional particularities and related issues and concerns or the results of previous management actions (e.g. silviculture treatments, forest roads, etc.) in the territory. This can help in understanding the effects of a given management action or issues related for example to forest age distribution, wildlife habitat, biodiversity, First Nations values, etc. In the Local Panel context, this will contribute to clarify and consider regional particularities and related issues in the management plans more efficiently (issue pointed out in many regions of Québec). In the regions of Bas-Saint-Laurent (Robert, 2013) and Capitale Nationale, field visits were organized before the Local Panel meetings. The participants found these visits very useful in connecting people, understanding the concerns and interests of each other, and enhancing willingness to collaborate during the meetings. However, field visits are time consuming and much effort is required to organize the visits (coordination, logistics, safety, etc.). Video projections in the DT could be a good alternative to field visits.

By using more sophisticated techniques such as nature rendering engines (i.e. coupled with FC-DSS), accurate 3D forest portrayals resulting from different alternative management plans could be visualized from different viewing perspective at different time horizons. The large wall screens add realism to 3D images and allow the "immersion" of the viewers, which helps to figure out the visual impact of the alternative plans (i.e. more tangible results). For instance, in Mauricie region, the experts we interviewed indicated that the majority of participants would have appreciated visualizing the results of a given solution, claiming: "*we would like to see what it [a given solution] looks like*". 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." The participants can also interact with the images by changing the perspective view, challenging the parameters of the models generating the results, defining new targets, etc. This can be facilitated by integrating sliders in the graphical user interface of the forest users and stakeholders. Salter *et al.* (2009) reported that the ability to dynamically explore the visualizations of plans and see real-time changes in indicator metrics (in the context of Landscape Immersion Laboratory (LIL) experiments in UBC were considered particularly informative by the participants, and appeared to increase participants' understanding of the plans, particularly participants with average knowledge level. The visualization capabilities of DT also facilitate the work of scientists, decision support specialists, and facilitators. Meitner *et al.* (2005) reported that CALP visualization system at UBC (see Section 3) enabled researchers to see forestry modeling outputs in new ways and helped them in detecting errors and evaluating models' limitations and assumptions. Moreover, dialogue between interdisciplinary team members increased while misunderstandings tended to decrease. Visualization could also simply assist experts/facilitators/decision support specialists in presenting and explaining complex concepts (e.g. ecological issues, decision support models and their outputs, planning process, etc.) However, to avoid misinterpretation, visualization and interactive tools should be used with caution. Finally the physical layout of the DT can improve interactions among the Local Panel members. According to Artman and Persson (2000), sitting around a table with common artefacts presenting shared data and being able to monitor each interlocutor's eyes at the same time is the best way to start a creative discussion with a common focus. We believe that different configurations are possible. In addition, using Internet offers an alternative to participants less familiar with discussions in public meetings to express their opinions, and therefore, complements face-to-face meetings.

6 CONCLUSION

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 now widespread (Têtu, 2014). By taking advantage of existing decision support tools combined with these new technologies, developing FC-DSS and implementing a DT in the province of Québec will be possible. FC-DSS and a DT offer many advantages to decision makers, planners, analysts and forest users. Implementing a DT would support sustainable forest management planning. Many of the Local Panels' issues could be addressed and the participatory planning would be substantially improved. The use of the DT can be extended to other participatory mechanisms such as the Operational Panels or public and First Nations consultations. Further developments are certainly needed to enhance the capabilities of the proposed FC-DSS. Developing FC-DSS along with additional functionalities is very promising for the implementation of a DT in the province of Québec. The DT(s) to implement could be multi-disciplinary to allow other sectors (e.g. urban planning, waste management, environmental management) to benefit from the facilities and the technologies.

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