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Unified Framework for Modelling the Canadian Forest Products Value Chain: An Instantiation for the Lumber Industry

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Abstract. The Canadian forest products sector is a vital contributor to the economy, yet it has been facing challenges in recent years which have resulted in a search for improvement opportunities in order for the sector to remain competitive in a global marketplace. In this context, simulation and optimization models have been useful tools in guiding decision makers and stakeholders in finding opportunities throughout the forest products supply chain (SC). As the number, variety and complexity of these SC models grow constantly, there is an increasing need for formalized methods and standard practices to facilitate their development and support users and practitioners alike in understanding, integrating and improving them. According to a recent systematic literature review in the domain, a common and integrated language and modelling approach is lacking in this area. As a first step towards creating a generic modelling framework, this research report presents some efforts towards a novel unified framework for the lumber industry. Inspired from existing generic frameworks, a preliminary version of the proposed approach allows for modelling and organizing several decisions processes of the lumber SC, which is subsequently, validated using a survey of experts. The proposed framework identifies the main decision-making processes together with the most important key-performance indicators employed across the lumber SC at the strategic, tactical and operational decision levels, from the forest to the final products distribution.

Keywords. Modelling methodologies, business processes modelling, framework, forest products supply shain (SC), conceptual model, lumber.

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1. Introduction

Supply chains (SCs) in the forest industry can be viewed as complex networks, encompassing multiple autonomous interacting units. In view of such complexity and the importance of forest industries for Canada, it is not surprising that substantial effort has been dedicated to studying forest products SCs in recent years (e.g., Jerbi *et al.*, 2012; Santa-Eulalia *et al.*, 2011a; among several other works). While an increasing number of mathematical and computer models are being developed to study various facets of SCM (Supply Chain Management) theory and practice in forest products industry, it is becoming evident that a complete and integrated formal structure covering the whole chain would be necessary for guiding the development of and the evaluation of these models (Vahid *et al.*, 2014). In fact, there is no common representation and understanding (or even a common vocabulary) of the different components and decision processes within the forest value chain. In this sense, the literature lacks a general modeling framework providing a collective understanding (from both an industrial and academic perspective) of the value chain that functions as a sound basis for the study of forest and industry strategies, supply chain configurations, and planning approaches.

An overview of the existing literature on SC modelling frameworks (Vahid *et al.*, 2014) showed that there is a lot of variation in using the term "framework". Furthermore many studies offer models designed for a distinct type of SCs that cannot be extended to other application areas without being drastically changed in terms of structure or formulation. Additionally, while SC modelling and simulation for the forest products industries have been employed in the literature for well over a decade, Vahid *et al.* (2014) found surprisingly few studies claiming to present frameworks for such a purpose and even those identified were either too general to be considered forest-industry-specific, or too narrowly focused on one application area. While no forest-industry-specific frameworks have been developed to date, the authors suggest that there exist general purpose frameworks and standards that would potentially be applicable to the case of the forest products SCs, such as the SCOR (Supply Chain Operations Reference) model or FAMASS

(FORAC Architecture for Modelling Agent-based Simulation for Supply chain planning) framework.

Ultimately, by having a common understanding, a novel framework in this area would enhance (i) the cooperation of different and multidisciplinary members of the community (including academics and practitioners), and (ii) the information and knowledge sharing throughout the community.

Thus, this report proposes a first effort towards a unified framework for knowledge modelling of the planning and scheduling processes of forest products value chains that can be used by both academics and practitioners. In addition, the general principles of the proposed framework are instantiated in the lumber industry, thus a detailed version of the framework for this industrial sector is provided.

In order to do so, this document is organized into 5 sections. First, Section 2 provides methodological details of this research. Section 3 is dedicated to the survey and its results while Section 4 presents the final framework. The conclusions and future steps are included in Section 5. Several appendices are provided at the end of the document.

2. Methodology

Due to the nature of this research effort (i.e. a qualitative instrumental research), our approach employed a qualitative methodology. The development of the framework in this work is conducted in four main phases, as depicted in Figure 1: (1) a Systematic Literature Review (SLR) of the existing frameworks; (2) preliminary framework development; (3) consulting experts in academia and industry, and (4) final framework development and delivery.

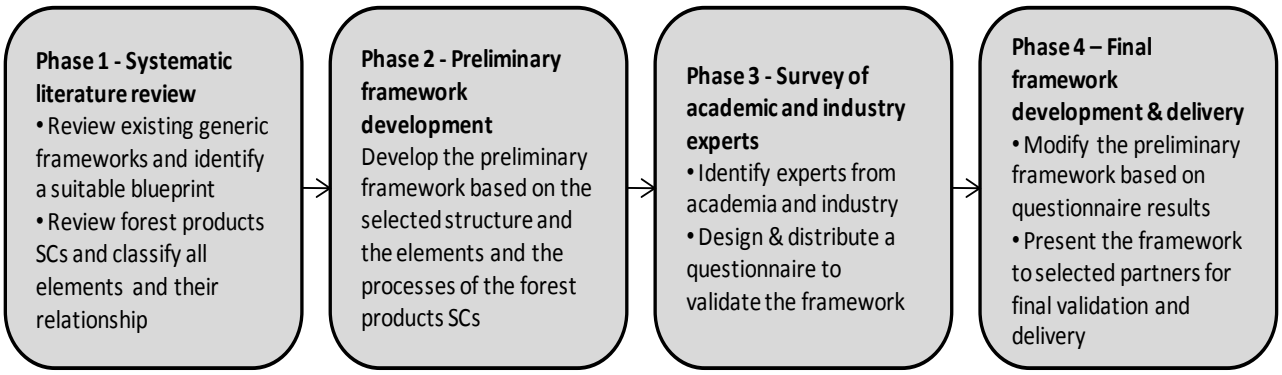

Figure 1: Project steps for developing a unified modelling framework for forest products SCs

In the first phase, 57 articles were reviewed while the modelling framework FAMASS (Santa-Eulalia *et al.*, 2012) was identified as the basis for the framework development of this project. In the second phase, the preliminary framework for the lumber products value chain was created, encompassing a collection of potential planning processes and the relationship among them. Validation of the preliminary framework was conducted with 35 experts by an online questionnaire in the third phase. Finally, in the fourth phase, the preliminary framework was modified based on the results of the online survey and a final framework was developed.

Details about these phased are provided in the next sub-sections.

2.1 Phase 1 - Systematic literature review (SLR)

In order to analyze existing frameworks and highlight some concepts, methodologies, and guidelines that would be useful by acting as a blueprint for a forest industry-specific framework, an SLR has been conducted. The idea was to provide a synthesis of studies that has transparent guidelines and is reproducible. In total, 57 articles were reviewed and 32 frameworks were identified, 9 of which were relevant to the forest products industries, but none specifically developed for it.

FAMASS, a modelling framework first developed by Santa-Eulalia et al. (2012), was identified as one of the suitable frameworks to use as a guide for this project. It creates a top-down approach to analyze and understand the simulation steps (from a large-scale system view to individual agents). Consequently, any supply chain can be decomposed into various interacting units and the necessary requirements to create a simulation model can be expressed in details.

As part of the FAMASS methodology, a supply chain is analyzed to identify all the different entities that are included in it, using a "supply chain planning and scheduling cube", shown in Figure 2. This cube is made up of various blocks, and each block represents an entity that can perform all or part of planning, scheduling, and execution activities of the supply chain. For example, long term planning of sawmills' activities can be represented with a "strategic-manufacturing-facilities" block.

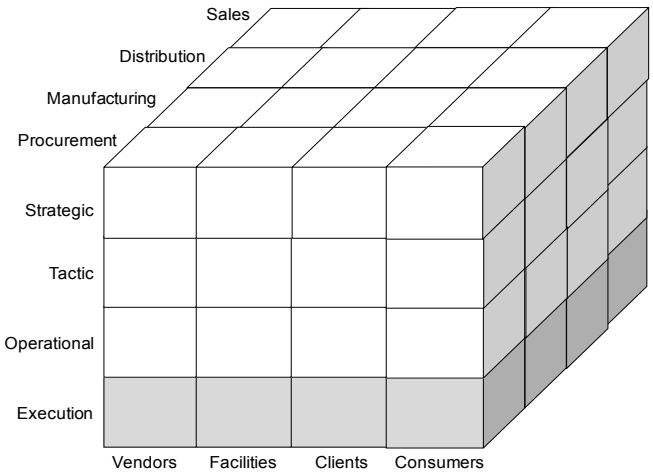

Figure 2: Supply chain planning and scheduling cube, FAMASS (Santa-Eulalia et al., 2012)

SC cube has emerged from the work of Shapiro (Shapiro, 2000) where three dimensions of the SCM were identified as: intertemporal, functional, and spatial, the three axes of the cube. Intertemporal dimension addresses the different decision levels in the SC, which are long-term, mid-term, and short-term. The functional dimension includes different SC functions such as procurement, manufacturing, distribution, and sales. The spatial dimension refers to geographically dispersed entities like vendors, facilities, clients, and customers. This framework is therefore easily adaptable to model a wide variety of SCs, and has the ability to incorporate

agents, which are a natural way to represent SCs due to their capacity to simulate multiple behaviours.

2.2 Phase 2 - Preliminary framework development

To develop our preliminary framework in the second phase of the project, all potential planning processes and processors within the SC of the forest products industry were identified. The preliminary framework was comprised of a collection of these processes and the relationships among them. In order to demonstrate the applicability of our proposed framework, the scope of the project was limited to planning and scheduling activities of the lumber products SC. We decided to focus on the lumber SC: (i) to have a first research effort within a limited timeframe that will lead the research team towards a complete framework in the future; (ii) the importance of this industry in Canada; (iii) the availability of literature; as well as (iv) the available expertise within the research team. The "execution" level in the SC planning cube was not considered to keep a global perspective of the system.

Derived from Figure 2, each highlighted rectangle in Figure 3 represents a processing or distribution unit within the lumber products SC. Harvest Unit (vendor 1) performs the harvesting and log distribution activities. Log Sort Yard (vendor 2) represents either the integrated log sorting operations of a harvesting unit, or operations of an external unit that buys the logs from the harvesting unit, then sorts and delivers them to various facilities based on their demand. Sawmill (facility 1) represents all activities of a sawmill including sawing, drying, finishing, and distribution. Value Added Plant (client 1) is a generic unit that can represent a variety of value added plants (also known as remanufacturing), such as structural lumber producers or furniture manufacturers. Market Agent (client 2) represents the retailer and is the source of demand in the SC.

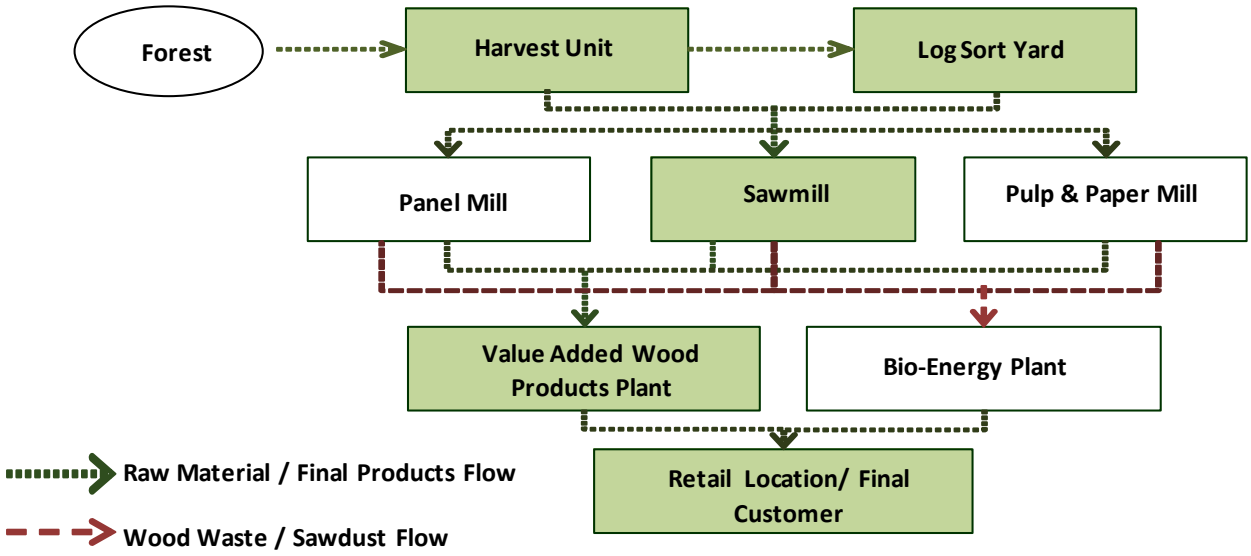

Figure 3: A typical forest products supply chain (Vahid et al., 2014)

The relevant decisions and processes of the lumber products SC were initially identified from existing literature in the field (Vahid et al., 2014). In accordance with the structure of FAMASS, the identified processes were categorized separately for the three decision-making levels. A selection of these processes at the strategic level is shown in Table 1 as an example. Columns represent the spatial dimension (which SC unit the process belongs to), and the rows represent the functional dimension (which function of the SC benefits from the process).

Additionally, the aggregated information flow among different SC members at different decision making levels is shown in Figure 4.

While the preliminary framework encompassed different processes and decisions related to the Canadian lumber SC, it had to be validated to make sure that any processes would be omitted. Furthermore, the concepts of short-term or long-term planning are context-dependant and vary among different SC members. A planning horizon of one year may be considered short-term for harvest operations, but long-term for a retailer. The following phase ensured the validation part.

Table 1: Strategic process mapping example for a lumber products SC according to FAMASS

Spatial Dimension	Vendor 1 (Harvest unit)	Vendor 2 (Log sort yard)	Facility 1 (Sawmill)	Client 1 (Value-added plant)	Client 2 (Market agent)
Functional dimension					
Procurement					
Forest land acquisitions and harvesting contracts	✓				
Access road design	✓				
Determining raw material procurement strategy				✓	
Manufacturing					
Location of facilities		✓	✓	✓	
Choosing production/harvesting capacities and technologies	✓	✓	✓	✓	
Determining product families			✓	✓	
Distribution					
Location of distribution centers			✓	✓	✓
Logistics resource investments	✓	✓	✓	✓	✓
Choosing transportation strategies	✓	✓	✓	✓	✓
Sales					
Selection of markets	✓	✓	✓	✓	✓
Pricing strategy	✓	✓	✓	✓	✓
Service strategy	✓	✓	✓	✓	✓

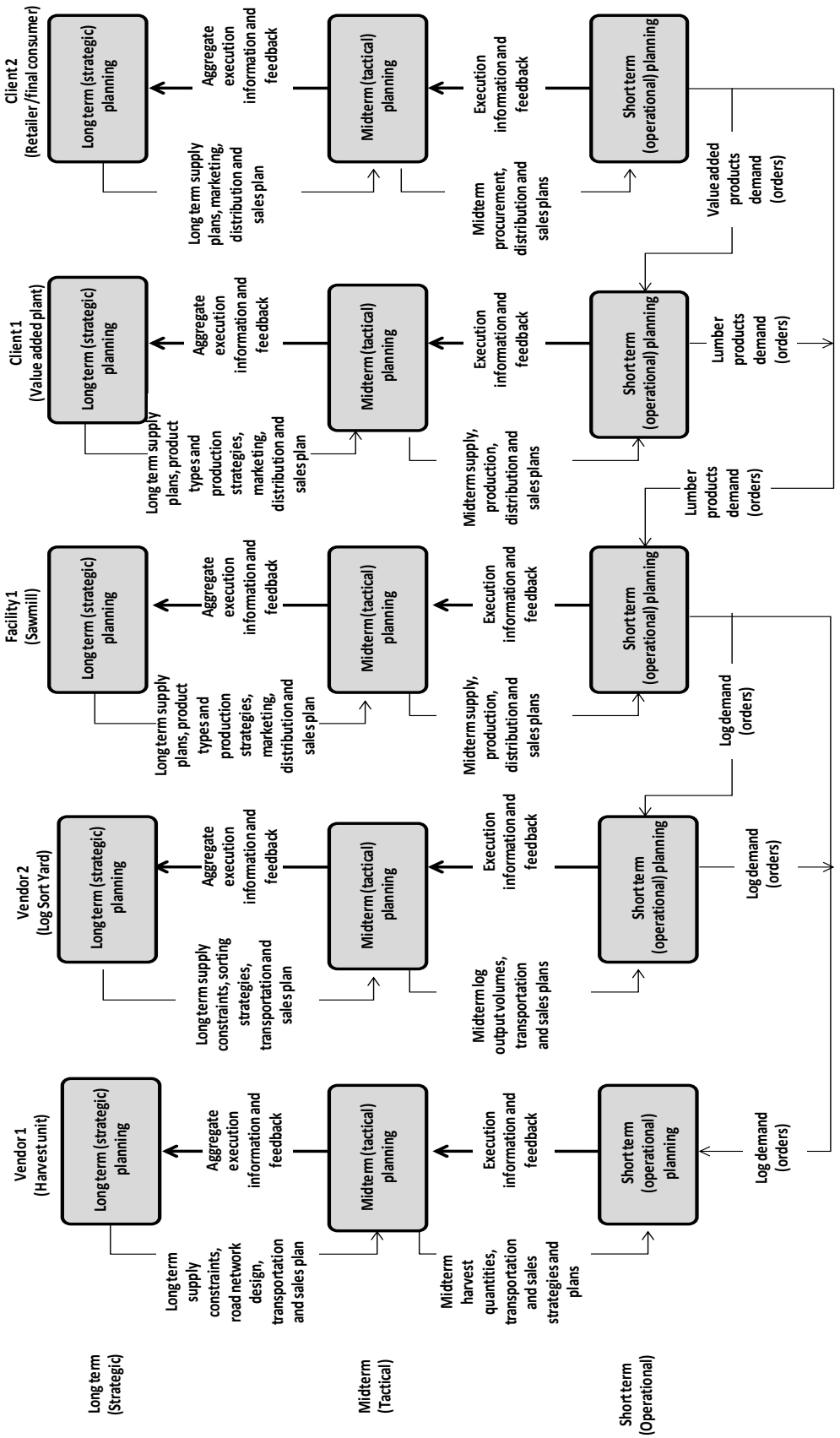

Figure 4: Information flow in the lumber products SC

2.3 Phase 3 - Survey of academic and industry experts

The preliminary framework, as a conceptual model (CM), needed to be validated for "determining that the theories and assumptions underlying the conceptual model are correct and that the model representation of the problem entity is "reasonable" for the intended purpose of the model" (Sargent, 2005). One of the primary CM validation techniques is "experts' validation" which includes specialists on the system evaluating the CM to determine if it is reasonable and correct (Sargent, 2005). This was the method used in our work for validating the developed framework. In particular, we selected a population of experts on the subject of Canadian forest products SC modelling and analysis and requested their participation in an online survey. The participants were selected based on their relevant academic publications or research project involvements within the past five years. While the majority of them are academics, there were also participants from government agencies and industrial research centers. Although face-to-face meetings or workshops would have provided an opportunity to discuss the preliminary framework, it was not practical considering the large number of surveyed experts across Canada. Therefore, an online questionnaire was designed and sent to all selected experts. More details about the survey description and data analysis are provided in Section 3.

2.4 Phase 4 - Final framework development and delivery

The next and final phase of the project includes collection and analysis of questionnaire responses in order to modify and improve the preliminary framework. These analyzes will be explained with more details in the next sections.

3. Survey description and data analysis

In order to get experts' opinions about all of the processes to include in the framework and capture the right time frame for each planning decision, we prepared a survey encompassing 34 questions. The criteria identified for selecting these experts were that they should have:

1. A master's or PhD degree (to ensure a minimum research experience and be comfortable with some of the more abstract questions in the survey);

2. Published at least one article in a peer reviewed journal or presented a paper at a conference in the past five years on mathematical or simulation modelling with a focus or a case study in the Canadian forest industry SC (any of the following: harvesting, log sorting, lumber products, or value-added manufacturing);

3. Experience in this research field, involving working experience in the industry, research and/or students' supervision related to the topics.

Based on these criteria, a population of 86 experts on the subject of Canadian forest products SC modelling and analysis was identified. Among this initial selection, 35 experts accepted to participate and to fill out the online survey. Participants were mainly from Quebec and British Colombia, but their level of experience in the field varied considerably.

The questionnaire was divided into five sections, each focusing on a specific operation area within a generic Canadian lumber products value chain, as highlighted in Figure 5. Specifically, each section represented a processing or distribution unit within this SC:

A. "Harvest unit" performs the harvesting and log distribution activities;
B. "Log sort yard" represents either the integrated log sorting operations of a harvesting unit or operations of an external unit that buys the logs from the harvesting unit and then sorts and delivers them to various facilities based on their demand;
C. "Sawmill" represents all activities of a sawmill including sawing, drying, finishing, and lumber distribution;
D. "Value added wood products plant" is a generic unit that can represent a variety of value added plants (also known as remanufacturing), such as structural lumber producers or furniture manufacturers;
E. "Retail unit" represents the retailer or the final customer and is the source of demand in the value chain.

The operational units shown in Figure 5 may be part of an integrated forest company, or may be operating independently. For example, the harvest unit may be a logging contractor, or may be part of a larger forest products company.

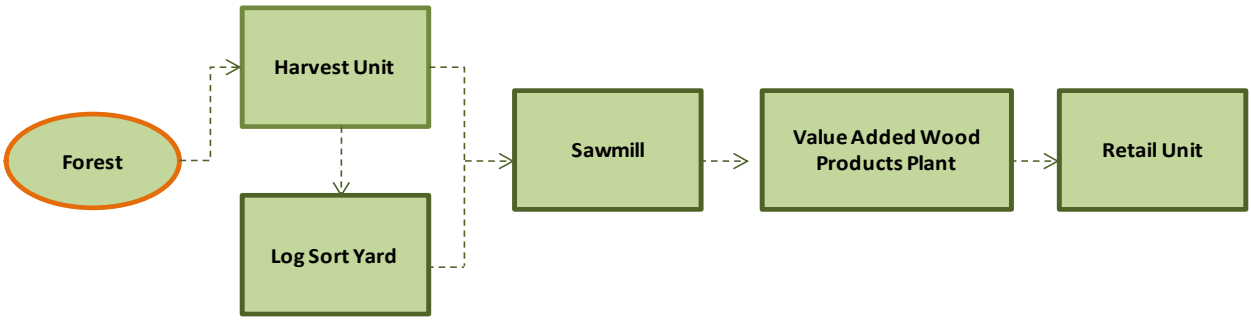

Figure 5: Supply chain of lumber products

The last part of the survey included some open-format questions that were concerned with the possible benefits of the survey for academia and industry, as well as the best way to distribute the outcome of this research project to academics and industry practitioners. It also investigated whether breaking down the SC units into more specialized "sub units" would be helpful for modelling processes and decisions of the value chains or not.

For each of the five SC units, the survey included the same five categories of questions, in a multiple-choice format:

1. Assigning the best time frame to the long term, midterm, and short term planning horizons in each business unit. For example, for a harvesting unit, how long is the mid-term planning horizon?
2. Selecting the best planning horizon for specific decisions made in each business unit. For example, should decision "forest land acquisitions" in harvest unit be considered as long term, midterm or short term?
3. Identifying relevant planning decisions that were not listed in the previous section and assigning them the best time frame for making those decisions.
4. Identifying which Key Performance Indicators (KPIs) are used for measuring the performance of each business unit of the section. The respondents could choose their answers among the proposed KPIs (more than one was possible) or add other KPIs that were not listed.
5. The last question was about the categories of information shared between a business unit and the downstream or upstream value chain members. The respondents could choose more than one category of information among proposed options while they could add

more categories that were not listed. The five categories of questions in this survey are summarized in Figure 6.

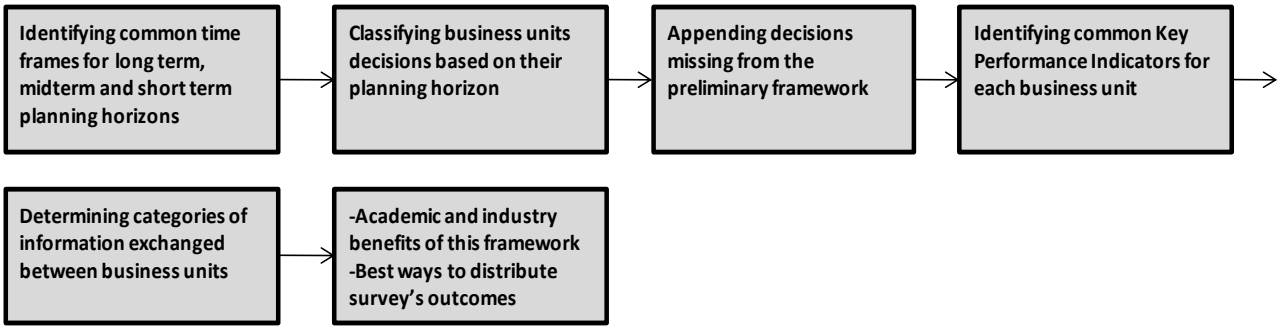

Figure 6: The purposes of the different questions of the survey

3.1 Data collected and statistical analysis

Overall 35 respondents answered the 34 questions of the questionnaire. Most of the questions were multiple choices, but some questions of each section did not suggest any options and the respondents needed to provide their own answers (i.e., open-ended questions). It was therefore possible to use statistical tools like Kruskal-Wallis test, median, and inter quartile range to analyze some of the respondents 'answers, as explained in the next sections.

3.2 Survey Responses

3.2.1 Identifying common time frames for long term, midterm and short term planning horizons

The purpose of the first question was to determine the best time frames for long term, midterm and short term planning horizons of each processing or distribution unit within the lumber products value chain. The available options were 1 day, 1 week, 1 month, 6 months, 1 year, 5 years, 25 years, 150 years, and more than 150 years.

We first applied the Kruskal-Wallis test to be sure that the length of the long term, midterm, and short term horizons, as three different variables, were independent for each business unit. The Kruskal–Wallis test is a "nonparametric statistical test that assesses the differences among three or more independently sampled groups on a single, non-normally distributed continuous variable" (McKight *et al.*, 2010). We used a nonparametric test because our data could not be

considered as normally distributed and continuous (i.e., did not meet the criteria for parametric test). This type of test begins by ordering the scores from the lowest to the highest, ignoring the group where the scores come from. The lowest score gets a rank of 1, the second-lowest gets a rank of 2, and so forth. If two or more scores are the same, they are "tied". "Tied" scores get the average of the ranks; thus if there are four identical values occupying the first, second, third, and fourth lowest scores, all would get a rank of 2.5. The sum of the ranks is calculated for each group, leading to the calculation of H, the variance of the ranks among groups. If there are more than five scores in each group, H is approximately chi-square distributed and the degree of freedom is the number of group minus one (McKight *et al.*, 2010). In our case, the groups, long term, midterm and short term, were almost 100% independent based on this test, the H calculation being very high with a degree of freedom of 2.

We next used the median and the inter quartile range (IQR) to obtain a summary of the center distribution and, considering the dispersion of data, identify the best time frame to represent the responses. The median is less affected by outliers and non-normally distributed data. We also assumed that planning horizon time frames do not necessarily have to be continuous and without gap between IQRs, as mentioned by Gupta and Maranas (2003). Median is the middle value of a list of numbers while IQR is a range to display dispersion of the middle 50% of the numbers. It is equal to the difference between the upper and lower quartiles. The lower bound of the IQR is called the first quartile (Q1) and the upper bound of the inter quartile range is called the third quartile (Q3). Q2 is the median (Munro, 2005). To find the quartiles and median, the first step is to put the scores (n scores) in order, from the smallest to the largest one. The median is at position (n + 1)/2 and is called depth of the median. If the depth of the median is a whole number, it will identify the score that has the median value in the list. If the depth of the median ends in .5, the value of the median is the average of the values that have that depth. To continue to compute the quartiles, the depth of Q1 and Q3 is n/4. If the depth of the quartiles is a whole number, then it will identify the scores which have the values of Q1 and Q3. If the quartile depth is a fraction, interpolation is applied. More specifically, if the depth is 4.25, we compute the value that is 1/4 of the way between the values of the scores at depths 4 and 5.

For example, assume the data from 10 scores arranged from smallest to largest: 2, 2, 4, 11, 11, 15, 25, 29, 35, and 40. In that case, the depth of the median would be (10 + 1)/2 = 5.5 and the

average of the 5^{th} and 6^{th} number would be (11+15)/2=13. The depth of Q1 and Q3 would therefore be calculated as 10/4=2.5, so interpolation would be necessary. Q1 would be = 2 + (.5*(4-2)) = 3 and Q3 = 29 + (.5*(35-29)) = 32. The IQR would finally be (3, 32).

The scores in our cases are time frames that respondents have assigned to the long term, midterm, and short term concepts in each business unit. Table 2 shows distribution of responses for each possible time frame concerning the harvest unit. Similar tables for other business units are given in the appendix.

Table 2: Distribution of responses for determining the length of planning horizons for the "harvest unit"

Harvest unit	Long term	Percentage	Midterm	Percentage	Short term	Percentage
>150 years	5	14%	0	0%	0	0%
150 years	8	23%	0	0%	0	0%
25 years	9	26%	4	11%	0	0%
5 years	10	29%	16	46%	3	9%
1 year	3	9%	11	31%	8	23%
6 months	0	0%	2	6%	10	29%
1 month	0	0%	2	6%	8	23%
1 week	0	0%	0	0%	5	14%
1 day	0	0%	0	0%	1	3%
Total respondents	35		35		35	

Using these results, median and IQR calculations showed that long term planning for harvesting activities should cover 5 to 150 years, midterm planning 1 to 5 years, and short term planning 1 month to 1 year. The same statistical analysis was conducted for other SC business units, as shown in Table 3 and Table 4.

Table 3: Median of long term, midterm, and short term planning horizons in all business units

Business unit	Median (in years)		
	Long term	**Midterm**	**Short term**
Harvest unit	25	5	.5
Log sort yard	5	1	.08
Saw mill	5	1	.08

Table 3: Median of long term, midterm, and short term planning horizons in all business units (Continued and end)

Business unit	Median (in years)		
	Long term	Midterm	Short term
Value added wood products plant	5	1	.08
Retail unit	5	.5	.02

Table 4: IQR of the long term, midterm, and short term planning horizons in all business units

Business unit	Long term	Midterm	Short term
Harvest unit	(5 years - 150 years)	(1 year - 5 years)	(1 month - 1 year)
Log sort yard	5 years	(6 months - 1 year)	(1 week - 1 month)
Saw mill	(5 years - 25 years)	(6 months - 5 years)	(1 week, 6 months)
Value added wood products plant	(5 years - 25 years)	(6 month - 1 year)	(1 week - 21 weeks)
Retail unit	(1 year - 5 years)	(1 month - 1 year)	(1 week - 1 month)

3.2.2 Classifying business units decisions based on their planning horizon

The second category of questions aimed to choose the planning horizons that would best describe the identified decisions of each business unit. While most of the answers formed a consensus, some varied to the extent that allocating one planning horizon to those decisions was not possible. Disagreements among experts were manifested in two distinct ways: 1) either the answers were divided between two different options, or 2) answers were spread out among many different options. For example, one of the decisions attributed to the "harvest unit" was "determining wood procurement strategy (public/private land, contract with logging companies)". Based on the results, 49% of the respondents categorized this decision as long term and 43% categorized it as midterm. However, for another decision of the same unit, "determining order penetration point", the responses were more widely spread: 18% in long term, 18% in midterm, 18% in short term, 6% as not relevant, and 39% as don't know.

The summary of answers in consensus reached and no consensus related to the decisions of each business unit is shown in Figure 7. The distribution of the answers for all business units is given in the appendix in tables A5, A6, A7, A8, and A9. Three colors are used in the appendix tables: The red color indicates that the decision is categorized as long term based on the consensus. Similarly, green and orange represent the decisions categorized as midterm and short term, respectively. There is no color for decisions where a consensus was not reached. The list of these decisions is given in table A10 in the appendix.

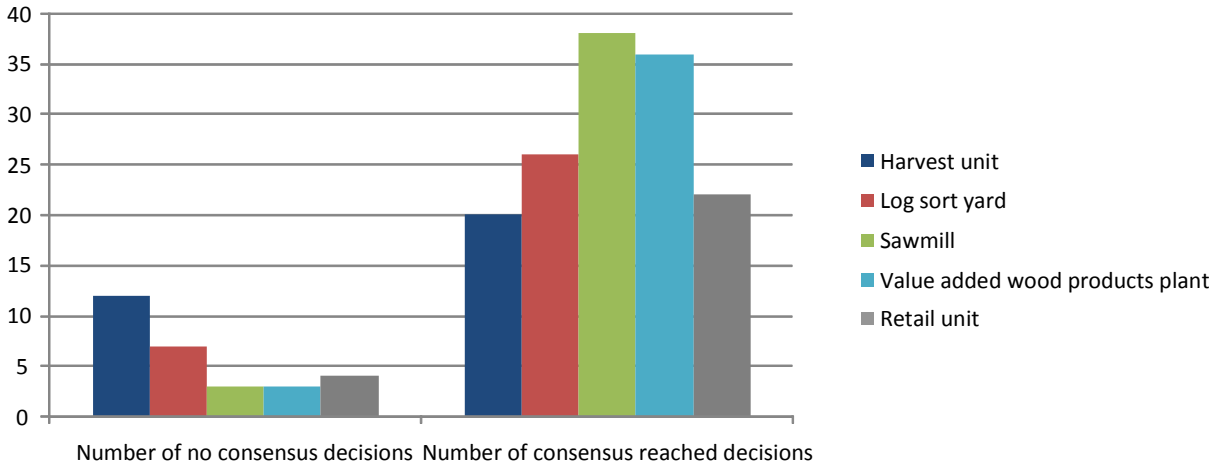

Figure 7: Consensus results of decisions for each business unit

Since not all the planning decisions could be categorized with a consensus, we decided to put more weight on the answers of a few respondents who had specialized expertise in areas relevant to those decisions. Among the 35 respondents, five specialists were chosen for this purpose. In addition to these five experts, we consider the response of a specialist for decision “access road design and construction” as well as another specialist for decisions “selection of markets”, “customer segmentation” and “determining final products families”. These experts’ opinion was then used to validate the controversial questions and highlight a consensus. For example, for “determining wood procurement strategy” in “harvest unit”, three experts among the selected five chose long term as the best time frame. Therefore the final consensus on the time frame for this decision was set as long term. The final time frames for the controversial decisions according to the selected experts are given in the table A11in the appendix. The decisions “Determining order penetration” for “harvest unit”, “log sort yard”, “sawmill”, and “value added

wood products plant", "determining pricing strategy" in "log sort yard", "determining service strategy" in "log sort yard", "customer segmentation" in "log sort yard", and "Available-to-promise (ATP)" in "log sort yard", are the ones for which there exists no consensus at all, despite referring to five experts' answers. The summary of the final best timeframes for the decisions are given in the tables A12, A13, A14, A15, and A16 in the appendix.

3.2.3 Appending decisions missing from the preliminary framework

In the questions 3, respondents were invited to add any decisions that were not listed in questions 2 and that they believed should be considered. Respondents were also asked to indicate the suitable time frame for these decisions. The original answers of respondents are shown in the tables A17, A18, A19, A20, and A21 in the appendix.

We studied all of the proposed decisions and selected those that could be added in the framework regarding expert's suggestions, without replicating existing decisions. Table 5 shows the added decisions and their timeframes.

Table 5: Additional decisions for all business units

Business unit	Decisions	Timeframe
Harvest unit	Determining harvest residue strategies	Long term
	Human resource planning	Midterm/ Short term
	Harvesting process	Midterm
	Contingency planning	Long term
	Bucking decisions	Short term
Log sort yard	Determining processed residue strategy	Mid term
	Human resource planning	Midterm/Short term
Sawmill	Determining processed residue strategy	Midterm
	Human resources planning	Midterm/Short term
Value added wood products	Customer service	Mid term
	Human resource planning	Midterm/Short term
Retail units	Marketing strategy	Midterm/Short term
	Human resource planning	Midterm/Short term

3.2.4 Identifying common Key Performance Indicators (KPIs) for each business unit

The forth category of questions tried to determine the Key Performance Indicators (KPIs) that are used for measuring the performance of the business units. While KPIs like total cost, profit, and lead time captured experts' attention, back order and total revenue were the ones the less selected in all sections. The following figure exhibit the percentages of each KPI in the related business unit regarding respondents' answers. For example, if we look at the harvest unit, 80% of the respondents (i.e., 28 of 35 respondents) selected total cost as a KPI. Ranking of the KPIs in each business unit based on percentages of respondents who chose them is given separately in the tables A22, A23, A24, A25, and A26 in the appendix.

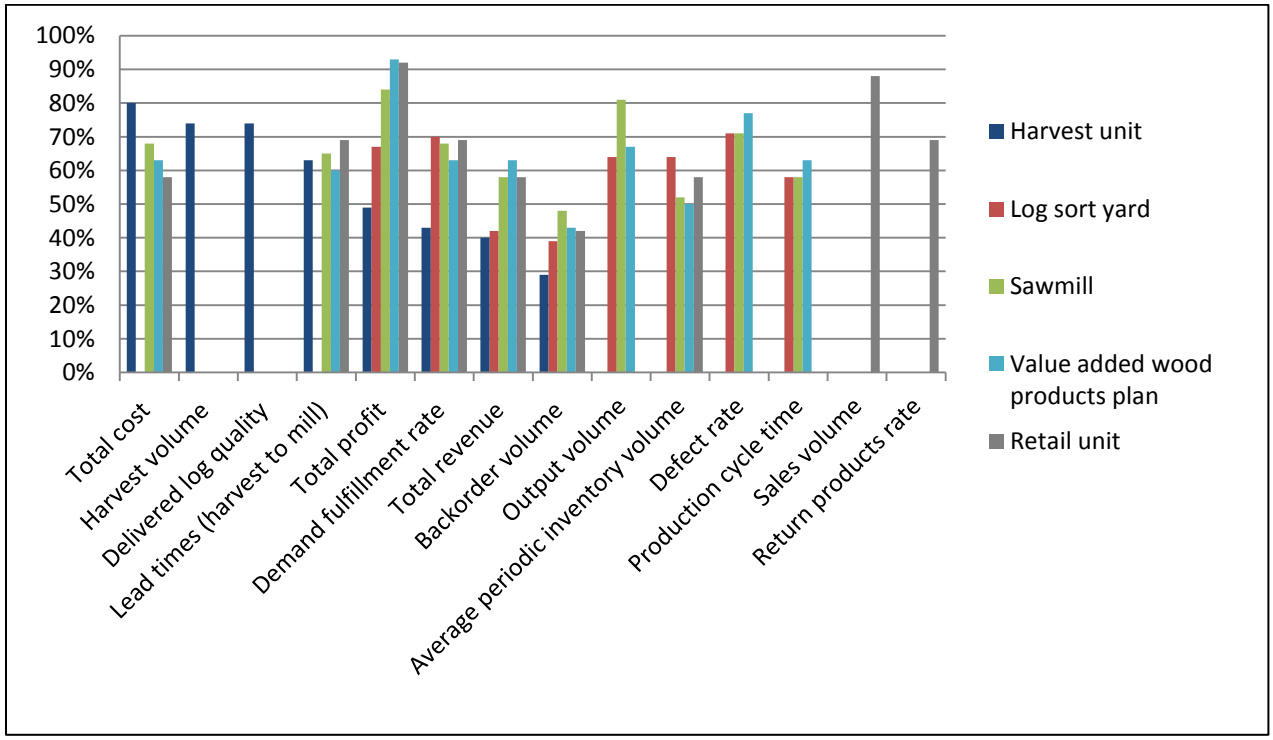

Figure 8: KPIs in all business unit

Moreover, the respondents were invited to add KPIs not represented in the survey. The original answers of respondents are given in the table A27 in the appendix. Based on their suggestions, Table 6 shows the relevant KPIs that have been added in our framework while Table 7 shows all existing and additional KPIs together.

Table 6: Additional KPIs for all business units

Harvest unit	Log sort yard	Sawmill	Value added wood product plants	Retail unit
Unit profit	Storage conditions	Lumber recovery factor	-	-
Unit cost	-	Current asset value	-	-
Machine capacity utilization	-	Environmental impact	-	-
Environmental impact	-	Energy utilization	-	-

Table 7: All KPIs for all business units

Harvest unit	Log sort yard	Sawmill	Value added wood products plan	Retail unit
Total cost	Total profit	Total cost	Total cost	Total cost
Harvest volume	Demand fulfilment rate	Lead times (harvest to mill)	Lead times (harvest to mill)	Lead times (harvest to mill)
Delivered log quality	Total revenue	Total profit	Total profit	Total profit
Lead times (harvest to mill)	Backorder volume	Demand fulfilment rate	Demand fulfilment rate	Demand fulfilment rate
Total profit	Output volume	Total revenue	Total revenue	Total revenue
Demand fulfilment rate	Average periodic inventory volume	Backorder volume	Backorder volume	Backorder volume
Total revenue	Defect rate	Output volume	Output volume	Average periodic inventory volume
Backorder volume	Production cycle time	Average periodic inventory volume	Average periodic inventory volume	Sales volume
Unit profit (m3/log)	Storage conditions	Defect rate	Defect rate	Return products rate
Unit cost	-	Production cycle time	Production cycle time	-
Machine capacity utilization	-	Lumber recovery factor	-	-
Environmental impact	-	Current asset value	-	-
-	-	Environmental impact	-	-
-	-	Energy utilization	-	-

3.2.5 Determining categories of information exchanged between business units

The remaining questions were about the categories of information that are received from or sent to the downstream business units. For example, for "harvest unit", this question refers to the category of information received by "harvest unit" from the "forest". As shown in Figure 9, 97% of respondents chose "available stand volume", while less than 47% thought that service feedback would be an information item shared between the two entities. The percentages of all the proposed categories of information for each business unit are shown in following graph. Ranking of the categories of information which are received from or sent to the downstream business units, based on percentages of respondents who chose them, is given separately in the tables A28, A29, A30, A31, A32, A33, A34, A35, and A36 in the appendix.

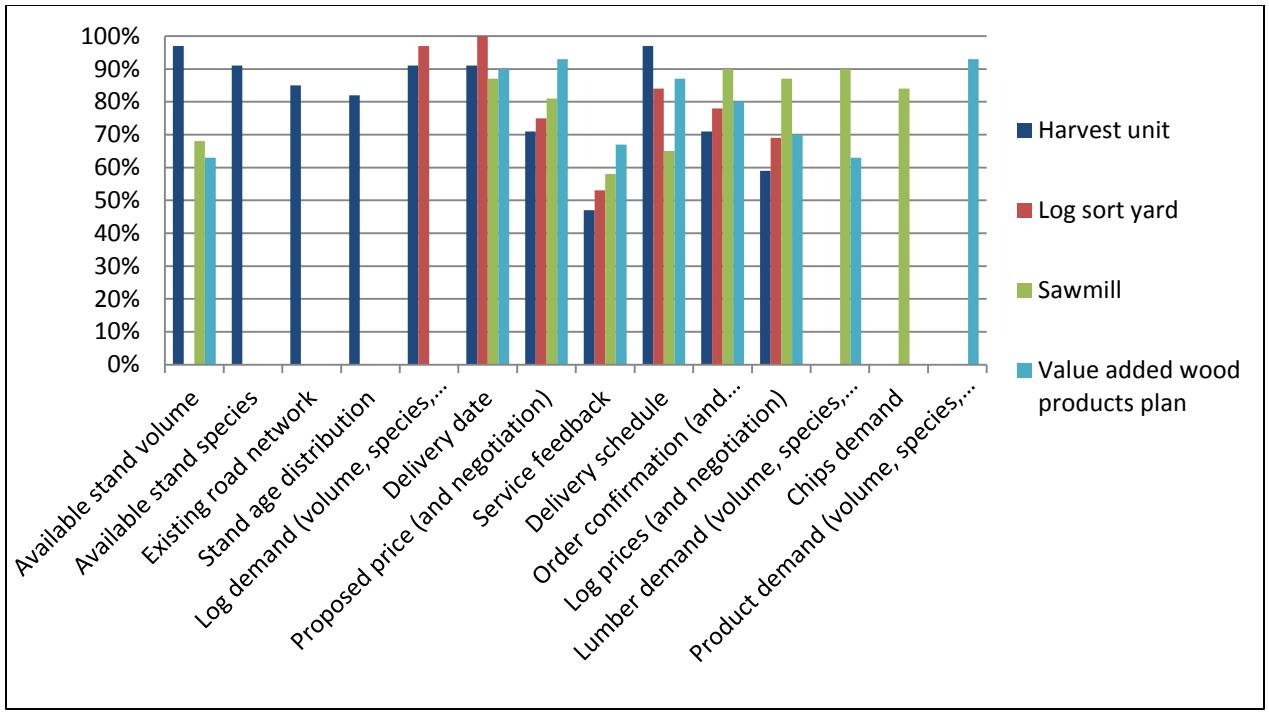

Figure 9: Information received from or sent to downstream SC members by all business units

In these questions, the respondents had again the possibility to add any categories of information not considered in our list. The original answers of respondents are given in the tables A37, A38, A39, and A40 in the appendix. Following tables show the selected categories of information for addition to the final framework based on experts' suggestions. Table 12 and 13 show all categories of information received/sent together.

Table 8: Additional categories of information for "harvest unit"

Information categories received from the "forest"	Information categories received from downstream SC members	Information categories sent to downstream SC members
Standing volume by log grade	Residue demand for bio-energy	Log characteristics (volume/ species/quality)
Log quality/grades	Log yard capacity utilization	Length distributions
Ecological conditions	Degrade due to handling	Order substitutions
Topology	Log length accuracy	-
Stem condition	-	-

Table 9: Additional categories of information for "log sort yard"

Information categories received from downstream SC members
Log characteristics (volume/ species/quality)
Cost of storage
Projected supply of logs

Table 10: Additional categories of information for "sawmill"

Information categories received from downstream SC members	Information categories sent to downstream SC members
Expected change in product portfolio	Lumber quality class
-	By-products characteristics
-	Lumber price

Table 11: Additional categories of information for "value added wood products plant"

Categories of information sent to the downstream members
Transport damage
Product prices and negotiations

Table 12: Information received by each business unit from downstream SC members or the forest

Harvest unit	Log sort yard	Sawmill	Value added wood products plan
Available stand volume (from forest)	Log demand(volume, species, quality)	Available stand volume	Available stand volume
Available stand species (from forest)	Delivery date	Delivery date	Delivery date
Existing road network (from forest)	Proposed price (and negotiation	Proposed price (and negotiation	Proposed price (and negotiation
Stand age distribution (from forest)	Service feedback	Service feedback	Service feedback
Service feedback	Log volume/ species/quality	Lumber demand (volume, species, quality)	Lumber demand (volume, species, quality)
Log demand(volume, species, quality)	Cost of storage	Chips demand	Product demand (volume, species, quality)
Delivery date	Projected supply of logs	Expected change in product portfolio	-
Proposed price (and negotiation	-	Lumber quality class	-
Standing volume by log grade	-	By-products characteristics	-
Log quality/grades	-	Lumber price	-
Ecological conditions	-	-	-
Topology	-	-	-
Stem condition	-	-	-
Demand for residue for bio-energy	-	-	-
Log yard capacity utilization	-	-	-
Degrade due to handling	-	-	-
Log length accuracy, quality of bush sort, etc.	-	-	-
Log volume/ species/quality	-	-	-
Length distributions	-	-	-
Order substitutions	-	-	-
Log volume/ species/quality	-	-	-

Table 13: Information sent by each business unit to downstream SC members

Harvest unit	Log sort yard	Sawmill	Value added wood products plan
Delivery schedule	Delivery schedule	Delivery schedule	Delivery schedule
Order confirmation (and negotiations)	Order confirmation (and negotiations)	Order confirmation (and negotiations)	Order confirmation (and negotiations)
Log prices (and negotiation)	Log prices (and negotiation)	Log prices (and negotiation)	Log prices (and negotiation)

3.2.6 General Questions

In the "General Questions" section of the survey, the respondents could mention the academic and industrial benefits of such a framework. The list of respondents' opinions about these benefits is shown below.

Benefits for academics

- A greater understanding of the planning constraints of the forest product industry;
- Understanding of the involved factors in designing a sustained supply chain ;
- Fostering research in areas where a better understanding of the process or more efficiency is needed;
- Facilitating the modelling efforts;
- Providing a unique framework for comparing the different research outcomes in different studies;
- To encapsulate the decision process of the forestry sector in smart way that makes it easier to make simulations and built scenarios for the benefit of the industry;
- Improving the relevance of the academic models to the industrial problems;
- Improving coordination and cooperation potential across research units at a national and international level;
- Determining the decisions that have to be made in each section and each business unit;
- To better communicate with the industry by having a common vocabulary;

- Better understanding how upstream/downstream dependencies (or the complexity of a value chain) impact the success of a node/the success of the whole production chain;
- A useful reference for academic research on monitoring the performance of each "agent" along the value chain;
- Helping to identify steps which are potential bottlenecks;
- Helping policy makers to make better decisions;
- More consistency between models being developed leading to the better integration.

Benefits for industry

- Assurance of availability of wood at the right time and at the right price and quality;
- Allowing for better global view of the overall process;
- Reducing the study cost and required modelling time while providing robust results;
- Have a standard framework that makes integration and synchronization easier;
- Facilitating identification of relevant problems;
- Facilitating communication with researchers;
- Reducing the start-up cost of partnership with research groups;
- Allowing researchers to compare different supply chains or elements in those supply chains;
- Increasing awareness of upstream /downstream information needs;
- Opportunity for risk/benefit sharing;
- Understanding the important decisions in each business unit;
- This framework allows the industry to better choose their actions to meet the demand of the customers;
- Industry will be able to schedule plans more accurately and be able to respond more rapidly to market changes;
- By understanding the flow of entire forest products industry, industrial people would potentially look into the decision making improvement;
- Identifying the value chain allows all parts of the value chain to recognize where they fit in and how their actions impact the rest;

- Leading to opportunities for greater efficiency throughout and therefore a competitive value chain ;
- Providing tools and education to practitioners;

A third question tried to determine the best way to distribute the outcomes of this project. In this regard, the collection of the respondents' suggestions is shown below.

Best ways to distribute the outcomes

- To academics, the best methods would be publishing papers, conferences/workshops, peer reviewed literature. To industry practitioners, it would be Industry Magazines, trade shows, trade journals, conference presentations, webcasts, workshops, industrial associations/ FP Innovation / industrial publications;
- Journal article in a journal that is read by both academics and industry practitioners (e.g. Forestry Chronicle);
- Selecting a few key topics and making oral presentations;
- A report on the designed framework and example of case studies would be sufficient to introduce the framework;
- Research report with executive summary, associated webinar (on demand);
- The industry must also be involved in this research so as to achieve a more realistic framework. Then the outcome can be presented to industry through a seminar. The outcomes should also be sent to managers after the seminar, so they have enough time for further review. Finally, receiving their feedback seems quite important;
- With academics, developing a software application will suffice. Industry may require a 3rd party to adopt the model and use the model on the behalf of the industry;
- Linking with FP Innovations would be beneficial given their connections to businesses spanning the entire value chain;
- Three-ring binder guide to "production planning in the forest value chain", sets of power point for hands on training;

3.2.6.1 Dividing business units to subunits

In order to demonstrate the autonomy in decision-making within large units, all units (harvest unit, sawmill, etc.) of the framework are sub-divided into more specialized "sub units" or "agents" that carry out specialized processes. For example, a sawmill is divided into four different "agents": sawing, drying, finishing, and distribution. We therefore asked the respondents whether this division was helpful for modelling processes and decisions of the value chain or not. In this regard, 82% of respondents believe this division is helpful and 18% of them do not. The second part of the question concerned the levels of decision-making for these "sub units". Based on respondents' answers, short term seems the most adequate level of decision making while a high percentage (36%) of them believed that all levels of decision making should be used to represent these "sub units", as shown in Table 14.

Table 14: Levels of decision making for sub-units

Levels	Percentages
Short term	30%
Midterm	6%
Long term	0%
Midterm, Short term	18%
Long term, Midterm, Short term	36%
None	9%

4. Validated framework

According to the opinion of outside experts collected during the survey, the preliminary framework needed to be modified to reflect forest industry's reality. A first change concerned the necessity to add specific KPIs as well as the time duration of planning horizons for each agent. Since the goal of this project is to help in creating a common language for describing products or processes in the lumber products value chain, we identified commonly accepted lengths for long term, midterm, and short term planning horizons for all the decisions made in each business unit. In addition we assigned all decisions of all business units to suitable timeframes, and identified KPIs and categories of information flow related to the different business units within this lumber products SC.

The schematic figure for the preliminary framework also included too many information elements to be easily comprehended. Therefore, the framework was simplified to include only a few examples of information shared between the different businesses units. These shared information items are currently highlighted using orange arrows in Figure 10, a simplified version of the complete framework. A complete version of the validated final framework is shown in Figure 11, which encompasses different business units and agents of the lumber products value chain, the decisions that need to be made in each business unit, the three dimensions of FAMASS model, common lengths for time frames of the planning horizon, KPIs, and examples of information flow between business units.

As a result, researchers and practitioners whose goal is to model a lumber products value chain could use the combination of the final framework and the accompanying tables to facilitate their modelling efforts. For example, according to the final framework, the modeller could focus on the “harvesting agent” in “harvest business unit” (vendor 1), taking into account all the decisions related to procurement and manufacturing that this agent has to make in the mid-term planning horizon covering 1 to 5 years. This information can be found in the tables (A41, 12, and 13). Furthermore, the KPIs “harvest volume”, “delivered log quality”, “unit cost”, “machine capacity utilization”, and “environmental impact” should be among the ones considered to measure the performance of this agent. Consequently, it would be possible to develop supply chain models that closely represent the industry according to experts.

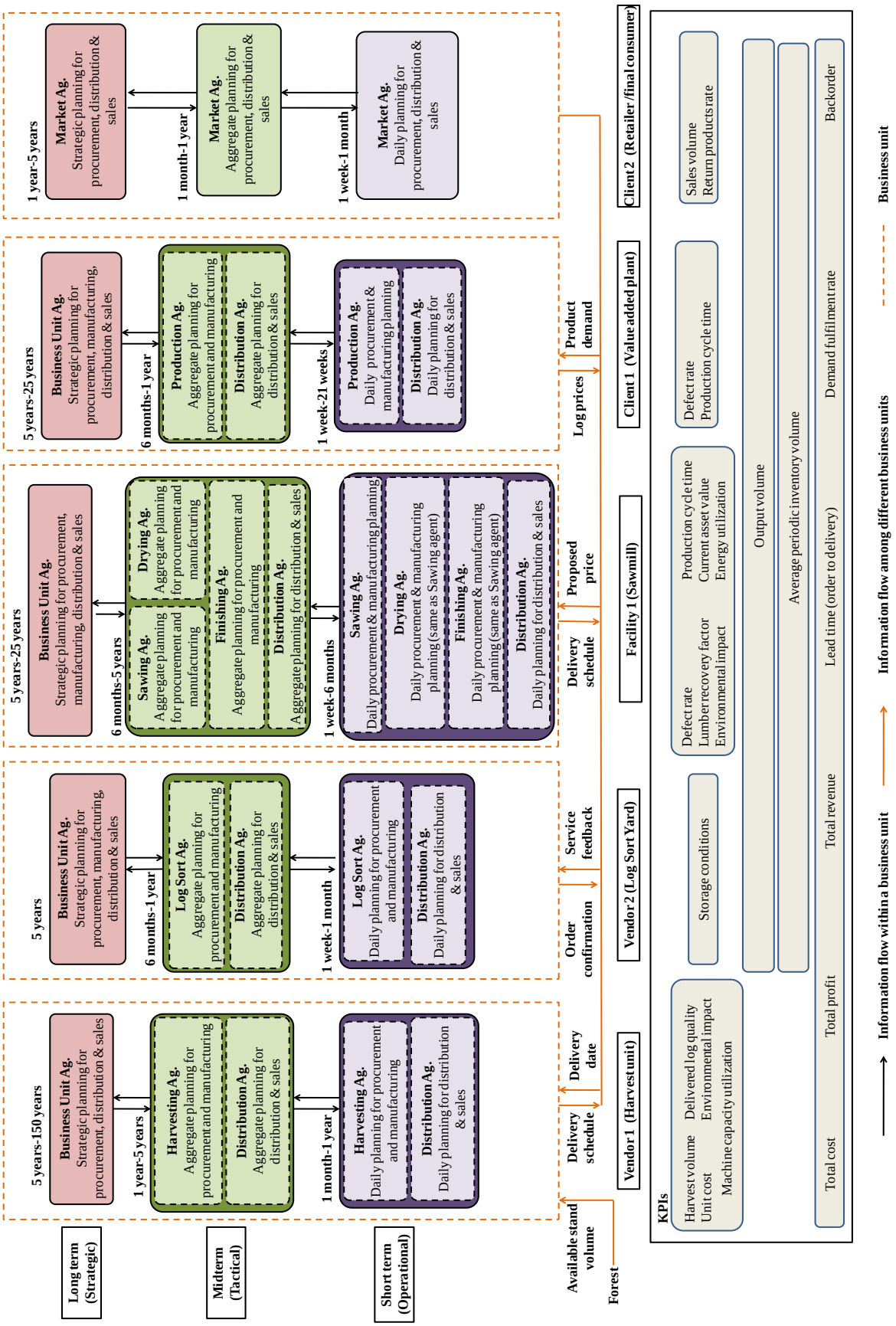

Figure 10: Validated framework

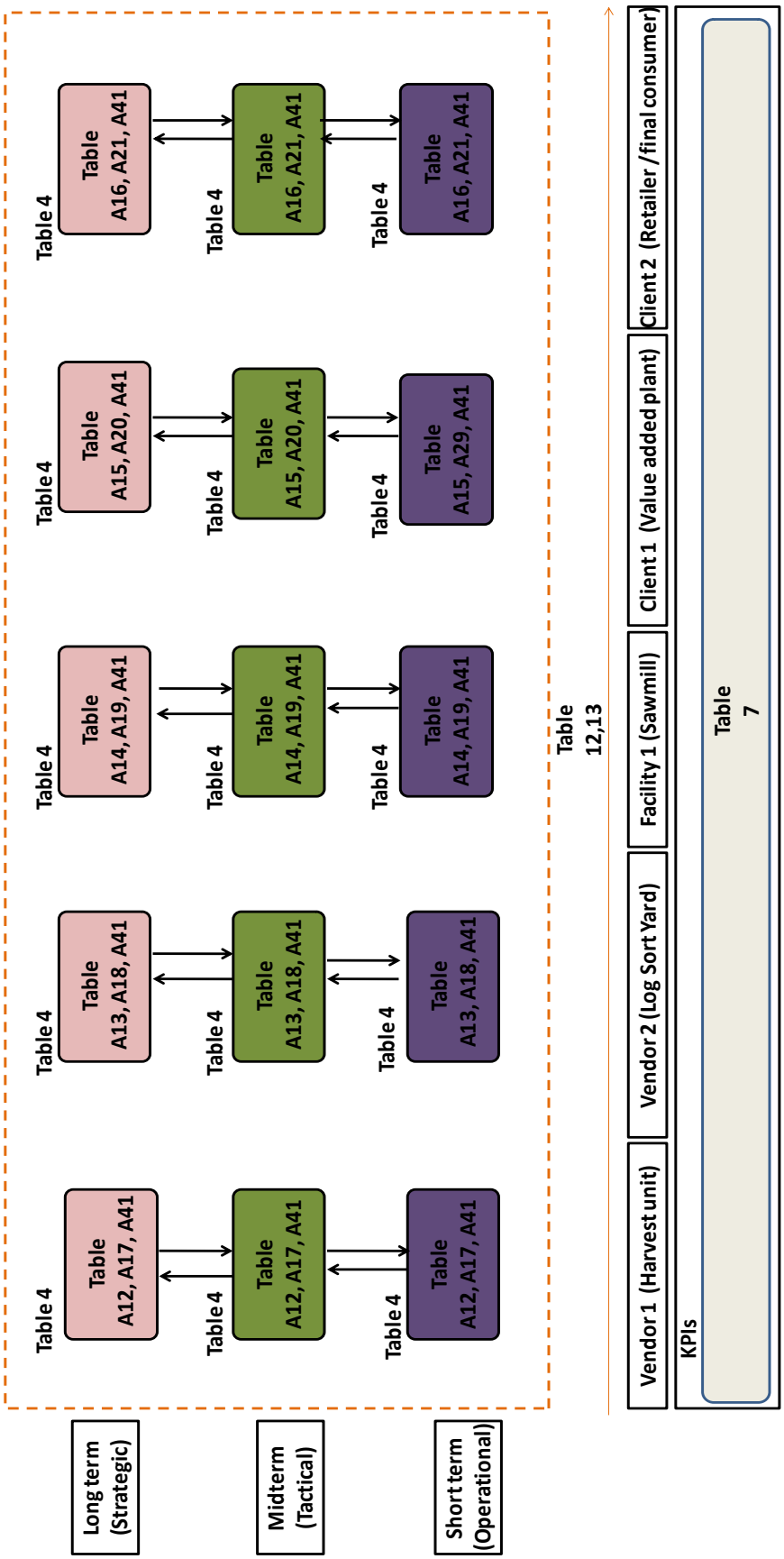

Figure 11: Validated framework and corresponding tables

5. Conclusions

In this research, we presented a modelling framework for the lumber products value chain in a Canadian context. In order to present this final framework, four phases were conducted. In the first phase, a systematic literature review was completed to analyze existing frameworks, methodologies, and guidelines proposed in the literature. Based on the review, the FAMASS approach was selected as the modelling basis for this project. A preliminary framework was next designed in the second phase based on the selected model. In order to validate the framework and increase its credibility and usefulness, an online questionnaire distributed to the expert community was then conducted with 35 specialists. Data were analyzed and the results summarized in several tables. In the final phase, we modified the preliminary framework based on the results of the survey and presented the final framework for the lumber products SC. Such a framework could benefit both academics and industrial practitioners in their SC analysis and modelling efforts by highlighting the key factors, decisions, and constraints involved when designing a supply chain while facilitating communication between academics and the industry by having a common vocabulary.

Based on the existing literature and the results of the questionnaire, an ontology of terms in lumber products SC could be prepared which would help the efforts in creating a common language for describing products or processes in the SC. Additionally, in the future a similar process could be carried out for other parts of the forest products SC such as bio-energy or pulp and paper to extend the current framework.

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Appendix

Table A1: Distribution of responses for determining the length of planning horizons for the "log sort yard"

Log sort yard	Long term	Percentage	Mid term	Percentage	Short term	Percentage
>150 years	0	0%	0	0%	0	0%
150 years	0	0%	0	0%	0	0%
25 years	7	22%	1	3%	0	0%
5 years	19	59%	4	13%	1	3%
1 year	5	16%	12	38%	2	6%
6 months	0	0%	11	34%	3	9%
1 month	0	0%	3	9%	12	38%
1 week	1	3%	0	0%	11	34%
1 day	0	0%	1	3%	3	9%
Total respondents	32		32		32	

Table A2: Distribution of responses for determining the length of planning horizons for the "sawmill"

Sawmill	Long term	Percentage	Mid term	Percentage	Short term	Percentage
>150 years	0	0%	0	0%	0	0%
150 years	0	0%	0	0%	0	0%
25 years	14	45%	1	3%	0	0%
5 years	14	45%	8	26%	1	3%
1 year	2	6%	13	42%	5	16%
6 months	0	0%	4	13%	3	10%
1 month	0	0%	4	13%	10	32%
1 week	1	3%	0	0%	6	19%
1 day	0	0%	1	3%	6	19%
Total respondents	31		31		31	

Table A3: Distribution of responses for determining the length of planning horizons for the "value added wood products plant"

Value added wood products	Long term	Percentage	Mid term	Percentage	Short term	Percentage
>150 years	0	0%	0	0%	0	0%
150 years	0	0%	0	0%	0	0%
25 years	10	32%	1	3%	0	0%
5 years	18	58%	4	13%	1	3%
1 year	3	10%	17	55%	2	6%

Table A3: Distribution of responses for determining the length of planning horizons for the "value added wood products plant" (Continued and end)

Value added wood products	Long term	Percentage	Mid term	Percentage	Short term	Percentage
6 months	0	0%	4	13%	4	13%
1 month	0	0%	5	16%	12	39%
1 week	0	0%	0	0%	8	26%
1 day	0	0%	0	0%	4	13%
Total respondents	31		31		31	

Table A4: Distribution of responses for determining the length of planning horizons for the "retail unit"

Retail unit	Long term	percentage	Mid term	percentage	Short term	percentage
>150 years	0	0%	0	0%	0	0%
150 years	0	0%	0	0%	0	0%
25 years	4	14%	0	0%	0	0%
5 years	15	54%	3	11%	0	0%
1 year	7	25%	11	39%	3	11%
6 months	2	7%	5	18%	2	7%
1 month	0	0%	9	32%	7	25%
1 week	0	0%	0	0%	12	43%
1 day	0	0%	0	0%	4	14%
respondents	28		28		28	

Table A5: Distribution of responses for determining the length of planning horizons for the "harvest unit" decisions (For color legend see section 3.2.2 of the report)

Decisions	Respondents	Long term	Mid term	Short term	Not relevant	Don't know
Determining wood procurement strategy (public/private land, contract with logging companies)	35	49%	43%	6%	0%	3%
Forest land acquisitions	35	71%	23%	0%	6%	0%
Determining harvesting regime and regeneration strategies	35	71%	20%	6%	3%	0%
Access road design and construction	34	41%	38%	21%	0%	0%

Table A5: Distribution of responses for determining the length of planning horizons for the "harvest unit" decisions (Continued) (For color legend see section 3.2.2 of the report)

Decisions	Respondents	Long term	Mid term	Short term	Not relevant	Don't know
Investments in information technology (e.g., to have access to latest demand or inventory information)	35	29%	54%	9%	6%	3%
Determining order penetration point	33	18%	18%	18%	6%	39%
Choosing harvesting capacities and technologies	35	29%	60%	11%	0%	0%
Logistics resource investments (e.g., log yards)	35	43%	51%	6%	0%	0%
Choosing transportation strategies	35	29%	51%	20%	0%	0%
Selection of markets (which mills to supply)	35	14%	57%	23%	6%	0%
Customer segmentation (which logs to which mills)	35	3%	37%	54%	6%	0%
Determining pricing strategy	35	6%	40%	37%	3%	14%
Determining service strategy	35	11%	40%	14%	3%	31%
Log supply contracts with downstream members	35	11%	63%	20%	0%	6%
Log class planning	35	6%	43%	37%	3%	11%
Aggregate harvest plan	35	26%	57%	14%	0%	3%
Aggregate silvicultural regime planning	34	47%	44%	3%	3%	3%
Route definition / trans shipment yard location and planning	34	24%	41%	32%	0%	3%
Allocation of harvesting and transportation equipment to cutting blocks	35	0%	34%	66%	0%	0%
Allocation of harvest blocks to mills (for integrated harvest companies)	35	0%	46%	51%	3%	0%
Aggregate maintenance planning and temporary facility shutdown determination	35	0%	46%	43%	6%	6%

Table A5: Distribution of responses for determining the length of planning horizons for the "harvest unit" decisions (Continued and end) (For color legend see section 3.2.2 of the report)

Decisions	Respondents	Long term	Mid term	Short term	Not relevant	Don't know
Aggregate transportation planning	35	0%	51%	37%	0%	11%
3rd party logistics contracts	35	6%	43%	31%	0%	20%
Aggregate demand planning for different customer segments	34	3%	56%	18%	0%	24%
Customer contracts	35	9%	51%	31%	0%	9%
Demand forecasting	35	6%	66%	23%	3%	3%
Daily log supply planning	35	0%	0%	97%	3%	0%
Daily harvest plans	35	0%	0%	97%	3%	0%
Process control	35	0%	6%	86%	0%	9%
Daily carrier loading/unloading plans	34	0%	0%	94%	3%	3%
Daily carrier selection and routing	35	0%	0%	94%	3%	3%
Managing incoming customer orders	35	0%	0%	89%	3%	9%

Table A6: Distribution of responses for determining the length of planning horizons for the "log sort yard" decisions (For color legend see section 3.2.2 of the report)

Decisions	Respondents	Long term	Mid term	Short term	Not relevant	Don't know
Determining wood procurement strategy	32	56%	25%	9%	3%	6%
Investments in information technology (e.g., to have access to latest inventory information)	33	64%	24%	3%	3%	6%
Determining order penetration point strategy	32	16%	31%	6%	6%	41%
Determining location of facilities	33	73%	9%	6%	6%	6%
Logistics resource investments	33	73%	15%	6%	3%	3%
Choosing transportation strategies	33	39%	45%	6%	6%	3%
Selection of markets (which mills to supply)	33	33%	36%	15%	9%	6%

Table A6: Distribution of responses for determining the length of planning horizons for the "log sort yard" decisions (Continued) (For color legend see section 3.2.2 of the report)

Decisions	Respondents	Long term	Mid term	Short term	Not relevant	Don't know
Customer segmentation (e.g. which logs to which mills)	33	21%	33%	33%	9%	3%
Determining pricing strategy	32	22%	34%	22%	6%	16%
Determining service strategy	32	31%	28%	16%	0%	25%
Log supply contracts with downstream members	33	6%	76%	9%	3%	6%
Aggregate log supply planning	32	19%	59%	9%	3%	9%
Log sort yard layout design	33	52%	36%	9%	0%	3%
Log yard management policies	33	48%	33%	12%	0%	6%
Allocation of logs to mills	32	0%	56%	34%	6%	3%
Aggregate maintenance planning and temporary facility shutdown determination	33	6%	61%	21%	3%	9%
Production policies	33	27%	42%	15%	6%	9%
Aggregate transportation planning	33	9%	64%	12%	6%	9%
Inventory policies (review policy, safety stock level, etc.)	32	22%	66%	9%	0%	3%
Warehouse management policies	31	19%	61%	10%	3%	6%
3rd party logistics contracts	32	13%	63%	9%	3%	13%
Demand forecasting	33	18%	61%	15%	3%	3%
Available to- promise (ATP) aggregate planning	33	6%	27%	33%	3%	30%
Determining ATP allocation rules	31	16%	42%	19%	0%	23%
Daily log supply planning	33	0%	0%	91%	6%	3%
Process control	33	3%	3%	85%	3%	6%
Product quality control	33	3%	3%	91%	0%	3%
Daily carrier loading/unloading plans	32	0%	3%	88%	3%	6%
Daily carrier selection and routing	33	0%	0%	91%	3%	6%

Table A6: Distribution of responses for determining the length of planning horizons for the "log sort yard" decisions (Continued and end) (For color legend see section 3.2.2 of the report)

Decisions	Respondents	Long term	Mid term	Short term	Not relevant	Don't know
Warehouse/DC inventory	32	3%	22%	63%	3%	9%
ATP consumption	33	0%	6%	64%	0%	30%
Inventory rationing	32	0%	16%	59%	0%	25%
Managing incoming customer orders	33	0%	3%	88%	0%	9%

Table A7: Distribution of responses for determining the length of planning horizons for the "sawmill" decisions (For color legend see section 3.2.2 of the report)

Decisions	Respondents	Long term	Mid term	Short term	Not relevant	Don't know
Determining wood procurement strategy	31	74%	23%	3%	0%	0%
Investments in information technology (e.g., to have access to latest inventory information)	31	68%	29%	0%	3%	0%
Determining order penetration point strategy	31	26%	32%	0%	6%	35%
Determining location of production facilities	31	84%	6%	0%	6%	3%
Determining location of distribution centers	31	81%	13%	0%	3%	3%
Logistics resource investments	31	58%	29%	0%	3%	10%
Choosing transportation strategies	31	39%	52%	6%	0%	3%
Determining final product families	31	32%	45%	10%	6%	6%
Selection of markets	31	29%	61%	6%	3%	0%
Customer segmentation (e.g. which products to which customers)	31	23%	58%	19%	0%	0%
Determining pricing strategy	31	16%	48%	29%	3%	3%
Determining service strategy	31	26%	42%	23%	0%	10%
Lumber supply contracts with downstream members	31	10%	74%	16%	0%	0%
Aggregate log supply planning	31	13%	65%	13%	3%	6%
Lot sizing (determining the production batch quantity)	31	10%	42%	42%	0%	6%

Table A7: Distribution of responses for determining the length of planning horizons for the "sawmill" decisions (Continued) (For color legend see section 3.2.2 of the report)

Decisions	Respondents	Long term	Mid term	Short term	Not relevant	Don't know
Aggregate production planning (includes determining production campaign lengths)	30	7%	50%	33%	0%	10%
Production policies	31	16%	61%	19%	0%	3%
Determining product-quality mix	31	6%	55%	35%	3%	0%
Wood drying load planning	31	3%	27%	67%	0%	3%
Aggregate maintenance planning and temporary facility shutdown determination	31	6%	61%	29%	0%	3%
Aggregate transportation planning	31	3%	81%	16%	0%	0%
Determining inventory policies (review policy, safety stock level, etc.)	31	10%	74%	13%	0%	3%
Warehouse management policies	31	13%	68%	13%	0%	6%
3rd party logistics contracts	31	10%	68%	10%	0%	13%
Demand forecasting	31	10%	74%	16%	0%	0%
Available to- promise (ATP) aggregate planning	31	0%	45%	29%	0%	26%
Determining ATP allocation rules	31	3%	45%	23%	0%	29%
Allocation of customers to mills and distribution centers (DC)	31	0%	58%	29%	3%	10%
Daily log supply planning	31	0%	0%	94%	3%	3%
Daily production/drying /finishing plans	31	0%	0%	97%	3%	0%
Sawing pattern selection based on incoming logs	30	0%	6%	90%	0%	3%
Process control	30	3%	3%	83%	0%	10%
Product quality control	31	0%	7%	90%	0%	3%
Work-in-progress and final product inventory control	31	0%	6%	87%	0%	6%

Table A7: Distribution of responses for determining the length of planning horizons for the "sawmill" decisions (Continued and end) (For color legend see section 3.2.2 of the report)

Daily carrier loading/unloading plans	30	0%	0%	97%	3%	0%
Daily carrier selection and routing	30	0%	0%	97%	3%	0%
Warehouse/DC inventory management	31	0%	17%	80%	0%	3%
ATP consumption	31	0%	3%	65%	0%	32%
Inventory rationing	31	0%	10%	65%	3%	23%
Customer inventory management and replenishment	31	0%	16%	71%	3%	10%
Managing incoming customer orders	31	3%	6%	84%	0%	6%

Table A8: Distribution of responses for determining the length of planning horizons for the "value added wood products plant" decisions (For color legend see section 3.2.2 of the report)

Decisions	Respondents	Long term	Mid term	Short term	Not relevant	Don't know
Determining lumber and raw material procurement strategy	31	58%	32%	3%	0%	6%
Investments in information technology (e.g., to have access to latest inventory information)	31	74%	13%	0%	3%	10%
Determining order penetration point strategy	30	37%	13%	10%	0%	40%
Determining location of production facilities	31	87%	6%	0%	0%	6%
Determining location of distribution centers	31	81%	6%	0%	3%	10%
Logistics resource investments	31	68%	13%	3%	0%	16%
Choosing transportation strategies	31	52%	29%	10%	0%	10%
Determining final product families	31	35%	45%	6%	3%	10%
Selection of markets	31	42%	48%	3%	0%	6%
Customer segmentation (e.g. which products to which customers)	31	16%	65%	10%	0%	10%
Determining pricing strategy	31	19%	55%	13%	0%	13%

Table A8: Distribution of responses for determining the length of planning horizons for the "value added wood products plant" decisions (Continued) (For color legend see section 3.2.2 of the report)

Decisions	Respondents	Long term	Mid term	Short term	Not relevant	Don't know
Determining service strategy	31	26%	45%	10%	0%	19%
Wood products supply contracts with downstream members	31	23%	61%	10%	0%	6%
Aggregate lumber supply planning	30	13%	60%	10%	0%	17%
Lot sizing (determining the production batch quantity)	31	10%	48%	35%	0%	6%
Aggregate production planning (includes determining production campaign lengths)	31	10%	55%	23%	0%	13%
Production policies	31	26%	52%	13%	0%	10%
Determining product-quality mix	31	6%	58%	29%	0%	6%
Aggregate maintenance planning and temporary facility shutdown determination	30	10%	60%	20%	0%	10%
Aggregate transportation planning	31	10%	68%	16%	0%	6%
Determining inventory policies (review policy, safety stock level, etc.)	31	26%	58%	10%	0%	6%
Warehouse management policies	30	23%	60%	10%	0%	7%
3rd party logistics contracts	31	19%	52%	16%	0%	13%
Demand forecasting	31	10%	65%	16%	0%	10%
Available to- promise (ATP) aggregate planning	31	0%	45%	26%	0%	29%
Determining ATP allocation rules	31	6%	42%	23%	0%	29%
Allocation of customers to mills and distribution centers (DC)	31	3%	52%	29%	0%	16%
Daily lumber supply planning	30	0%	0%	90%	0%	10%
Daily production plans	31	0%	0%	87%	3%	10%

Table A8: Distribution of responses for determining the length of planning horizons for the "value added wood products plant" decisions (Continued and end) (For color legend see section 3.2.2 of the report)

Decisions	Respondents	Long term	Mid term	Short term	Not relevant	Don't know
Process control	31	0%	10%	77%	0%	13%
Product quality control	31	0%	13%	77%	0%	10%
Work-in-progress and final product inventory control	31	0%	6%	81%	0%	13%
Daily carrier loading/unloading plans	30	0%	0%	90%	3%	7%
Daily carrier selection and routing	31	0%	0%	90%	3%	6%
Warehouse/DC inventory management	31	0%	6%	84%	0%	10%
ATP consumption	31	0%	3%	65%	0%	32%
Inventory rationing	31	0%	13%	61%	0%	26%
Customer inventory management and replenishment (CMI)	31	0%	19%	65%	0%	16%
Managing incoming customer orders	31	0%	10%	77%	3%	10%

Table A9: Distribution of responses for determining the length of planning horizons for "retail unit" decisions (For color legend see section 3.2.2 of the report)

Decisions	Respondents	Long term	Mid term	Short term	Not relevant	Don't know
Determining wood products procurement strategy	28	57%	29%	4%	0%	11%
Investments in information technology (e.g., to have access to latest inventory information)	28	79%	11%	0%	4%	7%
Determining order penetration point strategy	28	46%	21%	0%	4%	29%
Determining location of distribution centers	28	86%	4%	0%	0%	11%
Logistics resource investments	28	75%	7%	4%	0%	14%
Choosing transportation strategies	28	54%	32%	4%	0%	11%
Selection of markets	27	52%	41%	0%	0%	7%

Table A9: Distribution of responses for determining the length of planning horizons for the "retail unit" decisions (Continued and end) (For color legend see section 3.2.2 of the report)

Decisions	Respondents	Long term	Mid term	Short term	Not relevant	Don't know
Customer segmentation (e.g. which products to which customers)	28	39%	39%	14%	0%	7%
Determining pricing strategy	28	39%	29%	21%	0%	11%
Determining service strategy	28	39%	25%	18%	0%	18%
Aggregate wood products supply planning	28	29%	50%	7%	0%	14%
Aggregate transportation planning	28	21%	54%	11%	4%	11%
Determining inventory policies (review policy, safety stock level, etc.)	28	21%	61%	4%	0%	14%
Warehouse management policies	28	29%	61%	0%	0%	11%
3rd party logistics contracts	28	18%	57%	7%	0%	18%
Demand forecasting	27	26%	48%	15%	0%	11%
Available to- promise (ATP) aggregate planning	28	0%	50%	21%	0%	29%
Determining ATP allocation rules	28	14%	36%	21%	0%	29%
Daily wood products supply planning	28	0%	4%	86%	0%	11%
Daily carrier loading/unloading plans	28	0%	0%	86%	0%	14%
Daily carrier selection and routing	28	0%	0%	89%	0%	11%
Warehouse/DC inventory management	28	0%	14%	75%	0%	11%
ATP consumption	28	0%	4%	64%	0%	32%
Inventory rationing	28	0%	14%	57%	0%	29%
Customer inventory management and replenishment	28	0%	11%	64%	0%	25%
Managing incoming customer orders	28	0%	7%	82%	0%	11%

Table A10: Decisions with no consensus in the survey round

Decisions	Business unit
Determining wood procurement strategy	Harvest unit
Access road design and construction	Harvest unit
Determining order penetration point	Harvest unit, Log sort yard, Sawmill, Value added wood products plant
Logistics resource investments (e.g., log yard)	Harvest unit
Determining pricing strategy	Harvest unit, Log sort yard, Retail unit
Determining service strategy	Harvest unit, Log sort yard, Retail unit
Log class planning	Harvest unit
Aggregate silvi-culture regime planning	Harvest unit
Route definition/transhipment yard location and planning	Harvest unit
Aggregate maintenance planning and temporary facility shut down determination	Harvest unit
Allocation of harvest blocks to mills (for integrated harvest companies)	Harvest unit
3rd party logistics contracts	Harvest unit
Choosing transportation strategies	log sort yard
Selection of markets	Log sort yard, Value added wood products plant
Customer segmentation	Log sort yard, Retail unit
Available-to-promise (ATP) aggregates	log sort yard
Determining final products families	Sawmill, Value added wood products plant
Lot sizing (Determining the production batch quantity)	Sawmill
Determining ATP allocation rules	Retail unit

Table A11: Finalized time frames for "no consensus" decisions with the help of "expert interviews"

Decisions	Business unit	Time frame
Determining wood procurement strategy	Harvest unit	Long term
Access road design and construction	Harvest unit	Long term
Logistics resource investments (e.g., log yard)	Harvest unit	Midterm
Determining pricing strategy	Harvest unit	Midterm

Table A11: Finalized time frames for "no consensus" decisions with the help of "expert interviews" (Continued and end)

Decisions	Business unit	Time frame
Determining pricing strategy	Retail unit	Long term
Determining service strategy	Harvest unit	Midterm
	Retail unit	Long term
Log class planning	Harvest unit	Midterm
Aggregate silvi-culture regime planning	Harvest unit	Long term
Route definition/transhipment yard location and planning	Harvest unit	Short term
Aggregate maintenance planning and temporary facility shut down determination	Harvest unit	Mid term
Allocation of harvest blocks to mills (for integrated harvest companies)	Harvest unit	Short term
3rd party logistics contracts	Harvest unit	Midterm
Choosing transportation strategies	Log sort yard	Long term
Selection of markets	Log sort yard	Long term
	Value added wood products plant	Midterm
Customer segmentation	Log sort yard	Long term
	Retail unit	Midterm
Available-to-promise (ATP) aggregates planning	Log sort yard	Short term
Determining final products families	Sawmill	Midterm
	Value added wood products plant	Midterm
Lot sizing (Determining the production batch quantity)	Sawmill	Short term
Determining ATP allocation rules	Retail unit	Midterm

Table A12: Final list of decisions and their planning horizons for "harvest unit"

Decisions	Time frame
Determining wood procurement strategy (public/private land, contract with logging companies)	Long term
Forest land acquisitions	Long term
Determining harvesting regime and regeneration strategies	Long term
Access road design and construction	Long term

Table A12: Final list of decisions and their planning horizons for "harvest unit" (Continued)

Decisions	Time frame
Aggregate silvicultural regime planning	Long term
Determining harvest residue strategies	Long term
Contingency planning	Long term
Investments in information technology (e.g., to have access to latest demand or inventory information)	Mid term
Choosing harvesting capacities and technologies	Mid term
Logistics resource investments (e.g., log yards)	Mid term
Choosing transportation strategies	Mid term
Selection of markets (which mills to supply)	Mid term
Determining pricing strategy	Mid term
Determining service strategy	Mid term
Log supply contracts with downstream members	Mid term
Log class planning	Mid term
Aggregate harvest plan	Mid term
Aggregate maintenance planning and temporary facility shutdown determination	Mid term
Aggregate transportation planning	Mid term
3rd party logistics contracts	Mid term
Aggregate demand planning for different customer segments	Mid term
Customer contracts	Mid term
Demand forecasting	Mid term
Harvesting process	Midterm
Human resource planning	Midterm/ Short term
Bucking decisions	Short term
Customer segmentation (which logs to which mills)	Short term
Route definition/trans shipment yard location and planning	Short term
Allocation of harvesting and transportation equipment to cutting blocks	Short term
Allocation of harvest blocks to mills (for integrated harvest companies)	Short term
Daily log supply planning	Short term

Table A12: Final list of decisions and their planning horizons for "harvest unit" (Continued and end)

Decisions	Time frame
Daily harvest plans	Short term
Process control	Short term
Daily carrier loading/unloading plans	Short term
Daily carrier selection and routing	Short term
Managing incoming customer orders	Short term

Table A13: Final list of decisions and their planning horizons for "log sort yard"

Decisions	Time frame
Determining wood procurement strategy	Long term
Investments in information technology (e.g., to have access to latest inventory information)	Long term
Determining location of facilities	Long term
Logistics resource investments	Long term
Choosing transportation strategies	Long term
Selection of markets (which mills to supply)	Long term
Customer segmentation (e.g. which logs to which mills)	Long term
Log supply contracts with downstream members	Mid term
Aggregate log supply planning	Midterm
Allocation of logs to mills	Mid term
Aggregate maintenance planning and temporary facility shutdown determination	Mid term
Production policies	Mid term
Aggregate transportation planning	Mid term
Inventory policies (review policy, safety stock level, etc.)	Mid term
Warehouse management policies	Mid term
3rd party logistics contracts	Mid term
Demand forecasting	Mid term
Determining ATP allocation rules	Mid term
Determining processed residue strategy	Midterm
Human resource planning	Midterm/Short term

Table A13: Final list of decisions and their planning horizons for "log sort yard" (Continued and end)

Decisions	Time frame
Available to- promise (ATP) aggregate planning	Short term
Daily log supply planning	Short term
Process control	Short term
Product quality control	Short term
Daily carrier loading/unloading plans	Short term
Daily carrier selection and routing	Short term
Warehouse/DC inventory management	Short term
ATP consumption	Short term
Inventory rationing	Short term
Managing incoming customer orders	Short term

Table A14: Final list of decisions and their planning horizons for "sawmill"

Decisions	Time frame
Determining wood procurement strategy	Long term
Investments in information technology (e.g., to have access to latest inventory information)	Long term
Determining location of production facilities	Long term
Determining location of distribution centers	Long term
Logistics resource investments	Long term
Choosing transportation strategies	Mid term
Determining final product families	Mid term
Selection of markets	Mid term
Customer segmentation (e.g. which products to which customers)	Mid term
Determining pricing strategy	Mid term
Determining service strategy	Mid term
Lumber supply contracts with downstream members	Mid term
Aggregate log supply planning	Mid term
Aggregate production planning (includes determining production campaign lengths)	Mid term
Production policies	Mid term

Table A14: Final list of decisions and their planning horizons for "sawmill" (Continued and end)

Decisions	Time frame
Determining product-quality mix	Mid term
Aggregate maintenance planning and temporary facility shutdown determination	Mid term
Aggregate transportation planning	Mid term
Determining inventory policies (review policy, safety stock level, etc.)	Mid term
Warehouse management policies	Mid term
3rd party logistics contracts	Mid term
Demand forecasting	Mid term
Available to- promise (ATP) aggregate planning	Mid term
Determining ATP allocation rules	Mid term
Allocation of customers to mills and distribution centers (DC)	Mid term
Determining processed residue strategy	Midterm
Customer service	Mid term
Human resource planning	Midterm/Short term
Lot sizing (determining the production batch quantity)	Short term
Wood drying load planning	Short term
Daily log supply planning	Short term
Daily production/drying /finishing plans	Short term
Sawing pattern selection based on incoming logs	Short term
Process control	Short term
Product quality control	Short term
Work-in-progress and final product inventory control	Short term
Daily carrier loading/unloading plans	Short term
Daily carrier selection and routing	Short term
Warehouse/DC inventory management	Short term
ATP consumption	Short term
Inventory rationing	Short term
Customer inventory management and replenishment (CMI)	Short term
Managing incoming customer orders	Short term

Table A15: Final list of decisions and their planning horizons for "value added wood products plant"

Decisions	Time frame
Determining lumber and raw material procurement strategy	Long term
Investments in information technology (e.g., to have access to latest inventory information)	Long term
Determining location of production facilities	Long term
Determining location of distribution centers	Long term
Logistics resource investments	Long term
Choosing transportation strategies	Long term
Determining final product families	Mid term
Selection of markets	Mid term
Customer segmentation (e.g. which products to which customers)	Mid term
Determining pricing strategy	Mid term
Determining service strategy	Mid term
Wood products supply contracts with downstream members	Mid term
Aggregate lumber supply planning	Mid term
Lot sizing (determining the production batch quantity)	Mid term
Aggregate production planning (includes determining production campaign lengths)	Mid term
Production policies	Mid term
Determining product-quality mix	Mid term
Aggregate maintenance planning and temporary facility shutdown determination	Mid term
Aggregate transportation planning	Mid term
Determining inventory policies (review policy, safety stock level, etc.)	Mid term
Warehouse management policies	Mid term
3rd party logistics contracts	Mid term
Demand forecasting	Mid term
Available to- promise (ATP) aggregate planning	Mid term
Determining ATP allocation rules	Mid term
Allocation of customers to mills and distribution centers (DC)	Mid term

Table A15: Final list of decisions and their planning horizons for "value added wood products plant" (Continued and end)

Decisions	Time frame
Customer service	Mid term
Human resource planning	Midterm/Short term
Daily lumber supply planning	Short term
Daily production plans	Short term
Process control	Short term
Product quality control	Short term
Work-in-progress and final product inventory control	Short term
Daily carrier loading/unloading plans	Short term
Daily carrier selection and routing	Short term
Warehouse/DC inventory management	Short term
ATP consumption	Short term
Inventory rationing	Short term
Customer inventory management and replenishment (CMI)	Short term
Managing incoming customer orders	Short term

Table A16: Final list of decisions and their planning horizons for "retail unit"

Decisions	Time frame
Determining wood products procurement strategy	Long term
Investments in information technology (e.g., to have access to latest inventory information)	Long term
Determining order penetration point strategy	Long term
Determining location of distribution centers	Long term
Logistics resource investments	Long term
Choosing transportation strategies	Long term
Selection of markets	Long term
Customer segmentation (e.g. which products to which customers)	Mid term
Determining pricing strategy	Long term
Determining service strategy	Long term

Table A16: Final list of decisions and their planning horizons for "retail unit" (Continued and end)

Decisions	Time frame
Aggregate wood products supply planning	Mid term
Aggregate transportation planning	Mid term
Determining inventory policies (review policy, safety stock level, etc.)	Mid term
Warehouse management policies	Mid term
3rd party logistics contracts	Mid term
Demand forecasting	Mid term
Available to- promise (ATP) aggregate planning	Mid term
Marketing strategy	Midterm/Short term
Human resource planning	Midterm/Short term
Determining ATP allocation rules	Midterm
Daily wood products supply planning	Short term
Daily carrier loading/unloading plans	Short term
Daily carrier selection and routing	Short term
Warehouse/DC inventory management	Short term
ATP consumption	Short term
Inventory rationing	Short term
Customer inventory management and replenishment (CMI)	Short term
Managing incoming customer orders	Short term

Table A17: Suggested decisions to add to the preliminary framework for "harvest unit" decisions

Decisions	Time frame
Sustainable yield planning	**Long term**
Forest land sales	Long term
Utilization of harvest residue	Long term
Workers or staff (human resources)	Mid/Short term
Negotiation	Mid term
Distribution	Mid/Short term
Natural disturbances	Short term

Table A17: Suggested decisions to add to the preliminary framework for "harvest unit" decisions (Continued and end)

Decisions	Time frame
Revise regeneration strategies based on climate change impacts	Long term
Bucking instruction	-
Price list determination (bucking struction)	-
Distribution to reload centers	-
Remanufacturing facilities	-
Ports for offshore shipping	-
Distribution centers in major urban centers	-

Table A18: Suggested decisions to add to the preliminary framework for "log sort yard" decisions

Decisions	Time frame
Lumber recovery and by-products utilization	Mid term
Energy consumption	Mid term
Employees shifts	Short term
Union negotiation	Short term

Table A19: Suggested decisions to add to the preliminary framework for "sawmill" decisions

Decisions	Time frame
Employee accommodation	Long term
Environment concerns	Long term
Storage conditions	Mid term

Table A20: Suggested decisions to add to the preliminary framework for "value added wood products plant" decisions

Decisions	Time frame
Union Negotiation	Mid term
Customer service/warrantee	Long term
Quantifying the added value to the lumber product	Long/Mid term
Human resource	-
Development projections' price	-

Table A21: Suggested decisions to add to the preliminary framework for "retail unit" decisions

Decisions	Time frame
Marketing strategy	Mid/Short term
Customer service	Mid/Short term

Table A22: Ranking of KPIs in "harvest unit"

KPI	Sum	Respondents	Percentage
Total cost	28	35	80%
Harvest volume	26	35	74%
Delivered log quality	26	35	74%
Lead times (harvest to mill)	22	35	63%
Total net profit	17	35	49%
Demand fulfillment rate	15	35	43%
Total revenue	14	35	40%
Backorder volume	10	35	29%

Table A23: Ranking of KPIs in "log sort yard"

KPI	Sum	Respondents	Percentage
Demand fulfillment rate	23	33	70%
Total Profit	22	33	67%
Output volume	21	33	64%
Average periodic inventory volume	21	33	64%
Total cost	20	33	61%
Lead time (order to delivery)	19	33	58%
Total revenue	14	33	42%
Backorder	13	33	39%

Table A24: Ranking of KPIs in "sawmill"

KPI	Sum	Respondents	Percentage
Total profit	26	31	84%
Output volume	25	31	81%
Defect rate	22	31	71%
Total cost	21	31	68%
Demand fulfillment rate	21	31	68%
Lead Time (order to delivery)	20	31	65%
Total revenue	18	31	58%
Production cycle time	18	31	58%
Average periodic inventory volume	16	31	52%
Backorder	15	31	48%

Table A25: Ranking of KPIs in "value added wood products plant"

KPI	Sum	Respondents	Percentage
Total profit	28	30	93%
Defect rate	23	30	77%
Output volume	20	30	67%
Total revenue	19	30	63%
Total cost	19	30	63%
Production cycle time	19	30	63%
Demand fulfillment rate	19	30	63%
Lead Time (order to delivery)	18	30	60%
Average periodic inventory volume	15	30	50%
Backorder	13	30	43%

Table A26: Ranking of KPIs in "retail unit"

KPI	Sum	Respondents	Percentage
Total profit	24	26	92%
Sales volume	23	26	88%
Lead Time (order to delivery)	18	26	69%
Demand fulfillment rate	18	26	69%
Return products rate	18	26	69%
Total cost	15	26	58%
Total revenue	15	26	58%
Average periodic inventory volume	15	26	58%
Backorder	11	26	42%

Table A27: Suggested KPIs to add to the preliminary framework

Harvest unit	Log sort yard	Sawmill	Value added wood product plants
Return to log	Contribution to system wide allocation effectiveness	Lumber recovery factor	Asset value employment
Delivered wood cost	Storage conditions	Current asset value	-
Productivity	-	Environmental impact	-
Consistent log quality	-	Energy utilization	-
Forest productivity	-	-	-
Ecosystem condition	-	-	-
Watershed condition	-	-	-
Biodiversity	-	-	-
Unit cost	-	-	-
Unit profit	-	-	-
Residual forest condition	-	-	-
Machine capacity utilization	-	-	-

Table A28: Information received by "harvest unit" from the "forest"

Information categories	Sum	Respondents	Percentage
Available stand volume	32	33	97%
Available stand species	30	33	91%
Existing road network	28	33	85%
Stand age distribution	27	33	82%

Table A29: Information received by "harvest unit" from downstream SC members

Information categories	Sum	Respondents	Percentage
Log demand (volume, species, quality)	31	34	91%
Delivery date	31	34	91%
Proposed price (and negotiation	24	34	71%
Service feedback	16	34	47%

Table A30: Information sent by "harvest unit" to downstream SC members

Information categories	Sum	Respondents	Percentage
Delivery schedule	33	34	97%
Order confirmation	24	34	71%
Log prices (and negotiation)	20	34	59%

Table A31: Information received by "log sort yard" from downstream SC members

Information categories	Sum	Respondents	Percentage
Delivery date	32	32	100%
Log demand (volume, species, quality)	31	32	97%
Proposed price (and negotiation)	24	32	75%
Service feedback	17	32	53%

Table A32: Information sent by "log sort yard" to downstream SC members

Information categories	Sum	Respondents	Percentage
Delivery schedule	27	32	84%
Order confirmation (and negotiations)	25	32	78%
Log prices (and negotiations)	22	32	69%

Table A33: Information received by "sawmill" from downstream SC members

Information categories	Sum	Respondents	Percentage
Lumber demand (volume, species, quality)	28	31	90%
Delivery date	27	31	87%
Chips demand	26	31	84%
Proposed price (and negotiation)	25	31	81%
Service feedback	18	31	58%

Table A34: Information sent by "sawmill" to downstream SC members

Information categories	Sum	Respondents	Percentage
Order confirmation (and negotiations)	28	31	90%
Log prices (and negotiations)	27	31	87%
Delivery schedule	20	31	65%

Table A35: Information received by "value added wood products plant" from downstream SC members

Information categories	Sum	Respondents	Percentage
Product demand (volume, species, quality)	28	30	93%
Proposed price (and negotiation)	28	30	93%
Delivery date	27	30	90%
Service feedback	20	30	67%

Table A36: Information sent by "value added wood products plant" to downstream SC members

Information categories	Sum	Respondents	Percentage
Delivery schedule	26	30	87%
Order confirmation (and negotiations)	24	30	80%
Log prices (and negotiations)	21	30	70%

Table A37: Suggested categories of information to add for "harvest unit"

Information categories received from the "forest"	Information categories received from downstream SC members	Information categories sent to downstream SC members
Standing volume by log grade	Demand for residue for bio-energy	Log quality
Log quality	Log yard capacity utilization	Length distributions
Residue and access	Degrade due to handling	Order substitutions
Hydrological network (for stream crossings and implications on seasonal harvest block accessibility)	Log length accuracy, quality of bush sort, etc.	Order substitution notices (from last-minute plan changes)
Topology (for block-machine compatibility and road construction)	-	Log volume/ species/quality
Species-wise stem diameter distribution	-	Costs and log alternatives
Stem defect distribution	-	Wood characteristics
Stand-wise sylviculture treatment history	-	Wood supply
Log quality/grades	-	-
Terrain	-	-
Stand condition/spacing/diameter	-	-
Associated costs	-	-
Volume / stem	-	-
Soil condition	-	-
Ground condition	-	-
Available stand location	-	-
volume per product	-	-

Table A38: Suggested categories of information to add for "log sort yard"

Information categories received from downstream SC members	Information categories sent to downstream SC members
Log freshness	Log volume/ species/quality (if not included in order)
-	Cost of storage
-	Log freshness
-	Projected supply of logs

Table A39: Suggested categories of information to add for "sawmill"

Information categories received from downstream SC members	Information categories sent to downstream SC members
Expected change in product portfolio	Lumber quality class
Other by-products from the sawmill production	By-products characteristics
Sawdust	Supply of products
-	Lumber price

Table A40: Suggested categories of information to add for "value added wood products"

Information categories received from downstream SC members	Information categories sent to downstream SC members
Quality consistency	Quality consistency
-	On time delivery
-	Transport damage
-	Claims
-	Product prices and negotiations
-	Lumber price
-	Product supply
-	Product prices

Table A41: List of all decisions in the lumber products SC, categorized according to FAMASS framework

Decisions	Business unit	Spatial	Functional	Intertemporal
Determining wood procurement strategy (public/private land, contracts with logging companies)	Harvest unit	Vendor	Procurement	Long term
	Log sort yard	Vendor	Procurement	Long term
	Sawmill	Facility	Procurement	Long term
	Value added plant	Client	Procurement	Long term
	Retail unit	Client	Procurement	Long term
Forest land acquisitions	Harvest unit	Vendor	Procurement	Long term
Determining harvesting regime and regeneration strategies regime and regeneration strategies	Harvest unit	Vendor	Procurement	Long term
Access road design and construction	Harvest unit	Vendor	Procurement	Long term
Aggregate silvicultural regime planning	Harvest unit	Vendor	Procurement	Long term
Determining harvest residue strategies	Harvest unit	Vendor	Procurement	Long term
Contingency planning	Harvest unit	Vendor	Procurement	Long term
Investments in information technology (e.g., to have access to latest demand or inventory information)	Harvest unit	Vendor	Procurement	Mid term
	Log sort yard	Vendor	Procurement	Long term
	Sawmill	Facility	Procurement	Long term
	Value added plant	Client	Procurement	Long term
	Retail unit	Client	Procurement	Long term
Choosing harvesting capacities and technologies	Harvest unit	Vendor	Manufacturing	Mid term
Logistics resource investments (e.g., log yards)	Harvest unit	Vendor	Distribution	Mid term
	Log sort yard	Vendor	Distribution	Long term
	Sawmill	Facility	Distribution	Long term
	Value added plant	Client	Distribution	Long term
	Retail unit	Client	Distribution	Long term
Choosing transportation strategies	Harvest unit	Vendor	Distribution	Mid term
	Log sort yard	Vendor	Distribution	Long term
	Sawmill	Facility	Distribution	Mid term
Choosing transportation strategies	Value added plant	Client	Distribution	Long term
	Retail unit	Client	Distribution	Long term

Table A41: List of all decisions in the lumber products SC, categorized according to FAMASS framework (Continued)

Decisions	Business unit	Spatial	Functional	Intertemporal
Selection of markets (which mills to supply)	Harvest unit	Vendor	Sales	Mid term
	Log sort yard	Vendor	Sales	Long term
Selection of markets	Sawmill	Facility	Sales	Mid term
	Value added plant	Client	Sales	Mid term
	Retail unit	Client	Sales	Long term
Determining pricing strategy	Harvest unit	Vendor	Sales	Mid term
	Log sort yard	Vendor	Sales	-
	Sawmill	Facility	Sales	Mid term
	Value added plant	Client	Sales	Mid term
	Retail unit	Client	Sales	Long term
Determining service strategy	Harvest unit	Vendor	Sales	Mid term
	Log sort yard	Vendor	Sales	-
	Sawmill	Facility	Sales	Mid term
	Value added plant	Client	Sales	Long term
	Retail unit	Client	Sales	Long term
Log supply contracts with downstream members	Harvest unit	Vendor	Sales	Mid term
	Log sort yard	Vendor	Sales	Mid term
Log class planning	Harvest unit	Vendor	Procurement	Mid term
Aggregate harvest plan	Harvest unit	Vendor	Procurement	Mid term
Aggregate maintenance planning and temporary facility shutdown determination	Harvest unit	Vendor	Manufacturing	Mid term
	Log sort yard	Vendor	Manufacturing	Mid term
	Sawmill	Facility	Manufacturing	Mid term
	Value added plant	Client	Manufacturing	Mid term
Aggregate transportation planning	Harvest unit	Vendor	Distribution	Mid term
	Log sort yard	Vendor	Distribution	Mid term
	Sawmill	Facility	Distribution	Mid term
	Value added plant	Client	Distribution	Mid term
	Retail unit	Client	Distribution	Mid term

Table A41: List of all decisions in the lumber products SC, categorized according to FAMASS framework (Continued)

Decisions	Business unit	Spatial	Functional	Intertemporal
3rd party logistics contracts	Harvest unit	Vendor	Distribution	Mid term
	Log sort yard	Vendor	Distribution	Mid term
	Sawmill	Facility	Distribution	Mid term
	Value added plant	Client	Distribution	Mid term
	Retail unit	Client	Distribution	Mid term
Aggregate demand planning for different customer segments	Harvest unit	Vendor	Sales	Mid term
Customer contracts	Harvest unit	Vendor	Sales	Mid term
Demand forecasting	Harvest unit	Vendor	Sales	Mid term
	Log sort yard	Vendor	Sales	Mid term
	Sawmill	Facility	Sales	Mid term
	Value added plant	Client	Sales	Mid term
	Retail unit	Client	Sales	Mid term
Harvesting process	Harvest unit	Vendor	Procurement	Midterm
Human resource planning	Harvest unit	Vendor	Procurement	Midterm/ Short term
	Log sort yard	Vendor	Procurement	Midterm/ Short term
	Sawmill	Facility	Procurement	Midterm/ Short term
	Value added plant	Client	Procurement	Midterm/ Short term
	Retail unit	Client	Procurement	Midterm/ Short term
Bucking decisions	Harvest unit	Vendor	Manufacturing	Short term
Customer segmentation (e.g. which logs to which mills)	Harvest unit	Vendor	Sales	Short term
	Log sort yard	Vendor	Sales	Long term
Customer segmentation (e.g. which products to which customers)	Sawmill	Facility	Sales	Mid term
	Value added plant	Client	Sales	Mid term
	Retail unit	Client	Sales	Mid term

Table A41: List of all decisions in the lumber products SC, categorized according to FAMASS framework (Continued)

Decisions	Business unit	Spatial	Functional	Intertemporal
Route definition/trans shipment yard location and planning	Harvest unit	Vendor	Distribution	Short term
Allocation of harvesting and transportation equipment to cutting blocks	Harvest unit	Vendor	Procurement	Short term
Allocation of harvest blocks to mills (for integrated harvest companies)	Harvest unit	Vendor	Procurement	Short term
Daily log supply planning	Harvest unit	Vendor	Procurement	Short term
	Log sort yard	Vendor	Procurement	Short term
	Sawmill	Facility	Procurement	Short term
Daily harvest plans	Harvest unit	Vendor	Procurement	Short term
Process control	Harvest unit	Vendor	Manufacturing	Short term
	Log sort yard	Vendor	Manufacturing	Short term
	Sawmill	Facility	Manufacturing	Short term
	Value added plant	Client	Manufacturing	Short term
Daily carrier loading/unloading plans	Harvest unit	Vendor	Distribution	Short term
	Log sort yard	Vendor	Distribution	Short term
	Sawmill	Facility	Distribution	Short term
	Value added plant	Client	Distribution	Short term
	Retail unit	Client	Distribution	Short term
Daily carrier selection and routing	Harvest unit	Vendor	Distribution	Short term
	Log sort yard	Vendor	Distribution	Short term
	Sawmill	Facility	Distribution	Short term
	Value added plant	Client	Distribution	Short term
	Retail unit	Client	Distribution	Short term
Managing incoming customer orders	Harvest unit	Vendor	Sales	Short term
	Log sort yard	Vendor	Sales	Short term
	Sawmill	Facility	Sales	Short term
	Value added plant	Client	Sales	Short term

Table A41: List of all decisions in the lumber products SC, categorized according to FAMASS framework (Continued)

Decisions	Business unit	Spatial	Functional	Intertemporal
Managing incoming customer orders	Retail unit	Client	Sales	Short term
Determining location of production facilities	Log sort yard	Vendor	Manufacturing	Long term
	Sawmill	Facility	Manufacturing	Long term
	Value added plant	Client	Manufacturing	Long term
Log sort yard layout design	Log sort yard	Vendor	Manufacturing	Long term
Log yard management policies	Log sort yard	Vendor	Manufacturing	Long term
Aggregate log supply planning	Log sort yard	Vendor	Procurement	Midterm
	Sawmill	Facility	Procurement	Midterm
Allocation of logs to mills	Log sort yard	Vendor	Procurement	Midterm
Production policies	Log sort yard	Vendor	Manufacturing	Midterm
	Sawmill	Facility	Manufacturing	Midterm
	Value added plant	Client	Manufacturing	Midterm
Inventory policies (review policy, safety stock level, etc.)	Log sort yard	Vendor	Distribution	Midterm
	Sawmill	Facility	Distribution	Midterm
	Value added plant	Client	Distribution	Midterm
	Retail unit	Client	Distribution	Midterm
Warehouse management policies	Log sort yard	Vendor	Distribution	Midterm
	Sawmill	Facility	Distribution	Midterm
	Value added plant	Client	Distribution	Midterm
	Retail unit	Client	Distribution	Midterm
Available-to-promise (ATP) aggregate planning	Log sort yard	Vendor	Sales	Midterm
	Sawmill	Facility	Sales	Midterm
	Value added plant	Client	Sales	Midterm
	Retail unit	Client	Sales	Midterm
Determining Available-to-promise (ATP) allocation rules	Log sort yard	Vendor	Sales	Midterm
	Sawmill	Facility	Sales	Midterm
	Value added plant	Client	Sales	Midterm
	Retail unit	Client	Sales	Midterm

Table A41: List of all decisions in the lumber products SC, categorized according to FAMASS framework (Continued)

Decisions	Business unit	Spatial	Functional	Intertemporal
Daily log supply planning	Log sort yard	Vendor	Procurement	Midterm
	Sawmill	Facility	Procurement	Midterm
Determining processed residue strategy	Log sort yard	Vendor	Manufacturing	Midterm
	Sawmill	Facility	Manufacturing	Midterm
Product quality control	Log sort yard	Vendor	Manufacturing	Short term
	Sawmill	Facility	Manufacturing	Short term
	Value added plant	Client	Manufacturing	Short term
Warehouse/DC inventory management	Log sort yard	Vendor	Distribution	Short term
	Sawmill	Facility	Distribution	Short term
	Value added plant	Client	Distribution	Short term
	Retail unit	Client	Distribution	Short term
Available-to-promise (ATP) consumption	Log sort yard	Vendor	Sales	Short term
	Sawmill	Facility	Sales	Short term
	Value added plant	Client	Sales	Short term
	Retail unit	Client	Sales	Short term
Inventory rationing	Log sort yard	Vendor	Distribution	Short term
	Sawmill	Facility	Distribution	Short term
	Value added plant	Client	Distribution	Short term
	Retail unit	Client	Distribution	Short term
Determining location of distribution centers	Sawmill	Facility	Distribution	Long term
	Value added plant	Client	Distribution	Long term
	Retail unit	Client	Distribution	Long term
Determining final product families	Sawmill	Facility	Manufacturing	Midterm
	Value added plant	Client	Manufacturing	Midterm
Lumber supply contracts with downstream members	Sawmill	Facility	Sales	Midterm
Lot sizing (determining the production quantity)	Sawmill	Facility	Manufacturing	Short term
	Value added plant	Client	Manufacturing	Midterm
Aggregate production planning (includes determining production campaign lengths)	Sawmill	Facility	Manufacturing	Midterm
	Value added plant	Client	Manufacturing	Midterm
Determining product-quality mix	Sawmill	Facility	Manufacturing	Midterm
	Value added plant	Client	Manufacturing	Midterm

Table A41: List of all decisions in the lumber products SC, categorized according to FAMASS framework (Continued and end)

Decisions	Business unit	Spatial	Functional	Intertemporal
Wood drying load planning	Sawmill	Facility	Manufacturing	Short term
Allocation of customers to mills and distribution centers (DC)	Sawmill	Facility	Sales	Midterm
	Value added plant	Client	Manufacturing	Midterm
Daily production /drying/finishing plans	Sawmill	Facility	Manufacturing	Short term
Sawing pattern selection based on incoming logs	Sawmill	Facility	Manufacturing	Short term
Work-in-progress and final product inventory control	Sawmill	Facility	Manufacturing	Short term
	Value added plant	Client	Manufacturing	Short term
Customer inventory management and replenishment (CMI)	Sawmill	Facility	Sales	Short term
	Value added plant	Client	Sales	Short term
Customer inventory management and replenishment (CMI)	Retail unit	Client	Sales	Short term
Wood products supply contracts with downstream members	Value added plant	Client	Sales	Midterm
Aggregate lumber supply planning	Value added plant	Client	Procurement	Midterm
Customer service	Value added plant	Client	Sales	Midterm
Daily lumber supply planning	Value added plant	Client	Procurement	Short term
Daily production plans	Value added plant	Client	Manufacturing	Short term
Aggregate wood products supply planning	Value added plant	Client	Procurement	Midterm
Daily wood products supply planning	Value added plant	Client	Procurement	Midterm
Marketing strategy	Retail unit	Client	Sales	Midterm / Short term