ESI4312: Operations Research 1
Spring 2018

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Case Study - Part 1

Section 1: Rules

1. **Goal:**
   This assignment is designed to reinforce in you the idea that OR can solve important practical problems. In order to do so, you are asked to read and understand a case description that portrays a practical application of OR. You are then asked to design your own solutions and recommendations using the techniques and software we have described in class. Finally, you will write a report that summarizes your findings that can be of benefit for both an OR practitioner and a decision maker not well-versed in analytical techniques. This project will require that you apply the concepts learned in class to the solution of a realistic industrial problem.

2. **Project tasks:**
   At a high level, this assignment consists in the completion of the following steps:

   (a) Read through the case description.
   (b) Identify its relevant components.
   (c) Develop optimization models to support analysis.
   (d) Implement and debug models.
   (e) Analyze model results and generate insight from their solutions.
   (f) Develop recommendations for what to do in this practical application.
   (g) Write a final report.

3. **Timeline and due dates:**
   This assignment should be completed according to the following timeline:

   (a) Submit report for Part 1: March 29th. (Part 2 will be distributed in late March).
   (b) Submit report for Part 2: April 19th.

   Projects submitted late will not be graded.

4. **Weights of tasks in the final project grade:**
   The weight of each part of the assignment is as follows:

   (a) Report for Part 1: 65%.
   (b) Report for Part 2: 35%.

5. **Groups:**
   This case study will be performed in groups of 3 or 4 students. Individual students have the option of specifying the names of up to 4 other students they do not wish to be teamed with. However, groups are set by the instructor and cannot be changed. The only situation the instructor will reconsider group compositions is if some group members drop out of the class leaving a group with 2 or less members. Based on feedback received, the groups are as follows:

Group #	Member 1	Member 2	Member 3	Member 4
1	Adams, Lauren	Cory, Michael	Schmidt, Madeline	Tomasino-Perez, Walter
2	Alegria, Jose	Rinehart, Maria	Salhi, Sharif	Taieb, Tobi
3	Arnold, Katelyn	Boudreau, Claire	Castelli, Leanne	LaNasa, Trey
4	Assing, Ariana	Coutinho, Gabriel	Patel, Harsh	Somers, Nicolette
5	Berk, Molly	Garcia, Yanely	Lu, Jackie	Whitehurst, James
6	Bloss, Briana	Fernandez, Angelica	Omana, Andres	Shah, Tirthan
7	Carrie, Alexa	Roorda, William	Tanghal, Jaysse	Vaca, Valentina
8	del Olmo, Luca	Dempsey, Erin	Lapscher, Karen	Mariosa, Fernando
9	Eason, Damani	Montero, Nathalie	Shedd, Leander	Sheehan, Courtney
10	Fischzang, Marc	Greitz, Elisabeth	Grosse, Danielle	Osuna, Andres
11	Gall, John	Hahn, Mary	Vincent, Victoria	Zubillaga, Javier
12	Gao, Ning	Kent, Manuel	Martin, Sheridan	Mussa, Mauricio
13	Garcia, Nestor	Lueck, Daniel	Parrilla, Oscar	Santivanez, Jose
14	Mena, Erik	Ocanto, Orlando	Plante, Hunter	Silva, Daniel
15	Rivera, Gabriel	Salerno, Joseph	Shank, Robert	Vega, Carlos

6. **Group work:**
The completion of this project requires a fair amount of work, so I strongly recommend that you get started as soon as possible. Completing each part of the project as a group is important as it will stimulate your understanding of the material. Dividing the work between team members without discussing the outcome within the group is a bad idea. Remember that your team members can make mistakes and that you will not get a better grade than your teammate because your part of the project is right and his/her part is wrong.

7. **Grades:**
Your grade will be based on the correctness, relevance, presentation but also on creativity, clarity, rigor, and originality of your results, recommendations and analyzes. Ideally, the grade of each team member in a group should be the same. However, it is common that, in college projects, one group member is extremely active or one group member does not participate (and tries to take advantage of the hard work of his/her group mates). I want to reward hard working individuals and penalize slackers. Therefore, I require each member of each group to assess his/her contributions to the project and the contributions of his/her teammates. Suppose for example Group 1 is composed of Ann, Bill and Charles. Ann should write, for example, that she evaluates her own contribution to 50%, Bill's contribution to 50% and Charles' to 0% and sign her evaluation. Bill should write, for instance, that he evaluates his contribution to 60%, Ann's to 40% and Charles' to 0% and sign his evaluation. Charles should write, for example, that he evaluates his contribution to 33.3%, Ann's to 33.3% and Bill's to 33.3% and sign his evaluation. It is acceptable that the different evaluations do not agree with each other. If significant difference occurs, we will investigate the reason of these discrepancies. For small differences in the work load carried out by team members, the individual evaluations will be used to adjust the group grades to deserving and less deserving individuals using the formula

$$\text{Individual Grade} = \left(1 + \text{Project Contribution} - \frac{1}{\text{Group Size}}\right) \text{Team Grade}$$

where Project Contribution is a percentage obtained from your individual evaluations, Group Size is the size of your group, and Team Grade is the base grade for the assignment. For large differences in the work load carried out by team members, Individual Grade will be obtained on a case by case basis.

Section 2: About case studies

Case studies are assignments that are less structured than traditional homework in that they do require you to sift through a significant amount of information to determine and identify what are the key issues arising in a particular problem, and weight what is important and what is not in solving this specific problem. You will find that there might not be a direct question stated that can be answered in a few lines. Part of the assignment is for you to precisely define the problem and issues you wish to address, and to outline how you can determine whether your analysis lead to a satisfactory answer to the question. This will in term force you to consider alternative ideas about what and how to tackle the problem, and what resource and techniques will be necessary to provide an adequate recommendation. In particular, it might be that several options open themselves up for analysis, and you will need to develop an action plan as to how to decide which way to go, and what would be the best fit for the application, both with respect to the quality of the analysis, but also the ease of its implementation.

With this in mind, instructions for this case study will remain relatively intentionally vague. However, there are natural steps in tackling such a decision/management problem. First, you will need to read carefully through all of the material given in the case description. In this step, it is important that you perform a critical read of the material and ask yourself questions. You will want to determine what are the pressing issues, and why they have arisen. You should also consider what would be wrong with continuing with current ways, as opposed to changing course. You should also think through whether there is evidence that action is needed, whether it is clear that significant gains could be achieved, and estimate what those gains would be.

Second, you will have to categorize the types of issues that might be at stake in your problem, ranking them from what you think are the most relevant to the least relevant. To achieve this, you will need to make sure you have a good command and understanding of the background of the case study. You will then need to flesh out some of these more important questions and determine what types of solutions are possible/desirable for the problem. In doing so, you must be cognizant of what can be achieved from a technological standpoint *[outsourcing production to Mars, even if visionary, is not likely to fit within any current business situation]*, but also within the business culture and background that is presented. There should be also a place in your thinking about what are the legal and ethical implications of the type of solutions you propose *[Fooling customers by providing them with a lower quality product than they purchased is, for instance, unlikely to meet legal and ethical standards]*.

Third, you will have to go back to the knowledge set you have acquired from this class, previous classes, and your own personal academic and scholarly background to decide what tools to use to answer the problems you have identified as primarily impacting the situation described in the case. This step might require you to re-learn some techniques you have learned in the past. In real life, you probably would have to also learn new techniques you were never exposed to. You will then have to apply these tools to obtain solutions and recommendations. It is important that you understand the techniques you use sufficiently to defend your conclusions, and that you only present solutions that you can explain. In practice, it is not reasonable to assume that one will blindly follow your recommendations, especially if they come from an analysis that you do not yourself understand.

Forth, you will have to synthesize and present your findings inside of a report. This report should be developed so that a decision maker who asked you to tackle the project can understand the problem and the recommendations proposed, even if s/he has not had formal analytical training. The technical analysis however should be included and the technical information provided should be sufficient for an analyst to verify. You will have to make judicious use of appendices to create such a dual-purpose document. With this in mind, your report should clearly state what you have identified as the core problems of the case, and also emphasize why those are the important issues underlying this situation. The report should also discuss what other approaches could have been taken for the solution of this problem, and should argue why the path you selected was the most appropriate. Different factors can come into play here from technical/theoretical/algorithmic considerations to some that are based on experience. The report should then go into a clear presentation of the solution you obtained and the recommendations you have.

More information about the structure of the report is given next.

Section 3: Report

Once you have conducted the analysis required by the case study, you will write a report. Next, you will find a brief description of each section, its purpose and structure.

1. **Title page:**
   The title page should predominantly display the title of the report. This title should reflect some informative characteristics of the report content. The title page should also list the names of the authors, their affiliation, group number and contact information. Finally, the title page should contain the course name for the class for which the case was studied, the name of the person to whom the report is submitted, and the date of submission. It is best if your title page is simple and functional.

2. **Executive summary:**
   Typically, an executive summary is read by senior management. This summary should not involve mathematical derivations and should be readable by a layman. It is used to decide what action to take, and who to involve in its implementation. Therefore, the executive summary should present an overview of the whole report. It is significantly longer than abstracts found in technical journals. Although there is no page requirement, I would recommend that it is kept between one and two pages. The executive summary should include a description of the topic area of the report, the goals of the study, what approaches where used, a statement of the key findings and recommendations of the study. Finally, it should touch on what gains would be achieved from implementing the recommendations laid out in the document.

3. **Table of contents page:**
   A table of contents helps the reader understand how the report is structured. It should contain the headings, subheadings, and page numbers of each section. If the report contains numerous figures and tables, a list of figures and a list of tables may also be included. Finally, a list of symbols, abbreviations, and terminology may also be included after the table of contents, if the report makes abundant use of them.

4. **Introduction:**
   The introduction sets the stage for what will be presented in the report. In particular, it should contain an overview of the situation, an identification of the key issues underlying the problems at hands, and a description of the task that was set-up in this case study, together with a case for why it would be significant to the reader. Although the introduction may contain a description of the problem that were identified to be of prominent importance, and discuss their significance, it does not typically list the important findings or recommendations of the project. The introduction should also give a clear description of the report's aim, and what its organization is. A description of the report organization is important as it helps the readers locate which sections are most important for them to read.

   The following components may be included in the introduction:

   - <u>Background:</u> State succinctly what the background of the study is.
   - <u>Purpose:</u> State what the aim of the study is.
   - <u>Scope:</u> State what is considered part of the study and what is not.
   - <u>Method:</u> State succinctly what the tools and methods are that will be used in providing a set of recommendations. If your approach involves solving mathematical program you should provide a high level description of the model.
   - <u>Limitations:</u> State what factors, if any, have been hampering the full development of your analysis.

- Assumptions: It might be that, in the process of performing your analysis, you realize that the problem is too complicated. If so, you will have to make some simplification to render the problem easier to address. State what were the assumptions used in the analysis of the case. These assumptions might relate to how the system operate. They might also relate to models or data availability. Do not simplify your problem to such an extent that your analysis becomes irrelevant.

The introduction is not a place where you should write down mathematical formulas.

5. **Case study report body:**
The structure of the main body of your case analysis will depend on the type and magnitude of analysis you have carried. In general, this section of the report would look very different depending on the type of audience (*e.g.*, management or engineering), the discipline or field, and even the type of work (*e.g.*, data collection, survey, or model analysis). Ultimately, you as the writer will have to decide what structure best support your explanation of the case, the methods and models you use, and the recommendations you are making. It should be clear however that this section focuses on analysis and solutions. Consider and assess possible solutions in terms of theoretical grounding, strengths and weaknesses and possibly risk factors.

It is likely that your report will at least contain: (I would recommend that the title of your headings be chosen so that they provide informative descriptions to the contents of the section)

- Context: In such a subsection, you should present the central issue you will be analyzing, in what situation it arises, what decisions have already been made, and what decisions must still be made. This section should focus on established facts.
- Methodology: In such a subsection, you should clearly identify the type of problem this case study is putting forward. You should also explain and justify your choice for the tools and analysis you will perform. If several approaches are competing, you should discuss the rationale of why you selected one approach over another. You should present clearly what are the decision criteria and the assumptions of your model. This is also where data would be discussed (analysis in appendix and summary info in body).

  If your approach involves solving a mathematical program, you should describe this model here. Your model should be presented succinctly in algebraic form, and extensive discussion of the meaning of variables, IVRs, and constraints, and objective should be provided. You should comment on the nature of the problem (whether it is linear or nonlinear, integer or continuous, ...). Also describe the methodology that is appropriate to solve such a problem and comment about whether or not you expect the solution to be obtained quickly, to be globally optimal, and how the capability of the method you use to produce reliable solutions.
- Findings:

  In this section, you should describe the results that you obtain from your models and analyzes and summarize the results of your findings. Such a section should also discuss how you decide what is acceptable/not acceptable as a solution. If using an optimization model, this would involve reporting the outcome of the software. The details of GAMS implementations are not very relevant here, and anything unusual about the derivation of your GAMS model would probably be better reported in an appendix. Presenting the solution in a way that can be understood is of crucial importance. Visual aids are often helpful in effectively communicating these results. Long tables full of numbers are not likely to be of direct use and probably should be relegated to an appendix. Expanding on the meaning of the solution and its relevance is also important. In particular, it is often of value to argue in layman's terms why the solution proposed makes sense. Any idea that you can have to convince the reader that your model does indeed provide reasonable answers should be employed here. This includes testing the model on small sets of data, testing the model on data sets that are trivial, verifying that model outcomes are predictable, ... You should also evaluate the benefits of these models (whenever possible). Finally, you can also relate some observations you have made regarding the solution time of the model and/or the intensity of the computing effort needed.

- Recommendations: In such a subsection, you should present an action plan for the recommendations. In a case study, you want to ensure that your recommendations are fairly detailed. In particular, they should clearly indicate who is to take action, when actions must be taken, what steps must be accomplished, and how to asses whether the actions are taken appropriately and whether they result in intended consequences. For instance, you might establish that there are three possible scenarios for the future of the company. In each one of these scenarios, a different set of actions would be required. For each scenario, your report should clearly state who is responsible and what action they should take.

6. **Conclusion:**
   Every report should include a concluding statement. This conclusion should restate the aim of the project and summarize of the analysis presents achieves it. It should also highlight the key findings and recommendations of the project, as well as its basic limitations.

7. **Appendices:**
   Appendices are sections of your document that provide additional or supporting information. They also provide evidence of your research and analysis. Typically, the information presented in appendices is not essential to understanding the main findings and recommendations of the case. However, it is information that would be of interest to an expert reader seeking to verify your findings. It might also provide additional illustrative material. Typical material included in appendices include detailed calculations, screenshots of decision support systems, codes, tables for the raw data of models, computer codes, tables for the raw results of model, ... Tables, charts, graphs and diagrams may be included within the report or added in the appendices. Used in the appendix, they avoid cluttering up the main text. All illustrations should be clearly labeled and numbered, and referred to in the report Appendices should not be seen as a dumping ground for hundreds of pages of numbers, or unformatted computer outputs. Your last appendix should be comprised of the "signed statements of contribution to the project" as discussed in Section 1. Appendices are normally listed as Appendix A, Appendix B, Appendix C, and so forth. As is the case for the main sections of your report, appendices should be given a clear and informative title.

8. **Reference list:**
   In this section, you should list all of the resources you have used in the analysis of the problem, and in the writing of the report. Do not include references that are not mentioned in the report. It is important that you are consistent in the style you use for references. I prefer that references be listed in alphabetical order of first author.

An electronic copy of each report must be submitted on E-learning by the the project deadline. The name of the report file should be "ESI4312-Spring-2018-CaseStudyPartI-GroupXX" where XX is replaced by your group number.

Section 4: Case grading and common mistakes

The primary factors that will influence the grade you receive for this assignment are the quality, rigor and creativity of the models, analyzes and insights you produced. Another important factor is the care you take in writing your report. It is expected that your report will be typeset, free of typos and grammatical errors, and will be polished. The quality of a report is not directly related to the number of pages it contains. Therefore, I do not impose limits or have guidelines on how long your report should be. Your goal should however to produce a crisp and concise description of your work and recommendations, as decision makers tend to want succinct, meaningful, and to-the-point reports to read.

Next, you will find a list of common pitfalls in the analysis of cases studies and in the redaction of associated reports:

1. **Failure to identify the real problem:** A crucial part of the case is to crystallize a very clear problem definition from extraneous information. Focusing instead on the background of the case study while missing important underlying issues is a common problem in reports.

2. **Failure to identify the required level of analysis:** Problems faced in practice can arise at strategic, tactical and operational levels. It is important that the techniques and methods, and levels of details in the analysis proposed be appropriate for the type of problem that is described in the case.

3. **Failure to identify for whom the issue is a problem:** There are typically various actors described in a case study. They might all face different and potentially divergent issues. It is important that the study addresses the problem of the decision maker that has the authority to implement recommendations.

4. **Failure to examine alternatives:** There are typically different ways to attack a problem. Different models and different approaches can be used. In selecting one approach, it is important to identify and clearly state the reason why it is chosen, and provide at least a high level examination of possible alternatives.

5. **Failure to present a realistic solution:** Although in this type of exercise, the solution you describe will not be implemented, it is important to propose a solution that will fit within the parameters of the case study. In particular, assumptions that would make the implementation of a proposed solution improbable should be rejected. Students should strive to make sure that the solution they propose falls within the realm of what is reasonable technologically for the application.

6. **Failure to address the specific issues:** Posing assumptions is a natural part of a case study where not all details are clearly presented and posed. However, the process of posing assumptions should not be used as a way to dodge some of the specific issues that are being posed in the problem. Also, neglecting to study a particularly impactful part of the case is a common pitfall.

7. **Failure to support ideas with evidence from research, studies or models:** Although common sense is a good gauge to measure recommendations by, it is important that proposals and recommendations be supported from models, common practice, analytical studies, ... In particular, solutions stated without effort to convince the reader of their benefits are not desirable.

Section 5: Case Description (*from P.A.V., S.P.B., S.C.F., and B.B.J.)*

The president of the Okanagan Lumber Company of Prince George, British Columbia, has asked a management consulting firm to consider possible uses of operations research techniques in the company. After a study of Okanagan's operations, the consultants have recommended that one of the most promising areas for the application of operations research was in improving the rules used for allocating logs among the company's five sawmills and its one plywood mill; the allocation decision is a difficult one because of the large number of possible alternatives and because of the complex interdependences among the alternatives. On the basis of the recommendation, the president of Okanagan has appointed an operation research (OR) group and has assigned it the task of developing a log allocation model for the plywood mill and the sawmills.

5.1 The log test

The first part of the project is an extensive log test which is intended to establish a new scheme for classifying logs and for determining the value of the products obtained from the different log classes in the sawmills and the plywood mill. More specifically, the objectives of the test were to determine the factors which affected the recovery of lumber and veneer from timber, to classify the logs into homogeneous classes (as measured by the quality and quantity of their end products), and to measure the average yield for each log type in each possible use.

The OR group assumed that the geographic area from which a log came would not affect the yield (other characteristics being equal) and that the five sawmills would achieve very nearly the same recovery of lumber from the same timber. The group found that it was important, however, to classify logs according to species and diameter. In addition there were certain secondary characteristics (such as the presence of more than a minimum amount of sway along the long axis of the trunk) which might make a log unacceptable for the plywood mill (and hence useful as a sawlog only). Logs which met the current standards for the plywood mill were called “peelers," while the other logs were called “sawlogs." The accompanying table shows the log classifications: the designations peeler and sawlog refer to the uses which would have been chosen for the logs *before* the study was undertaken.

Species	Name	Diameter range (inches)
1	Peeler	12 to 20
1	Peeler	Over 20
1	Sawlog	Under 16
1	Sawlog	16 to 24
1	Sawlog	Over 24
2	Peeler	12 to 20
2	Peeler	Over 20
2	Sawlog	12 to 20
2	Sawlog	Over 20
3	-	12 to 17
3	-	Over 17
4	-	All

One of the major purposes of the OR study was to reconsider the previous choices of peelers and sawlogs. Accordingly, a sample from each of the log classes from species 1, 2 and 3 was sent to the sawmills, where yield was carefully measured, and another sample from each class was sent to the plywood mill, where the yield of veneer was measured. The fourth species was considered suitable for the sawmills only. The Appendix gives a summary of the lumber and veneer yields for each of the log classes. The lumber yields could be converted to revenue (and then to contribution) figures quite easily, but the sales revenue from timber going into the plywood mill could not be calculated easily because the value of the veneer was a function of the plywood production mix, and obtaining the best yield therefore involved determining the best product mix. The problem of determining the best log and product mix in plywood and lumber was therefore of interest to the company.

5.2 Log allocation for the Quesnel region

Nearby forests supplied logs to the five sawmills and the Quesnel plywood mill. The mill managers and the regional managers met before the logging season started to determine a cutting schedule by species and to decide what quantities of each species would be shipped to each mill. Table 1 gives the forecasts of log availability for the season.

The logging season starts in April, and at that time the logging crews need to know what portion of the estimated supply of each species should go to the plywood mill and what portion should go to the sawmills. The logs sent to the sawmills are cut into lengths of 32 feet; the sawmills would then divide the logs further into 16-foot lengths. The logs destined for the plywood mill would be cut into 34-foot lengths; later these would be divided into 8-foot blocks for processing into veneer. In general, the straighter, larger-diameter logs with fewer defects were sent to the plywood mill. The Quesnel mill had the capacity to handle at most 18,500 MBF (thousand board feet) [1] of timber per year.

Table 1: Logs available during the season

Species	Log description	Diameter range	Availability (MBF)
1	Peeler	12 to 20	5,544
1	Peeler	over 20	4,972
1	Sawlog	under 16	4,224
1	Sawlog	16 to 24	13,596
1	Sawlog	over 24	29,348
2	Peeler	12 to 20	5,302
2	Peeler	over 20	2,948
2	Sawlog	12 to 20	21,406
2	Sawlog	over 20	7,612
3	Sawlog	12 to 17	7,524
3	Sawlog	over 17	10,076
4	all		85,008

[2]

The logs which arrived at the sawmills were processed into lumber. The only capacity limitation at the sawmills was headrig saw capacity. The amount of that capacity required to cut a specified number of board feet of lumber was primarily a function of the size of the log being cut; saw speed was independent of the log's diameter, so that differences in time per board foot were primarily a result of differences in the volume per unit of length for logs of various diameters. Table 2 gives the headrig saw time required for each of the log classes. (Determining the values in the table was one of the early tasks of the OR group.)

Four of the sawmills had one saw each, the fifth mill had three saws. Most of the sawmills operated two shifts per day, but one of the smaller mills operated only one shift. The sawmills (and also the Quesnel plywood mill) operated on a 51-week, five-day, eight-hour-per-shift schedule; see Table 3. The sawmills lost about 13 percent of their operating time for breakdowns and delays. The OR team assembled information on the net realization of revenue per MBF for each type of log converted to lumber in the mills; these figures are included in the Appendix.

[1] The basic unit of volume used by the timber industrial is a board foot (BF), which is defined as the volume of a one-foot by one-foot by one-inch piece of wood

[2] The figures are arrived at by multiplying the expected percentage of all logs falling into each class by the total logs for the season. The expected percentages were found in the log test.

Table 2: Headrig saw times

Species	Name	Diameter range (inches)	Minutes per board foot (BF)
1	Peeler	12 to 20	0.007
1	Peeler	Over 20	0.005
1	Sawlog	Under 16	0.010
1	Sawlog	16 to 24	0.006
1	Sawlog	Over 24	0.004
2	Peeler	12 to 20	0.007
2	Peeler	Over 20	0.005
3	-	12 to 17	0.008
3	-	Over 17	0.005
4	-	All	0.010

Table 3: Headrig capacity and shifts of different sawmills

Sawmill	Number of headrig saws	Number of shifts per day
Alexandria	1	1
Hulatt	1	2
Soda Creek	1	2
Wells	3	2
Woodpecker	1	2

5.3 The Quesnel plywood mill

The production process in the plywood mill was considerably more complicated than that of the sawmills. Figure 1 gives a schematic picture of the process. Incoming logs were stacked in tiers in the mill yard and taken as needed into the mill. In outline, the process in the mill was first to debark the logs, and then to cut them into blocks. Next, the logs were steamed to soften the wood fibers. They were then ready for peeling, a process which removed a thin layer of veneer in a continuous strip from the log (in much the same manner as paper is unwound from a roll.) The peeled veneer was then sent to the clipper, where it was cut manually into sheets of the size needed to form plywood panels. Next, the veneer was sorted into the heartwood and sapwood (which held different proportions of moisture) and was passed through a dryer. After that, the veneer was graded (and patched if necessary). Finally, layers of veneer were glued together into the various plywood products made by the mill; the panels were trimmed after gluing and were then ready for shipment.

The OR group considered the various operations of the mill in detail and, in particular, determined the capacities of the parts of the mill. As outlined above, the first step in processing logs was to remove their bark (with a ring of scraper knives in the debarker) and then to cut them into eight-foot sections, called peeler blocks. The blocks were then loaded into a concrete vault, where they were steamed for 8 to 16 hours to soften the wood fibers for the peeling operation. There were four steaming vaults at Quesnel. These vaults provided ample capacity for any feasible production level even during the winter, when logs had to be steamed for long periods of time.

After steaming, the blocks were ready for the lathe and clipper operations. They were placed on a lathe and revolved against a knife which was bolted to a movable carriage. The lathe was a massive machine, sufficiently well bedded to withstand any shock or vibration that could have interfered with the smooth action of the block on the cutting knife. In order to maintain constant thickness of veneer as the diameter for the block decreased during cutting, a gear from the main drive automatically adjusted the position of the knife. At first contact with the knife, the blocks did not produce full length veneer; the uneven start was caused by unevenness in the shape of the block. It was necessary therefore to “round up" the block before a continuous layer of veneer could be obtained. In the interest of maximum recovery, certain usable pieces of the round-up veneer were salvaged for ultimate use in the interior layers of plywood panels.

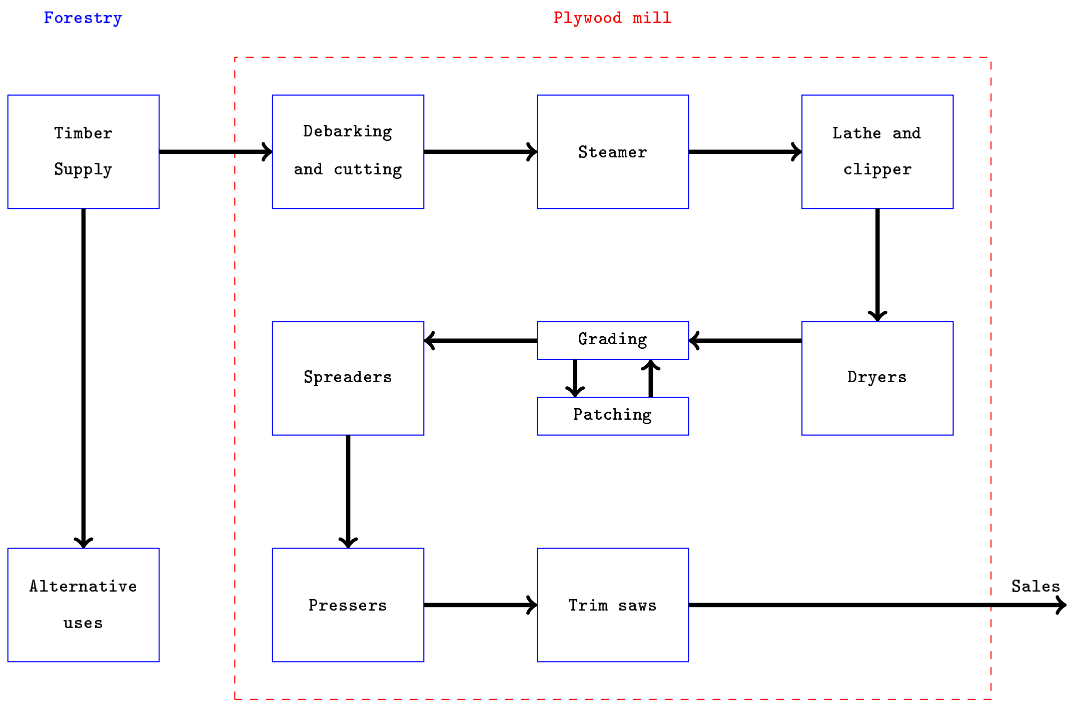

Figure 1: Plywood mill process schematic

At Quesnel the veneer was peeled to produce thicknesses of one-tenth inch and one-sixth inch. The veneer was peeled at these two thicknesses. It shrank a bit during drying, but the glue in the finished panels compensated for the shrinkage during drying.

The peeled veneer next went to a system of conveyors which carried it to the clipper, where an operator cut as much as possible of the veneer to 27-inch and 54-inch widths, using a manually activated drop-knife. Because of knots and other defects in the veneer, some of it had to be cut into narrower width, called strips, which would be used in interior layers of panels.

The output of the lathe at Quesnel was constrained by the clipper. Since the clipper speed was independent of the veneer thickness (and the clipper's output depended only on the number of surface square feet it processed), greater volumes of thicker veneer could be produced. Table 4 gives the output rates of the clipper for various log classifications. The lathe and clipper were operated two shifts a day, although an additional 32 hours a week was available on overtime. There were 12 workers in the lathe and clipper crew.

After peeling and clipping, the veneer was sorted into heartwood and sapwood. Sapwood is the outer layer of wood on a tree; it contains much more moisture than does the inner heartwood. Consequently, veneer made from sapwood required longer drying times in the mill than did veneer made from heartwood.

The sorted veneer was loaded into the dryer. Pieces of veneer were placed side by side in the loading section until the section was filled. The entire load was then pushed onto the dryer's conveyor belt. The veneer was carried through the dryer by a series of rollers which operated at whatever speed was appropriate for the particular type of veneer in the load. The maximum temperature of the dryer was 380 degrees fahrenheit and the minimum time required to move a piece of veneer through the dryer was seven minutes. At that time setting, the dryer would process 652 surface square feet per minute. The time required to dry specific pieces of veneer to the desired moisture level varied, however according to the thickness and species of the veneer and according to whether it was heartwood or sapwood. As the veneer came out of the dryer it passed through a moisture detector; sheets which had not been dried sufficiently were sent through the dryer again. Table 5 gives the required drying times (at normal operating temperatures) of different species

Table 4: Lathe and clipper productivity

			Net surface square feet (3/8-inch basis) per hour	
Species	Log description	Diameter	1/10-inch	1/6 inch
1	Peeler	12 to 20	10,500	17,500
1	Peeler	Over 20	8,850	14,800
1	Sawlog	Under 16	10,700	17,900
1	Sawlog	16 to 24	9,750	16,300
1	Sawlog	Over 24	8,200	13,700
2	Peeler	12 to 20	8,500	14,200
2	Peeler	Over 20	7,750	13,000
2	Sawlog	12 to 20	8,060	13,500
2	Sawlog	Over 20	7,800	13,100
3	-	12 to 17	8,950	15,400
3	-	Over 17	9,800	16,400

for the thicknesses produced at Quesnel. The dryer was operated on three shifts and experienced about 11 percent downtime. A crew of six was required to feed the dryer and to stack the dried veneer.

Table 5: Data on drying times

	Required dryer times (minutes)					
	Species 1		Species 2		Species 3	
Thickness (inches)	Heart	Sap	Heart	Sap	Heart	Sap
One-tenth	7.0	12.0	10.5	19.0	5.5	11.0
One-sixth	8.5	18.5	14.0	21.0	9.0	15.0

Proportion of heartwood to sapwood

Species	Heart/sap
1	44/55
2	12/88
3	55/45

The dried veneer was next routed to veneer graders, who had a thorough knowledge of veneer grades and gluing characteristics. The graders considered the size and number of defects in the veneer and the grain characteristics of the wood. They classified the veneer into grades B (the highest), C, and D; veneer grades below D were called noncertifiable (NC).

Part of the job of the graders was to identify pieces of veneer which should be patched. In the patching operation, knots, pitch pockets, and other defects were replaced with good veneer whose color and texture were similar to the color and texture of the surrounding wood. A machine cut a hole in the veneer to be repaired. Almost simultaneously, the machine cut a patch of the same shape from other veneer and automatically fitted the patch into the hole. The entire operation took about three seconds.

After grading and patching, the veneer was ready to be used in assembling plywood panels. A panel consisted of either three or five layers of veneer which were glued together (with adjacent layers placed with their grains running at right angles of one another, as shown in Figure 2). Most types of veneer could be used in building one or more plywood products. In addition, a particular product could be made in several different ways. For example $\frac{1}{2}$ CD-5 meant a panel of five layers, a finished thickness of one-half inch, a grade C face (or front) and a grade D back. Such panel could be produced with various species of veneer

Table 6: Glue usage in plywood

Core thickness (inches)	Coreline footage (surface square feet) per batch
One-tenth	6,500
One-sixth	5,900

for the front and back. In addition, there was some choice as to the veneer for the middle layer (called the center) and the other two interior layers (called cores). Table 7 shows the product which were currently being made at Quesnel and the choices of veneer which could be used in those products.

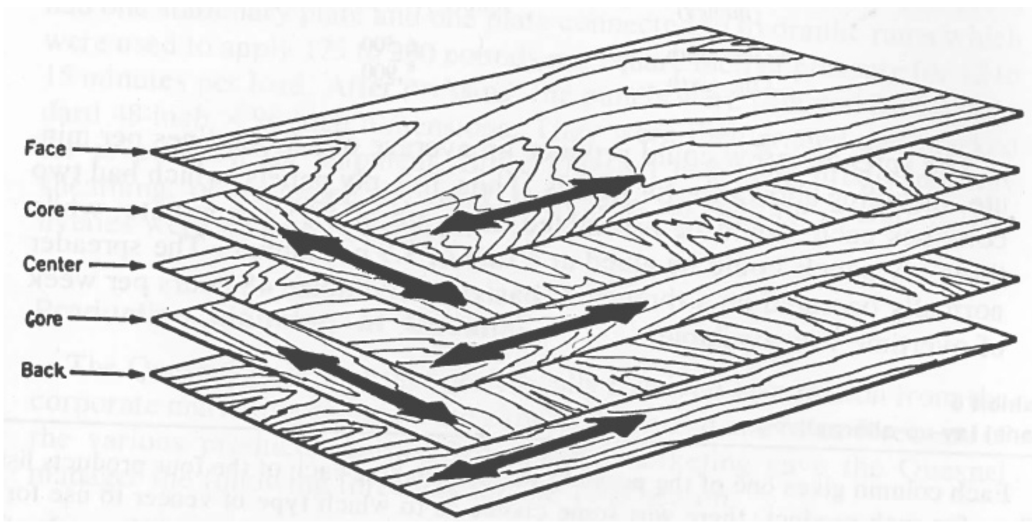

Figure 2: Names of plywood panels

The assembly of veneer into plywood panels took place at a machine called a *glue spreader*. The machine had large rolls which transferred glue from storage troughs onto veneer pieces, coating both sides of the veneer a the same time. In addition, there were other rolls, called *doctors rolls* which wiped the main rolls so that they would have only the desired amount of glue. The spreader operation required a crew of four. The crew placed a piece of pressboard on a platform in front of the gluer spreader and then placed on the board the piece of veneer which would be the face of a panel or an assembled product. The next layer of veneer called *a core*, was passed through the spreader to coat both of its sides with an even thickness of glue. The core was carefully laid on top of the face, with its grain running at right angles to that of the face. If the panel was to have five layers (or plies), the center (or middle layer) was next placed on top of the coreline, with its grains at right angles to that of the core. Another core was then glued and added to the pile, and then the back piece of veneer was added to complete the first panel and the front for the next panel was placed on the stack. For three-ply panels, the core of a panel was followed by the back completing that panel, and then the front for the next panel was placed on the stack. The process was repeated until a load was finished.

The amount of glue required for each core layer depended on the thickness of the core. Glue was prepared in batches which cost $80 each. Table 6 shows the amount of coreline footage (surface square feet of core material) which could be handled with one batch of glue:

The spreader crew could produce an average of 3.9 corelines per minute, including allowance for delays. Thus, five-ply panels, which had two corelines each could be assembled at a rate of 1.95 per minute, while three-ply panels could be glued at a rate of 3.9 per minute. The spreader normally operated on a three-shift basis: an additional 48 hours per week of overtime was available.

Table 7: Panel lay-up alternatives

Each column gives one of the possible ways of making each of the four products listed. Thus, for each product there was some choice as to which type of veneer to use for the layers of the product. For five-ply panels, it is assumed that both cores will be made of the same material.
Veneer specifications * are given as “thickness-species-minimum veneer grade"

Product 1: Mill stamp 3/8 CD-3

	A	B	C	D	E
Face	1/10-2-C	1/10-2-C	1/10-3-C	1/10-1-C	1/10-1-C
Core	1/6-1-NC	1/6-2-NC	1/6-3-D	1/6-1-NC	1/6-2-NC
Back	1/10-2-D	1/10-2-D	1/10-3-D	1/10-1-D	1/10-1-D

Product 2: Mill stamp 1/2 CD-3

	A	B	C
Face	1/6-3-C	1/6-3-C	1/16-2-C
Core	1/6-2-NC	1/6-2-NC	1/6-2-NC
Back	1/6-1-D	1/6-2-D	1/6-2-D

Product 3: WSP 11/2 CD-3

	A	B	C	D	E
Face	1/6-2-C	1/6-1-C	1/6-2-C	1/6-1-C	1/6-1-C
Core	1/6-2-D	1/6-1-D	1/6-3-C	1/6-3-D	1/6-2-D
Back	1/6-2-D	1/6-1-D	1/6-2-D	1/6-1-D	1/6-1-D

Product 4: Mill stamp 1/2 CD-5

	A	B	C	D	E	F	G
Face	1/10-3-C	1/10-3-C	1/10-3-C	1/10-1-C	1/10-2-C	1/10-1-C	1/10-1-C
Cores	1/10-3-D	1/10-1-NC	1/10-2-NC	1/10-1-NC	1/10-2-NC	1/10-3-D	1/10-2-D
Center	1/10-3-D	1/10-1-NC	1/10-2-NC	1/10-1-NC	1/10-2-NC	1/10-3-D	1/10-3-NC
Back	1/10-3-D	1/10-3-D	1/10-3-D	1/10-1-D	1/10-2-D	1/10-1-D	1/10-1-D

* Higher grades of the same thickness from the same species can always be substituted.

Once the panels had been assembled they were pressed, an entire stack at a time, to complete the bound of the wood and the adhesive. The press had one stationary plate and one plate connected to hydraulic rams which were used to apply 175 to 200 pounds per square inch of pressure for 12 to 15 minutes per load. After pressing, the panels were trimmed to the standard 48-inch × 96-inch dimensions. They were then graded and marked for preparation for shipment. Since Quesnel had been producing only sheathing, or unsanded plywood, there was no sanding operation. Deliveries were made by boxcars.

5.4 Production planning at Quesnel

The Quesnel plant manager periodically received information from the corporate marketing group on the expected demand and price forecasts of the various products. Marketing gave the Quesnel manager the forecasts for the season presented in Table 8.

Deciding on the best product mix was a difficult task. There was a seemingly infinite number of product mixes that could be produced to use the forecast log supply. The Quesnel manager wanted to choose the mix that would show the highest profits for the plant, but since plywood produces were joint products (*i.e.*, were produced simultaneously from the same process), costs could not be assigned easily to individual products and determining which products were most profitable was therefore difficult.

Table 8: Forecasts

Product	Forecast net realization per thousand surface square feet (after discounts)	Sales limits set by marketing (in panels)	
		Minimum	Maximum
Mill stamp 3/8 CD-3	$204	-	250,000
Mill stamp 1/2 CD-3	$264	5,000	50,000
WSP 11/2 CD-3	$276	800,000	2,000,000
Mill stamp 1/2 CD-5	$284	-	250,000

Scheduling production was another difficult part of the mill manager's job. He had some flexibility in determining the number of shifts which were scheduled, but Okanagan wanted to provide steady employment for its people, and so the main flexibility was in the amount of overtime used. Workers on the first shift received $10.00 per hour; those on the swing shift received an additional $0.30, while those on the owl shift received $0.60 above the base rate. Any overtime work was paid at $1\frac{1}{2}$ times the first-shift rate. (There were no shift bonuses for overtime.) The pay scale did not vary significantly between operations.

5.5 Appendix

Realization for logs sent to the sawmills

The realizations per thousand board feet (MBF) for the various log classes are given below. The realizations are net of discounts, sales commissions, and log transportation to the mill.

Species	Log description	Diameter Range	Net Realization/MBF
1	Peeler	12 to 20	$146.40
1	Peeler	over 20	$126.64
1	Sawlog	under 16	$156.60
1	Sawlog	16 to 24	$115.12
1	Sawlog	Over 24	$98.40
2	Peeler	12 to 20	$123.60
2	Peeler	Over 20	$92.80
2	Sawlog	12 to 20	$118.00
2	Sawlog	Over 20	$98.20
3	-	12 to 17	$141.76
3	-	Over 17	$96.36
4	All		$126.88

Recovery of veneer, by grade, for logs sent to the plywood mill

Species	Log description	Diameter Range	Percent of veneer of each grade B	C	D	NC	Surface square feet (3/8-inch) basis per BF)
1	Peeler	12 to 20	4	44	52	-	2.72
1	Peeler	over 20	4	39	57	-	2.29
1	Sawlog	under 16	1	30	66	3	2.77
1	Sawlog	16 to 24	3	25	68	4	2.53
1	Sawlog	Over 24	3	15	76	6	2.12
2	Peeler	12 to 20	-	52	48	-	2.20
2	Peeler	Over 20	-	36	64	-	2.01
2	Sawlog	12 to 20	-	23	72	5	2.09
2	Sawlog	Over 20	-	39	56	5	2.03
3	-	12 to 17	-	60	4	36	2.32
3	-	Over 17	-	50	3	47	2.54

Notes:

1. Species 4 is not suitable for peeling.
2. Grade recoveries are after estimated waste.
3. Net yields include upgraded veneer obtained by patching.
4. Volume of veneer is usually expressed in terms of surface square feet on a 3/8-inch basis – *i.e.*, the unit of measure is defined as a piece which is one foot by one foot by three-eights inch. The first four columns for each log type give the *percentage* yields of each grade. The last column gives the volume yield of veneer for each board foot (BF) of log of that particular type.