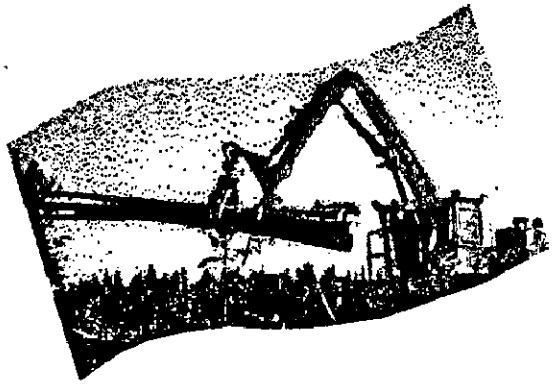
Safety in the forestry industry Technical improvement of harvesting machines



ÉTUDES ET RECHERCHES

Serge Massé
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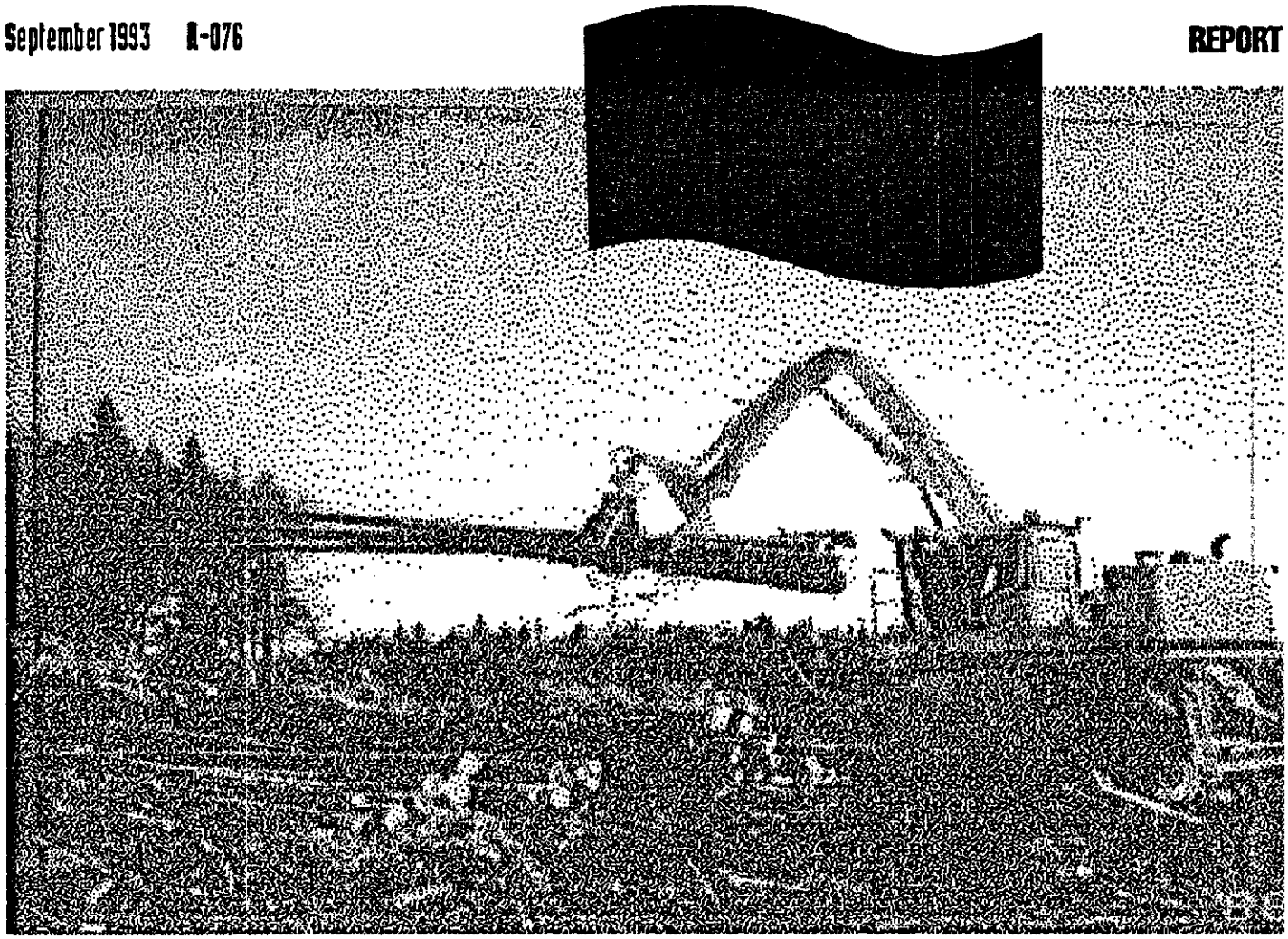
September 1993 R-076 REPORT



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Safety in the forestry industry Technical improvement of harvesting machines

Serge Massé, Vincent Cesta
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Safety Engineering Programme, IRSST

ÉTUDES ET RECHERCHES

REPORT

This study was financed by the IRSST. The conclusions and recommendations are those of the authors.

3th Quarter 1993.

PREFACE

This report is mainly intended for people working in the forestry sector, at the decision-making as well as at the operational level.

Before beginning to read it — or while reading it — the reader would benefit by consulting the definitions presented in Appendix 2 in order to become familiar with certain unusual technical terms used in this report.

To make the report easier to read, the data presented in the various tables have been intentionally limited to the essential ones. These are covered again in more detail in the various related appendices, which the reader is invited to consult.

2. OBJECTIVES

The objectives of this technical study are many:

- To identify the machines and parts of machines that are the most problematic in terms of accident potential, breakdown frequency, and design flaws;
- To identify the probable causes of these problems;
- To evaluate and group in order of importance, the accident risks present during machine maintenance, repair or modification operations;
- To develop recommendations and improvements that can be carried out over the short, medium and long term;
- To suggest avenues of research and development in machine safety, including the training of operations and maintenance personnel, in order to increase the level of *machine reliability, maintainability* and *availability* so as to reduce accident risks, ensure *system performance assurance*, and finally, to promote efficiency.

3. METHODOLOGY

This study was produced from data collected in the field from foremen, equipment owners and workers, as well as from accident reports. A method was then developed by the authors which consisted of defining the machines in terms of zones and systems to make the analysis easier.

3.1 Site visits and data collection

The data analyzed in this study originates from six forestry sites belonging to five companies located in Mauricie, on the North Shore, in Gaspé, and in the Lac St-Jean region. Of them, three sites carried out completely mechanized cutting, while the other carried out mixed cutting.

This data was collected during meetings and interviews with operators and mechanics, foremen and owners of forestry machines[3]. During these meetings, various topics involving work organization and work activities were discussed, particularly those related to equipment maintenance and repair.

As well, 229 machines used in forestry operations on the participating sites were also inventoried, as well as the breakdowns that occurred on these machines and the modifications made to them.

3.2 Technical strategy and analysis of results

The technical strategy first consisted of reviewing 255 accident and incident cases that involved feller, skidder and delimber operators and/or owners. The accidents that occurred during maintenance and repair operations (96 cases reported) were then given particular attention, and in the light of the information collected from the people met in the interviews, typical accident scenarios (see Appendix 6) were considered.

This data was than reviewed and analyzed in relation to different specific factors and parameters, namely those presented in Table 1.

Table 1 Factors and parameters for analyzing the accident and incident cases reported as well as the data from interviews

FACTOR	PARAMETERS
Worker	• Accident scenario, lesion (seat, type)
Interventions	• Maintenance, breakdown, repair, modifications
Task	• Activities, movements, tools used, interrelationships in teamwork (exchange of information, etc.), training required
Machine	• Type, zone, system and part of system, parts
Environment	• Night work, condition and topography of the land, meteorological conditions

3.2.1 Classification of machines by zones and systems

To analyze the machines from an engineering standpoint, they were first divided and classified by zone and by system. The description and the characteristics of each of these zones and systems are presented in Appendix 2 (definitions) and Appendix 3 (characteristics). For each of the zones, four systems were chosen: the mechanical, hydraulic, electrical, and the so-called "safety/protection" system. The characteristics and the features of each of them involve different intervention modes and tools.

These intervention zones, which include the hood, cabin, boom/head, running carriage and chassis, contain systems that are relatively similar in terms of difficulty of access as well as the level and/or types or risks related to them. This classification by zone and by functional system allows a brief deductive evaluation of the characteristic repair, maintenance and modification activities specific to these machine parts, as well as to some extent, the abilities required to carry them out.

3.2.2 Data analysis and risk classification

The data retained was then analyzed in order to identify the various design problems specific to the different zones and systems of each type of machine. Each design problem was in turn examined, taking into account both the functional use of the machine and the work context.

The main causes of the design problems were then identified, and classified in order of importance in terms of potential risks as 16 risk evaluation factors (see Appendix 4), with seven factors related to task execution and nine to system failure resulting from the identified design flaws, namely:

Risk factors related to task execution

- difficult access to the intervention zone;
- working at heights and/or on a slippery surface;
- working in a confined space;
- experience and ability required to carry out repair;
- handling of heavy parts;
- interrelationships and communication within the teamwork context;
- interventions during the night.

Risk factors related to system failure

- inherent fragility of the part;
- durability of the part for the operation (in terms of strength and reliability);
- maintenance frequency;
- breakdown frequency;
- preparation time before the intervention;
- repair time;
- repair cost;
- availability of special tools;
- impact of the breakdown on production.

A list of the problems identified and ranked in order of importance in terms of risks is found in Appendix 12, Tables 1, 2, and 3 for the feller, skidder and delimber, respectively.

Finally, once the data collected was analyzed and the present and potential problems identified, a list of recommendations was developed. These recommendations are presented in a general way at the end of the report and in a detailed way in Appendices 1A, 1B and 1C. They are then related to their different causes and include a reference on the ease (or difficulty) of carrying them out over the short, medium or long term, or the expertise required, as described in Appendix 5. They are also classified in order of importance in terms of impact on safety improvement.

4. PROFILE OF COMPANIES THAT PARTICIPATED IN THE STUDY

At the time of the study, the six sites from which the analyzed data in this report originated, had 435 production workers and 31 cutting foremen; annual production totalled 2.4 million cubic metres.

The data was collected from 47 operators, 16 of whom owned their machines and 26 were mechanics, with 24 of these also being owners of their machines. Their average number of years of forestry experience was 17.7 years, 5.5 of which were in the jobs that they held at the time of the study.

Appendix 7 presents the makes and models encountered for each type of machine considered (feller, cable or grapple skidder, and delimber). The 229 machines inventoried were distributed as follows:

- 22.7% (52) of the machines were used for felling;
- 59.8% (137) of the machines were used for skidding;
- 17.5% (40) of the machines were used for delimbing.

The forestry production time for the sites visited was 160 to 240 hours for two weeks. Each group of machines normally consisted of a feller, three skidders, and one delimber. The feller is generally in operation throughout the entire production period.

Table 4 Main breakdowns involving the delimber

ZONE	SYSTEM	PART OR GROUP OF PARTS
Hood	Hydraulic *	• Motor
	Mechanical	• Cooling, filtration, transmission, spider gear reducer
	Electrical	• Wiring, starter, alternator
Cabin	Mechanical	• Frame, structure
Running carriage	Hydraulic	• Motor
	Mechanical	• Tracks, drive, bolts under the machine
Boom, head	Hydraulic	• Motor
	Mechanical	• Telescopic drive, boom structure, holding arm and knife arm

* With the hydraulic system, breakdowns involving the cylinders and hoses appear as a constant for all zones except the cabin

5.3 List of modifications to the machines

Several modifications (see Appendix 9) were carried out on the tree harvesting machines by the users. The main goals of these modifications were to increase the reliability of the machine and its productivity, make maintenance and repair easier, simplify the operator's work, and increase safety. The following table presents some characteristic modifications that were carried out.

Table 5 Examples of modifications to the machines

MACHINE	ZONE	MODIFICATIONS CARRIED OUT
Feller	Hood	• Increasing the capacity of the motor and fuel tank
	Cabin	• Changing the seat, eliminating the screen guard, installing an emergency exit
	Chassis	• Installing a leveling stabilizer, handles, running board
	Boom	• Rebuilding or strengthening the boom, installing hose protectors
	Head	• Installing an inserted-teeth saw, a buncher arm, etc.
	Running carriage	
Skidder	Hood	• Increasing the power of the motor and transmission
	Cabin	• Installing doors, windows, screen guard
	Chassis	• Installing or modifying a running board, installing fenders and handles
	Boom/grapple/winch	• Installing a protector for rear cylinder, installing a system to prevent slings from becoming entangled
	Running carriage	• Reinforcing the differential and the axles, replacing the seals
Delimber	Hood	• Installing raising system for the plate above the motor
	Cabin	• Installing air conditioning and a knob for adjusting the lighting
	Chassis	• Installing stabilizer cylinder, stabilizer, platform
	Boom/grapple/winch	• Installing system for removing the cable without having to dismantle the boom

5.4 List of the main improvements suggested by the workers

A list of the improvements suggested by the workers is presented in Appendix 10. These improvements mainly involve:

- cabin layout: seat, screen guard, lighting, soundproofing, air conditioning, etc.;
- safe circulation of people on the machine: handrail, running board, etc.;
- machine reliability: overheating, risk of fire; condition of the running carriage, design flaws, choice of materials, standards, etc.;
- ease of maintenance: weight of cables, oil drainage, waste oil recovery, rapid availability of the required parts, availability of distributors' services, availability of engineering services, etc.

6. ANALYSIS OF RESULTS

It is important to mention, in relation to the scope and the limitations of the results of the analysis of the data collected on accidents and incidents, the fact that some companies systematically record all events, accidents or incidents that may lead to lost work time, while others compile only those accidents that were reported to the CSST. Although such data is not completely consistent, we nevertheless felt it essential to analyze all this information, as collected, despite its limitations, because it allowed the risk factors that must be taken into account in analyzing machinery design problems to be identified or specified.

It is also important in collecting data relating to the machinery, and to its use and maintenance, to keep in mind that this extensive and diverse data was collected during interviews, and that, often, the inventories of breakdowns and modifications were drawn up from what the people interviewed remembered (workers, foremen and machine owners).

It should be remembered, however, that for the breakdowns inventoried, all the makes and (all the) models of machines may not have been mentioned. It should also be noted that the frequencies of reported breakdowns could only be interpreted as relative frequencies and not absolute ones. Despite these limitations, we are convinced that sufficiently complete data has been collected on the modifications carried out on forestry machinery and the breakdowns that occur most frequently or are the most costly, and that it is a faithful reflection of this working environment.

5. RESULTS

This chapter presents a simple summary of the data collected. For more detailed information, refer to the appendices indicated in the text of the report.

5.1 Accidents and events reported

Of the 255 accidents and incidents that were reported (see Appendix 6.1), it was noted in particular that:

- only 10% (24) of them involved accidents that resulted in lost time compensatable by the CSST (Québec Workers' Compensation Board);
- 65.1% (166) involved skidders;
- 64.7% (165) involved skidder operators;
- 34.9% (89) occurred in the cable and sling zone.

Of the 96 events attributable to maintenance and repair activities which were reported (see Appendix 6.2), it was noted that:

- 33.3% (31) involved fellers;
- 31.3% (29) involved skidders;
- 14.6% (14) occurred in the cable and sling zone;
- 54.2% (52) occurred during repairs.

5.2 List of the main breakdowns

The following tables illustrate the main breakdowns involving the feller, skidder and delimber. For more details, refer to Appendix 8.

Table 2 Main breakdowns involving the feller

ZONE	SYSTEM	PART OR GROUP OF PARTS
Hood	Hydraulic *	• Oil cooling, valves, motor, pumps
	Mechanical	• Motor, oil filtration and cooling, transmission, spider gear reducers
Running carriage	Hydraulic	• Motor
	Mechanical	• Tracks, drive
Boom	Mechanical	• Main boom and stick boom
Head	Hydraulic	• Motor
	Mechanical	• Saw, buncher
Chassis	Mechanical	• Slew ring, frame

* With the hydraulic system, breakdowns involving the cylinders and hoses appear as a constant for all zones except for the cabin

Table 3 Main breakdowns involving the skidder

ZONE	SYSTEM	PART OF GROUP OF PARTS
Hood	Hydraulic *	• Pumps, gaskets
	Mechanical	• Cooling, pumps, gaskets
	Electrical	• Starter, alternator
Running carriage	Hydraulic	• Brake cylinder
	Mechanical	• Brakes, wheels, torque transfer
Chassis	Mechanical	• Torque transfer, gaskets, underside protective plate, central pin
Winch **	Mechanical	• Drive, cable, slings
Grapple **	Mechanical	• Main booms, grapples, articulation

* With the hydraulic system, breakdowns involving the cylinders and hoses appear as a constant for all zones except for the running carriage and the winch
** Mutually exclusive accessories

6.1 Analysis and inventory of breakdowns, modifications and improvements

The data collected during the interviews was analyzed and this analysis was used to draw up an inventory of the breakdowns that were reported and of the modifications made to the machines. It was also used in drawing up a list of the planned or suggested modifications (see Appendix 10).

Furthermore, these interviews helped refine our understanding of the context in which these machines are used, and in particular, provide us with a better understanding of the effect and the importance, in relation to operations and interventions, of the following parameters: planning of cutting, nature and topography of the land, mode of operation, mentality and working conditions, subcontracting, services of forestry companies, preventive maintenance, dealers, training, information, etc.

These meetings also enabled us to learn about certain clever and innovative inventions produced by small Quebec companies (Appendix 11) in the field of forestry machinery.

Furthermore, the machine owners also carry out repairs and/or modifications themselves on their equipment. Their principal motivation is to:

- accelerate production;
- increase the reliability of the machine by reducing breakdowns;
- make maintenance and repair easier;
- make operation easier;
- increase safety.

In the case of fellers, it is noted that, although there are machines designed specifically to carry out the felling operation, most of the fellers operating in Quebec are the result of changes to a hydraulic excavator; therefore, the mechanical and hydraulic systems are the ones most affected by this change. Furthermore, the resulting hybrid machine has a higher centre of gravity, a greater displacement of the centre of gravity, and a greater weight than a "real" feller; there is therefore a greater risk of rollover and a higher frequency of breakdown. Most of the modifications later carried out on the feller (hybrid or not) are mainly in the hood and chassis zones.

It is also noted that for skidders, most of the changes carried out are on the mechanical system in the chassis zone. These modifications require the use of specific tools and involve the handling of large heavy parts.

For the delimber, the main components undergoing modifications are located in the boom/head and chassis zones. Hence, as in the case of the feller, the mechanical system is the first one targeted by the modifications. It is also noted that the running carriage zones seem to pose fewer problems than in the feller, because the delimbing work is carried out along the edge of the road, which is less constraining for the machine.

The data analysis finally reveals the main problems that result or may result in risks. These (mentioned in Table 6 below and presented in detail in Appendix 12) should be given priority in a subsequent technical study.

Table 6 List of the main problems affecting fellers, skidders and delimbers

MACHINE	PROBLEMS MENTIONED
Feller	• Motor overheating; • Machine catching fire; • Upper frame cracking; • Boom cracking; • Hydraulic system that leaks, breaks, becomes clogged.
Skidder	• Transmission and drive shaft failing; • Axles breaking; • Differential breaking; • Brakes wearing out quickly.
Delimber	• Motor overheating; • Machine catching fire; • Hydraulic motor of the boom's telescopic drive breaking frequently; • Boom chains breaking; • Spider gear reducers breaking.

7. CONCLUSION

The most important element to be retained from this study is the concept of *system performance assurance* which is translated as the adaptation of machines — fellers, skidders and delimbers — to the utilization conditions.

We in fact observed that, in general, the machines studied are not adapted, in terms of *safety, operability, reliability, maintainability* and *availability*, nor are they adapted to the terrain or to the climatic conditions of our forests. This lack of adaptation also makes preventive maintenance on these machines problematic.

Inevitably, under these conditions, failures are frequent and the subcontractors have to deal with an urgent need to accelerate the repair and production work as well as do long hours to make up for lost time.

In the end, this inadaptation, this low level of system performance assurance, translates into losses in production time, high costs for breakdown and modification, as well as inadequate preparation of the equipment for carrying out the work, with a consequent increase in risks and accidents. In such a context, safety becomes one burden too many, and accidents are minimized, forgotten, and even accepted without a report being made.

One of the main reasons for this inadaptation of machines is the lack of coordination of research, design and development activities to produce machines that correspond to the specific needs of Quebec users.

As an example, most of the fellers now in use are built using the base of a machine dedicated to excavation (hydraulic shovel) which is converted by a distributor or an authorized agent of the manufacturer by adding a motor hood, a hydraulic system for the felling head, a modified cabin, a boom (main boom and stick boom) and a felling head, and where all the equipment is supplied by another manufacturer specialized in his field. As a result, none of these participants has the required competence nor the complete responsibility (nor wants it) for the finished product.

Furthermore, the development and adaptation work is generally carried out in the field of operations, mainly by trial and error. The expertise gained during these tests is not necessarily passed on to the manufacturers, and consequently, the resulting new developments are not integrated into the new machines being produced.

The skidder and the delimber, like the feller, have design problems — particularly, in the case of the skidder, problems of accessibility and layout of the hood and the cabin — which also make preventive maintenance difficult, which in turn contributes to an increase in the frequency of breakdown, the number of interventions and the accident risks.

In short, the inadaptation of the machinery has a negative impact at several levels, namely:

- high costs for modification, repair and maintenance;
- costs related to the need for keeping larger inventories of parts;
- cost for disputes involving invalidated warranties as a result of modifications made to the machine, even though required;
- difficult relationship with the distributor, etc.

All these elements in the end have an impact on worker safety and the profitability of the activities.

Lastly, we should mention that we also observed that the training of maintenance personnel is clearly insufficient and that that of operators is inadequate from the technical standpoint, which they themselves recognize and deplore.

8. RECOMMENDATIONS

From the results of this study, various means are listed to improve the system performance assurance of person-machine-product-environment systems. Their goal is mainly to contribute to a reduction in risks resulting from the operation of tree harvesting machines and from the various maintenance, verification, repair and modification interventions.

As previously mentioned, the recommendations that follow are general ones. These are covered in a specific and detailed manner for each machine in Appendices 1A, 1B and 1C. They are then linked to the various related causes and include a reference on the ease (or difficulty) in carrying them out in terms of time — the short, medium or long term — or the level of expertise required, as described in Appendix 5. They are also ranked in order of importance in relation to their effect on improving safety.

A) Developing **design codes** for the machines, taking into account:

- conditions and constraints specific to forestry operations in Quebec;
- repairs, modifications and new developments on the machines;
- appropriate verification, maintenance and repair methods and procedures.

B) Developing **user, maintenance and repair manuals** that take into account the integration of the functional subassemblies produced by the different manufacturers into the basic, new, or existing machines.

C) Developing information, verification, repair, maintenance and modification **technical data sheets** for the most critical machine parts in order to increase the safety, rapidity and quality of the interventions.

D) Developing **plans, charts and diagrams** for easier and more rapid diagnosis of mechanical, hydraulic or electrical problems, depending on the case. These documents must be designed to be placed in the cabin, available to the operator, and simple and easy to consult.

E) Designing and developing **tool kits** to accelerate the maintenance and verification tasks that are carried out on the machines, as well as make them easier and safer.

F) Developing **specialized training programs** adapted to the machinery operators, mechanics and owners in order to increase the safety and quality of their interventions.

G) Developing, in collaboration with the machine distributors or with independent shops, **exchange programs for retooled parts** in order to guarantee, within a short period, the *maintainability* and the *availability of the machines*.

H) Developing and implementing **preventive maintenance programs** in order to increase the *reliability* and *availability* of these machines.

I) Developing and implementing **predictive maintenance programs** in order to increase the *reliability*, *maintainability* and the *availability of the machines*.

J) Implementing the **use of a logbook** in order to record all the interventions carried out on the machine.

K) Developing and making **tools and special equipment** available — in the case of heavy parts, for example — for easier handling, verification, maintenance, repair or modification interventions by the operators and mechanics.

L) Forming a **committee to establish standards and design codes** for tree harvesting machines. This committee must include participants with a role to play at the operational level, as well as representatives of various disciplines (designers, specialists in techniques and in health and safety, manufacturers, etc.).

M) Carrying out research using a multidisciplinary approach which can include the collaboration of health and safety professionals (ergonomists), engineers (mechanical and structural), mechanics, welders, machine operators and owners, whose mandate will be to:

- identify and analyze the needs of the machine operators, mechanics and owners;
- evaluate proposed modifications or those already carried out on actual machines (lifting door, side grapples, etc.);
- propose standards and/or design codes;
- participate in implementing the preceding recommendations;
- ensure that the information and the expertise acquired is disseminated.

1. Pourcentage de travailleurs ayant subi un accident, avec perte de temps, compensé par la CSST, par rapport aux travailleurs exposés.

2. Source : Statistique Canada, Emplois, gains et durée du travail, catalogue 72-002; CSST, Fichier STAT-35, mise à jour : printemps 1988).

3. Cloutier, E., Pelletier, C., *La sécurité en forêt - Machinerie et conditions de travail*, Rapport de recherche, IRSST, mars 1993, 35 p. et annexes.

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APPENDIX 1

RECOMMENDATIONS

APPENDIX 1A

RECOMMENDATIONS CONCERNING THE FELLER

PROPOSED IMPROVEMENTS FOR THE FELLER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1A.1 Machine that catches fire (Hood; All systems)			
1. Electrical short circuit (cut electrical wires)	• Ensuring that all electrical wires are installed in conduits that meet the standards (1)	Short term	Level 2
2. Presence of oil on the motor and hot components (turbo, exhaust pipes, etc.)	• Moving the exhaust pipe to the outside (2, 6, 7, 11)	Short term	Level 3
3. Oil leaks (hydraulic, lubrication, etc.)	• Designing and installing a fire barrier between the motor and hydraulic system (2, 3)	Short term	Level 3
4. Inadequate fire extinguishing system	• Installing an efficient and reliable automatic fire extinguishing system; to do so, making use of the suppliers' expertise and knowledge (4)	Short term	Level 4
5. Poor understanding of fire extinguishing system (installation, verification, repair, etc.) by mechanics and operators	• Developing technical and preventive maintenance data sheets (1, 5, 6, 8, 11)	Medium term	Level 3
6. Problematic shape and layout of the hood, resulting in difficult access for maintenance, ventilation and repair	• Developing a training program on preventing and extinguishing fires, as well as an inspection program (5)	Long term	Level 2
7. Poor ventilation inside the hood (quantity and location of poorly adapted ventilation openings)	• Establishing standards and design codes for the layout of the hood zone and for the installation of the automatic, semi-automatic or manual fire extinguishing system (4, 6)	Long term	Level 4
8. Presence of fir tree needles and wood debris	• Carrying out research and development work to reorganize the hood zone by considering the following:	Long term	Level 4
9. Infiltration of needles and fine particles through the radiator screen guard and the hood ventilation openings	— easy access for maintenance and mechanical repairs		
10. Inadequate screen guard to prevent piercing of the radiator by branches	— improving the ventilation		
11. Overheating of the motor (see article 1A.3)	— controlled elimination of accumulations of oil and debris to a place that is easily maintained (6, 7, 8, 9, 10, 11)		

1 The number in the titles refers to the number that corresponds to the problems listed in order of importance and required intervention priority in Appendix 12A

2 The comments in parentheses in the titles refer to the zone(s) and system(s) involved

3 The numbers in parentheses in each recommendation refer to the specific causes (column 1) to which the recommendation applies

4 Short term: < 6 months; medium term: 6 to 24 months; long term: > 24 months

PROPOSED IMPROVEMENTS FOR THE FELLER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1A.2 Upper frame cracks (Chassis; Mech.)			
1. Designed for excavation and not for felling	• Developing a reinforcement procedure for the frame (1, 2)	Short term	Level 3
2. Plates and welds subject to stress exceeding permitted values	• Developing a technical data sheet for maintenance and verification (3)	Medium term	Level 3
3. Lack of standards and design codes	• Developing a design code (3)	Medium term	Level 4
4. Main boom and stick boom too heavy	• Designing a lighter and stronger boom (main boom and stick boom) (4)	Long term	Level 4
	• Developing an R & D project in order to design a frame adapted to the utilization conditions (1, 2)	Long term	Level 4
1A.3 Machine that overheats (Hood; Mech.)			
1. Motor size not adapted to needs	• Increasing the power of the motor and the maintenance frequency (1, 2)	Short term	Level 2
2. Poor motor maintenance	• Increasing the fan capacity (3)	Short term	Level 2
3. Undersized and unadjusted fan	• Developing a checklist for verifying the capacity of the cooling system (4)	Short term	Level 2
4. Insufficient radiator cooling capacity	• Developing a maintenance technical data sheet on the inhibitor and glycol mixture, the tension in the fan belt, as well as the position of the blades (5)	Short term	Level 3
5. Inappropriate glycol and water mixture for the work and operation requirements	• Changing the location or position of the radiator (4)	Medium term	Level 2
6. Cooling system subject to deposits in the radiator (lack of inhibitor or improper mixture)	• Increasing the radiator capacity (4, 7)	Medium term	Level 3
7. Insufficient capacity of the circulating pump	• Designing and developing a more effective protective screen guard, of appropriate shape and geometry, to protect the radiator from branches and particles (8)	Medium term	Level 4
8. Poor protection of the radiator by the screen guard			
9. Improper radiator shape, insufficient number and poor layout of fins — which promotes plugging and contributes to a reduction in the flow of cooling air	• Carrying out research and development (R&D) on a new shape of radiator as well as on the shape and layout of the fins, including the optimum number required (3, 4, 6, 9)	Long term	Level 5
10. Inefficient hood ventilation	• Considering the effect of overheating in the R&D work in reorganizing the hood zone (10)	Long term	Level 5

1 The number in the titles refers to the number that corresponds to the problems listed in order of importance and required intervention priority in Appendix 12A

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PROPOSED IMPROVEMENTS FOR THE FELLER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1A.4 Boom (main boom, stick boom) that cracks (Boom; Mech.)			
1. Lack of adequate knowledge about repair and maintenance	• Developing a technical data sheet for preventive maintenance and repair (1)	Medium term	Level 3
	• Reinforcing the existing structure on the machine (2)	Medium term	Level 4
2. Inadequate design (design, structure, etc.) for the application	• Carrying out Research and Development work to develop a lighter and stronger material (2)	Long term	Level 5
3. Lack of standards and design code	• Carrying out a study to develop a design code and establishing design standards (2, 3, 4)	Long term	Level 5
4. Difficult access to certain intervention zones			
1A.5 Track spider gear reducer (Run. carriage; Mech.)			
1. Lack of oil in the transmission	• Developing a technical data sheet for maintenance to indicate maintenance and verification requirements (1, 2)	Medium term	Level 3
2. Frequent and difficult maintenance			
3. Overload and premature wear (machine designed for different requirements)	• Increasing the capacity of the spider gear reducers (3)	Long term	Level 4
1A.6 Swivel joint (Chassis; Hydr.)			
1. Frequent and difficult maintenance	• Developing a tool kit for verification and maintenance (1)	Medium term	Level 3
2. Leaks from connections between the different hydraulic circuitry	• Developing a technical data sheet for maintenance and verification (1)	Medium term	Level 3
	• Developing a training program on maintenance and verification (1)	Medium term	Level 3
3. Overload and premature wear (machine designed for different requirements)	• Carrying out Research and Development work to decrease the number of lines and make maintenance easier and increase durability (2, 3)	Long term	Level 5

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CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1A.7 Hydraulic valves (Hood; Hydr.)			
1. Lack of competence to properly repair, modify or add functions (and valves) 2. Inadequate filtration system 3. Insufficient number of functions 4. Inadequate tuning of the product 5. Too small flow capacity	• Developing data sheets to inform operators and mechanics on the maintenance of gang valves (1)	Short term	Level 3
	• Supplying a verification, maintenance and repair kit containing: wrenches, pressure gauges, flowmeter, connectors and maintenance data sheets (1)	Short term	Level 3
	• Developing, by taking into account the different makes of machines and heads, the identification of lines and components in order to provide a diagram and technical data sheets which the workers can easily consult (1)	Medium term	Level 3
	• Developing a system to improve filtration and make maintenance easier (2)	Medium term	Level 4
	• Doing research and development on a more versatile gang valve, allowing changes and additions of functions without modifications (3, 4, 5)	Long term	Level 4
	• Developing a design code for the gang valve. This code should allow gang valves to be manufactured that provide easier access for maintenance and diagnosis (1)	Long term	Level 4
	• Training experts in hydraulic systems. (1)	Long term	Level 5

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PROPOSED IMPROVEMENTS FOR THE FELLER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1A.8 Boom cylinder (Boom; Hydr.)			
1. Overload (machine designed for different requirements)	• Carrying out Research and Development to produce cylinders offering protection against limit of travel overload and able to withstand the conditions in the working environment (1, 2)	Long term	Level 4
2. Lack of protection with respect to the working environment			
3. Lack of standards and design code	• Developing design code (3)	Long term	Level 4
1A.9 Motor head, valves, turbo (Hood; Mech.)			
1. Oil and/or filter change not carried out	• Keeping a logbook up-to-date, recording such things as oil and fuel consumption, the degree of contamination of the oil, the maintenance carried out (1, 2)	Short term	Level 1
2. Inadequate repair or replacement motor not appropriate for needs			
3. Poor design of turbo components (lack of durability, short lifetime, etc.)	• Initiating an oil analysis program (1)	Long term	Level 2
	• Implementing a parts exchange program (2)	Long term	Level 2
	• Implementing a predictive maintenance program (1)	Long term	Level 4
1A.10 Hydraulic pump (Hood; Hydr.)			
1. Lack of special tools for diagnosing problems	• Supplying a diagnostic tool kit containing: wrenches, pressure gauges, flowmeter, connectors, and the maintenance manual (1, 2)	Short term	Level 3
2. Inadequate modifications, repairs, maintenance			
3. Contaminated oil	• Carrying out development to improve the filtration system (3)	Medium term	Level 4
4. Premature wear	• Studying the effect of vibrations on pump wear (4)	Medium term	Level 4
5. Lack of training	• Developing a procedure and technical means for isolating the pump in order to diagnose the problems without having to dismantle everything (2)	Long term	Level 3
6. Insufficient volume capacity	• Initiating a predictive maintenance program by studying vibrations and the oil analyses (2, 3, 4)	Long term	Level 3
	• Developing a training program for personnel who maintain and repair hydraulic system components (5)	Long term	Level 3

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CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1,2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
	• Reviewing and modifying the hydraulic circuitry by taking into account the different makes of machines and felling heads available (2)	Long term	Level 4
	• Designing and tuning a new transmission equipped with a greater number of outlets for adding additional pumps (6)	Long term	Level 4
1A.11 Tilting cylinder (Machine; Hydr.)			
See causes in 1A.8	• *See recommendations in 1A.8*		
1A.12 Sprocket (Run. carriage; Mech.)			
1. Inadequate repair and maintenance	• Developing a technical data sheet for verification, maintenance, repair (1)	Short term	Level 3
2. Tools not available on the site	• Developing a kit for verification and preventive maintenance (1)	Medium term	Level 3
3. Problems of adaptation to the application	• Developing a training program on repair welding (1)	Long term	Level 3
4. Premature wear	• Implementing a parts exchange program (2)	Long term	Level 2
	• Carrying out research to design a new chain wheel adapted to the application, taking into account the choice of material, tooth shape, the treatment of materials, etc. (3, 4)	Long term	Level 5
1A.13 Large slew bearing and ring gear (Chassis; Mech.)			
1. Difficult to maintain	• Developing a data sheet on the maintenance of the bearing and on the choice of lubricant (1)	Short term	Level 3
2. Overload due to the bending moment exerted by the boom assembly (main boom, stick boom, felling head and shafts)	• Starting a development project in order to eliminate breakdowns in the bearing and the ring gear and to make verification and maintenance easier by improving the seal, easier access from the hood, etc. (2, 3)	Long term	Level 5
3. Overload due to the moment of inertia related to the rotating masses (main boom, stick boom, felling head and shafts)			

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CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1A.14 Hydraulic traction motor (Run. carriage; Hydr.)			
1. Lack of power and not adapted to use on forest terrain	• Increasing the hydraulic power (1, 5)	Short term	Level 2
2. Oil leaks	• Developing a technical data sheet for maintenance (2, 3, 4, 5)	Short term	Level 3
3. Oil contamination	• Developing a system for improving filtration (3)	Medium term	Level 2
4. Inadequate verification and maintenance	• Developing a training program (2, 3, 4, 5)	Medium term	Level 3
5. Premature wear	• Developing a tool kit for verification and maintenance of the hydraulic circuitry (4)	Medium term	Level 3
1A.15 Boom cylinder (Boom; Hydr.)			
See causes in 1A.8	• *See recommendations in 1A.8*		
1A.16 Hydraulic pivot motor (Hood; Hydr.)			
See causes in 1A.14	• *See recommendations in 1A.14*		
1A.17 Saw shaft bearing (Head; Mech.)			
1. Jamming of the saw due to inadequate kerf width	• Developing a data sheet explaining the forces involved and the consequences of these forces. This work should be carried out by considering the various type of heads. (1, 2, 3)	Short term	Level 4
2. Stresses on the bearing resulting from the weight of the trees, poor grip on the trees, and the initial impact of the saw on the tree	• Developing an appropriate lighting system (4)	Medium term	Level 3
3. Different head configurations	• Developing a data sheet for verification and maintenance of the saw bearing (5)	Medium term	Level 3
4. Poor visibility at night (insufficient lighting) leading to harmful impact	• Developing a design code and establishing design standards (1, 2, 3)	Medium term	Level 4
5. Difficult and neglected maintenance	• Initiating a Research and Development project to improve the sawing and bunching functions as well as to make bearing maintenance easier (1, 2, 3)	Long term	Level 5

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PROPOSED IMPROVEMENTS FOR THE FELLER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1A.18 Track roller guard and pad (Run. carriage; Mech.)			
1. Design not adapted to the terrain and environment 2. Poor repair procedure 3. Lack of protection	• Producing a technical data sheet for maintenance that explains the welding procedure (2)	Short term	Level 3
	• Developing a design code for track pads and guard that takes into account the widening of the tracks, carried out when needed, and that determines the maximum width permitted (1, 3)	Medium term	Level 4
	• Developing a training program in welding (2)	Medium term	Level 3
	• Carrying out Research and Development to obtain a track pad that is well adapted to forest operating conditions (1)	Long term	Level 4
1A.19 Knives (Head, Mech.)			
1. Inadequate saw kerf width (jamming) 2. Tree weight poorly supported 3. Different types of heads *See also causes in 1A.17*	• Developing a data sheet explaining the forces involved and the consequences of these forces on the machine. This work should be carried out by considering the various types of heads in use. (1, 2, 3)	Medium term	Level 4
	• *See also recommendations in 1A.17*		
1A.20 Track cylinder (Run. carriage; Hydr.)			
See causes in 1A.8	• *See recommendations in 1A.8*		
1A.21 Main boom (Boom; Mech.)			
See causes in 1A.4	• *See recommendations in 1A.4*		

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CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1,2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1A.22 Idler (Run. carriage; Mech.)			
1. Inadequate tools for on-site repairs	• Encouraging the worker to plan and carry out the major repairs (ex.: boring) in the shop to the extent possible (1)	Short term	Level 2
2. Inadequate on-site repairs	• Producing a data sheet for repairs, welding, boring (1, 2)	Short term	Level 3
3. Maintenance difficult to predict	• Developing a technical data sheet presenting the list of verifications to be carried out (3)	Short term	Level 3
4. Premature wear	• Developing a verification kit consisting of thickness and wear gauges (3)	Medium term	Level 3
5. Inadequate design for the application	• Implementing a parts exchange program (4)	Long term	Level 2
	• Developing a training program on repair welding (1)	Long term	Level 3
	• Carrying out Research and Development (choice of equipment, shape of teeth, treatment of materials) to produce new chain wheels and idlers adapted to the application (5)	Long term	Level 5
1A.23 Leveler switch (Cabin; Elec.)			
1. Lack of durability	• Establishing an installation standard (eventually from existing standards) for electrical wiring (1, 2, 3)	Short term	Level 2
2. Premature wear	• Developing a data sheet recommending microswitches, reinforcement for wiring, as well as wire coverings more resistant to wear (1, 2, 3)	Short term	Level 2
3. Short circuit	• Carrying out a study of the electrical and electromechanical circuits in order to perfect principles for choosing circuits and materials whose failures do not put workers in danger (4)	Medium term	Level 4
4. Maintenance difficult to predict			

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CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1A.24 Hoses, tubes (Hood; Hydr.)			
1. Lack of identification	• Developing a physical means for rapid identification of hoses (1)	Short term	Level 2
2. Lack of adequate hose protection	• Installing hose protectors (2)	Short term	Level 2
3. Oil leaks	• Producing a technical data sheet to optimize the use of rigid tubes (2, 3, 4)	Medium term	Level 2
4. Crushed and/or worn tubes	• Producing a diagnostic chart (5)	Medium term	Level 2
5. Inadequate repair/modification	• Producing a technical data sheet on the installation and protection of flexible hoses (2)	Medium term	Level 3
6. Lack of technical knowledge (ex.: characteristics of components)	• Developing a training program on hose maintenance and repair (1, 5, 6)	Medium term	Level 3
7. Lack of tools	• Supplying a kit containing jigs and tools for replacing hoses and connections (5, 7)	Medium term	Level 3
8. Inadequate accessibility	• Carrying out research and development to create a better hose layout and improve access to them (2)	Medium term	Level 3
9. Design does not conform to needs	• Producing a diagram that illustrates the hydraulic lines, identifies the hoses, connections, and indicates their diameters. These diagrams should be developed by taking into account the different makes of basic machines and heads (1, 5)	Medium term	Level 3
10. Lack of standards and design code	• Standardizing the type of connections used (1, 5, 8)	Long term	Level 4
	• Developing a design code on the choice and installation of hoses, tubes and connections (10)	Long term	Level 4

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PROPOSED IMPROVEMENTS FOR THE FELLER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1A.25 Oil cooler (Hood; Hydr.)			
1. Cracks in joints 2. Vibration, impact 3. Inadequate design 4. Lack of volume capacity 5. Poor thermal capacity	• Designing better attachments and finding a material for insulating the cooler from vibrations (1, 2)	Short term	Level 2
	• Developing and disseminating a procedure in the form of a technical data sheet for welding and repairs on coolers (1, 2)	Short term	Level 3
	• Supplying a data sheet for choosing a cooler adapted to needs, particularly in terms of flow, temperature and resistance to vibrations (1, 2, 3, 4, 5)	Medium term	Level 3
	• Carrying out research to reduce the dimensions and to optimize the role of the oil tank's thermal energy dissipator in order to eliminate the cooler (4, 5)	Long term	Level 4
1A.26 Hydraulic saw motor (Head; Hydr.)			
See causes in 1A.14	• *See recommendations in 1A.14*		
1A.27 Seat (Cabin; Mech.)			
1. Fatigue and lost time related to inadequate design 2. Confined space resulting from the presence of the seat in certain maintenance operations on the machine's controls *See also causes in 1A.28*	• Carrying out research to develop an ergonomic seat adapted to the needs of the operator and maintenance personnel (1, 2)	Long term	Level 5
	• *See also recommendations in 1A.28*		

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PROPOSED IMPROVEMENTS FOR THE FELLER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1A.28 Cabin layout (Cabin; Mech.)			
1. Lack of space and poor layout 2. Lack of identification on the dashboard (ex.: ground level) 3. Poor access to the control panel (need to remove the seat) for maintenance 4. Inadequate air conditioning, heating 5. Lack of visibility 6. Lack of emergency exits	• Planning for a location for a tool box and an attachment system for rollovers (1)	Short term	Level 2
	• Adding a position indicator for rotation and differences in level (2)	Short term	Level 2
	• Improving instrument lighting (2)	Medium term	Level 3
	• Including a condition indicator for the hydraulic system (2)	Medium term	Level 3
	• Developing means for making maintenance easier (2, 3)	Medium term	Level 3
	• Optimizing space while taking ergonomic criteria into account (1)	Long term	Level 4
	• Carrying out Research and Development to produce a new cabin that provides an adequate field of vision, incorporates cabin air conditioning and heating, and has windows that can be used as emergency exits (4, 5, 6)	Long term	Level 5
	• *See also recommendations in 1A.27*		
1A.29 Saw teeth (Head; Mech.)			
1. Inadequate saw kerf width (jamming) 2. Weight of the tree 3. Impact when cut is started 4. Different types of teeth	• *See recommendations in 1A.17 et 1A.19*		
1A.30 Stem buncher (Head; Mech.)			
1. Inadequate saw kerf width (jamming) 2. Weight of the trees 3. Different types of heads 4. Insufficient lighting and poor visibility during the night	• Developing appropriate lighting system (4)	Medium term	Level 3
	• *See also recommendations in 1A.17 and 1A.19*		

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PROPOSED IMPROVEMENTS FOR THE FELLER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1A.31 Leveler cylinder (Chassis; Hydr.)			
See causes in 1A.8	• Reviewing the design of the hydraulic circuitry in order to control the lateral forces and the torsion forces in the leveling cylinders of the cabin and ensuring that they operate safely and reliably • *See also recommendations in 1A.8*	Medium term	Level 4
1A.32 Track (Run. carriage; Mech.)			
1. Poor quality material	• Developing a training program for welding (1, 2)	Short term	Level 3
2. Inadequate repairs	• Developing a data sheet on welding repairs (2)	Short term	Level 3
3. Premature wear	• Developing a data sheet that presents verification and repair methods for track as well as methods for replacing pins (2, 3, 4)	Short term	Level 3
4. Maintenance difficult to predict			
5. Lack of guides and supports to ensure a proper weight distribution on the track	• Producing a verification kit containing a micrometer, hardness tester, thickness and wear gauge, a spherometer for measuring curvature, etc. (1, 3, 4)	Medium term	Level 3
6. Inadequate design for the application			
7. Lack of guidelines for determining the width of track required	• Carrying out research and development to design types of new track that are more resistant to breaking and wear (ex.: rounded shape) and that have lugs intended for specific forestry requirements (1, 4, 5, 6, 7)	Long term	Level 5
1A.33 Running board (Chassis; Mech.)			
1. Operator slips and falls due to the lack of an antiskid surface	• Carrying out research using a multidisciplinary approach which could include the collaboration of engineers (mechanical, structural), ergonomists, mechanics, welders, machine operators and owners, whose mandate will be to study the identified needs (handrail, running board, lighting under the steps, etc.), to develop solutions, and to ensure that they are tuned directly on site (1, 2, 3)	Medium term	Level 4
2. Lack or insufficient number or poor location of handles			
3. High frequency of repairs			
4. Difficult access to cabin			

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CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
	• Developing a design code for the machine that takes into account all the workers' needs (1, 2, 3)	Long term	Level 4
	• Carrying out a research and development project, which, while considering cabin reorganization, focuses on improved access and safety (1, 2, 3, 4)	Long term	Level 4
1A.34 Torque converter (Hood; Hydr.)			
1. Oil leaks	• Developing a technical data sheet (1, 2)	Short term	Level 3
2. Vibrations	• Developing a data sheet for maintenance and verification (1, 2)	Short term	Level 2
1A.35 Emergency exit (Cabin; Mech.)			
1. Lack of emergency exits in the event of rollover	• Developing cabin design standards	Long term	Level 4
2. Possible jamming of the sole emergency exit	• *See also recommendations in 1A.28*		
1A.36 Screen guard (Cabin; Mech.)			
1. Branches that remain caught	• Reviewing and modifying present standards to allow screen guards to be replaced with a transparent material such as polycarbonate (1, 2, 3, 4)	Medium term	Level 3
2. Branches that are jill-poked through the window by the screen guard	• Developing (R & D) a new type of cabin with improved visibility and that eliminates the screen guard (1, 2, 3, 4)	Long term	Level 5
3. Windows difficult to clean	• *See also recommendations in 1A.28*		
4. Reduction in visibility			
See also causes in 1A.28			

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CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1,2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1A.37 Starter (Hood; Elec.)			
1. Frequent breakdown	• Implementing the use of a logbook for recording breakdowns (1)	Short term	Level 1
2. Insufficient power	• Increasing the power (2)	Short term	Level 2
	• Implementing a parts exchange program to ensure constant quality of repair (1)	Long term	Level 2
1A.38 Hydraulic oil tank (Hood; Hydr.)			
1. Vibrations	• Designing better attachments to insulate the tank from vibrations (1)	Medium term	Level 2
2. Poor welding	• Developing and disseminating welding procedures in the form of a technical data sheet (2)	Medium term	Level 3
3. Excessive accumulation of debris at the bottom of the tank	• Designing a tank with, for example, an accumulator pocket located at the bottom of the tank — or any other appropriate means — for eliminating the accumulated debris without previously having to empty the tank (3)	Medium term	Level 3
1A.39 Track pin (Run. carriage; Mech.)			
1. Poor quality material *See also causes in 1A.32*	*See recommendations in 1A.32*		
1A.40 Lighting (Boom; Elec.)			
1. General shutdown of the lighting system when the machine fails	• Providing an emergency lighting system for general shutdown due to failure of the machine (1)	Short term	Level 2
2. Loss of distance perception during the night	• Designing a lighting system with at least two independent circuits so as to minimize the risk of total loss of lighting in the event of an electrical failure (1)	Medium term	Level 3
3. Insufficient lighting of operations from the cabin (ambient lighting)	• Designing new more efficient lighting methods; reflected, movable light, etc. (2, 3, 4)	Medium term	Level 4

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CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
4. Lack or improper position of a supplementary lighting system on the boom and the main boom, which makes it difficult to see the operations carried out by the felling head and results in impact of the mechanical components on tree trunks and branches	• Initiating a Research and Development project to improve the quality of the ambient lighting in the operations area and the supplementary lighting at the felling head (2, 3, 4)	Long term	Level 5
1A.41 Alternator (Hood; Elec.)			
1. Insufficient power 2. Abnormally high frequency of breakdown	• Carrying out periodic adjustment of the belts (1)	Short term	Level 2
	• Carrying out an evaluation of the electrical requirements in order to choose the proper alternator. This information could be disseminated in the form of a technical data sheet. (1)	Medium term	Level 3
	• Developing a technical data sheet on alternator verification and maintenance (2)	Medium term	Level 3
1A.42 Air conditioning (Cabin; Mech.)			
1. Need to leave (or habit of leaving) the cabin door open to reduce discomfort due to heat; consequences: filthier cabin, increased noise level and increased risk in the event of a rollover	• Equipping fellers with an air conditioning system (1)	Short term	Level 0
	• Establishing reference criteria for choosing air conditioning appropriate to needs and for determining a proper location that minimizes vibrations and allows easy access for maintenance	Medium term	Level 3

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CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1A.43 Pivot spider gear reducer (Hood; Mech.)			
1. Presence of debris in the transmission oil 2. Oil leaks 3. Overload	• Developing a technical data sheet for pivot spider gear reducer verification and maintenance (1, 2)	Short term	Level 3
	• Developing a Research and Development project to add a second spider gear reducer to adapt the machine to the specific requirements of forestry use (3)	Medium term	Level 4
	• Carrying out a Research and Development project to produce a more powerful spider gear reducer (3)	Long term	Level 5
1A.44 Hoses (Boom; Hydr.)			
See causes in 1A.24	• *See recommendations in 1A.24*		
1A.45 Track lugs (Run. carriage; Mech.)			
See causes in 1A.32	• *See recommendations in 1A.32*		
1A.46 Traction hoses (Run. carriage; Hydr.)			
See causes in 1A.24	• *See recommendations in 1A.24*		

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3 The numbers in parentheses in each recommendation refer to the specific causes (column 1) to which the recommendation applies

4 Short term: < 6 months; medium term: 6 to 24 months; long term: > 24 months

PROPOSED IMPROVEMENTS FOR THE FELLER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1,2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1A.47 Chain guard (Run. carriage; Mech.)			
1. Lack of protection	• Carrying out Research and Development to design a guard that is well integrated into forestry operations (1)	Long term	Level 4
See also causes in 1A.18	• *See also recommendations in 1A.18*		
1A.48 Bolts (under the underframe) (Run. carriage; Mech.)			
1. Lack of bolt protection	• Installing a protection kit (1)	Short term	Level 0
	• Integrating the protection kit into the chassis (development required) (1)	Medium term	Level 4
1A.49 Handles (Chassis; Mech.)			
1. Lack or insufficient number or poor location of handles	• *See recommendations in 1A.33*		
1A.50 Antiskid surface (Chassis; Mech.)			
1. Operator slips and falls due to the lack of an antiskid surface	• *See recommendations in 1A.33*		

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APPENDIX 1B

RECOMMENDATIONS CONCERNING THE SKIDDER

PROPOSED IMPROVEMENTS FOR THE SKIDDER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1B.1 Transmission (Chassis; Mech.)			
1. Inadequate maintenance	• Establishing a parts exchange program (1)	Short term	Level 2
2. Lack of standards and design code	• Developing a tool kit for easier maintenance and repair (1)	Medium term	Level 3
3. Inadequate design for the application	• Developing a technical data sheet for maintenance and repair (1, 2)	Medium term	Level 3
4. Overload, wear, fatigue	• Developing a training course for maintenance and repair (5)	Medium term	Level 3
5. Lack of training for making diagnosis, for carrying out maintenance and repair	• Setting up a predictive and preventive maintenance program (1)	Long term	Level 4
	• Developing a design code that takes into account the forces involved as well as the heat generated, vibrations, impacts, etc. (2, 3, 4)	Long term	Level 4
1B.2 Drive shaft (Chassis; Mech.)			
See causes in 1B.1	• *See recommendations in 1B.1*		
1B.3 Axles (Chassis; Mech.)			
See causes in 1B.1	• *See recommendations in 1B.1*		
1B.4 Brakes (Run. carriage; Mech.)			
1. Overload	• Identifying and evaluating the problems involving existing brakes (1, 2)	Medium term	Level 3
2. Premature fatigue and wear	• Developing methods to improve the brakes on existing machines (1, 2, 3)	Long term	Level 4
3. Inadequate design for the application	• Initiating a Research and Development program to design more reliable brakes (3)	Long term	Level 5

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4 Short term: < 6 months; medium term: 6 to 24 months; long term: > 24 months

PROPOSED IMPROVEMENTS FOR THE SKIDDER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1B.5 Differential (Chassis; Mech.)			
See causes in 1B.1	• *See recommendations in 1B.1*		
1B.6 Tires (Run. carriage; Mech.)			
1. Maintenance difficult due to difficult handling (heavy and large tires)	• Developing tools or equipment integrated into the machine to make tire changing easier (1)	Medium term	Level 3
2. Accelerated wear on tires due to skidding on mountainous, soft and/or uneven terrain	• Developing equipment and procedures to make tire handling easier (1)	Medium term	Level 4
	• Initiating a Research and Development project to design tires that are more resistant to wear and punctures, and whose traction and performance are similar to that obtained with chains (2)	Long term	Level 5
1B.7 Spider gear reducers (Run. carriage; Mech.)			
See causes in 1B.1	• *See recommendations in 1B.1*		
1B.8 Chains (Run. carriage; Mech.)			
1. Demanding and difficult maintenance and repair	• Providing training on chain maintenance and repair (1)	Short term	Level 3
2. Premature wear	• Developing a technical data sheet on chain verification and maintenance (1)	Short term	Level 3
3. Premature fatigue	• Developing a tool kit to measure wear on chains and their permanent deformation (1)	Medium term	Level 3
4. Overload	• Initiating a project to improve the chain tightening method (1)	Long term	Level 3
	• Initiating a Research and Development project to perfect chain link patterns that are adjusted on the sides only (1)	Long term	Level 4
	• Initiating a Research and Development project to find the best materials and the best chain link patterns (2, 3, 4)	Long term	Level 4

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PROPOSED IMPROVEMENTS FOR THE SKIDDER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1,2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1B.9 Main boom bracket (Boom\grapples; Mech.)			
1. Difficult maintenance and repair due to lack of tools and training	• Developing a data sheet on maintenance and repair (1)	Short term	Level 3
	• Initiating a training program on maintenance, welding and boring (1)	Medium term	Level 4
2. Inadequate design for purpose	• Initiating a program for analyzing breakdowns and proposing modifications (2, 3)	Medium term	Level 4
3. Excessive impacts and overloads			
4. Lack of standards and design code	• Developing a design code for the requirements of the application (2, 3, 4, 5)	Long term	Level 4
5. Difficult maintenance due to inaccessibility	• Initiating a Research and Development project to produce a grapple that can be lowered to ground level for maintenance and repair (5)	Long term	Level 4
1B.10 Boom pin (Boom\grapple; Mech.)			
1. Impacts and overload	• Developing a technical data sheet for verification, maintenance and repair (1)	Short term	Level 3
2. Premature wear			
3. Difficult maintenance	• Initiating a program for analyzing breakdowns and premature wear in order to eliminate or reduce them (2, 3)	Medium term	Level 4
4. Lack of standards and design code	• Developing a design code (4)	Long term	Level 4
1B.11 Grapple pin (Boom\grapple; Mech.)			
See causes in 1B.10	• *See recommendations in 1B.10*		

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PROPOSED IMPROVEMENTS FOR THE SKIDDER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1B.12 Arch cylinder (Boom\grapple; Hydr.)			
1. Limit of travel overload and impacts 2. Inadequate design for the application 3. Lack of standards and design code	• Carrying out Research and Development to produce cylinders that can withstand the limit of travel impacts and the conditions under which they are used (1)	Long term	Level 4
	• Developing a design code (2, 3)	Long term	Level 4
1B.13 Winch (Boom\winch; Mech.)			
1. Manual unwinding of cable too difficult	• Starting a project to evaluate the "DÉROUL-MATIC", a Quebec invention (1)	Medium term	Level 3
2. Difficult maintenance	• Developing a technical data sheet for easier maintenance and repair (2)	Short term	Level 3
3. Chain tension that is released due to relative movements between the trees and the machine during transportation (cable skidder converted into grapple skidder)	• Initiating, in the case of the grapple system mounted on a cable machine, a Research and Development project to design a system that automatically maintains the tension in the chain (3)	Medium term	Level 4
4. Insufficient capacity	• Initiating a Research and Development project to design a more reliable winch (4, 5)	Long term	Level 5
5. Inadequate design for the application	• Developing a design code (4, 5)	Long term	Level 5
1B.14 Shaft section (pivot region) and journal bearing (Chassis; Mech.)			
See causes in 1B.1	• *See recommendations in 1B.1*		
1B.15 Steering cylinder (Chassis; Hydr.)			
1. Excessive impacts and overload	• Carrying out Research and Development to produce cylinders offering protection against limit of travel overload and that can withstand the conditions of the working environment (1, 2)	Long term	Level 4
2. Lack of protection with respect to the work environment 3. Lack of standards and design code	• Developing a design code (3)	Long term	Level 4

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3 [illegible]

PROPOSED IMPROVEMENTS FOR THE SKIDDER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1,2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1B.16 Seat (Cabin; Mech.)			
1. Fatigue and lost time related to inadequate mechanical (suspension) and ergonomic design (shape, adjustments, etc.) 2. Insufficient cabin space to allow the seat the amplitude movements required to absorb impacts and vibrations 3. Confined space caused by the presence of the seat during maintenance operations	• Carrying out research to develop an ergonomic seat adapted to the needs of the operator and maintenance personnel. This work should be carried out at the same time that the cabin is reorganized (1, 2, 3)	Long term	Level 4
1B.17 Hydraulic valve gasket (Hood; Hydr.)			
1. Difficult and neglected preventive maintenance 2. Instantaneous excessive pressure 3. Heat and vibration 4. Addition of unexpected and more demanding pressure functions	• Developing a technical data sheet for gasket verification and maintenance (1) • Initiating a Research and Development project to design valve gaskets that are better adapted to the operating conditions (2, 3, 4)	Short term Long term	Level 3 Level 5
1B.18 Injection pump (Hood; Mech.)			
1. Inadequate and demanding maintenance 2. Premature wear 3. Frequent flow variation resulting from the many variations in motor load	• Developing a technical data sheet for pump adjustments, verification and maintenance (1) • Initiating a parts and pump exchange program (1, 2) • Initiating a project to develop a new speed regulator, pump and injector assembly that is more resistant to wear resulting from frequent load variations (2, 3)	Short term Medium term Long term	Level 2 Level 2 Level 5

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PROPOSED IMPROVEMENTS FOR THE SKIDDER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1B.19 Hydraulic pump (Hood; Hydr.)			
1. Lack of special tools for making diagnosis 2. Inadequate modifications, repairs and maintenance 3. Contaminated oil 4. Premature wear 5. Lack of training 6. Insufficient volume capacity	• Supplying a diagnostic tool kit containing: wrenches, pressure gauges, flowmeter, connectors and the maintenance manual (1, 2)	Short term	Level 3
	• Carrying out development to improve the filtration system (3)	Medium term	Level 4
	• Studying the effect of vibrations on pump wear (4)	Medium term	Level 4
	• Developing a procedure and technical means for isolating the pump in order to diagnose problems without having to dismantle everything (2)	Long term	Level 3
	• Initiating a predictive maintenance program based on the study of vibrations and oil analyses (2, 3, 4)	Long term	Level 3
	• Developing a training program for employees who carry out maintenance and repair on the hydraulic system components (5)	Long term	Level 3
	• Reviewing and modifying the hydraulic circuitry by taking into account the different makes of machines and accessories available (2)	Long term	Level 4
	• Designing and tuning a new transmission equipped with a greater number of outlets for adding additional pumps (6)	Long term	Level 4
1B.20 Gaskets (Run. carriage; Mech.)			
1. Delicate and difficult maintenance and repair 2. Radial and axial overloads in the wheels 3. High frequency of impacts and overloads on the wheels	• Developing a technical data sheet for maintenance and repair (1)	Short term	Level 3
	• Developing a tool kit (gauge, displacement measure, etc.) in relation to the make and model of machine (1)	Short term	Level 3
	• Initiating a training course for gasket maintenance and repair (1)	Medium term	Level 4
	• Initiating a replacement program for spider gear reducers whose gaskets are broken (1)	Long term	Level 4
	• Developing a design code that takes into account the forces and displacements to which the gaskets are subjected (2, 3)	Long term	Level 4

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PROPOSED IMPROVEMENTS FOR THE SKIDDER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1B.21 Winch shaft (Boom\winch; Mech.)			
1. Difficult to unwind the cable manually on certain models because it is impossible to disconnect the main winch shaft from the winch	• Starting a project to evaluate the effectiveness and ease of using the "DÉROUL-MATIC", a Quebec invention (1)	Short term	Level 2
2. Demanding maintenance	• Developing a data sheet on the verification, maintenance and repair of the winch shaft (2)	Medium term	Level 3
3. Inadequate design for the application	• Developing a design code for the shaft (3, 4)	Long term	Level 4
4. Frequent impacts and overloads			
1B.22 Emergency brake control protector (Cabin; Mech.)			
1. Lack of protector on the emergency brake control of certain John Deere skidders: the brake can then be disengaged by inadvertently hitting the control	• Installing a protector on the brake control of the machines (1)	Short term	Level 2
2. Lack of layout design code for the cabin and controls	• Developing a design code for the layout of cabins and controls (1, 2)	Long term	Level 4
1B.23 Brake cylinder (Run. carriage; Hydr.)			
1. Frequent use (wear)	• Developing a technical data sheet for cylinder verification, maintenance and repair (1)	Short term	Level 2
2. Overload	• Initiating a Research and Development project to better understand brake-related problems (2, 3, 4)	Medium term	Level 3
3. Inadequate design for certain applications	• Developing a brake-related design code (5)	Long term	Level 4
4. Lack of design code			
5. Demanding maintenance			

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PROPOSED IMPROVEMENTS FOR THE SKIDDER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1B.24 Grapple (Chassis; Mech.)			
1. Poor construction for the application 2. Overload, cracks, wear, breakdown 3. Inadequate materials 4. Frequent maintenance and repair 5. Lack of design code	• Developing a technical data sheet for verification, repair and welding (1) • Developing a design code for choosing materials and designing grapples (2, 3, 4, 5)	Short term Long term	Level 3 Level 4
1B.25 Underside of machine (Chassis; Mech.)			
1. Demanding work environment 2. Lack of protection 3. Inadequate repair 4. Lack of design code	• Installing a protection kit (1, 2, 3) • Initiating a Research and Development project to incorporate the required protection into the chassis (1, 2, 3) • Developing a design code (4)	Short term Long term Long term	Level 2 Level 4 Level 4
1B.26 Cabin layout (Cabin; Mech.)			
1. Lack of space and inadequate layout for an ergonomic seat that absorbs, for example, lateral vibrations, and for a tool kit that remains closed and in place in the event of rollover 2. Inadequate air conditioning and heating 3. Lack of visibility 4. Lack of system-condition and machine-stability indicators 5. Inadequate ergonomic layout, particularly in terms of visibility, access to instruments, etc.)	• Planning for a location for a tool box that remains anchored and closed during rollovers (1) • Installing an air conditioner (2) • Carrying out a study for replacing screen guards with "LEXAN" (3) • Adding a system-condition indicator (hydr., mech., elec., etc.) as well as a stability indicator to prevent rollovers (4) • Optimizing the cabin layout by taking ergonomic criteria and maintenance requirements into consideration (1, 5, 6, 7) • Carrying out Research and Development to produce a new cabin with a suitable field of vision, with air conditioning and heating, and with a seat	Short term Medium term Medium term Medium term Long term Long term	Level 2 Level 2 Level 3 Level 4 Level 4 Level 5

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CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1,2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
6. Difficult access to the control panels due to the space taken up by the seat 7. Lack of emergency exits	that can reduce vibrations along the three axes and with windows that can be used as emergency exits (1, 2, 3, 4, 5, 6, 7)		
1B.27 Water pump (Hood; Mech.)			
1. Poor adjustment of the belts 2. Inadequate preventive maintenance 3. Insufficient capacity 4. Overload and premature wear	• Developing a technical data sheet for easier preventive maintenance, belt adjustment, verification, repairs, etc. (1, 2)	Short term	Level 2
	• Developing a procedure for diagnosing proper operation of the pumps or their lack of capacity (1, 2, 3)	Medium term	Level 2
	• Initiating a study to learn the failure modes of pumps and to propose solutions (4)	Long term	Level 4
1B.28 Motor oil leaks (Hood; Mech.)			
1. Impacts, vibration, heat 2. Risk of fire 3. Excessive oil pressure inside the line 4. Preventive maintenance inadequate or lacking 5. Difficult access for maintenance, particularly for tightening head bolts	• Developing a technical data sheet for oil line verification and maintenance, pressure verification, the tightening of motor head bolts, etc. (1, 2, 3, 4)	Short term	Level 2
	• Developing a tool kit: pressure gauge, gauge, etc. (1, 2, 3)	Short term	Level 2
	• Initiating a Research and Development project to design a hood with easy access (4, 5)	Medium term	Level 4
	• Developing a design code that takes into account the space required for maintenance inside the hood (4, 5)	Long term	Level 4

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PROPOSED IMPROVEMENTS FOR THE SKIDDER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1B.29 Stability related to the width of the machine (Chassis; Mech.)			
1. Lack of stability on slopes 2. Potential risk of failure of the structure if widening (or lengthening) is done without engineering studies 3. Lack of design code	• Initiating a Research and Development project for evaluating the widening of machines for working on slopes, and eventually, proposing a design project (1, 2)	Long term	Level 4
	• Developing a design code for machine widening (3)	Long term	Level 4
1B.30 Stability related to machine length (Chassis; Mech..)			
See causes in 1B.29	• *See recommendations in 1B.29*		
1B.31 Fan (Hood; Mech.)			
1. Poorly adjusted fan (belt, pulley, blades) 2. Undersized fan 3. Impacts, vibration, premature wear 4. Lack of standards and design code	• Developing a technical data sheet for the maintenance and adjustment of fan pulleys, belts and blades (1)	Short term	Level 2
	• Developing a procedure for diagnosing operating problems and problems in lack of fan capacity (1, 2, 3)	Medium term	Level 2
	• Initiating a Research and Development project to optimize the flow of fresh air from the fan, around the motor, by taking into account the layout of the components near the motor as well as the shape and dimensions of the hood (1, 3)	Long term	Level 4
	• Developing a design code for choosing the fan and for hood layout (2, 4)	Long term	Level 4

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PROPOSED IMPROVEMENTS FOR THE SKIDDER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1B.32 Universal joint (Chassis; Mech.)			
1. Lack of training for diagnosis, maintenance and repair	• Developing a training course on maintenance and repair (1, 2)	Medium term	Level 3
2. Lack of standards and design code	• Developing a technical data sheet for maintenance and repair (2, 3)	Medium term	Level 3
3. Inadequate maintenance	• Developing a tool kit for easier maintenance and repair (3)	Medium term	Level 4
4. Inadequate design for the application	• Setting up a predictive and preventive maintenance program (2)	Long term	Level 3
5. Overload, wear, fatigue	• Developing a design code that takes into account the forces involved as well as the heat generated, vibrations, impacts, etc. (4, 5)	Long term	Level 4
1B.33 Sleeve (Chassis; Mech.)			
See causes in 1B.32	• *See recommendations in 1B.32*		
1B.34 Screen guard (Cabin; Mech.)			
1. Branches that remain caught	• Reviewing and modifying present standards to allow screen guards to be replaced with a transparent material such as polycarbonate (1, 2, 3, 4)	Medium term	Level 3
2. Branches that are jill-poked through the window	• Developing (R & D) a new type of cabin with improved visibility and that eliminates the screen guard (1, 2, 3, 4)	Long term	Level 5
3. Windows difficult to clean	• *See also recommendations in 1B.26*		
4. Reduction in visibility			
See also causes in 1B.26			
1B.35 Cables, slings (Boom\winch; Mech.)			
1. Premature breaking and wear of the strands	• Developing a technical data sheet for determining the choice of cables in relation to the diameter of the winch, the pulleys and the winch capacity. This data sheet must also provide information on repair and maintenance of cables and slings (1, 2, 3, 4)	Medium term	Level 3
2. Too heavy cables that become entangled			
3. Difficult and frequent maintenance and repair			
4. Frequent pricks and injuries			
5. Insufficient number of slings	• Installing a system to keep slings disentangled when not in use (2)	Medium term	Level 4

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PROPOSED IMPROVEMENTS FOR THE SKIDDER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
	• Evaluating the new automatic sling detaching system now being tested (2, 3)	Medium term	Level 4
	• Evaluating the "DÉROUL-MATIC" cable unwinder (2, 3)	Long term	Level 3
	• Initiating a Research and Development project for finding a winch-cable combination that is more resistant to wear and breakage (1)	Long term	Level 4
	• Initiating a Research and Development project for tuning special tools for repairing cables and slings (2, 3, 4)	Long term	Level 4
1B.36 Starter (Hood; Elec.)			
1. High frequency of breakdown	• Implement the use of a logbook for recording breakdowns (1)	Short term	Level 1
2. Insufficient power	• Increasing the power (2, 3)	Short term	Level 1
3. Frequent stops and start-ups	• Implementing a parts exchange program to ensure constant quality of the repairs (1)	Medium term	Level 3
1B.37 Alternator (Hood; Elec.)			
1. Insufficient power	• Carrying out a periodic adjustment of the belts (1)	Short term	Level 2
2. Abnormally high breakdown frequency	• Carrying out an evaluation of the electrical requirements in order to choose the proper alternator. This information could be disseminated in the form of a technical data sheet. (1)	Medium term	Level 3
	• Developing a technical data sheet on alternator verification and maintenance (2)	Medium term	Level 3
1B.38 Running board (Chassis; Mech.)			
1. Operator falling due to lack of antiskid surface 2. Lack or insufficient number or poor location of handles 3. High frequency of repairs	• Carrying out research using a multidisciplinary approach which may include the collaboration of engineers (mechanical, structural), ergonomists, mechanics, welders, machine operators and owners whose mandate will be	Medium term	Level 4

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CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1,2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
4. Difficult access to cabin	to study the needs identified (handrail, running board, lighting under the steps, etc.), to develop solutions, and to ensure that they are tuned on site (1, 2, 3)		
	• Developing a design code for the machine which takes into account all the workers' needs (1, 2, 3)	Long term	Level 4
	• Carrying out a Research and Development project, which, while considering cabin reorganization, focuses on improved access and safety (1, 2, 3, 4)	Long term	Level 4
1B.39 Handles (Chassis; Mech.)			
See causes in 1B.38	• *See recommendations in 1B.38*		
1B.40 Hoses, tubes (Hood; Hydr.)			
1. Lack of identification	• Developing a physical means for rapid identification of hoses (1)	Short term	Level 2
2. Lack of adequate hose protection	• Installing hose protectors (2)	Short term	Level 2
3. Oil leaks	• Producing a technical data sheet for optimum use of rigid tubes (2, 3, 4)	Medium term	Level 2
4. Crushed and/or worn tubes	• Developing a diagnostic chart (5)	Medium term	Level 2
5. Inadequate repairs and/or modifications	• Producing a technical data sheet on the installation and protection of flexible hoses (2)	Medium term	Level 3
6. Lack of technical knowledge (ex.: characteristics of components)	• Developing a training program on hose maintenance and repair of hoses (1, 5, 6)	Medium term	Level 3
7. Lack of tools	• Supplying a kit containing gauges and tools for replacing hoses and connectors (5, 7)	Medium term	Level 3
8. Inadequate accessibility	• Carrying out Research and Development to create a better hose layout and to improve access to it (2)	Medium term	Level 4
9. Design does not conform to needs			

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4 Short term: < 6 months; medium term: 6 to 24 months; long term: > 24 months

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
	• Producing a diagram that illustrates the hydraulic lines, identifies the hoses, connections, and indicates their diameters. These diagrams should be developed by taking into account the different makes of skidders and booms\grapples. (1, 5)	Medium term	Level 4
	• Standardizing the type of connections used (1, 5, 8)	Long term	Level 4
1B.41 Central pin (Chassis; Mech.)			
See causes in 1B.10	• *See recommendations in 1B.10*		
1B.42 Doors and windows (Cabin; Mech.)			
1. No door and emergency exit in the event of rollover	• Installing more than one door that may be used as an emergency exit (1)	Medium term	Level 4
2. Existing door that remains blocked	• Initiating a Research and Development project for producing a cabin, all of whose windows and doors are emergency exits. This work should be carried out at the same time as the research on the interior reorganization of the cabin (1, 2)	Long term	Level 5
See also causes in 1B.26 and 1B.34	• Developing standards for cabin design (1, 2)	Long term	Level 4
1B.43 Lighting (Boom\grapple; Elec.)			
1. General shutdown of the lighting system when the machine's electrical system fails	• Providing an emergency lighting system for general shutdown due to failure of the machine's electrical system (1)	Short term	Level 2
2. Loss of distance perception during the night	• Designing a lighting system with at least two independent circuits so as to minimize the risk of total loss of lighting in the event of failure of part of the machine's electrical system (1)	Medium term	Level 4
3. Insufficient lighting of operations from the cabin (ambient lighting)			

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CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
4. Lack or improper position of the supplementary lighting system on the boom\grapple and the stick boom, which makes it difficult to see the site and the operations carried out by the grapple, and results in injuries or a poor grip on the trees	• Designing new more efficient lighting methods: reflected, movable light, etc. (2, 3, 4)	Medium term	Level 4
	• Initiating a Research and Development project to improve the quality of the ambient lighting in the operations area and of the supplementary lighting in the operations zone (2, 3, 4)	Long term	Level 5
1B.44 Fenders (Chassis; Mech.)			
1. Overload and impacts	• Initiating a Research and Development project to design reinforced, lighter and dismountable fenders for easier maintenance (1)	Medium term	Level 4
2. Lack of standards and design code	• Developing a design code (2)	Long term	Level 4
1B.45 Motor oil filter (Hood; Mech.)			
1. Filter with a too small volume capacity	• Developing a technical data sheet describing filter maintenance and selection procedure in relation to needs (1, 2, 3)	Short term	Level 2
2. Filter with too coarse filtration	• Initiating a design project to increase the volume capacity of the filters and their filtering quality (1, 2, 3)	Medium term	Level 3
3. Inadequate maintenance; access difficult, too demanding, etc.	• Initiating a Research and Development project to improve access to the hood components, particularly the motor oil filters (3)	Medium term	Level 4
	• Initiating an oil analysis program for easier preventive maintenance (3)	Long term	Level 4

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APPENDIX 1C

RECOMMENDATIONS CONCERNING THE DELIMBER

PROPOSED IMPROVEMENTS FOR THE DELIMBER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1,2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1C.1 Machine that catches fire (Hood; All systems)			
1. Electrical short circuit (cut electrical wires)	• Ensuring that all electrical wires are installed in conduits that meet standards (1)	Short term	Level 2
2. Presence of oil on the motor and hot components (turbo, exhaust pipes, etc.)	• Moving the exhaust pipe to the outside (2, 6, 7, 11)	Short term	Level 3
3. Oil leaks (hydraulic, lubrication, etc.)	• Designing and installing a fire barrier between the motor and hydraulic system (2, 3)	Short term	Level 3
4. Inadequate fire extinguishing system	• Installing an efficient and reliable automatic fire extinguishing system; to do so, making use of the suppliers' expertise and knowledge (4)	Short term	Level 4
5. Poor understanding of fire extinguishing system (installation, verification, repair, etc.) by mechanics and operators	• Developing technical and preventive maintenance data sheets (1, 5, 6, 8, 11)	Medium term	Level 3
6. Problematic shape and layout of the hood, resulting in difficult access for maintenance, ventilation and repair	• Developing a training program on preventing and extinguishing fires, as well as an inspection program (5)	Long term	Level 2
7. Poor ventilation inside the hood (quantity and location of poorly adapted ventilation openings)	• Establishing standards and design codes for the layout of the hood zone and for the installation of the automatic, semi-automatic or manual fire extinguishing system (4, 6)	Long term	Level 4
8. Presence of needles and debris	• Carrying out research and development work to reorganize the hood zone, by considering the following: — easy access for maintenance and mechanical repairs — improving the ventilation — controlled elimination of accumulations of oil and debris to a place that is easily maintained (6, 7, 8, 9, 10, 11)	Long term	Level 4
9. Infiltration of fir tree needles and fine wood particles through the radiator screen guard and the hood ventilation openings			
10. Inadequate screen guard to prevent piercing of the radiator by branches			
11. Overheating of the motor (see article 1C.2)			

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PROPOSED IMPROVEMENTS FOR THE DELIMBER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1C.2 Machine that overheats (Hood; Mech.)			
1. Motor size not adapted to needs	• Increasing the power of the motor and the maintenance frequency (1, 2)	Short term	Level 2
2. Poor motor maintenance	• Increasing the fan power (3)	Short term	Level 2
3. Undersized and unadjusted fan	• Developing a checklist for verifying the capacity of the cooling system (4)	Short term	Level 2
4. Insufficient radiator cooling capacity	• Developing a maintenance technical data sheet concerning the inhibitor and glycol mixture, the tension in the fan belt, as well as the position of the blades (5)	Short term	Level 3
5. Inappropriate glycol and water mixture for the work and operation requirements	• Changing the location or position of the radiator (4)	Medium term	Level 2
6. Cooling system subject to deposits in the radiator (lack of inhibitor or improper mixture)	• Increasing the radiator cooling capacity (4, 7)	Medium term	Level 3
7. Insufficient flow capacity of the circulating pump	• Designing and developing a more effective protective screen guard, of appropriate shape and geometry, to protect the radiator from branches and particles (8)	Medium term	Level 4
8. Poor protection of the radiator by the screen guard	• Carrying out research and development (R&D) on a new shape of radiator as well as on the shape and layout of the fins including the optimum number required (3, 4, 6, 9)	Long term	Level 5
9. Improper shape of the radiator, insufficient number and poor layout of the fins — which promotes plugging and contributes to a reduction in the flow of cooling air	• Considering the effect of overheating in the R&D work in reorganizing the hood zone (10)	Long term	Level 5
10. Inefficient hood ventilation			

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3 [illegible]

PROPOSED IMPROVEMENTS FOR THE DELIMBER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1C.3 Hydraulic motor (Boom/head; Hydr.)			
1. Oil leaks 2. Oil contamination 3• Lack of training on the hydraulic system, particularly the motor 4. Inadequate verification and maintenance 5• Lack of tools for diagnosing problems 6. Lack of standards and design codes 7• Severe impacts and vibrations 8• Maintenance difficulties, need to climb, heavy weight, etc. 9• Premature wear	• Developing a technical data sheet for maintenance and repair (1, 2, 3, 4) • Developing a tool kit for verification and maintenance of the hydraulic line (1, 2, 4, 5) • Developing a training program on the maintenance and repair of the hydraulic motor (3) • Developing a system to improve hydraulic oil filtration (2) • Developing a technical data sheet that explains the forces involved and the consequences in relation to the types of booms and heads (3, 7) • Developing a design code (6) • Designing a handling system for heavy objects in the boom zone based on systems already developed on sites (in relation to the different makes) (8) • Initiating a development project to improve the means of access to the boom and around the hydraulic motor (8) • Initiating, with the manufacturers' cooperation, a Research and Development project to develop a more reliable and more durable motor-sprocket assembly (1, 2, 6, 7, 9)	Short term Medium term Medium term Medium term Medium term Medium term Medium term Long term Long term	Level 3 Level 3 Level 3 Level 4 Level 4 Level 4 Level 4 Level 4 Level 5
1C.4 Track spider gear reducers (Run. carriage; Mech.)			
1. Contamination of the hydraulic line 2. Lack of oil in the transmission 3. Frequent and difficult maintenance 4. Overload and premature wear (machine designed for different requirements)	• Developing a technical data sheet to indicate the maintenance and verification requirements (1, 2, 3) • Increasing the power of the spider gear reducer (4)	Medium term Long term	Level 3 Level 4

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CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1C.5 Telescopic boom driving roller chain (Boom/head; Mech.)			
1. Premature wear, stretching and breaking 2. Lack of preventive maintenance 3. Maintenance difficulties, need to climb, weight, etc.) 4. Very frequent severe impacts	• Developing a technical data sheet for maintenance and repair of roller chains (1, 2)	Short term	Level 3
	• Initiating a project to develop an automatic chain tensioner (1, 2, 3)	Medium term	Level 4
	• Initiating a Research and Development project to improve the means of access to the boom and around the hydraulic motor (3)	Medium term	Level 4
	• Initiating a Research and Development project to replace the chains with a flexible component that is more resistant to repeated impact and stretching in order to reduce the maintenance frequency and eliminate lubrication (1, 2, 3, 4)	Long term	Level 4
1C.6 Traction chain wheel (Run. carriage; Mech.)			
1. Inadequate repair and maintenance 2. Tools unavailable on the site 3. Problems of adaptation to the application 4. Premature wear	• Developing a technical data sheet for verification, maintenance and repair (1)	Short term	Level 3
	• Developing a verification and preventive maintenance kit (1)	Medium term	Level 3
	• Implementing a parts exchange program (2)	Long term	Level 2
	• Developing a training program on repair welding (1)	Long term	Level 3
	• Carrying out research to design a new chain wheel adapted to the application and taking into account the material, tooth shape, treatment of materials, etc. (3, 4)	Long term	Level 4
1C.7 Steel drive chain for the telescopic boom (Boom/head; Mech.)			
1. Too frequent cuts and breaks 2. Difficult and demanding maintenance	• Developing a technical data sheet for preventive maintenance and repairs (1, 2)	Short term	Level 3

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PROPOSED IMPROVEMENTS FOR THE DELIMBER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1,2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
3. Tension not maintained because of excessive stretching due to forces resulting from severe impacts	• Initiating a project to design and develop an automatic cable tensioner (2)	Medium term	Level 4
	• Initiating a study to reduce cable maintenance through a judicious choice of cables (in terms of type of materials) in relation to the diameter of the pulleys (1, 2, 3)	Medium term	Level 4
	• Initiating a Research and Development project to reduce the forces inherent in the support rollers and induced in the cables as well as to reduce the noise related to these rollers (1)	Long term	Level 4
1C.8 Cracks in the boom (Boom/head; Mech.)			
1. Lack of adequate knowledge about repair and maintenance	• Developing a technical data sheet for preventive maintenance and repair (1)	Medium term	Level 3
	• Reinforcing the existing material on the machine (2)	Medium term	Level 4
2. Inadequate design (design, material, etc.) for the application	• Carrying out a Research and Development project to develop a lighter and stronger material (2)	Long term	Level 5
3. Lack of design standards	• Carrying out a study to develop a design code and to establish design standards (2, 3, 4)	Long term	Level 5
4. Difficult access to certain intervention zones			
1C.9 Transmission shaft (Hood; Mech.)			
1. Vibration, impact, overloads	• Developing a technical data sheet for repair and maintenance (1, 3)	Short term	Level 3
2. Premature wear (bearings, main bearings, gaskets)	• Developing a tool and verification kit (3)	Medium term	Level 3
3. Poor repair	• Initiating a Research and Development project to design a couple (motor-transmission) that reduces or eliminates the vibrations propagated to the different components connected to the shaft (1, 2, 3, 4)	Long term	Level 4
4. Demanding repair			
1C.10 Hydraulic traction motor (Run. carriage; Hydr.)			
1. Lack of power and not adapted to use on forest terrain	• Increasing the hydraulic power (1,2)	Short term	Level 2

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PROPOSED IMPROVEMENTS FOR THE DELIMBER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
2. Premature wear	• Developing a technical data sheet for maintenance (2, 3, 4,5)	Short term	Level 3
3. Oil contamination	• Developing a system to improve filtration (3)	Medium term	Level 2
4. Inadequate verification and maintenance	• Developing a training program (2, 3, 4, 5)	Medium term	Level 3
5. Oil leaks	• Developing a tool kit for verification and maintenance of the hydraulic circuitry (4)	Medium term	Level 3
1C.11 Pivot hydraulic motor (Hood; Hydr.)			
See causes in 1C.10	• *See recommendations in 1C.10*		
1C.12 Knife cylinder (Head; Mech.)			
1. Lack of protection with respect to the work environment	• Carrying out Research and Development to produce cylinders offering protection against limit of travel overload and withstanding the conditions of the work environment (1)	Long term	Level 4
2. Lack of standards and design code	• Developing a design code (2)	Long term	Level 4
1C.13 Motor (Hood; Mech.)			
1. Lack of preventive and predictive maintenance	• Initiating the practice of using a logbook to ensure that the performance of the motor, its oil consumption, the oil analysis results, overheating and vibration, etc., correspond to the manufacturer's recommendations (1, 2)	Short term	Level 1
2. Lack of power	• Developing a technical data sheet on motor verification and maintenance (1, 3)	Short term	Level 3
3. Lack of mechanical training	• Initiating a training program on motor verifications and maintenance (1, 3)	Medium term	Level 3
4. Difficult access to motor because of the heavy protective plate over it that must be lifted (plate placed under the boom) and the limited space under the hood	• Initiating a motor oil analysis program (1)	Long term	Level 3
	• Initiating a Research and Development program for reviewing the design of the hood-boom-head assembly to facilitate access to the motor (4)	Long term	Level 4

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3 [illegible]

PROPOSED IMPROVEMENTS FOR THE DELIMBER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1C.14 Tilting cylinder (Boom/head; Hydr.)			
See causes in 1C.11	• *See recommendations in 1C.11*		
1C.15 Pivot spider gear reducer (Hood; Mech.)			
1. Presence of debris in the transmission oil	• Developing a technical data sheet on the verification and maintenance of pivot spider gear reducer (1, 2)	Short term	Level 3
2. Oil leaks			
3. Overload	• Developing a Research and Development project for adding a second spider gear reducer to adapt the machine to the specific requirements of forest use (3)	Medium term	Level 4
	• Carrying out a Research and Development project to produce a more powerful spider gear reducer (3)	Long term	Level 5
1C.16 Holding arm (Boom/head; Mech.)			
1. Cracks, breaks, premature wear	• Developing a data sheet for verifications or repairs (1, 2)	Short term	Level 3
2. Difficult maintenance due to the need to climb and the weight of the parts	• Developing a tool kit for easier verification and repair (1, 3)	Medium term	Level 3
3. Lack of tools	• Developing special tools, such as a boring machine, etc., for making certain on-site repairs easier (3)	Medium term	Level 4
4. Inadequate design for the application	• Initiating a project for developing means of access to the higher zones (2)	Medium term	Level 4
5. Overload due to impacts	• Initiating a project for developing means of handling heavy parts (2)	Medium term	Level 4
6. Lack of standards and design code	• Developing a design code that takes into account, among other things, the choice of material and the forces involved (4, 5, 6)	Long term	Level 4

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PROPOSED IMPROVEMENTS FOR THE DELIMBER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1C.17 Support rollers for the telescopic boom (Boom/head; Mech.)			
See causes in 1C.16	• *See recommendations in 1C.16*		
1C.18 Rubber sleeve (Boom/head; Mech.)			
See causes in 1C.16	• *See recommendations in 1C.16*		
1C.19 Knives (Boom/head; Mech.)			
See causes in 1C.16	• *See recommendations in 1C.16*		
1C.20 Idler (Run. carriage; Hydr.)			
1. Inadequate tools for on-site repairs	• Encouraging the workers to plan and carry out major repairs (ex.: boring) in the shop as much as possible (1)	Short term	Level 2
2. Inadequate on-site repairs	• Establishing a data sheet for repairs, welding, boring (1, 2)	Short term	Level 3
3. Maintenance difficult to predict	• Developing a technical data sheet presenting the list of verifications to be carried out (3)	Short term	Level 3
4. Premature wear	• Developing a verification kit that includes thickness and wear gauges (3)	Medium term	Level 3
5. Inadequate design for the application	• Implementing a parts exchange program (4)	Long term	Level 2
	• Developing a training program on repair welding (1)	Long term	Level 3
	• Carrying out Research and Development (choice of material, tooth shape, treatment of materials) for producing new chain wheels and idlers adapted to the application (5)	Long term	Level 5

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PROPOSED IMPROVEMENTS FOR THE DELIMBER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1C.21 Hoses and tubes (Hood; Hydr.)			
1. Lack of identification	• Developing a physical means for rapid identification of hoses (1)	Short term	Level 2
2. Lack of adequate hose protection	• Installing hose protectors (2)	Short term	Level 2
3. Oil leaks	• Producing a data sheet for optimum use of rigid tubes (2, 3, 4)	Medium term	Level 2
4. Crushed and/or worn tubes	• Producing a diagnostic chart (5)	Medium term	Level 2
5. Inadequate repair/modification	• Producing a technical data sheet on the installation and protection of flexible hoses (2)	Medium term	Level 3
6. Lack of technical knowledge (ex.: characteristics of components)	• Developing a training program on hose maintenance and repair (1, 5, 6)	Medium term	Level 3
7. Lack of tools	• Supplying a kit containing jigs and tools for replacing hoses and connections (5, 7)	Medium term	Level 3
8. Inadequate accessibility	• Carrying out Research and Development to create a better hose layout and improve access to them (2)	Medium term	Level 3
9. Design does not conform to needs	• Producing a diagram that illustrates the hydraulic lines, identifies the hoses, connections, and indicates their diameters. These diagrams should be developed by taking into account the different makes of basic machines and heads. (1, 5)	Medium term	Level 3
10. Lack of standards and design code	• Standardizing the type of connections used (1, 5, 8)	Long term	Level 4
	• Developing a design code on the choice and installation of hoses, tubes and connections (10)	Long term	Level 4
1C.22 Bolts under the machine (Chassis; Mech.)			
1. Lack of protection	• Installing a protection kit when the machine is purchased (1)	Short term	Level 2
	• Initiating a project for developing a protection kit integrated into the chassis of the machine.	Medium term	Level 4

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PROPOSED IMPROVEMENTS FOR THE DELIMBER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1C.23 Seat (Cabin; Mech.)			
1. Fatigue and lost time related to an inadequate design 2. Confined space resulting from the presence of the seat during certain maintenance operations on the machine's controls *See also causes in 1C.24*	• Carrying out Research and Development to produce an ergonomic seat adapted to the needs of the operator and not hindering the interventions of maintenance personnel (1, 2) • *See also recommendations in 1C.24*	Long term	Level 5
1C.24 Cabin layout			
1. Lack of space and poor layout 2. Lack of identification on the dashboard (ex.: ground level) 3. Poor access to the control panel (need to remove the seat) for maintenance 4. Inadequate air conditioning, heating 5. Lack of visibility 6. Lack of emergency exits	• Planning for a location for a tool box and an attachment system for rollovers (1) • Adding a position indicator for rotation and uneven ground (2) • Improving the lighting of instruments (2) • Including a hydraulic system condition indicator (2) • Developing means for easier maintenance (2, 3) • Optimizing the space by considering ergonomic criteria (1) • Carrying out Research and Development to produce a new cabin with adequate field of vision, with air conditioning and heating, and with windows that can be used as emergency exits (4, 5, 6) • *See also recommendations in 1C.23*	Short term Short term Medium term Medium term Medium term Long term Long term	Level 2 Level 2 Level 3 Level 3 Level 3 Level 4 Level 5

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PROPOSED IMPROVEMENTS FOR THE DELIMBER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1C.25 Tensioner attachment (Boom/head; Mech.)			
1. Inadequate design for the application 2. The tensioner's threaded rod bending and breaking from fatigue 3. Overload due to impacts 4. Difficult maintenance due to the need for climbing 5. Lack of standards and design code	• Developing a data sheet for repairs or verifications (2, 4) • Initiating a project for developing means of access to the higher zones (4) • Developing a design code that takes into account such things as the choice of material and the forces involved (1, 3, 5)	Short term Medium term Long term	Level 3 Level 4 Level 4
1C.26 Hoses (Boom/head; Hydr.)			
See causes in 1C.21	• *See recommendations in 1C.21*		
1C.27 Running board (Chassis; Mech.)			
1. Operator slips and falls due to lack of antiskid surface on the running board 2. Lack or insufficient number or poor location of running boards 3. High frequency of repair 4. Difficult access to the cabin	• Carrying out research using a multidisciplinary approach which may include the collaboration of engineers (mechanical, structural), ergonomists, mechanics, welders, machine operators and owners, whose mandate will be to study the needs identified (handrail, running board, lighting under the steps, etc.), to develop solutions and to ensure that they are adapted on site (1, 2, 3) • Developing a design code for the machine that takes into account all of the workers' needs (1, 2, 3) • Carrying out a Research and Development project which, while considering cabin reorganization, focuses on improved access and safety (1, 2, 3, 4)	Medium term Long term Long term	Level 4 Level 4 Level 4

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PROPOSED IMPROVEMENTS FOR THE DELIMBER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1C.28 Electrical wiring (Hood; Elec.)			
1. Difficult diagnosis due to lack of identification 2. Lack of standards and design code 3. Defective electrical circuits that cause fires and erratic behavior of the machines 4. Lack of protection against impacts and vibrations 5. Difficult access	• Doing the wiring in conformity with electrical standards and codes, such as SAE J 821a and J 210 (1, 2)	Medium term	Level 3
	• Carrying out a safety analysis on the electrical circuits in order to ensure that failures do not put the workers in danger (example: hydraulic valve activated by short circuit) (3)	Medium term	Level 3
	• Developing a design code for machine wiring consistent with electrical standards and codes and by considering a power supply for lighting distributed over several circuits so that the failure of one does not completely eliminate the lighting (1, 2, 4, 5)	Long term	Level 4
1C.29 Screen guard (Cabin; Mech.)			
1. Branches that remain caught 2. Branches that are jill-poked through the window 3. Windows difficult to clean 4. Reduction in visibility *See also causes in 1C.24*	• Reviewing and modifying present standards to allow screen guards to be replaced with a transparent material such as polycarbonate (1, 2, 3, 4)	Medium term	Level 3
	• Developing (R & D) a new type of cabin with improved visibility and that eliminates the screen guard (1, 2, 3, 4)	Long term	Level 5
	• *See also recommendations in 1C.24*		
1C.30 Cabin frame that cracks (Cabin; Mech.)			
1. Cabin not insulated from the vibrations from the chassis or inadequate means of attachment to the latter 2. Design code lacking or to be revised	• Developing a design code for the cabin structure or, if need be, revising the existing code (1, 2)	Medium term	Level 4
	• Initiating a Research and Development project to design a new cabin structure that takes into account the recommendations formulated in 1C.23, 1C.24, and 1C.29	Long term	Level 4

1 The numbers in the titles refer to the numbers that correspond to the problems listed in order of importance and required intervention priority in Appendix 12C

2 The comments in parentheses in the titles refer to the zone(s) and system(s) involved

3 The numbers in parentheses in each recommendation refer to the specific causes (column 1) to which the recommendation applies

PROPOSED IMPROVEMENTS FOR THE DELIMBER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1,2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1C.31 Starter (Hood; Elec.)			
1. High frequency of breakdown	• Implementing the use of a logbook for recording breakdowns (1)	Short term	Level 1
2. Insufficient power	• Increasing the power (2)	Short term	Level 1
	• Implementing a parts exchange program to ensure constant quality of repairs (1)	Medium term	Level 3
1C.32 Alternator (Hood; Elec.)			
1. Insufficient power	• Carrying out a periodic adjustment of the belts (1)	Short term	Level 2
2. Abnormally high frequency of breakdown	• Carrying out an evaluation of the electrical requirements in order to choose a proper alternator. This information could be disseminated in the form of a technical data sheet. (1)	Medium term	Level 3
	• Developing a technical data sheet on alternator verification and maintenance (2)	Medium term	Level 3
1C.33 Air conditioning (Cabin; Mech.)			
1. Need to leave (or habit of leaving) the cabin door open to reduce discomfort due to heat; consequences: filthier cabin, increased noise level and increased risk level in the event of rollover	• Equipping delimbers with an air conditioning system (1)	Short term	Level 0
	• Establishing reference criteria for choosing an air conditioner appropriate to needs and for determining a proper location that minimizes vibrations and allows good accessibility for maintenance	Medium term	Level 3
1C.34 Lighting (Boom/head; Elec.)			
1. General shutdown of the lighting system when the machine fails	• Providing an emergency lighting system for general shutdown due to failure of the machine (1)	Short term	Level 2

1 The numbers in the titles refer to the numbers that correspond to the problems listed in order of importance and required intervention priority in Appendix 12C

2 The comments in parentheses in the titles refer to the zone(s) and system(s) involved

3 The numbers in parentheses in each recommendation refer to the specific causes (column 1) to which the recommendation applies

4 Short term: < 6 months; medium term: 6 to 24 months; long term: > 24 months

PROPOSED IMPROVEMENTS FOR THE DELIMBER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
2. Loss of distance perception during the night 3. Insufficient lighting of operations from the cabin (ambient lighting) 4. Lack or improper location of supplementary lighting system on the boom and the stick boom, which makes it difficult to see the operations carried out by the delimber	• Designing a lighting system with at least two independent circuits so as to minimize the risk of total loss of lighting in the event of machine failure (1) • Designing new more efficient lighting methods: reflected, movable light, etc. (2, 3, 4) • Initiating a Research and Development project to improve the quality of the ambient lighting and the supplementary lighting (2, 3, 4)	Medium term Medium term Long term	Level 4 Level 4 Level 5
1C.35 Bolts under the machine (Run. carriage; Mech.)			
1. Lack of bolt protection	• Installing a protection kit (1) • Integrating the protection kit into the chassis (development required) (1)	Short term Medium term	Level 0 Level 4
1C.36 Motor oil filter (Hood; Mech.)			
1. Lack of preventive maintenance which results in motor failures 2. Inadequate filter 3. Filter difficult to reach due to the presence of the heavy protective plate above the hood of the motor, which leads to neglected maintenance	• Initiating a motor exchange program (1, 2) • Developing a data sheet on maintenance and choice of filters (1, 2) • Initiating a project for increasing the motor oil filtering capacity (2, 3) • Initiating a Research and Development project to improve access to the components located inside the hood, whose access is made difficult by the presence of the protective plate (3)	Medium term Medium term Long term Medium term	Level 2 Level 3 Level 4 Level 4
1C.37 Handrail (Chassis; Mech.)			
1. Lack or insufficient number or poor location of handrails 2. Operator slips and falls due to the absence of handrails 3. High frequency of repairs 4. Difficult access to the desired locations on the machine	• *See recommendations in 1A.27*		

1 The numbers in the titles refer to the numbers that correspond to the problems listed in order of importance and required intervention priority in Appendix 12C

2 The comments in parentheses in the titles refer to the zone(s) and system(s) involved

3 The numbers in parentheses in each recommendation refer to the specific causes (column 1) to which the recommendation applies

PROPOSED IMPROVEMENTS FOR THE DELIMBER

CAUSES OF BREAKDOWNS, STOPPAGES, ACCIDENTS, ETC. [1, 2]	RECOMMENDATIONS [3]	TIME FRAME [4]	R & D LEVEL
1C.38 Handles (Chassis; Mech.)			
See causes in 1C.37 (replace "handrail" by "handle")	• *See recommendations in 1C.27*		
1C.39 Antiskid surface (Chassis; Mech.)			
See causes in 1C.37 (replace "handrail" by "antiskid surface")	• *See recommendations in 1C.27*		

1 The numbers in the titles refer to the numbers that correspond to the problems listed in order of importance and required intervention priority in Appendix 12C

2 The comments in parentheses in the titles refer to the zone(s) and system(s) involved

3 The numbers in parentheses in each recommendation refer to the specific causes (column 1) to which the recommendation applies

4 Short term: < 6 months; medium term: 6 to 24 months; long term: > 24 months

APPENDIX 2

DEFINITIONS

APPENDIX 2 - DEFINITIONS[1]

Accident
Unplanned dangerous event or series of dangerous events, expected or not, that lead to occupational diseases, injuries, or death.

Adjustment
Activity that consists of physically changing the location parameters, either in rotation or translation, of the components of a machine or a device in order to obtain or reestablish the desired operating reliability and to assure availability.

Aptitude for maintenance
Characteristic of a machine that makes it easy, quick and safe to maintain.

Availability (of a system or machine)
Aptitude of a system or machine to be used with the desired reliability under given conditions and at a given moment. As a corollary, the measure of availability can be defined as the probability, based on the criteria mentioned, that this condition is obtained.

Danger
Circumstance that could lead to injuries to one or more people, or even death.

Design code
Technical and methodological guidelines issued by an association or a group of individuals on the definitions of objects, products, conditions, processes; on the tolerable limit values that apply to them; on acceptable methods for manufacturing, operation, maintenance, and/or use, etc.; and on which internal regulation is based.

Durability
A measure of useful life (a special case of reliability).

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1 For more information on the definitions, refer to the technical references in section 9 of the report.

Electrical system

The components, parts or an assembly of parts other than mechanical and hydraulic ones (valve solenoid, wiring, lighting, dashboard, instruments, control panel, etc.) for driving and controlling mechanical or hydraulic systems, for providing lighting and for ensuring the operation of other accessories necessary for production.

The proper selection of materials and electrical components, as well as interventions on the electrical system, involve a good knowledge of the standards — and the code — covering this particular technical field.

Hydraulic system

The components, parts or assembly of parts other than mechanical and electrical ones (valves, tubes, hoses, hydraulic motor, pumps, etc.) for containing (under pressure or not) a volume of hydraulic oil (circulating or not) that is used to transform, transfer or control the energy contained in the oil or to produce the desired forces.

Material selection (which is carried out by considering not only the ambient conditions and the utilization conditions but also the type and arrangement of the materials) and the selection of the oil used in relation to specific characteristics, are determinant in ensuring that the parts are strong enough to withstand the forces transmitted and the different possible types of ambient aggression (including people), minimize wear due to friction, and ensure that the desired functions are obtained (energy transport, transfer, etc.).

An intervention on the hydraulic system first assumes an ability to understand and visualize not only the operation of the mechanisms but also the magnitude and orientation of the forces in the components of these mechanisms. It also presupposes an ability to understand the effect of these forces on the materials, the effect of the chemical reactions of the materials among themselves, the effect of ambient aggression, and finally, the effect of the interventions — modification, repair, lubrication, etc. — in relation to these conditions. It finally assumes a good knowledge of fluid mechanics in order to be able to evaluate the effect of the operating conditions on the characteristics of the oil used, and vice-versa.

APPENDIX 2 - DEFINITIONS

Incident

An event that could lead to an accident.

Intervention

A general term used in this document as a substitute for the terms *operation*, *maintenance* (verification, adjustment, cleaning, oil change, lubrication, etc.) and *repair*.

Logbook

A document describing any event (incident, accident), intervention (repair, maintenance, etc.), related to the operation, maintenance, and in general, safe use of the machine.

Machine-zone

A restricted space, inside or outside the machine, which contains assemblies, that is, elements (parts, components) belonging to the *mechanical, hydraulic, electrical* and *safety-protection* systems (Refer to these definitions). Specific risks are associated with each machine-zone.

The feller has 6 zones, namely: the hood, chassis, running carriage, cabin, boom, and head. Grapple and cable skidders consist of 5 zones: the hood, chassis, cabin, running carriage, and the boom and grapple in one case, or the boom and winch in the other. The delimber is divided into 5 zones: the hood, cabin, running carriage, chassis, and the boom and head which are combined into one zone.

Maintainability

The ease with which a part, a group of parts, a system or a piece of equipment is returned to operating condition when repair and maintenance activities are carried out according to preestablished procedures with the human and material resources prescribed. As a corollary, the measure of maintainability can be defined as the probability, on the basis of the criteria mentioned, that this operating condition is obtained in a given time.

APPENDIX 2 - DEFINITIONS

Maintenance

A general term that designates all the actions carried out or to be carried out on a machine to increase its reliability, and therefore its availability. Maintenance includes repair, verification, adjustment, cleaning, tool changing, sharpening and lubrication activities.

Maintenance management

This includes all of the actions that allow a product (system, machine) to be maintained in, or returned to, a specified condition or to be capable of providing a specified service, in terms of quantity and quality, in a given time. As a corollary, maintenance is all of the actions that allow the desired reliability and maintainability of a product or a service rendered to be sustained.

Maintenance is divided into two major categories: preventive maintenance and corrective maintenance.

Mechanical system

The components, parts, or assembly of parts other than hydraulic and electrical ones, for producing, transmitting and transforming movement, torque, speed or work (ex.: frame, motor, gears, etc.).

Material selection (carried out by taking into account the ambient and utilization conditions) as well as the shape and arrangement of the materials are determinant in ensuring that the parts are strong enough to withstand the forces transmitted and the different possible types of ambient aggression (including people), as well as minimize wear due to friction.

An intervention on the mechanical system assumes an ability to understand and visualize the operation of the mechanisms as well as to understand the magnitude and orientation of the forces in the components of these mechanisms. It also assumes the ability to understand the effect of these forces on the materials, the effect of the chemical reactions of the materials between themselves, the effect of ambient aggression, and finally, the effect of the interventions — modification, repair, lubrication, etc. — in relation to these conditions.

APPENDIX 2 - DEFINITIONS

Modification

An activity carried out by one or more people which consists of changing or modifying the physical condition of certain parts of a machine in order to increase its reliability, availability, maintainability, efficiency, safety or other characteristics.

Operability

The ease with which a piece of equipment's operating actions produce the desired and prescribed effects, when these actions have been carried out by taking into account the quality of the information supplied, and without causing risks of accidents or the development of occupational diseases over the long term. As a corollary, the measure of operability can be defined as being the probability, based on the criteria mentioned, that the expected results of these operating actions are obtained in a given time.

Part of system or assembly

A combination of elements, parts, components, etc., found in a machine-zone and making up a given system. There are mechanical, hydraulic, electrical and safety-protection assemblies. These assemblies require special interventions that produce specific risks.

Predictive maintenance

Predictive maintenance is essentially conditional (dependent on the information that one has about the condition of a part or the system). It allows the predicted maintenance operations to be readjusted by assessing the evolution in the dysfunction detected as well as the time during which the equipment can continue to be used before breakdown.

Preventive maintenance

This is the maintenance that is carried out before failure and according to predetermined criteria (systematically in relation to the hours worked or the units produced), for the purpose of reducing the probability of a product failing or a service deteriorating.

Preventive maintenance may also be predictive.

APPENDIX 2 - DEFINITIONS

Production system

A group of procedures, methods, people, machines and tools, products, environments and environmental conditions, interrelated by certain rules to create a collective unit for the purpose of production.

Reliability

The probability that a piece of equipment or a machine will operate correctly for a given time and under specific utilization conditions.

Repair

An activity carried out by one or more people which consists of changing or modifying the physical condition of certain parts of a machine in order to reestablish its reliability, and therefore its availability.

Risk

An expression for the presence or possible presence of a dangerous event, defined in terms of seriousness and probability of occurrence.

Safety

In this document, safety means the absence of danger.

Safety and protection system

Elements, parts, or an assembly of parts for the purpose of warning the operator and protecting him from present, imminent or possible danger (ex.: alarm, extinguisher, etc.).

Safety device

A device that prevents a dangerous phase in the operation of a mechanism from being initiated or continuing when and as long as the presence of a person (or a part of his body) is detected or simply possible in the dangerous zone.

Standards

These are technical guidelines issued by official standardization organizations such as the BNQ, CSA, ANSI, NFPA, on definitions of objects, products, processes, acceptable limit values, etc., and on which legislation and regulations are based. This category also includes draft standards.

System

A combination or organized assembly of parts, elements, components, pieces of equipment, etc., intended for generating and transmitting the required energy for performing one or more desired functions. Machines are divided into four systems: *mechanical, hydraulic, electrical* and *safety-protection* systems.

System performance assurance

The capability of a system to satisfy *correctly* — that is, without failure and according to specific parameters (the physical integrity of individuals, operational modes, speed, pace, quality of the product and the environment, etc.) — one or more required functions under given *conditions of use*, at the *required time*, and *for the entire time necessary* to achieve the goal.

Technical data sheet

A document (illustrated or not) generally presented in the form of separate sheets, in pamphlet form, that provides a summary description of the technical data on products, industrial processes, methods, etc.

Verification

An activity whose purpose is to determine the availability of the components of a machine. This activity may require the use of tools or instruments.

APPENDIX 3

CLASSIFICATION OF MACHINES BY ZONES AND SYSTEMS

APPENDIX 3.1

CHARACTERISTICS OF MACHINE ZONES AND SYSTEMS

APPENDIX 3.1A

FELLER ZONES AND SYSTEMS

APPENDIX 3.1A

Table 1A: Characteristics of the feller zones

ZONE CHARACTERISTICS					
HOOD	**CABIN**	**CHASSIS**	**RUNNING CARRIAGE**	**BOOM**	**HEAD**
• Presence of: - gas, fuel - hot glycol - hot oil - oil leaks - intense heat • Limited space	• Heavy parts • Fragile parts • Parts sensitive to vibration • Limited space • Inadequate layout	• Heavy parts • Presence of debris, oil, grease • Difficult access • Difficult work	• Numerous parts • Heavy parts • Difficult access • Need to crawl in mud	• Heavy parts • Height > 2m • Need to climb • Frequent interventions	• Heavy parts • Difficult to manipulate • No need to climb

APPENDIX 3.1A

Table 2A: Content of the zones and systems of a feller on lugs

SYSTEM	HOOD	CABIN	BOOM	HEAD	RUNNING CARRIAGE	CHASSIS
MECHANICAL	• Diesel motor • Radiator • Transmission • Gear reducer • Injection pump • Exhaust • Fan • Clutch • Fuel tank • Muffler • Pivot spider gear reducers	• Seat • Air conditioning • Heater • Rollover protection • Door, windows • Screen guard • Control lever • Control pedal • Tool box • Emergency exit	• Main boom • Stick boom • Pivots • Pins • Journal bearing • Greasing system • Hydraulic tube protector • Connections	• Saw or knives • Structural frame • Gear reducer • Journal bearing, pins • Arm	• Profiled lugs • Bearing support • Cam follower • Track pads, pins • Tension wheel • Spring • Carriage drive reducer • Chain guard • Traction chain wheel • Idler	• Upper frame • Lower frame • Pivot support • Journal bearing • Leveling table • Protection kit • Pins, journal bearings • Counterweight • Bracket for main boom • Running board • Handrail
HYDRAULIC	• Valves, pumps • Hydraulic tank • Cooler • Hoses/tubes • Torque converter [1]		• Cylinders • Hoses, tubes	• Cylinders • Hoses • Hydraulic motor	• Hydraulic motor • Hoses, tubes • Brakes	• Leveling cylinder • Hoses, tubes • Pivot
ELECTRICAL	• Wiring • Lighting • Valve solenoid • Alternator • Starter	• Dashboard • Control panel • Instruments, switch • Lighting	• Wiring • Lighting			
SAFETY-PROTECTION	• Fire extinguishing system (automatic or manual)	• Soundproofing • Alarm • Fire extinguisher • Locking				

[1] The torque converter includes the gear reducer and the hydraulic pumps

APPENDIX 3.1B

SKIDDER ZONES AND SYSTEMS

APPENDIX 3.1B

Table 1B: Characteristics of skidder zones

ZONE CHARACTERISTICS					
HOOD	**CABIN**	**BOOM/WINCH**	**BOOM/GRAPPLE**	**RUNNING CARRIAGE**	**CHASSIS**
• Limited space • Need to climb • Unstable working posture • Difficult maintenance	• Heavy parts • Fragile parts • Parts sensitive to vibration • Limited space • Inadequate layout • Difficult access	• Very frequent interventions involving the cables and slings	• Heavy parts • Difficult access • Difficult maintenance • Difficult maintenance posture	• Heavy parts • Need to raise and support the machine (the weight of the machine: an important factor to consider before maintenance)	• Heavy parts • Need to raise and support the machine • Need to crawl under the machine • Work in mud, debris

APPENDIX 3.1B

Table 2B: Content of the zones and systems of a grapple skidder

SYSTEM	HOOD	CABIN	BOOM/GRAPPLE	RUNNING CARRIAGE	CHASSIS
MECHANICAL	• Diesel motor • Radiator • Exhaust • Fan • Clutch • Torque converter • *Muffler*	• Seat • Heater • Door • Screen guard, window • Control lever • Control pedal • Tool box • Steering wheel • Rollover protection • Shrub guard	• Frame • Pivot, journal bearing, pin • Grapple arm (grapple) • Lubrication system • Main boom bracket • Main boom pin	• Tires, chains • Brakes, wheel rim • Gear reducer (spider gear) • Greasing system	• Drive shaft • Front and rear frame • Sleeve • Fixed, articulated axles • Differential • Universal joint • Fuel tank • Journal bearing, grapple, blade • Counterweight • Means of access • Protection kit
HYDRAULIC	• Valves, pumps • Tank • Hoses/tubes • Torque converter[1]		• Hydraulic motor • Hoses, tubes • Swivel joint • Cylinder	• Hoses, tubes (brake)	• Cylinder, valves • Pump, oil tank • Hoses, tubes
ELECTRICAL	• *Alternator* • Wiring • Lighting • Valve solenoid • Starter	• Dashboard • Instruments • Lighting • Switch			• Lighting
SAFETY-PROTECTION	• Extinguisher (automatic or manual)	• Extinguisher • Locking mechanism • Alarm			

[1] The torque converter includes the gear reducer and the hydraulic pumps

APPENDIX 3.1B

Table 3B: Content of the zones and systems of a cable skidder

SYSTEM	HOOD	CABIN	BOOM/WINCH	RUNNING CARRIAGE	CHASSIS
MECHANICAL	• Diesel motor • Radiator • Exhaust • Fan • Clutch • Muffler	• Seat • Heater • Rollover protection • Door, screen guard, window • Control lever • Control pedal • Tool box • Steering wheel • Shrub guard	• Winch • Cable • Slings • Rollers • Rear bumper • Drum • Gear reducer • Frame • Boom • Brake • Cable guide	• Tires, chains • Brakes, wheel rim • Gear reducer (spider gear) • Greasing system	• Drive shaft • Front and rear frame • Sleeve • Fixed, articulated axles • Differential • Universal joint • Fuel tank • Journal bearing, grapple, blade • Counterweight • Means of access • Protection kit
HYDRAULIC	• Valves, pumps • Tank • Hoses/tubes • Torque converter[1]		• Hoses, tubes • Hydraulic motor	• Hoses, tubes (brake)	• Cylinder, valves • Pump, oil tank • Hoses, tubes
ELECTRICAL	• Alternator • Wiring • Lighting • Valve solenoid • Starter	• Dashboard • Instruments • Lighting			• Lighting
SAFETY-PROTECTION	• Extinguisher (automatic or manual)	• Extinguisher • Locking • Alarm			

[1] The torque converter includes the gear reducer and the hydraulic pumps

APPENDIX 3.1C

DELIMBER ZONES AND SYSTEMS

APPENDIX 3.1C

Table 1C: Characteristics of delimber zones

ZONE CHARACTERISTICS				
HOOD	**CABIN**	**CHASSIS**	**RUNNING CARRIAGE**	**BOOM/HEAD**
• Presence of: - gas, fuel - hot glycol - hot oil - oil leaks - intense heat • Limited space	• Heavy parts • Fragile parts • Parts sensitive to vibration • Limited space	• Heavy parts • Presence of debris, oil, grease • Difficult access • Difficult work	• Numerous parts • Heavy parts • Difficult access • Need to crawl in mud	• Heavy parts • Presence of oil and grease • Need to climb (height > 2 metres) • Frequent interventions

APPENDIX 3.1C

Table 2C: Content of the zones and systems of a delimber on lugs

SYSTEM	HOOD	CABIN	BOOM/HEAD	RUNNING CARRIAGE	CHASSIS
MECHANICAL	• Diesel motor • Radiator • Transmission • Gear reducer • Injection pump • Exhaust • Fan • Clutch • Fuel tank • Muffler • Pivot spider gear	• Seat • Air conditioning • Heater • Rollover protection • Door, windows • Screen guard • Control lever • Control pedal • Tool box • Emergency door	• Fixed frame (main boom) • Sliding frame (telescopic boom) • Carriage, journal bearing • Chains, cables, pivot, tail end of boom • Saw or knife (delimbing) • Butting saw • Grapple, holding arm • Greasing system • Tracks, bearings, rollers • Gear, cable tensioner	• Profiled lugs • Bearing bracket • Cam followers • Pads, pins • Tension wheel • Spring • Carriage drive reducer • Chain guard • Sprocket • Idler	• Upper frame • Lower frame • Pivot support • Journal bearing • Leveling table • Protection kit • Pins, journal bearings • Counterweights • Support for main boom • Running board • Handrail
HYDRAULIC	• Valves, pumps • Hydraulic tank • Cooler Hoses/tubes • Torque converter[1]		• Cylinders, hoses, tubes • Hydraulic motor, valves	• Hydraulic motor • Hoses, tubes • Brakes	• Leveling cylinder • Hoses, tubes • Pivot
ELECTRICAL	• Wiring • Lighting • Valve solenoid • Alternator • Starter	• Dashboard • Control panel • Instruments, switch • Lighting	• Lighting, cables (conductors) • Solenoid, insulated pulleys, electrical wires		
SAFETY PROTECTION	• Extinguishing system (automatic or manual)	• Soundproofing • Alarm • Extinguisher • Locking			

[1] The torque converter includes the gear reducer and the hydraulic pumps

APPENDIX 4

RISK EVALUATION FACTORS

APPENDIX 4 - RISK EVALUATION FACTORS

Table 1 - Risk evaluation: factors related to task characteristics

Factor	Evaluation scale
Local accessibility	0 - Easy access 1 - Slightly difficult access 2 - Difficult access
Weight of the part	0 - Less than 10 lbs 1 - From 10 to 50 lbs 2 - More than 50 lbs
Need to climb	0 - No climbing required 1 - Up to 2 metres 2 - More than 2 metres
Need to crawl	0 - No crawling required 1 - Slight difficulty at less than 2 metres 2 - Confined space at more than 2 metres
Teamwork	0 - One person 1 - Two people 2 - Three people
Difficulty carrying out the intervention during the night	0 - Not difficult 1 - Somewhat difficult 2 - Very difficult

APPENDIX 4 - RISK EVALUATION FACTORS

Table 2 - Factors related to the frequency and duration of the interventions as well as to the characteristics of the machine parts

Factor	Evaluation scale
Breakdown frequency	0 - Infrequent (0 to 1 time/year) 1 - Somewhat frequent (2 to 5 times/year) 2 - Frequent (more than 5 times/year)
Fragility of the part to impact and dust	0 - Part neither fragile nor sensitive 1 - Fragile or sensitive part 2 - Fragile and sensitive part
Impact of the breakdown on production	0 - Production volume is not reduced 1 - Production volume is reduced 2 - Stoppage of production
Experience and competence necessary for the intervention	0 - None or less than 2 years of experience 1 - From 2 to 5 years 2 - More than 5 years
Preparation time necessary before carrying out the intervention	0 - None 1 - 16 hours or less 2 - More than 16 hours
Repair time	0 - Less than 2 hours 1 - From 2 to 8 hours 2 - More than 8 hours
Repair costs	0 - Less than $1000 1 - From $1000 to $5000 2 - More than $5000
Need to use tools	0 - No tools or equipment required 1 - Light, simple, inexpensive tool or equipment 2 - Expensive, heavy, complex tool or equipment
Sensitivity of the part to the operation	0 - No sensitivity 1 - May become sensitive 2 - Very sensitive
Maintenance frequency	0 - Less than once a week 1 - Between once a week and once a day 2 - More than once a day

APPENDIX 5

RESEARCH AND DEVELOPMENT LEVELS AND STRATEGY

APPENDIX 12C - DELIMBER

Table 3: List of problems by priority class for the delimber

High Priority (Zone; System)	Average Priority (Zone; System)	Low Priority (Zone; System)
C.1 Fire (Ho; S/P)	C.6 Traction chain wheel (RC; M)	C.28 Electrical wiring (Ho; E)
C.2 Machine that overheats (Ho; M)	C.7 Cable (B, He; M)	C.29 Eliminating screen guard (Ca; M)
C.3 Hydraulic motor (B, He; H)	C.8 Head that cracks (B, He; M)	C.30 Cabin frame that cracks (Ca; M)
C.4 Spider gear reducer (RC; M)	C.9 Drive shaft (Ho; M)	C.31 Starter (Ho; E)
C.5 Chain (B, He; M)	C.10 Hydraulic traction motor (RC; H)	C.32 Alternator (Ho; E)
	C.11 Hydraulic pivot motor (Ho; H)	C.33 Air conditioner (Ca; M)
	C.12 Knife cylinder (B, He; H)	C.34 Lighting (B, He; E)
	C.13 Motor (Ho; M)	C.35 Bolts under the machine (RC; M)
	C.14 Tilting cylinder (B, He; H)	C.36 Filter (Ho; M)
	C.15 Pivot spider gear reducer (Ho; M)	C.37 Handrail (Ch; M)
	C.16 Holding arms (B, He; M)	C.38 Handles (Ch; M)
	C.17 Telescopic roller bearing (B, He; M)	C.40 Antiskid surface (Ch; M)
	C.18 Bearing (B, He; M)	
	C.19 Knives (B, He; M)	
	C.20 Idler (RC; M)	
	C.21 Hoses, tubes (Ho; H)	
	C.22 Underside of chassis (Ch; M)	
	C.23 Seat (Ca; M)	
	C.24 Layout (Ca; M)	
	C.25 Fastener (B, He; M)	
	C.26 Hoses (B, He; H)	
	C.27 Running board (Ch; M)	

Zone: Ho: Hood, Ch: Chassis, RC: Running carriage, B: Boom, He: Head, Ca: Cabin
System: S/P: Safety/Protection, M: Mechanical, H: Hydraulic, E: Electrical

APPENDIX 12C

LIST OF DELIMBER PROBLEMS

APPENDIX 12B - SKIDDER

Table 2 (continued): List of problems by priority class for cable and grapple skidders

High Priority (Zone; System)	Average Priority (Zone; System)	Low Priority (Zone; System)
	(Continued from previous page)	
	B.24 Grapple (Ch; M)	
	B.25 Underside breakdown (Ch; M)	
	B.26 Layout (Ca; M)	
	B.27 Water pump (Ho; M)	
	B.28 Oil leak (Ho; M)	
	B.29 Widening (Ch; M)	
	B.30 Lengthening (Ch; M)	
	B.31 Fan (Ho; M)	
	B.32 Universal joint (Ch; M)	
	B.33 Sleeve (Ch; M)	

Zone: Ho: Hood, Ch: Chassis, RC: Running carriage, B: Boom, He: Head, Ca: Cabin

APPENDIX 12B - SKIDDER

Table 2: List of problems by priority class for cable and grapple skidders

High Priority (Zone; System)	Average Priority (Zone; System)	Low priority (Zone; System)
B.1 Transmission (Ch; M)	B.6 Tire (RC; M)	B.34 Screen guard (Ca; M)
B.2 Drive shaft (Ch; M)	B.7 Spider gear reducer (RC; M)	B.35 Cable, slings (B, He; M)
B.3 Axles (Ch; M)	B.8 Chain (RC; M)	B.36 Starter (Ho; E)
B.4 Brake (RC; M)	B.9 Main boom bracket (B; M)	B.37 Alternator (Ho; E)
B.5 Differential (Ch; M)	B.10 Boom pin (B; M)	B.38 Running board, step (Ch; M)
	B.11 Grapple pin (B; M)	B.39 Handles (Ch; M)
	B.12 Arch cylinder (B; M)	B.40 Hoses (Ch; H)
	B.13 Winch (B, He; M)	B.41 Central pin (Ch; M)
	B.14 End shaft and journal bearing support (Ch; M)	B.42 Doors and windows (Ca; M)
	B.15 Steering cylinder (Ch; H)	B.43 Lighting (Ch; E)
	B.16 Seat (Ca; M)	B.44 Fenders (Ch; M)
	B.17 Valve gasket (Ho; H)	B.45 Handles (Ch; M)
	B.18 Injection pump (Ho; M)	B.46 Filter (Ho; M)
	B.19 Hydraulic pump (Ho; H)	
	B.20 Gasket (RC; M)	
	B.21 Drive shaft (B, He; M)	
	B.22 Emergency brake protector (Ca; M)	
	B.23 Brake cylinder (RC; H)	

(Continued on following page)

Zone: Ho: Hood, Ch: Chassis, RC: Running carriage, B: Boom, He: Head, Ca: Cabin
System: S/P: Safety/Protection, M: Mechanical, H: Hydraulic, E: Electrical

APPENDIX 12B

LIST OF SKIDDER PROBLEMS

APPENDIX 12A - FELLER

Table 1: List of problems by priority class for the feller

High Priority (Zone; System)	Average Priority (Zone; System)	Low Priority (Zone; System)
A.1 Machine that catches fire (Ho; All systems)	A.11 Tilting cylinder (B; H)	A.34 Torque converter (Ho; H)
A.2 Upper frame that cracks (Ch; M)	A.12 Sprocket (RC; M)	A.35 Emergency exit (Ca; M)
A.3 Machine that overheats (Ho; M)	A.13 Large bearing and ring gear Ch; M)	A.36 Screen guard (Ca; M)
A.4 Boom (main boom, stick boom) that cracks (B; M)	A.14 Hydraulic traction motor (RC; H)	A.37 Starter (Ho; E)
A.5 Track spider gear reducer (RC; M)	A.15 Boom cylinder (B; H)	A.38 Hydraulic oil tank (Ho; H)
A.6 Swivel joint (Ch; H)	A.16 Hydraulic pivot motor (Ho; H)	A.39 Track pin (RC; M)
A.7 Hydraulic valves (Ho; H)	A.17 Saw shaft bearing (He; M)	A.40 Lighting (B; E)
A.8 Boom cylinder (B; H)	A.18 Track pads (RC; M)	A.41 Alternator (Ho; E)
A.9 Motor head, valve, turbo (Ho; M)	A.19 Knives (He; M)	A.42 Air conditioning (Ca; M)
A.10 Hydraulic pump (Ho; H)	A.20 Track cylinder (RC; H)	A.43 Pivot spider gear reducer (Ho; M)
	A.21 Main boom (B; M)	A.44 Boom hoses (B; H)
	A.22 Idler (RC; M)	A.45 Track lugs (RC; M)
	A.23 Leveling switch (Ca; E)	A.46 Traction hoses (RC; H)
	A.24 Hoses, tubes (Ho; H)	A.47 Chain guard (RC; M)
	A.25 Oil cooler (Ho; H)	A.48 Bolts under the cabin (RC; M)
	A.26 Hydraulic saw motor (He; H)	A.49 Handles (Ch; M)
	A.27 Seat (Ca; M)	A.50 Antiskid surface (Ch; M)
	A.28 Cabin layout (Ca; M)	
	A.29 Saw teeth (He; M)	
	A.30 Stem buncher (He; M)	
	A.31 Leveling cylinder (Ch; H)	
	A.32 Track (RC; M)	
	A.33 Running board (Ch; M)	

Zone: Ho: Hood, Ch: Chassis, RC: Running carriage, B: Boom, He: Head, Ca: Cabin
System: S/P: Safety/Protection, M: Mechanical, H: Hydraulic, E: Electrical

APPENDIX 12A

LIST OF FELLER PROBLEMS

APPENDIX 12

LIST OF PROBLEMS RANKED IN ORDER OF IMPORTANCE

APPENDIX 11

Table 1: List of Quebec innovations involving the skidder

1. Recovery grapple for trees that are dropped on the road (installed on the side of the blade)

2. «DÉROUL-MATIQUE» automatic cable unwinder

3. Lifting door (door that acts as an elevator for getting on and off the machine)

4. Automatic sling detacher

APPENDIX 11

LIST OF QUEBEC INNOVATIONS TO BE CONSIDERED

APPENDIX 10C

Table 3: Modifications suggested by the workers for the delimber

Zone	System	Suggested modifications
Cabin	Mechanical	• Eliminating the screen guard and replacing the glazing with safety glazing • Improving the seat quality • Providing soundproofing • Adding air conditioning • Improving the interior layout • Optimizing the location of pedals and controls • Installing rearview mirrors
Chassis	Mechanical	• Installing stabilizers • Reducing the space between the steps • Adding an antiskid surface
	Electrical	• Installing a lighting system under the steps
Boom/Head	Hydraulic	• Improving the reliability of the knife cylinders
	Electrical	• Improving the lighting
Hood	Electrical	• Improving the lighting

APPENDIX 10C

MODIFICATIONS SUGGESTED FOR DELIMBERS

APPENDIX 10B

Table 2: Modifications suggested by the workers for cable and grapple skidders

Zone	System	Suggested modifications
Cabin	Mechanical	• Improving the seat quality • Improving the cabin layout • Installing rearview mirrors[1] • Changing the location of the seat[1]
Chassis	Mechanical	• Adding a running board • Adding a handle • Adding a retractable telescopic step • Improving stability by widening and lengthening the chassis of the machine • Sealing the underside of the machine • Improving the quality of the point of articulation
	Electrical	• Installing a lighting system under the steps
Hood	Electrical	• Improving the lighting level
	Mechanical	• Installing a hose for draining the oil
Boom/Winch	Mechanical	• Improving the quality of the cables and slings
Boom/Grapple	Mechanical	• Adding a shock absorber on grapple (grapple brake) • Adding an automatic chain tensioner[1]
Running carriage	Mechanical	• Improving the brake system

[1] Suggested modification in the case of a cable skidder to which a grapple was added

APPENDIX 10B

MODIFICATIONS SUGGESTED FOR SKIDDERS

APPENDIX 10A

Table 1: Modifications suggested by the workers for the feller

Zone	System	Suggested modifications
Cabin	Mechanical	• Improving the seat quality • Improving the soundproofing • Providing air conditioning • Improving the interior layout • Increasing the number of emergency exits • Eliminating the screen guard and replacing the glazing with a safety glazing • Attaching the tool box in an appropriate location
Hood	Hydraulic	• Reducing the noise from the hydraulic pump • Improving the cooling system
Chassis	Mechanical	• Reducing the space between the steps • Adding an antiskid surface
	Electrical	• Installing a lighting system under the steps
Boom	Electrical	• Adding adequate lighting to the working area
Traction train	Mechanical	• Improving the mechanical bearing system
	Hydraulic	• Improving the hydraulic traction system

APPENDIX 10A

MODIFICATIONS SUGGESTED FOR FELLERS

APPENDIX 10

LIST OF MODIFICATIONS SUGGESTED FOR FELLERS, SKIDDERS AND DELIMBERS

APPENDIX 9C

Table 4: Types of reported modifications carried out on delimbers

Zone	System	Modifications	Type
Hood	Hydraulic	• Installed a system for raising the protective plate above the motor	M P S
	Safety/Protection	• Installed an automatic extinguisher	P S
	Electrical	• Improved the lighting	R P S
Cabin	Mechanical	• Installed air conditioning	P S
		• Improved the lighting adjustment	P S
		• Installed a handrail on the roof	S
	Electrical	• Installed a "joy stick"	P S
	Safety/Protection	• Installed an extinguisher	P S
Boom/Head	Mechanical	• Made cable replacement easier	M P S
		• Reinforced the head	R P S
		• Modified the shape of the grapple arm	P R
		• Shortened the chain and removed a tensioner	R M P S
	Electrical	• Installed 24-volt bulbs	R P S
Chassis	Hydraulic	• Installed a stabilizer cylinder	P S
	Mechanical	• Installed an antiskid surface	S
		• Installed a movable boom to lift heavy parts	M S
		• Added stabilizers	P S
		• Installed running boards	P S
		• Installed handles	P S
		• Installed a platform	M P S
		• Reinforced the underpart of the carriage	R P

[1] R: Increasing the reliability of the machine
P: Increasing production
M: Making maintenance and repair easier
S: Making the operator's work easier and increasing his safety
Modifications of types R, P, M may have an impact on worker safety.

APPENDIX 9C

REPORTED MODIFICATIONS CARRIED OUT ON DELIMBERS

APPENDIX 9B

Table 3: Types of reported modifications carried out on skidders

Zone	System	Modifications	Type
Hood	Mechanical	• Increased the power of the motor	P R
		• Increased the power of the transmission	P R
	Hydraulic	• Combined the operation of the blade and blade grapple	P S
	Electrical	• Increased the power of the alternator	P R
Cabin	Mechanical	• Installed doors and windows	S
		• Installed a screen guard	S
		• Installed a seat and suspension	P S
		• Installed an emergency brake protector	S
Boom/ grapple, Boom/winch	Mechanical	• Installed a blade grapple	P S
		• Installed a system to prevent the slings from tangling	P S
		• Installed a rear cylinder protector	R P
Chassis	Mechanical	• Installed a blade grapple	P S
		• Installed a rear exit	P S
		• Improved access to the cabin	P S
		• Added a step to the access running board	P S
		• Installed a running board on the blade	P M S
		• Improved the machine's stability	R P S
		• Installed fenders	S
		• Widened the running board	P S
		• Improved access to the steering cylinder	M P
		• Reinforced the underside of the machine	R P
		• Installed handles	P S
	Hydraulic	• Installed a hydraulic cable cutter	P M S
	Electrical	• Installed lights	P S
Running carriage	Mechanical	• Reinforced the differential, drive shaft and the axles	P R

[1] R: Increasing the reliability of the machine
P: Increasing production
M: Making maintenance and repair easier
S: Making the operator's work easier and increasing his safety
Modifications of types R, P, M may also have an impact on worker safety.

APPENDIX 9B

REPORTED MODIFICATIONS CARRIED OUT ON SKIDDERS

APPENDIX 9A

Table 2: Types of reported modifications carried out on fellers in the boom, head and running carriage zones

Zone	System	Modifications	Type
Boom	Mechanical	• Rebuilt the main boom	R P S
		• Reinforced the stick boom	R P S
		• Installed a hose protector	R P
	Hydraulic	• Attached the hoses and connections to prevent wear by friction	R P
Head	Mechanical	• Installed an inserted-teeth saw	R P
		• Installed pads under the saw	R P S
		• Installed a stem buncher	P
	Hydraulic	• Installed a tree buncher cylinder (and hoses)	P
Running carriage	Mechanical	• Welded lugs on the track	R P S
		• Changed the traction chains	R P S
		• Installed chains to hold the track	R P S
	Hydraulic	• Changed the hydraulic traction motor	R P

[1] R: Increasing the reliability of the machine
P: Increasing production
M: Making maintenance and repair easier
S: Making the operator's work easier and increasing his safety
Modifications of types R, P, M may also have an impact on worker safety.

APPENDIX 9A

Table 1: Types of reported modifications carried out on fellers for the hood, cabin and chassis zones

Zone	System	Modifications	Type [1]
Hood	Mechanical	• Increased the power of the motor	R P
		• Increased the radiator capacity	R P
		• Moved the exhaust pipe from the compartment to the outside	R P
		• Enlarged the fuel tank	P
		• Enlarged the hood	M R P S
		• Changed the location of the radiator	R P
		• Enlarged the motor panel to create a platform	S
	Hydraulic	• Increased the power of the cooling system	R P
		• Changed the modular valves	R P
		• Installed a second cooling system	R P
	Electrical	• Increased the number of electrical circuits for lighting	R P S
	Safety/ Protection	• Installed a fire barrier between the motor and the hydraulic hoses	R M S
Cabin	Mechanical	• Replaced the seat	P S
		• Eliminated the screen guard	S
		• Installed an emergency exit	S
	Electrical	• Changed the location of the stabilizer adjustment handles	S
Chassis	Mechanical	• Installed leveling stabilizers	P S
		• Installed a system above the cabin for lifting heavy parts	M P S
		• Installed handles	P S
		• Installed a running board	P S
		• Reinforced the underside of the machine	R P
		• Improved access to the cabin	P S
		• Installed an antiskid surface	P S
		• Removed the counterweight	R
		• Protected the bolts under the machine	R P
	Hydraulic	• Changed the leveling cylinder	S P

[1] R: Increasing the reliability of the machine
P: Increasing production
M: Making maintenance and repair easier
S: Making the operator's work easier and increasing his safety
Modifications of types R, P, M may also have an impact on worker safety.

APPENDIX 9A

REPORTED MODIFICATIONS CARRIED OUT ON FELLERS

APPENDIX 9

LIST OF REPORTED MODIFICATIONS CARRIED OUT ON FELLERS, SKIDDERS AND DELIMBERS

APPENDIX 8C

Table 5: Breakdowns reported on delimbers one or more times per season

Zone	System	Types of breakdowns (approximate frequency; duration of repair) [1]
Hood	Hydraulic	Hose and pipe (12t/y; --) [1] Pivot hydraulic motor (3-4t/y; 4 h - 1w)
	Mechanical	Pivot spider gear reducer (1t/y; 3-4 h) Filter (150 h; --) Drive shaft (1t/y; 7 h) Machine that overheats (2t/m; --) Motor (4 000 h; --)
	Electrical	Starter (1-2t/y; --) Alternator (1-2t/y; --) Electrical wiring (1-6t/y; --)
	Safety/Protection	Fire
Cabin	Mechanical	Cabin frame that cracks (1t/y; --)
Running carriage	Hydraulic	Hydraulic track motor (1 000 - 5 000 h; --)
	Mechanical	Traction chain wheel (4 000 - 9 000 h; --) Spider gear reducer (1t/y; --) Bolts under the machine (4t/y; 8 h) Idler (1t/y; --)
Boom and head	Hydraulic	Knife cylinder (2-6t/y; --) Hose (2-6t/y; --) Tilting cylinder (1t/m; 1 d) Hydraulic motor (1 000 - 6 000 h; 1/2 h)
	Mechanical	Chain (3 500 - 6 000 h; 2-7 h) Sleeve (4-5t/m; --) Cable (1 000 h; 7 h) Grapple (4-5m; --) Break in the boom (4 000 h; --) Changing the knives (4t/y; --) Tensioner (1t/6m; 2 h) Telescopic boom roller bearing (1t/6-12m; 1 h)

[1] (Frequency; duration): when the value of a parameter is unknown, it is replaced by "--"

APPENDIX 8C

BREAKDOWNS REPORTED ON DELIMBERS

APPENDIX 8B

Table 4: Breakdowns reported on grapple skidders

Zone	System	Types of breakdowns (approximate frequency; duration of repair) [1]
Hood	Hydraulic	Hydraulic pump (2 185 h) [1]
	Mechanical	Motor (2 762 h) Motor's injection pump (1 196 h)
Chassis	Mechanical	Differential (3 303 h) Articulation drive shaft and joint (1 019 h) Central pins (2 664 h)
	Hydraulic	Steering cylinder (2 664 h)
Running carriage	Mechanical	Rear spider gear reducer shaft (1 859 - 3 969 h) Front and rear chain (1 196 h)
Grapple	Hydraulic	Arch cylinder (3 161 h)
	Mechanical	Main boom (3 303 h) Boom pin (4 500 - 6 500 h) Grapple pin (3 000 h)

[1] (Frequency; duration): when the value of a parameter is unknown, it is replaced by "--"

APPENDIX 8B

Table 3: Breakdowns reported on cable skidders

Zone	System	Types of breakdowns (approximate frequency; duration of repair) [1]
Hood	Hydraulic	Valve gasket (1t/4m; 7 h) [1] Hydraulic pump (4 000 h; --)
	Mechanical	Oil leak (500 - 1 000 h; --) Radiator fan (2t/y; --) Filter (150-250 h; --) Water pump (1t/y; --) Injection pump (1 000 - 2 000 h; --)
	Electrical	Starter (1-2t/y; 3 h) Alternator (1t/y; --)
Chassis	Mechanical	Plate underneath (3-4t/y; --) Transmission (1 000 - 5 000; 1 d-1 w) Drive shaft (1 000 - 4 000 h; --) Drive shaft joint (12t/y; 1-2 h) Central section of shaft, journal bearing (1 000 - 2 000 h; --) Central pin, articulation (4 000 - 5 000 h; 2 h) Sleeve (1-2t/y; 1-2 h) Axles (1t/m; --) Differential (bearing) (2 500 - 6 000 h; --)
	Hydraulic	Hose (1t/m; --) Steering cylinder (1t/m; 8 h)
Running carriage	Hydraulic	Brake cylinder (3-4t/y; 1/2 h)
	Mechanical	Wheel bearing, spider gear reducer (2 500 - 6 500 h; --) Tire (1t/w to 4/y; 4 h) Tire chain (1 200 - 2 000 h; 2-3 h) Wheel gasket (2t/y; --) Brake (2-6t/y; 8 h) Spider gear reducer (wheel) (2 500 - 6 500 h; 3 h)
Boom/Winch	Mechanical	Winch, winch drive shaft (3 000 - 6 000 h; --) Cable, sling (1t/1d-1w; --)

[1] (Frequency; duration): when the value of a parameter is unknown, it is replaced by "--"

APPENDIX 8B

BREAKDOWNS REPORTED ON SKIDDERS

APPENDIX 8A

Table 2: Breakdowns reported on fellers one or more times per season for the hood, cabin and running carriage zones

Zone	System	Types of breakdowns (approximate frequency; duration of repair) [1]
Boom	Hydraulic	Hose (1t/m; 1 d) [1] Boom cylinder Cylinder in the boom (1t/y; 1 h) Tilting cylinder (2-7t/y; --)
	Mechanical	Main boom (2-3t/y; --) Boom that cracks (1 000 - 2 000 h; 3 h)
Head	Mechanical	Saw shaft bearing (12t/y; --) Saw teeth (20 teeth/w; 1 h) Tree buncher (12t/y; 7 h) Knives (1t/y; 5 h)
	Hydraulic	Head cylinder (2-7t/y; --) Saw hydraulic motor (2t/y; --)
Chassis	Mechanical	Large bearing (5-6t/y; 24 h) Ring gear (5-6t/y; --) Upper frame that cracks (2 000 - 3 000 h; --)
	Hydraulic	Leveling cylinder (2t/y; --) Swivel joint hose (1-3t/y; --)

[1] (Frequency; duration): when the value of a parameter is unknown, it is replaced by "--"

APPENDIX 8A

Table 1: Breakdowns reported on fellers one or more times per season for the hood, cabin and running carriage zones

Zone	System	Types of breakdowns (approximate frequency; duration of repair) [1]
Hood	Hydraulic	Hydraulic accumulator (1t/y; 3-4 h) [1] Pivot modular valve (500-600 h; --) Hose and tubes (1t/m; --) Pump (1t/m; 1 d) Torque converter (1t/y; 3-4 h) Oil cooler (1t/w; --) Pivot hydraulic motor (2-3t/y; 3-4 h)
	Mechanical	Pivot spider gear reducer (1t/y; 3-4 h) Machine that overheats Head, valve, turbo (2 000 - 5 000 h; --)
	Electrical	Alternator (1-2t/y; --) Starter (1-2t/y; --)
	Safety/Protection	Machine that catches fire
Cabin	Electrical	Stabilizer switch
Running carriage	Hydraulic	Traction hose (2 000 h; --) Track cylinder (2t/y; 7 h) Traction hydraulic motor (1 000 - 5 000 h; --)
	Mechanical	Traction sprocket (4 000 - 9 000 h; --) Track spider gear reducer (1-2t/y; --) Track pin (1 000- 2 000 h; 1/2 j) Pad (1t/y; --) Track (3 000 - 4 000 h; --) Bolts under the machine (5-10t/y; 8 h) Idler (1t/y; --) Chain guard (1-2t/y; --) Pad lugs to be welded (1 000 - 2 000 h; --)

[1] (Frequency; duration): when the value of a parameter is unknown, it is replaced by "--"

APPENDIX 8A

BREAKDOWNS REPORTED ON FELLERS

APPENDIX 8

LIST OF BREAKDOWNS REPORTED ON FELLERS, SKIDDERS AND DELIMBERS

APPENDIX 7.2C

Table 4: **Distribution of the makes and models of delimbers reported on participating sites**

Make	Model	Number	Total
CAT	215	5	
	225	4	9
Hitachi	083	3	
	200	4	
	---	2	9
Komatsu	200	6	
	220	1	7
Case	1187 B	4	4
O and K	---	3	3
Drott	---	3	3
JCB	808	2	
	808 D	1	3
Insle	A 808	1	1
John Deere	790 B	1	1
TOTAL			40

APPENDIX 7.2C

DISTRIBUTION OF TYPES OF DELIMBERS REPORTED

APPENDIX 7.2B

Table 3: **Distribution of the makes and models of grapple skidders reported on participating sites**

Make	Model	Number	Total
John Deere	648	2	
	648 D	5	7
Clark	667	2	2
Timber	450	2	2
	TOTAL		11

APPENDIX 7.2B

Table 2: **Distribution of the makes and models of cable skidders reported on participating sites**

Make	Model		Number	Total
Timber	207		2	
	230		13	
	240		14	
	240	A	1	
	240	D	1	
	240	E	2	
	240	SE	1	
	240	GS	1	
	380		6	
	450		12	
	450	A	4	
	480		1	
	520		2	
	550		6	
	---		2	68
John Deere	540		1	
	540	B	2	
	640		12	
	640	D	2	
	740		11	28
Tree Farmer	C 6		7	
	C 6	D	2	
	C 5	D	1	
	C 7	T	1	
	C 8	C	1	12
CAT	518		6	
	528		4	10
Inter	S 9		1	
	S 10		2	3
Clark	664		2	
	667		1	3
Franklin	170	XL	2	2
	TOTAL			126

APPENDIX 7.2B

DISTRIBUTION OF TYPES OF SKIDDERS REPORTED

APPENDIX 7.2A

Table 1: Distribution of the makes and models of fellers reported on participating sites

	Make	Model		Number	Total
Feller-buncher					
	CAT	227		8	
		215		2	
		217		1	
		AC 200		4	15
	Timbco	2518		6	
		2520		3	
		---		2	11
	Hitachi	EX 200		3	
		270		1	
		123		1	
		083		2	7
	John Deere	643		2	
		693		1	
		693	D	1	
		743		1	5
	Case	1187	B	4	4
	B J 20	---		2	2
		Subtotal			44
Feller-forwarder					
	K2FF	---		2	
	Shortwood	---		4	6
Mini-feller					
	Kodelco	---		1	
	John Deere	---		1	2
		TOTAL			52

APPENDIX 7.2A

DISTRIBUTION OF TYPES OF FELLERS REPORTED

APPENDIX 7.2

DISTRIBUTION OF MACHINES REPORTED

APPENDIX 7.1

Table 1: Distribution of types of machines reported on participating sites

Type of machine	N	%
Feller		
Feller-buncher	44	19,1
Feller-forwarder	6	2,6
Mini-feller	2	1,0
Subtotal	52	22,7
Skidder		
Cable skidder	126	55,0
Grapple skidder	11	4,7
Subtotal	137	59,7
Delimber		
Delimber	40	17,6
TOTAL	229	100,0

APPENDIX 7.1

TYPES OF MACHINES REPORTED

APPENDIX 7

LIST OF MACHINES REPORTED

APPENDIX 6.2

Table 1 - Distribution of accidents and incidents occurring during maintenance and repair (96 cases)

MAIN VARIABLE	LEVEL OF IMPORTANCE (IN PERCENT (%))			OTHERS	NOT SPECIFIED
	LEVEL 1	LEVEL 2	LEVEL 3		
Machine involved	Feller (33.3)	Skidder (31.3)	Delimber (16.7)	(8.3)	(10.4)
Worker involved	Feller operator (29.2)	Skidder operator (28.1)	Delimber operator (15.6)	Mechanic, Welder (27.1)	---
Machine part involved	Differential, motor (21.9)	Felling or delimbing head (14.6)	Running board, handle (12.5)	(41.6)	(21.9)
Seat of lesion	Arm, hand, finger (43.8)	Eyes (15.6)	Leg (13.5)	(25.3)	(2.1)
Nature of the lesion	Contusion, crushing, ... (29.2)	Scrapes, cuts, ... (20.8)	Foreign bodies (18.8)	(28.1)	(3.1)
Causal agent	Machine part (42.7)	Tool, equipment (20.8)	Splinters, dust (19.8)	(15.7)	(1.0)
Tool or object used	Sling (41.7)	None (23.1)	Machine part (10.4)	(10.4)	(13.5)
Tool or object involved	Machine part (26.0)	Torch, drill, sledgehammer (24.0)	Nut, measuring tape, tool box (14.6)	(33.3)	(2.1)
Activity	Repair (54.2)	Maintenance (29.2)	--	--	(16.7)
Action	Welding, cutting, drilling, grinding (22.9)	Unhooking, changing, removing (18.8)	Verification, cleaning (18.8)	(53.1)	(5.2)
Type of accident	Bumping into (20.8)	Being hit by (16.7)	Falling (13.5)	(49.0)	--

APPENDIX 6.2

DISTRIBUTION OF THE ACCIDENTS AND INCIDENTS SUFFERED BY OPERATORS AND OTHER TRADES RELATED TO FORESTRY MACHINERY DURING REPAIR AND MAINTENANCE INTERVENTIONS (96 CASES REPORTED)

APPENDIX 6.1

Table 1 - Distribution of accidents and incidents (255 cases reported)

MAIN VARIABLE	LEVEL OF IMPORTANCE (IN PERCENT (%))			OTHERS	NOT SPECIFIED
	LEVEL 1	LEVEL 2	LEVEL 3		
Machine involved	Skidder (65.1)	Feller (16.5)	Delimber (10.2)	(3.5)	(4.7)
Worker involved	Skidder operator (64.7)	Feller operator (14.5)	Delimber operator (10.6)	Mechanic, Welder (10.2)	—
Machine part involved	Cable, sling (34.9)	Cabin, door, control (9.8)	Running board handle (9.0)	(28.3)	(18.0)
Seat of lesion	Arm, hand, finger (36.5)	Leg, foot, ... (16.9)	Eyes (16.1)	(27.4)	(3.1)
Nature of the lesion	Contusion, crushing, ... (27.5)	Scrapes, cuts, ... (21.2)	Flashes, foreign bodies (18.8)	(32.5)	
Causal agent	Machine part (34.9)	Wood, stump (22.0)	Splinters, dust (13.7)	(23.9)	(5.5)
Tool or object used	Sling, chain, cable (32.9)	None (24.0)	Welding machine, manual tools (16.1)	(14.2)	(13.7)
Tool or object involved	Sling, choke (25.1)	None (21.6)	Machine part (13.3)	(32.9)	(7.1)
Activity	Production (62.7)	Repair (20.4)	Maintenance (11.0)	--	(5.9)
Action	Walking (26.3)	Attaching a tree (22.4)	Detaching a tree (10.2)	(32.5)	(8.6)
Environment	Slippery surface (7.8)	Defective equipment (6.7)	Obstacles (rock, fallen tree, ...) (5.5)	(17.3)	(62.7)

APPENDIX 6.1

DISTRIBUTION OF THE ACCIDENTS AND INCIDENTS OF OPERATORS AND OTHER TRADES RELATED TO FORESTRY MACHINERY
(255 CASES REPORTED)

APPENDIX 6

ACCIDENTS AND INCIDENTS

2	ADAPTATION DEVELOPMENT	• Building one (or more) preproduction prototypes and testing them on differe forestry sites • Carrying out final tuning of the product in terms of productivity and ORMA • Developing means and methods for producing the product • Choosing the components for certain minor modifications to existing systems • Choosing or designing the means for evaluating and measuring the operation existing systems • Choosing or building the tools for easier maintenance and repair • Developing the operating and maintenance manual • Developing data sheets • Finalizing the design code • Finalizing the technical data sheets • Finalizing the content of the training program
1	REDUCED-SCALE APPLICATION	• Building, as needed, a batch of several production prototypes and testing the with several chosen users working under different operating conditions • Carrying out, in terms of ORMAS [1], the required tuning adjustments, if necessary • Finalizing the development of production means and methods • Final tuning of means for evaluating and measuring the operation of the existing systems • Finalizing the tuning of tools for easier preventive maintenance and repair • Finalizing the operating and maintenance manual • Finalizing the data sheets • Initiating future users to the new product
0	LARGE-SCALE APPLICATION	• Manufacturing the final product or having it manufactured • Setting up a sales, distribution, maintenance and repair service • Disseminating the information acquired during development • Ensuring that information generated by the users and dealers is returned to t manufacturer

[1] ORMAS: operability, reliability, maintenance, availability, safety

LEVEL	TITLE	GOALS AND RESPONSIBILITIES
5	RESEARCH	• Finding and testing new materials • Describing briefly the machine functions required • Defining in terms of ORMAS [1], the machine functions required • Defining the main points to be the subject of a specification
4	DESIGN	• Finalizing the definition of machine functions • Developing means for achieving the machine functions • Doing the engineering calculations • Verifying the result potential of the machine functions in terms of ORMAS[1] • Drawing up the preliminary content of a standard or a design code • Drawing up the preliminary content of a specification
3	DEVELOPMENT	• Building a test prototype and developing its functionality for the future utilization conditions and then evaluating the results • Finalizing the engineering calculations • Verifying and developing the ORMAS [1] potential • Finalizing the content of a specification or a technical data sheet • Defining the means of evaluating and measuring the proper operation and the performance of the different systems and subsystems (preventive and predictive maintenance) • Defining the tools necessary for easier and accelerated maintenance and repair interventions • Developing technical data sheets • Developing the content of training programs

[1] ORMAS: operability, reliability, maintenance, availability, safety