Time and Motion Study of Battery Powered Pruning Devices in Lake Taupo Forest

Forest Growers Research Ltd

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1 Executive Summary

Forme Consulting Group Ltd was engaged by Tim Petro representing Forest Growers Research Ltd to conduct a time and motion study on new battery powered pruning operations being trialled by NZ Forest Managers Ltd under the Precision Silviculture Programme (PSP).

Approximately two and a half days were spent observing a first lift pruning crew in Lake Taupo Forest and recording data to evaluate the potential and productivity of the new pruning system and identify any advantages, or limitations of the equipment.

The study focused on two pruners who had been given the battery pruners on a trial basis. Lance (Day one) was a new pruner having only been pruning for a number of weeks. Darren, (Day two and three) is a highly experienced pruner, having been pruning for 20+ years. This provided an extensive range of experience to observe as well as a difference in physical conditioning.

The study used a time-and-motion methodology which splits the working procedure into different elements including walk and select, battery pruning, lopper clean-up, epicormic, ladder and delays. The methodology is consistent with historical pruning studies completed by Forme. Data was captured using a combination of manual measurements and electronic app-based work study software.

Pruning data on a total number of 246 trees was captured during the studies. Average pruning time between an inexperienced pruner on day one and an experienced pruner on day two was identified as 3.034 mins and 2.932 mins respectively when using the battery powered pruners. This is only a 3% difference in pruning time per tree between an inexperienced and very experienced pruner.

The battery powered tool was less efficient than the conventional porter pruners in its current design (33% slower for trees with only class 1 whorls and 39% slower for trees had class 2 whorls).

Data analysis also found the average battery powered pruning time increases as the percentage of the class 2 whorls increased. This matches with the observations made on-site that the tool often required several attempts to cut through some of the larger branches. Furthermore, because of the size and design of the tool, slippage during cutting was observed frequently and coat hangers were often left that required double handling using the porter pruners, meaning the pruner had to always carry both tools.

The tool showed potential if further modifications on the shape, size and robustness of the tool can be implemented to achieve better performance when pruning large radiata pine branches as it appeared less physically demanding for the pruner than conventional porter pruners. This may attract different demographics to pruning work that have not traditionally been attracted to the physically demanding job.

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2 Introduction

Forme Consulting Group Ltd was engaged by Tim Petro representing Forest Growers Research Ltd to conduct a time and motion study on new battery powered pruning operations being trialled by NZ Forest Managers Ltd in the Lake Taupo Forest.

The intention of this study was to evaluate the potential and performance of the battery powered tools as a new mode of undertaking pruning operations. The study also looked to compare at a high level this work methodology to conventional pruning practices from data captured onsite in the same environment.

Forme observed two separate pruners working for Mahi Rakau Forest Management for two and a half days to make observations and record data that could be analysed to identify any advantages or limitations of the new systems.

3 Purpose

The purpose of the study was to determine the efficiency and effectiveness of the battery powered pruning and identify any strengths and weaknesses of the battery powered system compared with that of the industry standard porter pruner approach. By using a similar time and motion study methodology to previous studies by Forme and the forest service, it allowed emphasis to be placed on any elements which presented obvious differences between the two pruning methodologies. The battery powered pruning tools come from the horticultural industry and are used for cutting branches in vineyards, so suitability and assessing whether the tools were fit for purpose was also taken into consideration.

4 Operation

The pruning operation involved a first lift prune on approximately 5-year-old Pinus Radiata, planted at an approximate stocking of 840 stems per hectare. Inventory identified a current stocking of 750 – 850 sph and the pruning prescription prescribed a prune height of 3.5 metres with a pruned stocking of 330 sph with a target DOS of 18cm. The operation was undertaken across flat to rolling terrain, with little hindrance between trees.

5 Battery Powered Pruning Device

The devices being trialled was the Prunion handheld mechanical pruning device produced by Pellenc, which was paired with a Pellenc 250 battery pack, worn on the back like a backpack. This battery pack consisted of a ~250Wh lithium-ion battery with a temperature operating range of -5 - 35°C. The pruners were powered by a thick flexible cable connecting the handheld tool with the battery pack.

Figure 1: Pellenc Battery pruning kit set

The pruning shears consisted of 35mm pruning blades operated by an electrical motor to open and close at the press of a trigger. There is no muscular force required to open or close the blades and therefore prune a branch.

Figure 2: The Pellenc Prunion pruning tool being adjusted prior to beginning the day

6 Methodology

6.1 Time Study Elements

The time-and-motion study was split into elements, consistent with historic pruning studies completed by Forme. Data was captured using a combination of manual measurements and electronic app-based work study software.

6.1.1 Walk and Select

This element covers the time taken for the pruner to pick us his ladder, travel between trees, select a new tree and ends when he grabs his loppers/shears from his belt/pouch.

6.1.2 Battery Pruning

Any time that the pruner is pruning branches with the loppers or battery shears. Starts and ends when loppers/shears are removed from/returned to his belt.

6.1.3 Lopper Clean-up/Lopper Pruning

When branches reached the limits of the battery powered jaw, loppers were required to remove the branches. The blade design of the shears could often leave coat hangers, which is a quality control issue, and the pruner was required to remove these with their loppers.

6.1.4 Epicormic

Any time the pruner is removing epicormics or cleaning up the tree. Starts when loppers/shears are returned to belt or pouch and pruner either grabs machete or rubs tree with his hand. Ends when pruner grabs ladder or begins to move down ladder/move to next tree.

6.1.5 Ladder

Any time the pruner is handling or moving on the ladder. Movement can be up and down the ladder or setting the ladder up against the tree.

6.1.6 Delays

Delays were noted when any non-value adding element to the operation is observed.

6.1.7 Tree Measurements

Alongside the time and motion study elements, physical attributes of the tree were measured. These included:

- Number of Whorls
- Number of Branches
- Prune Height
- Class I or II whorls (C1 or C2)
  - Class I Whorls – Whorls that have one or fewer branches with at least 45mm diameter.
  - Class II Whorls – Whorls that have more than two branches with at least 45mm diameter.
- Hindrance between the trees

Distance between trees was not captured as this was not required for a comparison between the two pruning methodologies.

6.2 Pruners

The study focused on two pruners who had been given the battery pruners on a trial basis. Lance (Day one) was a new pruner having only been pruning for a number of weeks. Darren, (Day two and three) is a highly experienced pruner, having been pruning for 20+ years. This provided an extensive range of experience to observe as well as a difference in physical conditioning.

7 Results

During the two and half days' study, pruning cycles for a total of 246 trees were recorded. There were 76 trees pruned on day one, 110 trees pruned on day two and 60 trees pruned on day three. Day three studied the experienced pruner using traditional porter pruners over half a day. Studies on all three days were conducted on similar gentle to slightly hilly terrain.

7.1 Battery Pruning Day One

On day one, the study was conducted on an inexperienced pruner using the battery powered Pellenc pruners. The average time captured in decimal minutes and the corresponding 5th and 95th percentile values for each element are summarized in Table 1 below. The average total time per tree was 5.98 dec mins. Average pruning time (battery and lopper) observed on day one was 3.034 dec min. Of the total study time of 454.4 mins, 96.56 mins were observed as delays. These included 24.51 mins of mechanical delay due to the pruning tool braking, and 1.42 mins of operation delays (for operational briefings, questions etc). Other delays included 70.63 for lunch break at the midday. The first day's study was mainly conducted on relatively flat ground, with very little to no walking hindrance observed.

Table 1: Summary of Numerical Results of Day 1

Element	Average	5th Percentile	95th Percentile
Walk and select (mins)	0.495	0.244	0.843
Ladder (mins)	0.367	0.123	0.562
Battery Pruning (mins)	2.125	0.766	3.472
Lopper clean-up (mins)	0.909	0	2.068
Epicormic (mins)	0.811	0.355	1.331
Operational delays (mins)	0.019	N/A	N/A
Mechanical delays (mins)	0.322	N/A	N/A
Other delays (mins)	0.929	N/A	N/A

7.2 Battery Pruning Day Two

Studies on day two observed a highly experienced pruner using the battery powered tool. The average time captured in decimal minutes and the corresponding 5th and 95th percentile values for each element are summarized in Table 2 below. Of the total study time of 515.78 mins, 58.01 mins were observed as delays. These included 2.32 mins of operation delays (for operational briefings, questions etc) and 58.01 mins of other delays (for lunch break). Pruning was undertaken on mixed tree/ground conditions with a combination of trees on road edge, trees on a previous skid site (smaller trees) and some moderate sloping country. Average pruning time (battery and lopper) observed on day two was 2.932 dec min. Again, there was very little to no obvious hindrance observed during the study.

Table 2: Summary of Numerical Results of Day 2

Element	Average	5th Percentile	95th Percentile
Walk and select (mins)	0.289	0.086	0.519
Ladder (mins)	0.249	0	0.475
Battery Pruning (mins)	2.423	1.269	3.618
Lopper clean-up (mins)	0.509	0	1.675
Epicormic (mins)	0.670	0.251	1.242
Operational delays (mins)	0.021	N/A	N/A
Mechanical delays (mins)	N/A	N/A	N/A
Other delays (mins)	0.021	N/A	N/A

7.3 Porter - Pruning Day Three

On day three, studies observed the same experienced pruner as day two. However, for comparison purposes, the pruner was using the conventional porter pruners only. The average time captured in decimal minutes and the corresponding 5th and 95th percentile values for each element are summarized in Table 3 below. Average pruning time (lopper only) observed on day three was 2.244 dec min. Of the total study time of 207.85 mins, 1.88 mins were observed as other delays. Studies observed pruning on the road edge on mixed gentle flats with some steep sloping areas down to the road. While the pruner did not have to carry the battery powered pruning equipment such as the extra belt, sheave and battery backpack, hindrance remained the same as previous days and there was no obvious difference to the mobility or ease of movement through the trees evident. This confirmed initial thoughts on day one and two that wearing the battery pack etc made no difference to a pruners ability to walk and select trees in none to light hindrance levels. Heavy hindrance may affect mobility, however further studies are required to confirm this.

Table 3: Summary of Numerical Results of Day 3

Element	Average	5th Percentile	95th Percentile
Walk and select (mins)	0.304	0.143	0.578
Ladder (mins)	0.267	0	0.391
Battery Pruning (mins)	N/A	N/A	N/A
Lopper clean-up (mins)	2.244	1.117	3.712
Epicormic (mins)	0.617	0.617	1.114
Operational delays (mins)	N/A	N/A	N/A
Mechanical delays (mins)	N/A	N/A	N/A
Other delays (mins)	0.031	N/A	N/A

7.4 Tree Measurements

Tree measurement data such as pruned height, no. of branches, whorl classification and epicormic levels were recorded during the study. Epicormic levels were light for the most part, with occasional instances of medium epicormic shoots observed. However, no trees were observed as very heavy or heavy in this study and this is likely due to good genetic tree stock and management practices. The focus of this study was capturing the potential, performance and efficiency of the battery pruning tool; therefore, we have focused our analysis on the elements relating to pruning time which can be analysed in a direct comparison between the two pruning methodologies (battery vs. porter pruner). The focus of the analysis is therefore based on the average prune height, no. of branches and whorl classifications as opposed to walk and select and epicormics etc, and the results of these are summarised in Table 4 below.

Table 4: Summary of Tree attributes

	Average Prune Height (cm)	Average Number of Branches	Average Number of Class 1 Whorls	Average Number of Class 2 Whorls
Day 1	342.10	51.25	6.61	0.80
Day 2	318.30	50.50	6.50	0.80
Day 3	327.28	48.43	5.85	1.77

Day one and two included similar tree attributes, with similar number of branches and C1 and C2 whorls per tree. A higher proportion of class 2 whorls were observed on day three, likely because the pruning was completed along a road edge, resulting in larger branches. There are also some noticeable differences between the pruning height on day one and day two, likely caused by different pruning height assessments from the two operators.

8 Analysis

8.1 Pruning Time

Analysis of the results found the actual pruning time for different operators using the battery powered pruners were very similar at 3.034 mins and 2.932 mins for day one and day two respectively. This is only a 3% difference in pruning time between an inexperienced pruner and a very experienced pruner (20+ years). However, both operators were relatively new to using the battery powered pruners and appeared to still be figuring out the best way to operate the new tools. On day one the less experienced pruner tended to use the porter pruner more frequently, resulting in 14% less battery tool pruning time per tree compared to the time spent by the pruner on day two using their battery tool, while the time per tree was 17% higher for porter pruning time when compared with data collected per tree on day two. As the total actual pruning time was very similar for the two operators, the difference in the total number of trees pruned between day one and day two came down to the non-pruning elements such as walk and select (41% difference), ladder movement (32% difference) and epicormic clearance (17% difference).

8.2 Larger Branches Analysis

Observations identified that there may be a negative relationship between the battery powered tool and an increase in branch sizing due to the shape of the blades and size of the jaw. We have investigated the relationship between the total pruning time by the battery powered device and the number of Class 2 (C2) whorls (a whorl with two or more 45mm diameter branches). The relationship between the number of C2 whorls as a percentage of total whorls and battery pruning time element per tree is presented in Figure 3 below.

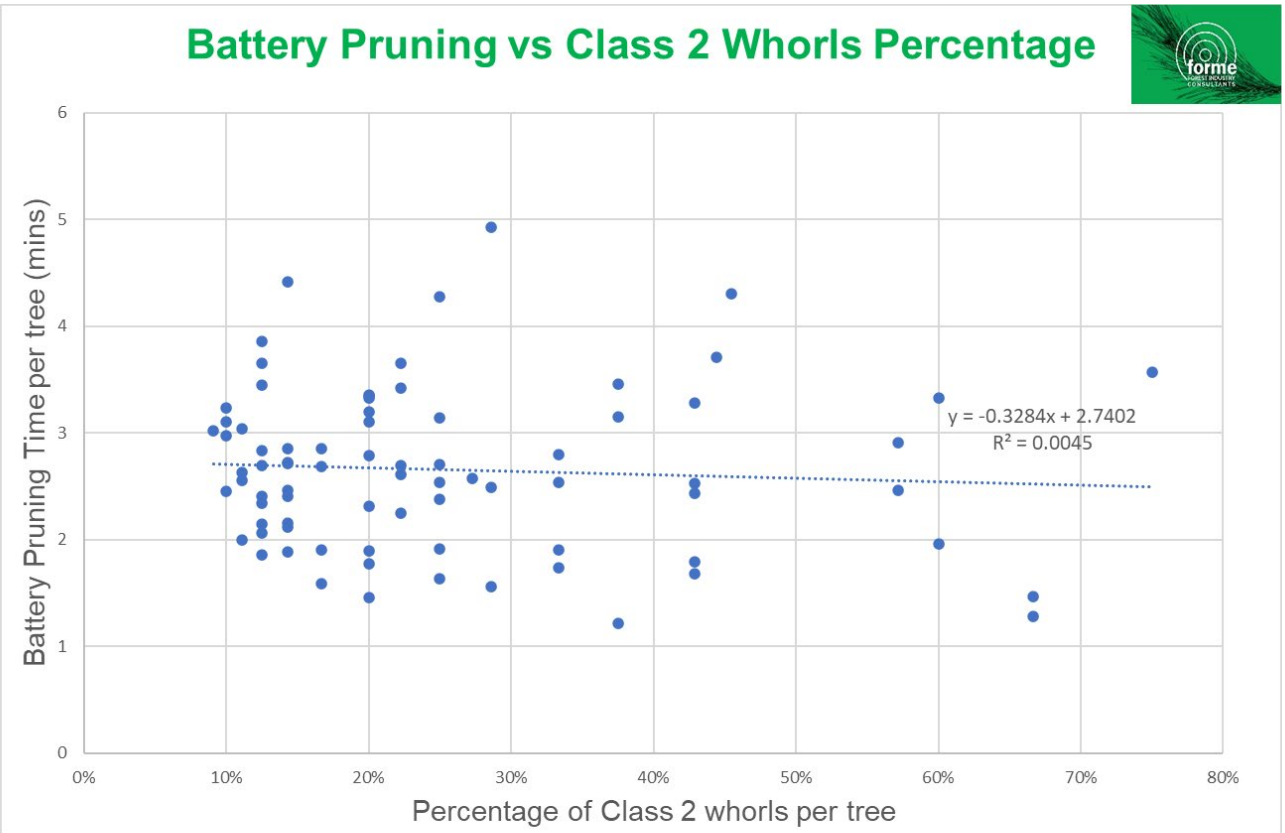

Figure 3: Relationship between Battery Pruning Time and Percentage of Class 2 whorls per tree

Due to a limited sample size, no clear trend is apparent with multiple instances of differing prune times at certain whorl percentages. However, it roughly appears that the battery pruning time drops as the percentage of Class 2 whorls increases as is to be expected. This matched the observations that the battery powered tool began to struggle when dealing with large branches, often requiring multiple cuts, and sometimes leaving coat hangers. These observations are further discussed in section 8.

In Figure 4 below, the linear regression was also generated for the relationship between lopper clean-up time and the percentage of C2 whorls.

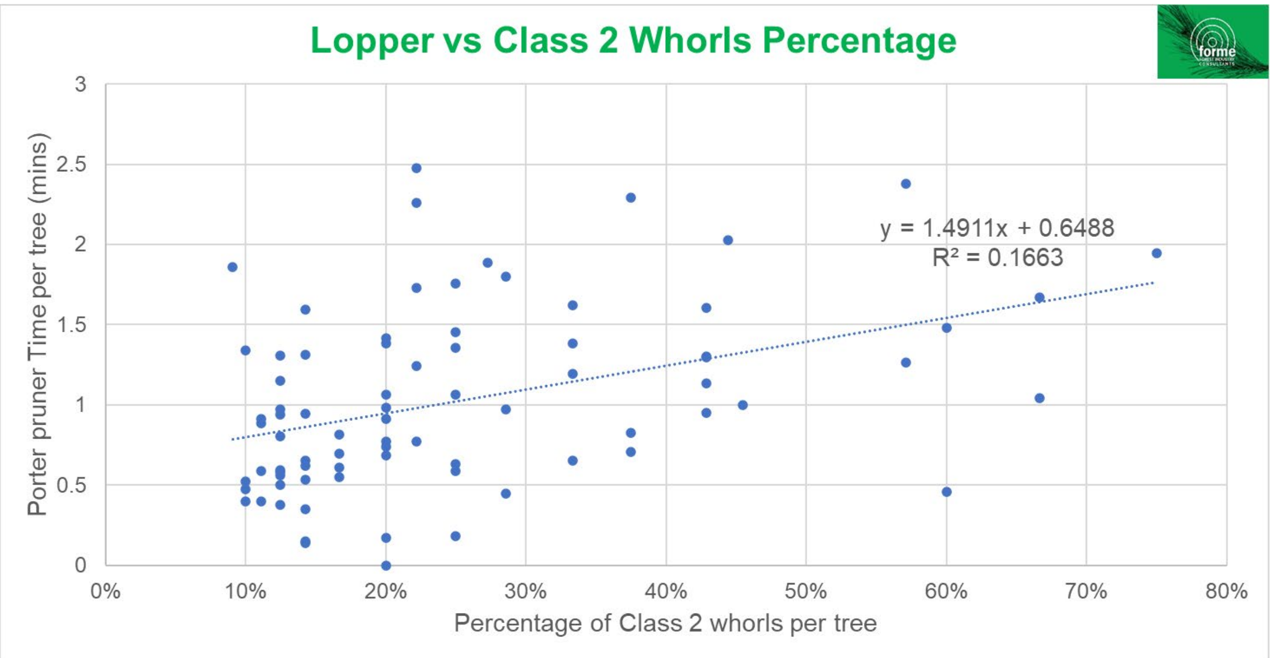

Figure 4: Relationship between Lopper clean up time and the percentage of Class 2 whorls

An increase in the use of porter pruners for cleaning up coat hangers and pruning larger branches is evident as the percentage of C2 whorls increases per tree. This lines up with observations during the study that often larger branches would be too large or difficult to cut with the battery pruner and that the porter pruners would be required to either cut the branch or complete a secondary clean up to remove coat hangers and meet quality control standards.

Furthermore, we have compared the average pruning time observed for trees with C1 whorls only, against the time for trees with both C1 and C2 whorls respectively and have summarized these in Table 5 below.

Table 5: Summary of average pruning time on different tree type

Tree Type	Average Time for Battery Pruning (Battery pruning + Lopper clean-up)	Average Time for Conventional Pruning (Lopper only)
Trees with Class 1 Whorls	2.467	1.665
Trees with Class 2 Whorls	3.684	2.244

The results above identify that the battery pruning tool in its current model and design does not match the efficiency that can be achieved by traditional porter pruners, especially when there are numerous class 2 whorls where the battery powered tools appear 39% slower than the conventional porter pruners. The battery powered pruners showed more promise and efficiency when pruning trees with class 1 whorls only (smaller branching) however, it is still 33% slower than the conventional lopper pruning.

9 Discussion

9.1 Conventional vs Battery Powered Observations

9.1.1 Shape and size of the tools

It was noticeable that the shape and size of the blades and jaw opening of the pruning tool have significant influence on cutting efficiency. The shape and thickness of the blade on the conventional pruner (so called the hit pruner or the porter pruner) was specifically designed for pruning radiata. The conventional pruners have sharpened blades with slightly lower shoulder and specific hooked blade that allows the pruner to fit over larger branches as well as provide leverage through the cut while mitigating any slippage from the branch. The blade design minimises the potential for coat hangers. (Hall & Mason., 1988)

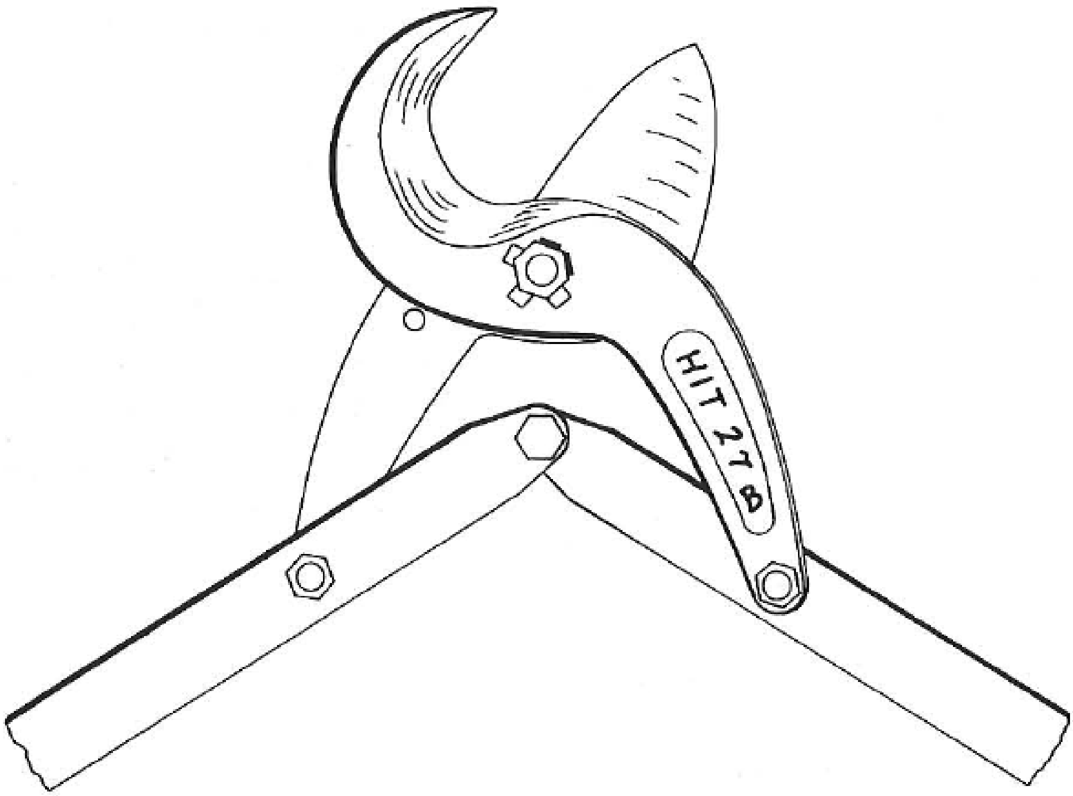

Figure 5: Example Diagram of a Hit Pruner (Hall & Mason, 1988)

Conversely, the battery pruning tool in its current form with it's conventional "secateur" shaped blades (Figure 6) is not specifically designed for cutting radiata pine branches, and focus on traditional small branch pruning found in vineyards etc. During the study, it was observed that the tool would frequently slide off the branch during a cut when pruning the larger branches as the blade would not close around the branch like the porter pruner design and would instead slide off. Another noticeable feature was that the battery pruning tool only has a cutting/sharp blade on one side, while the porter pruner has sharpened edges on both jaws to allow for the jaws to bite into the branch. The combination of these issues required the battery powered tool to make multiple cuts on larger or odd shapes branched, often struggling, or causing damage to the internal mechanisms when the weight of the branch sandwiched the blades. This could often lead to coat hangers being left behind which needed to be tidied up with the porter pruners. To truly understand the benefits of the battery powered pruner, the shape of the blades needs to be re-designed to be more similar to porter pruners as the constant switching between battery tool and porter pruners meant a large amount of unnecessary double handling which has a significant influence on the efficiency of the battery pruning tool and results in substandard pruning times when compared to traditional pruning methods.

Figure 6: A picture of the battery pruning tool (Pellenc, 2023)

9.1.2 Robustness of the tools

On day one, there were two mechanical failures recorded during the operation. Both times appeared to be caused by a similar issue involving an internal slider that had slid or twisted off its rail when too much shear force was applied on the battery pruner, potentially from the weight of the branch pressing against the blades when cutting. This failure resulted in jaw closure malfunctions. This could be fixed by opening the tool up and resetting the slider, but it was noted that the internal slider and other parts were plastic and may not have the required durability for long term use in the forest industry. Two separate pairs were broken by the same issue on the same day.

The issue could potentially be minimised by improving the cutting technique as it appears that it was caused by misuse or inappropriate technique as the pruner sometimes tried to separate the branches from the trunk by twisting the tool, as would be done with a pair of conventional loppers. Lance often used two hands to hold the tool, apply force to try and push the tool through the cut, which did not appear necessary as all that was required for the tool to successfully cut was to squeeze the trigger. This was reinforced by the fact that the issue was not noticed on day two, as Darren was using a different technique involving holding the branch's weight with his spare hand as he was cutting them and using his hand to throw them away instead of twisting the tool.

The combination of the two issues above identified that while the tool is simple to use, appropriate training and understanding of the tool is required if the use of this tool were to be scaled up across other forestry operations, as the breakdowns observed could cause large productivity issues if they were to happen frequently and highlighted the reliability issues that come with new technology.

9.1.3 Costs

In terms of the retail price, a set of Pellenc Prunion with 250P Ulib battery costs over $2,500 NZD, while a set of conventional porter pruner costs approximately $250 NZD. It must be noted that this is a significant increase in capital expenditure and the question as to whether contractors are likely to pay this increased price for a tool is yet to be verified.

9.1.4 Mobility

The tool is compact in size and there appeared to be no difference in mobility when the pruner was carrying the battery pruning tool and backpack, even when carrying the battery tool as well as the porter pruners. It is worth noting that the hindrance levels in the study block were light to none and this may differ if there is heavy hindrance where the electrical cable may snag on bushes or branches.

9.2 Battery Life

The battery life was recorded at the start of the day and the end of the day on both study days. The battery lasted an entire day as summarised in Table 6 below.

Table 6: Battery Summary

Study Day	Percentage at the Start	Percentage at the End
Day 1	97%	15%
Day 2	99%	5%

While the battery life appeared to sustain the workload in the current setup it should be noted that even on Day 2, only 110 trees were pruned using the battery powered tool. Darren identified that he would usually aim for closer to 150 trees per day and therefore it is not certain that the battery would last this long. It can be expected that the battery life will likely degrade after time with prolonged usage. Furthermore, if any modifications were made to the tool to improve the performance, a larger power source is likely needed.

9.3 Fatigue Level

In terms of fatigue level, observations appeared to identify a reduction in the physical effort when using the battery pruning tool compared with the conventional porter pruned. The younger pruner Lance claimed that he had not noticed any difference using the battery powered tool over the conventional porter pruners. The experienced pruner Darren identified a noticeable difference in fatigue level, claiming that the battery tool was much easier on the back, and he did not feel as physically tired at the end of the day. However, the battery tool left him with a slightly sore hand and wrist, as the strain on the body had moved from larger muscle groups (back, arms) to the hand and finger, potentially identifying the need for some research into the effect this may have on RSI etc. Both observed pruners were physically fit males, who may not benefit as extensively from a reduction in required physicality and strength as perhaps females might or a different demographic such as Asian immigrant or holiday workers. Figure 7 below shows Lance working with the battery pruning tool.

Figure 7: Lance working with the battery pruning tool

9.4 Opportunities and Limitations

Observations from the study identified some immediate opportunities or potential by using the battery powered tool. Initially it can be seen that a reduced physical effort is required to prune a tree, and this can add up to significantly less fatigue across a day than traditional pruning methods. This potentially opens the pruning job market to a more diverse crowd as it may not be as physically intensive as before. Furthermore, with the adaptations and modifications to the pruning blade size and shape are applied, a reasonable level of efficiency is likely to be achieved even with pruner that is not as fit or as experienced as existing pruners, as identified by the only 3% difference in pruning time between the inexperienced and very experienced pruners observed during the study.

However, there are also some obvious shortcomings about the tool. The tool is not as efficient or robust as the conventional porter pruners but is almost 10 times more expensive and the question would remain whether a pruning contractor would invest this much capital in the expensive tools so that they can attract a larger workforce pool.

10 Conclusion

During the two and a half days of time and motion studies, pruning data on a total number of 246 trees was captured. Average pruning time between an inexperienced pruner on day one and an experienced pruner on day two was identified as 3.034 mins and 2.932 mins respectively when using the battery powered pruners. This is only a 3% difference in pruning time per tree between an inexperienced and very experienced pruner. Although both operators were relatively new in using the tool, it identifies that pruning experience may not be a large influence in pruning times with the new tool. Hindrance did not appear to have any significant influence on the mobility of the pruner when carrying the battery pruning kit as opposed to conventional porter pruners.

Data analysis found the average battery powered pruning time increases as the percentage of the class 2 whorls increased. This matches with the observations made on-site that the tool often required several attempts to cut through some of the larger branches. Furthermore, because of the size and design of the tool, slippage during cutting was observed frequently and coat hangers were often left that required double handling using the porter pruners, meaning the pruner had to always carry both tools.

The battery powered tool was less efficient than the conventional porter pruners in its current design (33% slower for trees with only class 1 whorls and 39% slower for trees had class 2 whorls). However, the tool showed potential if further modifications on the shape, size and robustness of the tool can be implemented to achieve better performance when pruning large radiata pine branches as it appeared less physically demanding for the pruner.

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