Article

Using Conjoint Analyses to Improve Cable Yarder Design Characteristics: An Austrian Yarder Case Study to Advance Cost-Effective Extraction

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Abstract: Steep country harvesting has been identified as the main bottleneck to achieving greater profitability in the forestry sector of New Zealand and Australia. An improvement of efficiency, work safety and environmental sustainability should be realized by developing an advanced steep terrain timber harvesting system based on innovative Austrian technology. To identify the best suitable configuration of a cable yarder for steep terrain harvesting, user preferences based on an online survey (conjoint analysis) have been evaluated to answer the following questions: (1) What attributes of a new yarder design are most important to consumers? (2) Which criteria do stakeholders consider when selecting a cable yarder? (3) What are the weights representing the relative importance of criteria? Using eight specific design scenarios a fourth question, being which cable yarder concept is the best, was also answered. This case study shows that conjoint analyses is an effective tool to assess, rate and subsequently integrate design characteristics. Based on the results of the analysis, a cable yarder prototype will be manufactured in Austria and transferred to New Zealand for testing and demonstration.

Keywords: timber harvesting; cable yarding; steep terrain; conjoint; decision support; marketing research; mechanical engineering

1. Introduction

Mountain forests represent 23% of total Earth forest cover [1]. Forests play a significant role in the mountain economy by ensuring employment in several economic fields [2]. Proper utilization of mountainous forests is critical to ensure sustainability, protect the soil from erosion, conserve water and maintain a rich biodiversity. Forest operations in mountain areas are seldom performed by fully mechanized systems. The sector is still characterized by manual felling, while extraction of timber (logs, stems or whole trees) is typically done by cable yarders. Steep terrain can be defined by slopes over 40%, where traditional ground-based machinery becomes limited by capability, safety or regulations [3]. Due to the limits posed by steep terrain conditions, typically insufficient road network of mountain areas, limited storage and operational areas (pads, roadside areas, yards, etc.), those harvesting systems are more expensive and less flexible compared to mechanized ground-based systems in European

Nordic Countries [4]. A higher degree of mechanization in steep terrain conditions, coupling tower yarder and processor, can lead to significant improvements, particularly when whole-tree extraction techniques are applied [5].

Cable yarders are used in steep terrain timber harvesting worldwide due to their versatility and lower environmental impact than ground-based equipment. Harvesting the extensive areas of maturing plantation forestry on steep terrain has highlighted significant productivity and safety issues associated with the use of traditional systems. Chainsaw felling, followed by cable yarding extraction using choker-setters, with subsequent processing on a landing has been the mainstay of steep terrain harvesting in New Zealand for decades [6]. A high level of risks to forest workers operating these systems provides both the need, but also the potential benefits, of mechanizing the manual aspects of these systems [7,8]. Initiatives and innovations through both equipment development and application by industry are necessary to improve the efficiency of steep terrain timber harvesting and to eliminate the need for forest workers to be exposed to various hazards. The focus on mechanization and modernization of steep terrain harvesting systems are showing potential for significantly improving productivity, safety and ergonomics [9].

Cable-based yarding technology has a long tradition in Central Europe, the Pacific Northwest Region of the United States and Canada, and Japan [10]. During the 1960s, European sled yarder technology became well known; in the 1970s, mobile tower yarders began to replace them. The introduction of fluid power technology in the 1970s, the use of automatic carriage control since the mid-1980s and the integration of materials handling and processing functions into yarding machines were important steps for improvement. Outside of central Europe, only a few manufacturers have implemented this technology in their machines [10]. For example, in a survey of New Zealand yarders in 2012, of the 305 machines in use not a single one was based on European technology [11]. The results of the latest survey in 2018 showed one European tower yarder, the Koller K602H [12].

In New Zealand, the net stocked plantation forest area is 1.73 million hectares with an average volume per hectare of 552 m³ and an average annual harvest of 45,342 hectares. 30.7 million m³ of timber was harvested in 2016, an increase of 6.4% in 2015, with 31.4 million m³ expected to be harvested in 2018, assuming log prices remain strong [13]. The forestry sector has prospered in the last ten years with high log prices due to increased demand from China; generating 5.47 billion dollars in export revenue. The *Pinus radiata* plantings in the 1990s have started to reach maturity and will be harvested in the next 10 years with increased harvest volumes annually in what is referred to as the “wall of wood” [14]. As harvesting increasingly moves into these forests on steeper land and in smaller, more isolated holdings (e.g., farm forests), the challenges of maintaining international cost competitiveness and safe operations will mount. Five years ago the New Zealand forestry sector and the Ministry for Primary Industries identified steep country harvesting as the main bottleneck to achieve greater profitability in forestry [14]. Work safety is also a concern as the forest industry has experienced relatively high injury and fatality rates, with a long-term average fatality rate of five deaths per year and an annual serious harm injury rate of one for every 35 workers [15]. Harvesting operations on steep terrain need to keep pace with work demands and technology developments to make harvesting safer and reduce costs. Mechanization has been seen as the solution of these problems, as it is more productive than manual operations and removes people from the hazards of tree felling and choker-setting where most accidents happen [16]. A comprehensive survey of New Zealand yarders was carried out by Visser [17]. There were 305 machines operating of which two-thirds were tower yarders of the type commonly constructed in the Pacific Northwest in the 1970s and 1980s. The other third of the machines were swing yarders and most were built in 1990s. The rigging system of preference was North Bend whereby a large fall-block is used to bring the rigging to the ground. Interestingly, modern European motorized carriages were non-existent. While this type of technology is appropriate for the older larger scale clear-cut operations, modern silviculture has resulted in shorter rotations and smaller trees. As such, European size technology is no longer too small for the typical operation, but such stigma still exists. It is also interesting to note that there were

no integrated yarder-processor machines working in New Zealand, which are commonly employed in Europe. New innovations have occurred in the development of motorized grapple carriages that allow for the mechanization of the extraction phase for tower yarders, reducing exposure of workers on steep slopes. Such carriages have started to integrate GPS and camera technology, but no automation as yet. Another comprehensive survey of New Zealand yarders was conducted in 2018 and found several changes had occurred during the country's push toward mechanization [12]. The population of yarders had increased to 318 machines with an increase in the proportion of swing and excavator yarders; also the most common rigging system had shifted to mechanical grapple carriage extraction followed by more modern USA designed motorized slack-pulling carriages. While North Bend was still common the recently developed motorized grapple carriages gained widespread use on tower yarders, with more than 10% of machines using them and at least 3 manufacturers producing them.

The current technology in Australia is mainly larger swing yarders with mechanical grapple carriages. These yarders mainly work in whole tree (or large log) extraction in steep terrains of New South Wales, Victoria, Tasmania and South-East Queensland. Cable yarding is often applied in clear fell operations in pine or eucalypt stands in Australia [18,19]. One of the main issues with these types of large size yarders is the higher costs of extraction and thus need to be applied to areas with larger cutting volume per hectare. These large expensive machines often can't be effectively matched with thinning operations with lower harvest intensity (e.g., pine plantations on steep terrains in Victoria) because of their size and cost. The current Australian yarders do not have efficient (motorized or electric) carriages. There is a lack of small to medium size cable yarders that can efficiently operate under different circumstances. Also, in some parts of mountainous areas ground-based machines have been applied and pushed to their technical limits due to lack of modern cable yarding systems; which might cause serious soil compaction and erosion issues over a long term period. Ground-based machines also have a high roll-over risk in steep terrain [3].

Steep country forests already contribute more than 40% of New Zealand's annual log harvest, and this is forecast to rise to over 60% in coming years [20]. Harvesting and transport costs are typically 40%–60% of the delivered costs of logs, yet little research has been conducted on this topic in New Zealand since the late 1990s when the former Logging Industry Research Organization (LIRO) folded. Present harvesting methods on this terrain, such as cable logging, have changed little in the last 50 years [20]. Depending on factors such as small payloads, high fuel consumption, poor communication and organization, steep slopes and adverse weather, these operations can be costly and hazardous to workers on the ground [21,22]. The costs of harvesting on steep terrain are on average 40% more than harvesting on flat terrain [23]. Additionally, New Zealand will require more forest workers and machines to harvest the increasing annual volumes. Evidence of the increasing volumes harvested on steep terrain is supported by the population of yarders in New Zealand which continues to grow, with each of these machines requiring a crew of eight people on average [12,23].

If New Zealand is to remain competitive in international log markets, improvements in cable logging operations in terms of production, safety and ergonomics will be necessary [14]. Improvements can come about through new machines, equipment and methods. However, these must be studied through extensive field testing to determine their effectiveness and optimal application. The decision on which machines, equipment and methods should be founded on an analysis of already existing state-of-the-art technology and recently developed innovations, including prototypes which are available for testing. Therefore, it is necessary to refer to countries where highly innovative technology is used and where market-leading manufacturers are available. Austria is one of the leading countries including innovative companies and research centers. In Europe, 7 out of 15 manufacturers are located in Austria producing 29 out of 63 cable yarder types [24].

The objective of this study was to identify the best suitable configuration of a cable yarder for steep terrain harvesting in Australasia based on user's preferences. An online survey based on conjoint analysis was used to answer questions about (1) the most important attributes of the new product design, (2) criteria, which stakeholders consider when selecting a cable yarder, (3) weights

representing the relative importance of criteria, and finally (4) the identification of the best suitable cable yarder concept.

2. Materials and Methods

The identification of the best suitable cable yarder concept is a decision problem based on several alternatives to be evaluated by multiple criteria. A pool of several existing or potential cable yarder configurations are called scenarios or alternatives. In our case, these scenarios will be evaluated by criteria using a conjoint analysis.

2.1. Decision Problem

Every decision we make requires the balancing of multiple factors (i.e., criteria) [25]. The more alternatives and criteria are available the more complex the decision making becomes. Structuring complex problems well and considering multiple criteria explicitly leads to more informed and better decisions. For such cases multiple-criteria decision-making (MCDM) methods have been developed. MCDM is a sub-discipline of operations research that explicitly evaluates multiple conflicting criteria in decision making. Conflicting criteria are typical in decision processes: price is usually one of the main criteria, and some measure of performance is typically another criterion, easily in conflict with the price. In purchasing a cable yarder, price, performance, safety, and universal applicability may be some of the main criteria we consider—it is unusual that the cheapest cable yarder is the most efficient and the safest one. A schematic highlighting the integrated nature of a decision making process is presented in [25].

2.2. Conjoint Analysis—Survey Design and Procedure

Conjoint analysis is a survey-based statistical technique often used in market research that helps determine how people value different attributes that make up a new product or service [25]. Because the yarder under investigation is a new product, the method is very suitable for answering the research questions. The method was used to reveal the preferences concerning the relative importance of the seven pre-selected cable yarder attributes (Table 1) and to generate prioritized lists for selection/adaptation/manufacturing of a cable yarder for each of the eight scenarios (Table 2).

Conjoint analysis (also known as Choice modelling or Discrete Choice experiments) is a statistical technique to determine how people value (or weight) different features that make up an outcome of interest [26]. It has been recommended as the best approach, theoretically and practically, for valuing health-care benefits [27,28], but it is increasingly being used in other areas such as corporate strategic management, monetary-policy [29], and agronomy [30]. Conjoint analysis is not often used in the forestry sector and when used, focused on the definition of policy instruments [31], forest contracts [32], forest conservation programs [33] or initiatives to foster investments in the forestry sector [34]. Furthermore, no studies were identified in the field of forest engineering or forest machine manufacturing using conjoint analysis.

In this study, the participants were asked to consider the options where the primary question was as follows: Which of these two cable yarder concepts do you prefer? An internet-based software package known as 1000Minds (www.1000minds.com) was used to support the process. The software implements a method for deriving weights, known by the acronym PAPRIKA (Potentially All Pairwise Rankings of all possible Alternatives). The method involves respondents being asked (via the online software) to choose the attributes best suited to the cable yarder scenario by means of a series of binary selections (pairs of ‘hypothetical species’). Each hypothetical species is presented as a pair of attribute combinations. These simple pairwise-ranking questions are repeated with different pairs of hypothetical alternatives, all involving different combinations of the criteria and their attributes, until enough information about preferences has been collected to accurately rank the criteria and their attributes [35]. The number of questions asked is minimized because each time one is answered the

method eliminates all other possible questions that are implicitly answered as corollaries of those already answered; which reduces the workload on participants.

Two of the steps to create a decision model for conjoint analysis in 1000 Minds involve: (i) an a priori ranking of the levels of each criterion to allow the software to make the questions in the survey, and (ii) to enter the alternatives (i.e., cable yarder concepts), to further reveal how participant's preference values after the survey could generate prioritized lists for timber harvesting in steep terrain. Thus, to set up the model (prior to the survey), we used the six technical and one economic criteria listed in Table 1 and the attributes of each criterion were ranked a priori for each scenario. From participants' answers, preference values representing the relative importance (or 'weights') of the criteria were obtained via mathematical methods based on linear programming (explained in detail in [35]). The relative importance of an attribute (attribute weight) is calculated by dividing the importance of a certain attribute by the sum of the utility ranges for all attributes. Single attribute scores are derived by part-worth functions, in practice they are calculated by means of a computer algorithm (dummy variable regression, etc.). Finally, the utility of a product j to customer I is calculated as follows [35]:

$$R_{ij} = \sum_{k=1}^K \sum_{m=1}^{M_k} a_{ikm} x_{jkm} + \varepsilon_{ij} \quad (1)$$

where j = a particular product or concept included in the study design, R_{ij} = the ratings provided by respondent I for product j , a_{ikm} = part-worth associated with m^{th} level of the k^{th} attribute, M_k = number of levels of attribute, K = numbers of attributes, x_{jkm} = dummy variable that take on value 1 if m^{th} level of the k^{th} attribute is present in product j and 0 otherwise, ε_{ij} = error terms, assumed to be normal distribution with zero mean and variance σ^2 for i and j . 1000 Minds then ranked the eight cable yarder scenarios from first to last according to their 'total scores'. Each yarder under consideration is 'scored' according to its performance on the criteria, and then the corresponding point values across the criteria are summed to get the species' 'total score' [35].

2.3. Criteria (Attributes and Levels)

Attributes are features or characteristics of the product of interest, with two or more levels of performance or achievement; which in this study is the cable yarder. As a first step, a literature review and brainstorming of scientific and practical experts identified 67 characteristics to describe the performance of a cable yarder:

- Anchor ropes (number, length, dimensions)
- Area of application
- Average productivity
- Camera (infrared, radio frequency, size of display, price)
- Carriage/grapple (type, weight, opening width, opening procedure, generation of clamping force, price, camera included, maximum load, GPS position)
- Carrier
- Control system
- Cost of maintenance
- Driving speed during transfer
- Effort for mounting and dismounting – Uphill, Downhill
- Engine output
- Fuel consumption
- Haulback line (length, dimensions, price, max. operating hours of economic use, max. years of economic use)
- Lifting capacity
- Mainline (length, dimensions, price, max. operating hours of economic use, max. years of economic use)

- Number of people which are necessary for operating the system
- Price
- Propulsion principle of winches
- Rigging system/configuration
- Rope speed (outhaul)
- Skyline (length, dimensions, price, max. operating hours of economic use, max. years of economic use)
- Solutions for synchronizing winches
- Tower (height, assembly)
- Transport dimensions
- Weight
- Working dimensions
- Traction (core/full drum)

To reduce the complexity of the survey layout, the characteristics were categorized into very, average and less important. Finally, seven attributes with two to four levels were selected to be implemented in the survey (Table 1 and Table A1 in Appendix A).

Table 1. Attributes and levels for the design of a new yarder.

Attributes	Levels
(1) Slew/Swing capability	<ul style="list-style-type: none"> • Yes • No
(2) Carriage/grapple type	<ul style="list-style-type: none"> • Motorized slack-pulling carriage • Motorized grapple • Mechanical grapple
(3) Carriage lifting capacity = breakout force	<ul style="list-style-type: none"> • 4 tonnes • 7 tonnes • 10 tonnes
(4) Carrier	<ul style="list-style-type: none"> • Mobile yarder on tracks • Mobile yarder on wheels (truck mounted) • Excavator based
(5) Maximum extraction distance (skyline cable length)	<ul style="list-style-type: none"> • 400 m • 700 m • >1000 m
(6) Carriage/grapple speed (outhaul)	<ul style="list-style-type: none"> • 5 m s⁻¹ • 10 m s⁻¹ • 15 m s⁻¹
(7) Price	<ul style="list-style-type: none"> • 500,000 Euro (825,000 NZD) • 750,000 Euro (1,235,000 NZD) • 1,000,000 Euro (1,650,000 NZD) • 1,250,000 Euro (2,000,000 NZD)

2.4. Cable Yarder Scenarios

Eight cable yarder scenarios were defined for the purpose of evaluating the conjoint output. The scenarios take into account current available cable yarders, basic principles of new potential layouts and general objectives of harvesting companies and forest managers. The eight scenarios are considered to cover most general situations, and to account for the most relevant terrain and operational characteristics as well as legal requirements in New Zealand and Australia. If an attribute matches with the scenario it is marked with an x (Table 2).

Table 2. Cable yarder design scenarios for Australia and New Zealand.

	Scenario	S01	S02	S03	S04	S05	S06	S07	S08
Attribute	Level								
1	No	x	x		x	x		x	
	Yes			x			x		x
2	Mech. grapple								
	Motorized	x	x						
	slack-pulling								
	Motorized grapple			x	x	x	x	x	x
3	4 tonnes	x							
	7 tonnes		x						x
	10 tonnes			x	x	x	x	x	
4	Excavator			x					
	Tracks					x			x
	Wheels	x	x		x		x	x	
5	400 m								
	700 m	x	x	x	x	x			x
	>1000 m						x	x	
6	5 m/s	x							
	10 m/s		x	x	x	x		x	x
	15 m/s						x		
7	1250 k€						x		
	1000 k€							x	
	750 k€			x	x	x			
	500 k€	x	x						x

Each yarder design has its specific strengths. All scenarios are able to be manufactured from a technical point of view. The scenarios S01 and S02 are already existing cable yarders manufactured by Koller Ltd. The specifications of the machines are well defined and available on www.kollergmbh.com. The K 507, which represents S01, is a yarder for uphill, downhill and flat terrain logging. An 8 × 6 or 8 × 8 MAN truck with special reinforced frames is usually used as a carrier, which also drives an integrated processor. The maximum extraction distance is 1000 m, lifting capacity is four tonnes and carriage outhaul speed 8.4 m s^{−1}. The tower height is maximum 15 m, which can be reached by an optional available extendible tower. Commonly, this type of yarder is used together with a motorized slack-pulling carriage in standing skyline mode, which allows the treatment of convex terrain by the aid of artificial or natural supports. Yarding over convex terrain is one of the main advantages of the standing skyline system compared to the use of running skyline systems together with a mechanical grapple carriage. The K 702, which represents S02, is so far the most powerful and fastest Koller yarder for uphill, downhill and flat terrain logging. The machine is equipped with a self-supporting frame, allowing simple assembly on various trucks and trailers as well as easy worldwide export. The maximum extraction distance is 800 m, lifting capacity is eight tonnes and carriage outhaul speed 11 m s^{−1}. The tower height with extension can reach 15 m.

S03 to S05 are prototypes, which are able to be mounted on excavator (S03), truck (S04) or tracks (S05). They are electro-hybrid driven systems optimized for running skyline (high electric power transfer from haulback to mainline winch) and for live/standing skyline uphill. The excavator mounted option has no guylines, which allows quick installation and fast relocation. The maximum extraction distance for these scenarios depends on the cable dimensions and is about 1000 m. Lifting capacity is 9.2 to and carriage outhaul speed is up to 13 m s^{−1}. The maximum tower height is 10 m. The design with a split drum has been configured in a way, that the switch between live or standing skyline and running skyline modes makes no change in mechanical configuration necessary: Nowadays used systems from established manufacturers can only be operated in either running, live or standing skyline operation, respectively. An advantage is their implemented recuperation facility: The electric motors switch automatically into generation mode, if external forces are pulling on the winches. This is

necessary especially in running skyline mode, because the two necessary winches always switch back and forth in motor and generator-mode. In pure downhill operations, with the aid of electrical storage units, like the super capacitors used, it would be theoretically possible to operate without any need of external energy sources like diesel. Due to recuperation, the machine needs only up to 1/3 of the diesel of yarder systems with comparable power. Another advantage is its minimum use of consumables like hydraulic liquids or motor oils. This makes the yarder deployable even in environmentally sensitive or protected landscapes.

S06 and S07 are two variants of performance optimized machines. S06 is a swing yarder with a lifting capacity of 10 tonnes, an extraction distance of more than 1000 m and a carriage outhaul speed of 15 m s^{-1} . The price for this high-level machine is about €1250 k. S07 has no swing capability and the carriage outhaul speed is about 10 m s^{-1} . The price of the machine, which is about €1000 k is still relatively high. S08 is a price optimized yarder on tracks with a lifting capacity of seven tonnes, an extraction distance of 700 m and a carriage outhaul speed of 10 m s^{-1} . In all scenarios mentioned, European technology called “automatic mode” is incorporated: The tower “remembers” the last position of the carriage in the stand and—starting at the landing—the carriage drives automatically to this last stored position, if the operator at the tower just pushes one single button. On the other hand, starting at the felling place, the automatic mode allows to start the carriage which drives without human control to a position a few meters before the landing. At this position, the operator at the yarder takes over the control and does further processing at the landing. Anyhow, this automatic mode substantially relieves the operator from simple and monotonous tasks and is therefore much less exhausting. The automatic mode usually improves productivity, safety and ergonomics. Machines of Koller have been involved in defining the scenarios because the company is a partner in the national funded project “TechnoSteep,” which aims to develop a cable yarder based on European technology to be adapted according to New Zealand and Australian conditions. Based on the results of the analysis, the cable yarder prototype will be manufactured in Austria by Koller and transferred to New Zealand for testing and demonstration.

2.5. Participant Progress

Twenty-five people were invited to take part in the online survey and 14 people successfully completed the survey, which was a response rate of 56%. People invited include forest companies in Australia (Queensland, New South Wales, Victoria and Tasmania), who in turn were asked to distribute the survey to their (cable) harvesting operation’s contractors. Five out of ten persons participated in Australia. Fifteen industry logging supervisors or company operational managers that actively manage cable yarding crews from New Zealand were invited to participate in the conjoint analysis, of which nine responded. They ranged in experience from 3 to 30+ years and many had knowledge of European yarders because they visited European manufacturers or field demonstrations of European technology.

3. Results

3.1. Attributes Ranking and Weights

Pairwise comparisons performed by conjoint analysis generated a ranking of the attributes for each participant P1-P14 (Table 3). Carriage lifting capacity, price, slew/swing capability and carriage/grapple speed are those attributes which were ranked as most important criteria at least one time. Maximum extraction distance, carriage/grapple type and carrier were never ranked as most important attributes. On the other hand, the latter two attributes and slew/swing capability are the only attributes which have been ranked at least one time, as least important criteria. The ranking of the attributes correlates also with attribute weights calculated in Table 4. Carriage lifting capacity, most often ranked on first position is also the attribute with the highest attribute weight. Kendall’s coefficient of concordance W of the 14 participants’ marginal utility value rankings was 0.448.

Table 3. Ranking of importance of the seven attributes subjected to conjoint analysis involving 14 participating practitioners.

Attribute	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	Median	Mean
1	7th	7th	7th	4th	7th	7th	6th	3rd	2nd	1st	1st	1st	5th	4th	4.50	4.429
2	6th	5th	6th	6th	2nd	6th	5th	7th	7th	6th	5th	4th	3rd	6th	6.00	5.321
3	2nd	1st	1st	1st	1st	2nd	2nd	4th	5th	2nd	3rd	2nd	1st	3rd	2.00	2.179
4	5th	6th	3rd	7th	6th	5th	7th	6th	6th	7th	7th	7th	7th	7th	6.50	6.143
5	4th	4th	2nd	3rd	3rd	4th	4th	5th	3rd	5th	6th	5th	2nd	2nd	4.00	3.714
6	3rd	3rd	5th	2nd	5th	1st	1st	2nd	4th	3rd	4th	6th	6th	5th	3.50	3.571
7	1st	2nd	4th	5th	4th	3rd	2nd	1st	1st	4th	2nd	3rd	3rd	1st	2.75	2.643

3.2. Normalized Attribute Weights and Single Attribute Scores

The carriage lifting capacity was considered to be the most important criterion for use in the selection of cable yarders (Table 4) and this was weighted more highly than the other six criteria, with the exception of the price which was considered equally as important as carriage lifting capacity. For both attributes, the attribute weight is higher than 0.2. Carrier was the attribute with the lowest importance, whereas excavator based carriers are the least preferred configuration. Carrier and carriage/grapple type were those attributes with a score lower than 0.1.

Table 4. Normalized attribute weights and single attribute scores for cable yarder evaluation.

Attribute	Attribute Weight (Sum to 1)	Level	Single Attribute Score (0–100)
Slew/swing capability	0.106	No	0.0
		Yes	100.0
Carriage/grapple type	0.084	Mechanical grapple	0.0
		Motorized slack-pulling carriage	24.6
		Motorized grapple	100.0
Carriage lifting capacity (breakout force)	0.250	4 tonnes	0.0
		7 tonnes	61.8
		10 tonnes	100.0
Carrier	0.052	Excavator based	0.0
		Mobile yarder on tracks	68.8
		Mobile yarder on wheels	100.0
Maximum extraction distance (skyline cable length)	0.138	400 m	0.0
		700 m	70.3
		>1000 m	100.0
Carriage/grapple speed (outhaul)	0.160	5 m s ^{−1}	0.0
		10 m s ^{−1}	70.7
		15 m s ^{−1}	100.0
Price	0.210	\$1,875,000 (1,250,000 Euro)	0.0
		\$1,500,000 (1,000,000 Euro)	41.1
		\$1,125,000 (750,000 Euro)	68.8
		\$750,000 (500,000 Euro)	100.0

3.3. Ranking of Scenarios

The attributes of the eight cable yarder scenarios were evaluated by summarizing the products of the respective attribute weight with the single score attribute. In the best case the sum would have a score of 100% and in the worst case 0%. In realistic conditions, usually no scenario would fulfill the most preferable configuration for all attributes. This means, that a value of 80% is a reasonable result (Figure 1).

Figure 1. Evaluation of cable yarder scenarios by summarizing attribute values.

Three scenarios achieved summarized attribute values of approximately 80% and should be recommended for the new product design of a cable yarder for steep terrain timber harvesting in New Zealand and Australia. S03 is one of the best options because it has slew/swing capability, a motorized carriage/grapple and a carriage lifting capacity of 10 tonnes. The only disadvantage is, that the yarder is mounted on an excavator. On the other hand, this attribute has the lowest weight and therefore does not impact the overall result. S06 has the same summarized attribute level as S03. It has a better performance in terms of a truck as carrier, an extraction distance longer than 1000 m and a carriage speed of 15 m s^{-1} . The only weak point is, that the price is much higher than for all other scenarios. The best performance of all scenarios with a score of 81% has S08. It has average performance in terms of lifting capacity, carrier, extraction distance and carriage speed but the price is below 500 k€. The already existing machine K 507 (S01) has the poorest results of all eight scenarios. The machine has a lifting capacity of only four tonnes and therefore, hardly fulfills the requirements of harvesting operations in New Zealand and Australia. This result shows also the need of developing a new cable yarder which meets the demand of Australasian forest industry.

4. Discussion

The design and manufacture of mechanical systems is usually a time and cost intensive process. Therefore, it is important to have an accurate and precise decision making process, to avoid wasting time and money. For this task, conjoint analysis has been identified as a suitable method. An online survey based conjoint analysis was successfully completed to identify the best suitable cable yarder concept for the Australasian market.

4.1. Comparison with other Studies

Conjoint analysis is a relatively new approach for evaluating individual products or services, and it was not until the mid-1990s that the method came into use. Since then conjoint analysis has been applied to business analysis, market research and a number of environmental issues such as: energy, recreation, environmental evaluation, ecosystem management, consumer preferences for

environmentally certified products, public preferences regarding industrial projects and environmental policy development [36].

Product evaluation and marketing have used conjoint analysis over a long period, and it has been shown that product development will be able to make much use of conjoint analyses in the future [37]. Consumer behavior and other environmentally correlated behavior is an area where conjoint analysis may also work as an excellent tool to estimate how and why the public acts in certain ways [36].

Forestry may also be a subject of interest to decision makers, but the authors have found few conjoint studies in this sector. Most of the studies have focused on forest management [38,39], valuation of forest land uses [40,41] or forest conservation programs [33,42]. Only two studies were dealing with decisions on biomass [43] or wood harvesting [44]. It is very common to ask consumers about their preference for different products, also in the agricultural sector (e.g., oil, tomatoes, cheese, honey, coffee), but not really about the machines or systems which produce those products. In the forestry sector, the current study is novel and therefore opens a new horizon in forest machinery design and production.

4.2. Practical Implementation of Results

From the results (Figure 1) it appears that the most preferred cable yarder scenarios include S03, S06 and S08. Results indicate that medium to high lifting capability, swing capability, motorized carriage and maximum extraction length of 700 m to 1000 m are important technical aspects to the industry participants of this survey. These scenarios have different carrier types (mounted on truck or excavator) which may indicate the carrier type has less importance to industry users in this case study. The two attributes of greatest importance were carriage lifting capacity (i.e., breakout force) and cost. This is understandable with regard to a new yarder design of European origin destined for an Australasian or international markets with a stronger focus on efficient productive capability and less on flexibility. Cost is always of critical importance with any investment in new machinery, but performance is of higher importance in this case. Practitioners in Australasia have concerns that the traditional smaller size yarders developed in Europe will not meet the demands of the larger and faster growing timber in Australasia and the methods employed to extract the timber. A previous study on a European yarder (e.g., with five tonnes carriage lifting force) in New Zealand highlighted the limitations in its ability to generate high enough breakout forces to commence the extraction [45]. Specifically, when extracting full tree length *Pinus radiata* (e.g., average payload of 2.6 tonnes) the yarder sometimes stalled during breakout. A further study by Harrill & Visser [46] quantified breakout forces in commonly employed yarding methods in New Zealand and found breakout forces were on average 1.5 times the weight of the payload but in difficult scenarios could be up to 3.6 times the weight. Considering the average tree size in New Zealand is around two tonnes, it is understandable why the single attribute score was 0.0 for a carriage lifting force of 4 tonnes. It is common for more than one stem to be extracted per cycle in cable logging operations in Australasia; meaning that even a seven or ten tonnes carriage lifting capacity could be limiting in moderate to difficult conditions, respectively. One attribute with relatively low weight—see also Table 4—second only to carrier (0.052), was carriage type (0.084). While practitioners were less concerned about what carriage they employ, the most desired carriage type was the motorized grapple carriage. However, motorized grapple carriages are most often employed on live skyline systems to bring the carriage to the stem on the ground, as opposed to standing skyline systems where motorized slack-pulling carriages are employed that lower a drop-line with chokers to the ground [47]. The design requirements for the yarder's winch set and power train are very different for live compared to standing skyline systems. While European yarder manufacturers have a long history of designing yarders for standing skyline applications, live skylines are very rare [24]. Furthermore, yarders have historically been designed to employ primarily one skyline system (e.g., standing, live or running) and some sacrifices in performance and cost could be expected if the machine were designed for more than one skyline system. As such, commercial

success could depend on winch set performance when operated in the live skyline configuration, where speed, skyline lifting force and precise control of skyline brakes are critical.

4.3. Limitations

It was very helpful that project partners from New Zealand and Australia cooperate well with companies and contractors from the target countries. This also explains the high response rate of 56%. The total number of participants is relatively low but not smaller than in similar validated studies (e.g., [38]). The Kendall's coefficient of concordance indicates good reliability of the results. The participants need basic computer skills complete the online survey. The user interface and the algorithm to calculate preference values is not self-explanatory. Therefore, a manual was provided to explain the method and give more background information among the attributes and levels rated to them. Another major limitation of the technique is that for many real marketing problems the number of attributes is large which makes the number of product combinations to be rated very large and each individual product description may be very complex. Therefore, it was necessary to reduce the number of tower yarder characteristics from 67 to 7 attributes. This was a very strong reduction and some important specifications, like machine dimensions, weight, tower height and rope diameter, had to be ignored. For these characteristics, the machine manufacturer had to fall back on their own experiences or additional interviews with experts. Asking the participants about their preferences (pairwise rankings) of alternatives is limited by the fact that participants do not always have complete information about the alternatives and their characteristics. This is especially the case when rating innovations and prototypes. As an example, excavator systems were up to now, limited to the engine power used in the excavator. In high efficient electro-hybrid systems designed with the newest available technology, the power of the excavator could be additionally supported by electrical storage devices and less of an issue than perceived. Due to this fact, that this technology is not known by common applications in forestry, the assessment of well-established forestry managers can be understood, but must be critically reflected, when discussing these new technologies.

5. Conclusions

Conjoint analysis proved an effective tool in managing a multi criteria decision making (MCDM) process for the design of a new cable yarder. The process narrowed down 67 criteria of yarder design to a more manageable seven attributes with two to four levels each. The most suitable design according to the study's results is likely to be the S06 based on its carriage lifting capacity, length of skyline and associated mobility with truck mounted carrier. However, it is also the most expensive design option and therefore practitioners may lean towards the S03 (KX 800e) design if they are willing to sacrifice skyline length, a reduction in carriage speed and don't mind an excavator as the carrier. Both designs would be capable of extraction by grapple carriage which is highly desired in both Australia and New Zealand. The differences between the two machines may find them applied to different forest ownerships and operating conditions like larger corporate plantations or the smaller farm forests (i.e., woodlots) that are maturing in the near future.

The study results indicate that analytical methods could help technology developers to clearly identify the most important attributes when developing a new product to match with the customers' expectation. The results of this study would also be of use to local cable yarding contractors in New Zealand and Australia to make sure their operational requirements are considered prior to building a cable yarder. This may ease implementing and commercializing the cable yarder prototype in the future. Based on the results of the analysis, a cable yarder prototype will be manufactured in Austria and transferred to New Zealand for testing and demonstration.

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Appendix A

Table A1. Description of attributes and levels for the design of a new yarder.

Attributes	Levels	Description ¹
(1) Slew/Swing capability	• Yes	Yarders come with either a swinging boom or a fixed boom. Most swinging booms have a limited height of 10 to 20 m. Fixed boom yarders can have towers as tall as 30 m.
	• No	Swinging booms permit a wider skyline corridor and thereby reduce the number of yarder moves. This is a big advantage when grapple yarding.
(2) Carriage/grapple type		A swing boom yarder will provide more deflection for uphill yarding than is available to a fixed tower of the same height if the fixed tower has to set a log length back of the fill slope. On the other hand, fixed towers are usually taller than the booms on swing boom yarders.
		Carriages are described as either slack-pulling or nonslack-pulling. Slack-pulling refers to the ability to pull slack in the skidding line or have the skidding line pulled through the carriage. A non-slack-pulling carriage (e.g., grapple) has no means of allowing the skidding line to be contained in or pass through it. Without special rigging, this prevents lateral yarding. A slack-pulling carriage either permits the mainline to be used as a skid line and pulled through the carriage, or it has its own drum with a skid line that can be pulled out of the carriage to permit lateral yarding.
	• Motorized slack-pulling carriage • Motorized grapple • Mechanical grapple	A motorized slack-pulling carriage uses some type of power device in the carriage for pulling slack. The power may be in the form of mechanical springs, hydraulic motors, or diesel, propane-fueled or electrical engines. The carriage will clamp to the skyline and is remotely controlled by radio or by mechanical springs. A grapple carriage eliminates the need for a choker-setter and can save a lot of time. However, there are quite a few limitations associated with the grapple—you can only pick up trees/logs directly under the skyline. The design of a grapple carriage is similar to some of the mechanical slack-pulling carriages in that they must provide a means to open or close the grapple. This can be done with a line from the yarder (mechanical) or by using an engine or power device in the carriage (motorized). The grapple carriage cannot yard laterally unless it is side-blocked.
(3) Carriage lifting capacity = breakout force	• 4 tonnes • 7 tonnes • 10 tonnes	A higher lifting capacity assumes higher productivity of the harvesting system but needs bigger and more powerful machines.

Table A1. Cont.

Attributes	Levels	Description ¹
(4) Carrier		The carrier is the chassis of the yarder. Its function is to support the yarder equipment and allow transportation.
	<ul style="list-style-type: none"> • Mobile yarder on tracks • Mobile yarder on wheels (truck mounted) • Excavator based 	Mobile yarders on tracks can manage steep/rough grade, are stable on soft ground and very maneuverable. Tank-type carriers can absorb some landing irregularities whereas excavator based carriers are more robust mechanically. Track-mounted carriers are limited in self-propelled transfer. Excavator based machines may not need anchor ropes and they can be fast to move and set-up. However, they can have less power and are smaller than other types of yarders.
		Truck-mounted yarders are fast when moving long distances and they can use public roads. On the other hand, purchase costs and weight is higher and they require well-formed, suitable grades.
(5) Maximum extraction distance (skyline cable length)	<ul style="list-style-type: none"> • 400 m • 700 m • >1000 m 	A longer extraction distance allows to harvest a larger area but requires a longer skyline and other cables. This usually means to apply bigger and more powerful machines.
(6) Carriage/grapple speed (outhaul)	<ul style="list-style-type: none"> • 5 m s⁻¹ • 10 m s⁻¹ • 15 m s⁻¹ 	A higher line speed allows higher productivity but requires more sophisticated technology.
(7) Price ²	<ul style="list-style-type: none"> • 500,000 Euro • 750,000 Euro • 1,000,000 Euro • 1,250,000 Euro 	Bigger and more powerful machines as well as more sophisticated technology leads to a higher price.

¹ U.S. Forest Service [48]; ² Price has been also converted into New Zealand Dollars.

References

- Price, M.F.; Gratzner, G.; Duguma, L.A.; Kohler, T.; Maselli, D.; Romeo, R. (Eds.) *Mountain Forests in a Changing World—Realizing Values, Addressing Challenges*; FAO/MPS and SDC: Rome, Italy, 2011.
- Spinelli, R.; Visser, R.; Riond, C.; Magagnotti, N. A Survey of Logging Contract Rates in the Southern European Alps. *Small-Scale For.* **2017**, *16*, 179–193. [CrossRef]
- Visser, R.; Berkett, H. Effect of terrain steepness on machine slope when harvesting. *Int. J. For. Eng.* **2015**, *26*, 1–9. [CrossRef]
- Ghaffariyan, M.R.; Stampfer, K.; Sessions, J. Production Equations for Tower Yarders in Austria. *Int. J. For. Eng.* **2009**, *20*, 17–21. [CrossRef]
- Enache, A.; Kühmaier, M.; Visser, R.; Stampfer, K. Forestry operations in the European mountains: A study of current practices and efficiency gaps. *Scand. J. For. Res.* **2016**, *31*, 412–427. [CrossRef]
- Visser, R.; Harrill, H. Cable Yarding in North America and New Zealand: A Review of Developments and Practices. *Croat. J. For. Eng.* **2017**, *38*, 209–217.
- Bell, J.L. Changes in logging injury rates associated with use of feller-bunchers in West Virginia. *J. Saf. Res.* **2002**, *33*, 463–471. [CrossRef]
- Montorselli, N.B.; Lombardini, C.; Magagnotti, N.; Marchi, E.; Neri, F.; Picchi, G.; Spinelli, R. Relating safety, productivity and company type for motor-manual logging operations in the Italian Alps. *Accid. Anal. Prev.* **2010**, *42*, 2013–2017. [CrossRef]
- Visser, R.; Raymond, K.; Harrill, H. Developing Fully Mechanised Steep Terrain Harvesting Operations. In Proceedings of the 47th International Symposium on Forestry Mechanisation: Forest Engineering: Propelling the Forest Value Chain, Gerardmer, France, 23–26 September 2014; Available online: <https://www.formec.org/images/proceedings/2014/a23.pdf> (accessed on 22 November 2018).
- Heinimann, H.R.; Stampfer, K.; Loschek, J.; Caminada, L. Perspectives on Central European Cable Yarding Systems. In 2001—A Forest Engineering Odyssey, Proceedings of the International Mountain Logging and 11th Pacific Northwest Skyline Symposium, Seattle, WA, USA, 10–12 December 2001; pp. 268–279. Available online: <https://depts.washington.edu/sky2001/proceedings/papers/Heinimann.pdf> (accessed on 22 November 2018).
- Visser, R. Survey of Cable Yarders Used in New Zealand. Harvesting Technical Notes 2013, HTN06-03, 4p, Forest Growers Research. Available online: <https://fgr.nz/documents/download/4034> (accessed on 22 November 2018).

12. Harrill, H.; Visser, R. Survey of Yarders and Rigging Configurations: 2018. Harvesting Technical Notes 2018, HTN10-04, 9p, Forest Growers Research. Available online: <https://fgr.nz/documents/download/7391> (accessed on 22 November 2018).
13. NZFOA. New Zealand Plantation Forest Industry: Facts and Figures 2016/17. Available online: https://www.nzfoa.org.nz/images/stories/pdfs/Facts_Figures_2016_%C6%92a_web_version_v3.pdf (accessed on 30 January 2019).
14. Harrill, H. Improving Cable Logging Operations for New Zealand's Steep Terrain Forest Plantations. Ph.D. Thesis, School of Forestry, University of Canterbury, Christchurch, New Zealand, 2014.
15. Raymond, K. Safety benefits of a harvesting research programme. *N. Z. J. For.* **2014**, *59*, 9–13.
16. Raymond, K. Teleoperation of harvesting machinery for a safer future. In *Forest Engineering: Making a Positive Contribution, Abstracts and Proceedings of the 48th FORMEC Symposium 2015, Linz, Austria, 4–8 October 2015*; pp. 9–11. Available online: https://www.formec.org/images/proceedings/2015/formec_proceedings_2015_web.pdf (accessed on 22 November 2018).
17. Visser, R. *Benchmarking to Improve Harvesting Cost and Productivity: 2011 Update*. Harvesting Technical Notes HTN04-08; Future Forests Research Ltd.: Rotorua, New Zealand, 2012; p. 7.
18. Acuna, M.; Skinnell, J.; Mitchell, R.; Evanson, T. Bunching Stems in Steep Slopes for Efficient Yarder Extraction. CRC Forestry 2011, Hobart. Bulletin no. 17; 3p. Available online: <http://research.usc.edu.au/vital/access/services/Download/usc:17454/SOURCE1> (accessed on 22 November 2018).
19. Parschau, J. *Planning and Assessment for Cable Harvesting Systems for Selective Harvesting in Native Forests of New South Wales. Special Scholarship Project (SRP301) 2012*; University of the Sunshine Coast: Queensland, Australia, 2012; 32p.
20. FFR. Four Corners June 2010. Available online: <http://www.ffr.co.nz/system/files/newsletters/Four%20Corners%20June%202010.pdf> (accessed on 15 March 2016).
21. Amishev, D. Crew Best Practice—Costs and Productivity. Harvesting Technical Notes 2011, HTN03-07, 9p, Forest Growers Research. Available online: <https://fgr.nz/documents/download/3975> (accessed on 22 November 2018).
22. Slappendel, C.; Laird, I.; Kawachi, I.; Marshall, S.; Cryer, C. Factors affecting work-related injury among forestry workers: A review. *J. Saf. Res.* **1993**, *24*, 19–32. [[CrossRef](#)]
23. Visser, R. *Harvesting Cost and Productivity Benchmarking: 2013 Update*; Harvesting Technical Notes HTN06-06; Future Forests Research Ltd.: Rotorua, New Zealand, 2014; 6p.
24. Wassermann, C. Tower Yarders for Timber Harvesting—An Analysis of European Manufacturers and Models [Mastseilgeräte für die Holzernte—Eine Analyse des europäischen Herstellerangebotes]. Master Thesis, University of Natural Resources and Life Sciences Vienna, Wien, Vienna, 2018.
25. Belton, V.; Stewart, T. *Multiple Criteria Decision Analysis: An Integrated Approach*; Kluwer Academic Publishers: Boston, MA, USA, 2002; ISBN 978-1-4615-1495-4. 372p.
26. Graff, P.; McIntyre, S. Using ecological attributes as criteria for the selection of plant species under three restoration scenarios. *Austr. Ecol.* **2014**, *39*, 907–917. [[CrossRef](#)]
27. Krantz, D.H. A theory of magnitude estimation and cross-modality matching. *J. Math. Psychol.* **1972**, *9*, 168–199. [[CrossRef](#)]
28. Golan, O.; Hansen, P.; Kaplan, G.; Tal, O. Health technology prioritization: Which criteria for prioritizing new technologies and what are their relative weights? *Health Policy* **2011**, *102*, 126–135. [[CrossRef](#)] [[PubMed](#)]
29. Smith, C. Revealing Monetary Policy Preferences. Discussion Paper 2009/01. 2009. Available online: <http://www.rbnz.govt.nz/research/discusspapers> (accessed on 22 November 2018).
30. Smith, K.F.; Fennessy, P.F. The use of conjoint analysis to determine the relative importance of specific traits as selection criteria for the improvement of perennial pasture species in Australia. *Crop Pasture Sci.* **2011**, *62*, 355–365. [[CrossRef](#)]
31. Morgan-Davies, C.; Waterhouse, T. Future of the hills of Scotland: Stakeholders' preferences for policy priorities. *Land Use Policy* **2010**, *27*, 387–398. [[CrossRef](#)]
32. Arifin, B.; Swallow, B.M.; Suyanto, S.; Coe, R.D. A conjoint analysis of farmer preferences for community forestry contracts in the Sumber Jaya Watershed, Indonesia. *Ecol. Econ.* **2009**, *68*, 2040–2050. [[CrossRef](#)]
33. Kelly, M.C.; Germain, R.H.; Stehman, S.V. Family forest owner preferences for forest conservation programs: A New York case study. *For. Sci.* **2015**, *61*, 597–603. [[CrossRef](#)]

34. Aguilar, F.X. Investment preferences for wood-based energy initiatives in the US. *Energy Policy* **2009**, *37*, 2292–2299. [CrossRef]
35. Hansen, P.; Ombler, F. A new method for scoring additive multi-attribute value models using pairwise rankings of alternatives. *J. Multi-Crit. Decis. Anal.* **2008**, *15*, 87–107. [CrossRef]
36. Alriksson, S.; Öberg, T. Conjoint analysis for environmental evaluation—A review of methods and applications. *Environ. Sci. Pollut. Res.* **2008**, *15*, 244–257. [CrossRef]
37. Chen, C. Design for the environment: A quality-based model for green product development. *Manag. Sci.* **2001**, *47*, 250–263. [CrossRef]
38. Dennis, D.F. Analyzing public inputs to multiple objective decisions on national forests using conjoint analysis. *For. Sci.* **1998**, *44*, 421–428.
39. Klosowski, R.; Stevens, T.; Kittredge, D.; Dennis, D. Economic incentives for coordinated management of forest land: A case study of southern New England. *For Policy Econ* **2001**, *2*, 29–38. [CrossRef]
40. Nagashima, K.; Sands, R.; Whyte, A.G.D.; Bilek, E.M.; Nakagoshi, N. Forestry expansion and land-use patterns in the Nelson Region, New Zealand. *Landsc. Ecol.* **2001**, *16*, 719–729. [CrossRef]
41. González Gómez, M.; Olschewski, R. Valuation of forest land uses in the coastal region of Spain and Portugal. *Allg. For. Jagdztg.* **2008**, *179*, 219–225.
42. Kelly, M.C.; Germain, R.H.; Mack, S.A. Forest conservation programs and the landowners who prefer them: Profiling family forest owners in the New York City watershed. *Land Use Policy* **2016**, *50*, 17–28. [CrossRef]
43. Serenari, C.; Peterson, M.N.; Moorman, C.E.; Cubbage, F.; Jervis, S. Application of Choice Experiments to Determine Stakeholder Preferences for Woody Biomass Harvesting Guidelines. *J. Sustain. For.* **2015**, *34*, 343–357. [CrossRef]
44. Leszczyński, K. Different evaluations of motor-manual wood harvesting processes on the basis of conjoint analysis. *Croat. J. For. Eng.* **2010**, *32*, 165–172.
45. Evanson, T.; Hill, S. The Koller 602h Yarding System. Harvesting Technical Notes 2015, HTN08-01, 10p, Forest Growers Research. Available online: <https://fgr.nz/documents/download/4692> (accessed on 29 November 2018).
46. Harrill, H.; Visser, R. A Study of Breakout Forces in Cable Yarding. Harvesting Technical Notes 2017, HTN09-06, 6p, Forest Growers Research. Available online: <https://fgr.nz/documents/download/5987> (accessed on 29 November 2018).
47. Studier, D.D.; Binkley, V.W. *Cable Logging Systems*. Division of Timber Management; Forest Service, US Department of Agriculture: Portland, OR, USA, 1974; 205p.
48. U.S. Forest Service. Cable Logging Operations. Available online: <https://www.fs.fed.us/forestmanagement/equipment-catalog/cable.shtml> (accessed on 22 November 2018).

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