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Value Chain Optimization in Timber Supply Chain: Case Study in Gangwon-do

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Abstract

This study investigates to identify the impact factors of timber production cost on the relationship between production cost components and revenues generated by evaluating the entire timber supply chain. In this research, selected 13 logging zones as target areas and classified 14 forest production cost factors, six groups. Additionally, established 13 externalenvironmental factors with related stakeholders and forestry experts. And the BCR (Benefit Cost Ratio) method was then used to analyze the economics of each zone. Filled up a checklist and rated using 5 point scale for each target region, and extracted major cost factors for the production economy of the item. The analysis of major cost factors in the timber production revealed that wood grab equipment usage fee was the first ranked and forest trees purchase cost was ranked in the 2ndAlso, the 3rdranking was logging expenses, and transport cost, which accounted for 84% of the total cost, was ranked in the 4th. In addition, the rock land ratio, slope, timber payment (forest trees purchase cost), special timber, ratio of timber, DBH (Diameter at Breast Height), and mixed forest ratio were the factors that most affected the timber supply chain cost.

Key Words: timber production, timber harvest, timber harvest system, LCA, BCR

Introduction

Starting with the first basic forest plan of Korea Forest Service in 1973, the sixth basic forest plan is being implemented as of 2018. While it has been a time to grow and grow forests through restoration and sustainable forest management, now and the future is a time to economically produce and use these well-cultivated forests.

The Korea Forest Service estimates that the scale of the domestic forest industry, including timber and forest products, is 48 trillion won per year and that the public interest value is 126 trillion won per year.

This study focuses on economic forests, one of the 6th basic plans for forests. Currently, most timber producers judge profitability and economics from their own experience and subjective perspective. The logging company business feasibility review by rule of thumb causes problems of tree cost difference between the owners of trees and company, which causes a lot of friction with the forest owners.

Negotiations and countermeasures with mountain owners relying solely on these experiences and insights have triggered conflicts with forest production stakeholder, including the owner of a mountain, even before the business

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starts, this in turn has a fatal impact on the return of timber production. Thus, in this study, analyzed the share of cost factors in the production of objects, identified these cost factors and their associations with profitability, and used field checklists to analyze the increasing costs and external factors. Profitability reviews used BCR methods, and field checklists were used in 13 targeted regions, face-to-face surveys of forest experts, and field interviews.

The domestic research on the economics and profitability of timber production was initiated by Woo et al. (1978). Kim et al. (2000) uses GIS to calculate the workload for felling and bucking and yarding, skidding, cleaning process and used the market price reversal method to calculate the timber price. The Korea Forest Service (2006) developed a model for economic assessment and supply plan for the harvest and delivery of domestic timber. Han (2009) estimated productivity and production costs through data collection and analysis for each process during the harvest and transportation process and tried to approach the economic feasibility of net income through these data. Choi et al. (2012) studied ways to differentiate the prices of timber produced by the forest management certification, as a policy study for the production of timber. Lee (2013) performed productivity and cost analysis of the whole tree harvesting system using swing yarder, which is a harvesting system that makes up a large percentage of the timber production cost. Lee (2017) compared the productivity and harvest costs of each tree production system for the utilization of by-products. Hwang (2016) presented criteria for reviewing the improvement of existing forest road structures in consideration of the use of large wooden trucks and determining the method of wood transport to the timber market after logging.

For biomass development, which has recently become an issue in renewable energy, Kim (2018) analyzed the economic feasibility of wood pellet, a byproduct of timber, through cost benefits.

Materials and Methods

Study Area

The target areas are five regions in Jeongseon, Gangwon-do, one region in Yanggu, one in Goseong, three in Gapyeong, Gyeonggi-do, one in Suncheon, Jeollanam-do, one in Namwon, Jeollabuk-do, a total of 13 areas were targeted at one area in Taean, Chungcheongnam-do, Republic of Korea, and are shown in Table 1.

The trees, which were cut from 13 research sites, are divided into sawn wood and pulp. The timber is transported to a local sawmill, pulpwood will be transported to three regional pulp plants in Incheon, Asan and Gunsan. Pulpwood sells low and transportation cost is high because the factory is located far away.

Table 1. Target area

No.	Administrative district	Area	Licensed area (ha)	Growing Stock (m^3)	Mixed forest ratio (%) (conifer : broad leaved)
1	Gangwon-do Jeongseon	A	8.7	1,195	40:60
2		B	5.3	862	80:20
3		C	5.2	755	80:20
4		D	7.2	1,146	50:50
5		E	7.2	886	20:80
6	Gangwon-do Yanggu	F	12.1	1,370	30:70
7	Gangwon-do Goseong	G	28.0	2,688	60:40
8	Gyeonggi-do Gapyeong	H	7.7	1,125	10:90
9		I	15.4	1,711	10:90
10		J	6.4	882	80:20
11	Jeollanam-do Suncheon	K	11.5	1,520	70:30
12	Jeollabuk-do Namwon	L	6.0	1,065	90:10
13	Chungcheongnam-do Taean	M	6.5	782	90:10

Timber Harvesting Cost Factor

If 13 target regions are analyzed and the cost of forest production is divided, it can be classified as 14 components of six groups as shown in Fig. 1.

External environmental factors

External environmental factors, in addition to the cost factors required for the production of objects, may change their content and size depending on the circumstances of the production site. However, most of them rely on the experience of the producers. In this study, an external environmental factor was established using the results analyzed through 13 regional work experiences with forest project experts. Table 2 is describes external environmental factors.

Research method

First, collect the data of target sites, such as area, mixing ratio and distance, and classify the data, and analyzes the cost of producing objects in three target areas. After that the economic feasibility is analyzed using BCR, for each target area, a site checklist is prepared and a rating is set. Finally, major cost factors are extracted that affect the economic feasibility of the item (Fig. 2).

Benefit-Cost ratio (BCR) method

The used in this study Benefit Cost Ratio (BCR, B/C ratio) is also referred to as Profitability Index (PI), which shows the relative profitability of an investment business as the value of the cash inflow divided by the value of the cash outflow, Indicated by the following formula.

$$BCR = \frac{B}{C} = \frac{\Sigma \frac{B_t}{(1+i)^t}}{\Sigma \frac{C_t}{(1+i)^t}}$$

Where :

n: End of investment, Bt: Cash inflow at t point, i: Discount rate, Ct: Cash outflow at t point

BCR is mainly used to prioritize which investment should be made first. Select a project that is BCR > 1 (NPV > 0) when deciding whether to invest in a single in-

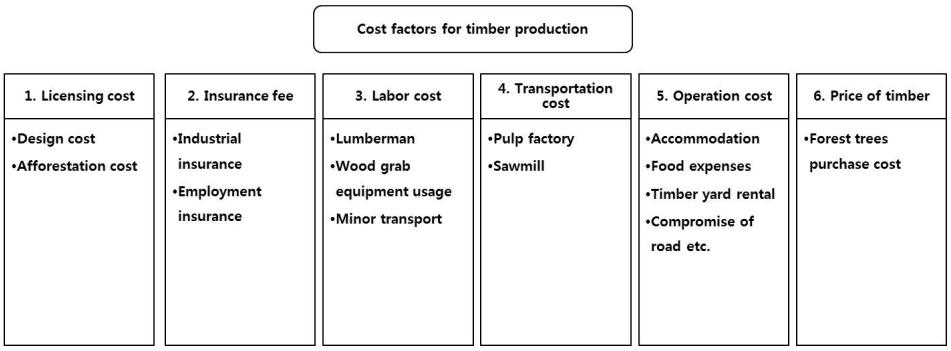

Fig. 1. Cost factor classification for timber harvesting.

Table 2. External environmental factors

Category	Classification	Unit
Forest stand condition	DBH (diameter at breast height)	cm
	Ratio of timber (commercial timber % on stands)	%
	Mixed forest ratio (conifer % on stands)	%
	Special timber (special timber % on stands)	%
Rock land ratio	Rock % in stands	%
Slope	Slope class	°
Work rods	Distance from the working areas to the landing	m
Accessibility	Number of people who can pass from the forest road to working areas	man
Timber payment	Forest trees purchase cost / ha to the forest owner	million won

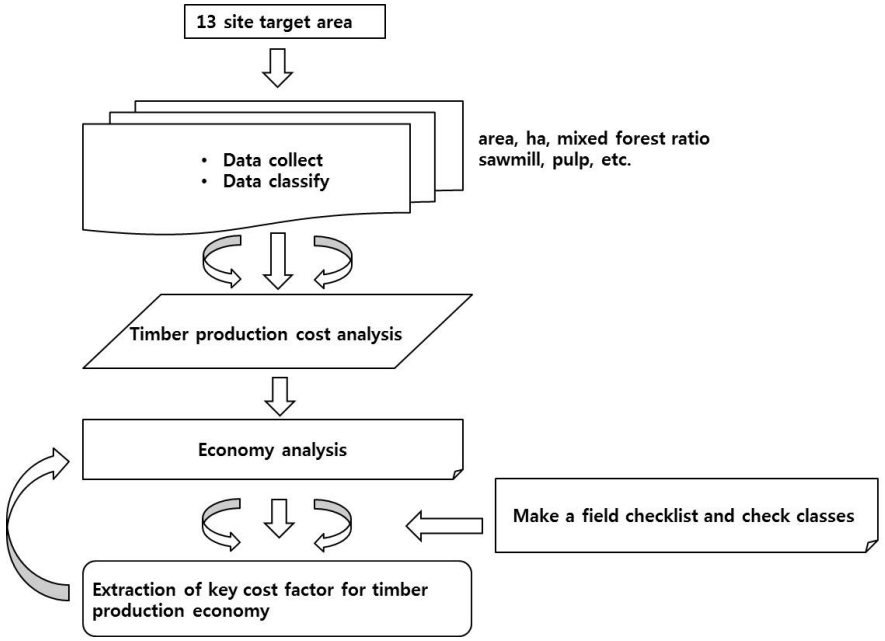

Fig. 2. Research procedure.

Table 3. Determine external factor ratings

Classification	Unit	A (Very good)	B (Good)	C (Normal)	D (Bad)	E (Worst)
DBH	cm	← Max (large)			Min (small) →	
Ratio of timber	%	← Max (higher)			Min (lower) →	
Mixed forest ratio	%	← Max (higher)			Min (lower) →	
Special timber	%	← Max (higher)			Min (lower) →	
Rock land ratio	%	← Min (lower)			Max (higher) →	
Slope	°	← Min (gentle)			Max (urgent) →	
Work rods	m	← Min (near)			Max (far) →	
Accessibility	man	← Min (few)			Max (many) →	
Timber payment	million won	← Min (cheaper)			Max (expensive) →	

vestment or a mutually independent investment project as a decision method.When selecting mutually exclusive projects, BCR may select the largest among investments in BCR > 1 (NPV > 0). Therefore, since there are short-term investment restrictions and cost factors can be calculated in this study, it is reasonable to use BCR as an important decision factor for capital efficiency.

Determining external factor ratings

The grading used in this study was graded based on a scale of 100 using a 5 point scale. The classification method was set based on face-to-face and oral surveys with five forest service experts. Table 3 gives the ratings for each category.

a conversion score of 100 points p

$p = Min + A \times (X-1)$

$A = (Max-Min)/(k-1)$

X = *average score*, $k = K$

Table 3 shows the method of determining external factors rating. DBH has the largest A and the smallest E. Ratio of timber is the ratio of commercial timber, with the highest A and the lowest E. Mixed forest ratio and special timber ratio is the highest for A and the lowest for E. Rock land ratio is the lowest in A and highest in E. Slope class is 5

steps, A is the most gradual and E is the most urgent slope. Work rods is closest to A and is farthest from E. Accessibility is the person who passes through the workplace in forest rod with the most A and the least E. Timber payment is paid per ha for wood to be bought by the mountain owner, A is the cheapest and E the most expensive.

Results and Discussion

Cost factors for the timber production at each site

Table 4 shows the harvest license information, volume and period in 13 target areas. If you look at the licensing information for area A, volume per ha is 137 m^3/ ha (1,195 m^3 ÷ 8.7 ha). Production volume is actual production (944

Table 4. Harvest license information, volume and period in 13 target areas

Area	Harvest license information			Production volume (ton)	Period (day)
	Licensed area (ha)	Volume (m^3)	Volume / ha (m^3)		
A	8.7	1,195	137 (1,195 ÷ 8.7)	944	64
B	5.3	862	163	583	17
C	5.2	775	145	778	27
D	7.2	1,146	159	518	30
E	7.2	886	123	361	25
F	12.1	1,370	113	1,647	59
G	28.0	2,688	96	2,494	61
H	7.7	1,125	146	1,062	38
I	15.4	1,711	111	2,515	46
J	6.4	882	138	1,054	32
K	11.5	1,520	132	1,913	38
L	6.0	1,065	178	2,067	24
M	6.5	782	120	1,113	24
Sum	127.2	16,007	125.7	17,049	485
Average	9.8	1,231.3	-	1,311.5	37.3

Table 5. Cost, revenue, profit and BCR (unit: million won)

Area	ha	Cost	Cost per ha	Revenue	Revenue per ha	Profit	Profit per ha	BCR
	ⓐ	ⓑ	ⓒ=ⓑ÷ⓐ	ⓓ	ⓔ=ⓓ÷ⓐ	ⓕ=ⓓ-ⓑ	ⓖ=ⓕ÷ⓐ	
A	8.7	93.9	10.8	83.5	9.6	-10.5	-1.2	0.89
B	5.3	44.1	8.3	46.7	8.8	2.6	0.5	1.06
C	5.2	65.9	12.6	71.0	13.6	5.1	0.9	1.08
D	7.2	58.3	8.1	42.0	5.8	-16.2	-2.2	0.72
E	7.2	39.7	5.5	35.6	4.9	-3.9	-0.5	0.90
F	12.1	143.4	11.8	159.5	13.2	16.2	1.3	1.11
G	28.0	325.5	11.6	292.6	10.5	-32.8	-1.1	0.90
H	7.7	68.6	8.9	71.0	9.2	2.4	0.3	1.04
I	15.4	160.0	10.4	193.3	12.5	33.3	2.1	1.21
J	6.4	57.7	9.0	78.1	12.2	20.4	3.2	1.35
K	11.5	118.4	10.3	223.2	19.4	104.8	9.1	1.89
L	6.0	64.9	10.8	81.8	13.6	16.9	2.8	1.26
M	6.5	74.2	11.4	84.0	12.9	9.8	1.5	1.13
Sum	127.2	1,314.6	-	1,462.7	-	148.2	1.1	-
Average	9.8	101.2	10.3	112.5	11.5	11.3	-	1.12

ton) and business period is 64 days.

BCR Analysis by area

The period of business in each target area and revenue per ha, and BCR are shown in Table 5. Four of the 13 areas (A, D, E and F) suffered losses.

The average BCR for 13 target areas was shown at 1.12, with the lowest BCR at 0.72 in D, and the highest at 1.89 in K, and the average BCR in 11 regions excluding the lowest and highest BCR was analyzed to be 1.08.

Fill in field checklist

The field checklist nine items were divided into five classes (A : Very Good, B : Good, C : Normal, D : Bad, E : Worst) as shown in (Table 6). In case of dbh, it is A at more than 36 cm, E is less than 10 cm. For rock land ratio, A is between 0 and 5%, and E is more than 41%. For slopes, A is less than 15° and E is more than 31°. For work rods, A is within 100 m and E is over 1,001 m. For accessibility, A is zero people and E is four or more people.

The rating and score of the nine items field checklist for 13 target areas are as shown in (Table 7), review on the calculation process of 56 points in region A is as follows. DBH (60)+Ratio of timber (60)+Mixed forest ratio (80)+ Special timber (20)+Rock land ratio (60)+Slope (60)+ Work rods (20)+Accessibility (60)+Timber payment (80)= 500÷9=55.55 (about 56).

Also, the A area has a score of 56, grade 4, Area B has a score of 69 grade 3, Area C ranked third with 64 points, area D ranked 5th with 47 points, area E rated 4 at 60, F with 62 points, G with 44 points, 5th grade, the H area is rated 3 with 67 points, area I ranked 2nd with 71 points, J is second grade with 76 points, K with 82 points, 1st grade, L area has 71 points, 2nd grade, the score in the M area was 67, and the score was third.

Timber production main cost factor analysis and external factor relationship

Timber production main cost factor analysis

An analysis of major cost factors in the timber production shows that the 1st rank was wood grab equipment usage fee (28%), 2nd place was (19%), 3rd place was logging expenses (19%), 4th place was transport cost (18%), 5th place was minimal transport (6%), 6th was cost of afforestation (4%), 7th was design cost (3%), finally 8th ranking came as operating expenses (3%) (Table 8). The ratio of ranking 1 to 4 was found to account for 84 percent of the total cost.

All the analysis results show that the biggest contributors to the production of the manufacture were wood grab equipment usage fee, logging expenses, timber payment and transport cost, which were analyzed as production cost factors that determine profitability.

Priority of main cost factor and external factor

Based on this, the results of the analysis on the priorities of main factors, external factors, and links that affect the timber production were as shown in Fig. 3. Rock land ratio, slope, timber payment, special timber, ratio of timber, dbh, and mixed forest ratio were the main factors that affected

Table 6. Field checklist category and classes

No	Item	Field checklist				
		A (Very good)	B (Good)	C (Normal)	D (Bad)	X (Worst)
1	DBH (cm)	≥36	26-35	16-25	11-15	≤10
2	Ratio of timber (%)	≥41	26-40	6-25	1-15	0
3	Mixed forest ratio (%)	≥71	51-70	31-50	11-30	≤10
4	Special timber (%)	≥21	16-20	6-15	1-5	0
5	Rock land ratio (%)	0-5	6-10	11-25	26-40	≥41
6	Slope (°)	<15	16-20	21-25	26-30	≥31
7	Work rods (m)	≤100	101-300	301-500	501-1,000	≥1,001
8	Accessibility (man)	0	1	2	3	4
9	Timber payment (million won)	≤0.90	0.91-1.20	1.21-1.80	1.81-2.50	≥2.60

Table 7. Field checklist rating results

Area	DBH	Ratio of timber	Mixed forest ratio	Special timber	Rock land ratio	Slope	Work rods	Accessi-bility	Timber payment	Score	Grade
	cm	%	%	%	%	°	m	man	million won	-	-
A	25	20	50	0	15	22	1,500	2	1	56	4
	C	C	B	E	C	C	E	C	B		
	60	60	80	20	60	60	20	60	80		
B	25	20	50	0	15	22	100	0	1	69	3
	C	C	B	E	C	C	A	A	B		
	60	60	80	20	60	60	100	100	80		
C	25	20	50	0	15	22	200	1	1	64	3
	C	C	B	E	C	C	B	B	B		
	60	60	80	20	60	60	80	80	80		
D	25	20	50	0	45	30	600	4	1	47	5
	C	C	B	E	E	D	D	E	B		
	60	60	80	20	20	40	40	20	80		
E	25	20	50	0	35	22	200	2	1	60	4
	C	C	B	E	D	C	B	C	B		
	60	60	80	40	80	60	40	60	40		
F	25	20	50	0	15	22	450	1	1	62	3
	C	C	B	E	C	C	C	B	B		
	60	60	80	20	60	60	60	80	80		
G	25	20	50	0	15	25	1,200	4	5.4	44	5
	C	C	B	E	C	C	E	E	E		
	60	60	80	20	60	60	20	20	20		
H	25	20	50	0	15	22	200	0	1	67	3
	C	C	B	E	C	C	B	A	B		
	60	60	80	20	60	60	80	100	80		
I	36	20	50	0	15	22	300	0	1	71	2
	A	C	B	E	C	C	B	A	B		
	100	60	80	20	60	60	80	100	80		
J	30	20	50	10	15	22	100	0	1	76	2
	B	C	B	C	C	C	A	A	B		
	80	60	80	60	60	60	100	100	80		
K	36	20	50	30	25	12	200	0	100	82	1
	A	C	B	A	C	A	B	A	B		
	100	60	80	100	60	100	80	100	80		
L	30	20	50	0	15	22	100	0	1	71	2
	B	C	B	E	C	C	A	A	B		
	80	60	80	20	60	60	100	100	80		
M	25	20	50	0	15	22	200	0	1	67	3
	C	C	B	E	C	C	B	A	B		
	60	60	80	20	60	60	80	100	80		

the timber production economy.

Priority 1 wood grabequipment usage fee had the greatest impact on the rock land ratio and slope, with priority 2 on the and priority 3 logging expenses was found to be to be closely related to the ratio of timber, special timber, dbh, and the cost of transport cost, which is a priority of four,

Table 8. Priority of timber production cost factors (unit: million won)

Area	ha	Licensing fees		Machinery usage fees			Transport (Factory)	Operating expenses	Timber payment	Total cost
		Design	Planting	Logging expenses	Wood grab	Minor transport (Landing)				
A	8.7	3.5	4.8	16.0	32.9	8.0	15.3	4.7	8.7	93.9
B	5.3	2.5	2.9	8.1	12.1	1.8	9.6	1.8	5.3	44.1
C	5.2	2.5	2.9	14.0	27.2	-	12.4	1.6	5.2	65.8
D	7.2	3.0	4.0	12.5	14.8	3.0	9.9	3.8	7.2	58.2
E	7.2	3.0	4.0	6.9	8.6	1.3	6.4	2.3	7.2	39.7
F	12.1	-	-	49.4	64.4	20.2	32.0	7.5	152.1	325.6
G	28.0	4.2	6.7	26.0	50.2	14.5	24.9	4.7	12.1	143.3
H	7.7	2.8	4.5	13.8	19.8	3.9	14.9	1.0	7.7	68.4
I	15.4	5.3	9.0	35.0	47.8	12.4	32.8	2.5	15.4	160.2
J	6.4	2.1	3.7	14.0	15.1	2.8	12.7	0.9	6.4	57.7
K	11.5	2.4	3.8	14.9	15.6	2.4	18.2	1.6	6.0	64.9
L	6.0	4.2	7.3	25.9	31.5	5.0	29.4	3.5	11.5	118.3
M	6.5	2.6	4.1	14.3	22.9	4.6	18.5	0.7	6.5	74.2
Sum	127.2	38.05	58.1	250.9	362.8	79.9	236.9	36.6	251.3	1314.3
%		3	4	19	28	6	18	3	19	100
Priority		⑦	⑥	③	①	⑤	④	⑧	②	-

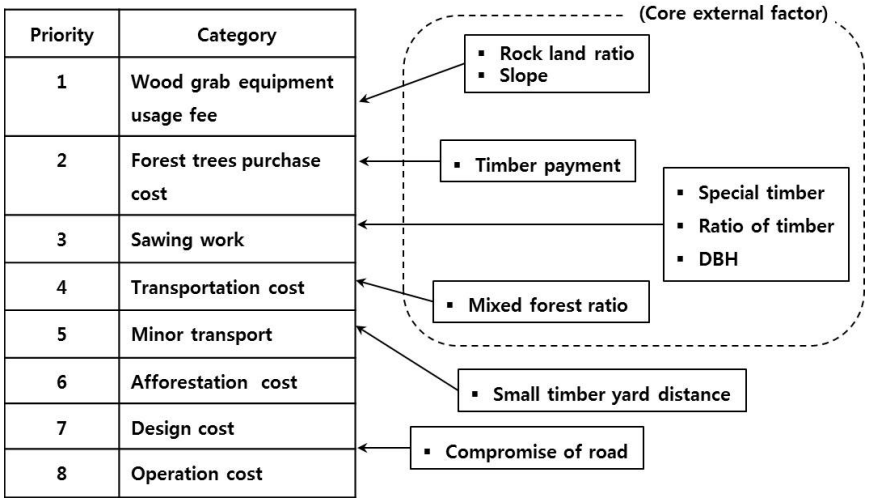

Fig. 3. Timber production cost factor and core external factor.

closely related to the mixed forest ratio.

Conclusion

This study conducted a study on the profitability efficiency through a Life Cycle Assessment (LCA) in 13 target areas nationwide.

In this study, 13 areas are collected and the data are classified into groups to determine the cost factors for timber production, for a target area, economic feasibility was analyzed using BCR method, and a site checklist was prepared and rated for each target area. And finally cost factors and external factors associated with earnings timber productivity profitability were identified and linked.

Cost factors for timber production divided into 14 production factors of 6 groups, the licensing fee in group 1 were design and afforestation cost, 2 group insurance premium, industrial insurance premium and employment insurance fee, 3 group working labor cost were wood maker, wood grab equipment usage fee, minor transport, the transport costs of the fourth group were pulp factory, lumber mill, operating expenses for groups 5 divided into housing costs, food expenses, land rent, accessibility, the six groups divided timber payment.

External environmental factors that can significantly affect the timber production were divided into five items forest stand condition, rock land ratio, slope, work rods, timber payment, and were divided into nine items dbh, ratio of timber, special timber, mixed forest ratio, rock land ratio, slope 5 grades, work rods, accessibility, timber payment etc. Based on the results of the study, major cost factors in the timber production, ranking first was wood grab equipment usage fee, and ranking second was the timber payment. The third place was logging expenses, and the fourth place was transport cost, with the ratio of first to fourth taking up 84 percent.

Results of analysis of main factors priorities, external factors, and links that affect the timber production, and rock land ratio, ratio of timber, DBH, mixed forest ratio turned out that had the greatest impact on the priorities that could affect the economics of the timber production.

This study provides hands-on experience and examples where we can analyze the cost factors needed to produce the trees on site and see how they affect profitability by linking them with external environmental factors. But with more target areas and more realistic objective data and figures, it is believed that a new forest business model for forest production could be developed.

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