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A Study on Transportation Optimization and Efficient Production Method of Raw Materials for Pellet for Construction of Supply Chain Management

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Abstract

This study designed a model of the efficient production schemes and raw materials transportation optimization of current South Korean's simple and monolithic distribution system of wood to build a SCM (supply chain management) as a basic level to establish a distribution of future by pellet production of raw materials costs and reduce transport costs, and specifically to forest of pallet to contribute to revitalizing the market. The result of each transportation costs after building the best transportation network from raw material supply area to demand area applying transport law was 964,600 thousands Won from 6 supply areas to 7 demand areas. And the result of each model's analysis to get the pellet's efficient production through production cost reduction showed that it reduced from 325,701 Won/t to 240,106 Won/t, results of existing efficient pellet for the production model 8,233 tons over 20,000 tons annual production capacity from the size of the expanded production capacity when the expansion. However, when the production size expanded to 50,000 Tons of the production, the effect was very small even though production cost decreased.

Key Words: SCM, pellet, transportation network, transportation optimization, operation research

Introduction

South Korea is a country who has been building the infrastructure of sustainable forest management and successful position as a forest green belt country. Also South Korea currently uses a forest not only a simple timber/wood production, protecting a natural disaster management but also recreation forest, forest healing and forest healing stages.

For forest welfare, South Korea is running the 5th round of specific concrete plan (2008 to 2017). SFM, a systematic implementation metrics, has been established by successful forest management and the result of forest policy provided, South Korea use a functional management control to optimize a variety of forest functions. But, the opposite side of the success of development resulted unbalanced age-class (of trees) by short term forest green belt implementation. And it is a very difficult situation to make a planned and strategic forest management because there has been lacking of a standardized guide or management schemes even though Forest Service and local government carry forward a forest working plan for each forest functional use. Also it is urgent to get a development of SCM network and tim-

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ber/wood production, with increasing of final-age tree quantities. Korean Government has been planning to increase timber/wood self-sufficiency from 17% (current rate) to 21% by 2017, and the self-sufficiency increase will be applied bigger in the future. The importance of supplying and development of alternative energy has been issued not only to increase timber self-sufficiency but also to become a low-carbon and green belt developing country and to cope with climate change. Timber pellets, which are paid attention as a classic environmental friendly energy source, became one of the most important energy sources for government because they can replace fossil energy, which has high dependency of importing from overseas countries. They will create new business/jobs and reduce greenhouse gas exhaustion. The domestic pellet market size is 64,013 tons in 2011, 173,790 tons in 2012, 550,271 tons in 2013 and it significantly shows the annual increase of more than 250%. However, if we look closely the forest market SCM network including pellet market, it is reality that the defect goods are still distributed because the total system is not established yet in the whole supply process of the production to end-customers (demand). Also, the average domestic pellet market price is above 300,000 Won/tons so it is not very competitive price compared to imported pellet.

Therefore, a new scheme is needed to build a system for understanding current pellet SCM process and to reduce production costs.

Materials and Methods

SCM (supply chain management)

SCM is supply chain management. It is a strategic technique and it includes managing the movement of raw materials in to an organization, certain aspects of the internal processing of materials into finished goods, and the movement of finished goods out the organization and toward the consumer. It is composed of SCP (Supply Chain Planning) and SCE (Supply Chain Execution). SCP (Supply Chain Planning) establish an optimized for everyday operation of the supply chain such as demand forecasts, global production, distribution, transport, delivery plan allocation, etc and SCE (Supply Chain Execution) is an application that supports performance of efficiency of services and information sharing between customers to satisfy demand in the center of enterprise application.

As this way, SCM is used in Shipbuilding, IT, Automotive and many other industries. In the forest industry, a few countries in Europe and north America, the developed forest countries, have built up successful SCM and have been carrying out F-SCM (Forest-Supply Chain Management). Previously, it only focused on forest afforestation and product management and paid no attention to materials and wood, distribution and retail management of by-products, wood products. In contrary, now, it is possible to integrated management through SCM so it considerably contributes of activation of forest industry by managing SCM systematic way from producing to final consumption place.

Wood pellet

Wood pellet is expected to expand of demand because of economically strong compared to oil price and other benefits. And it is expected to create new market related to pellet boiler and heat co-generation facilities. South Korea produced 8,500 tons of pellets, and imported 12,000 tons of

Table 1. Annual production and sales of pellets

Year	Total		Domestic		Import	
	Output	Consumption	Output	Consumption	Output	Consumption
2009	20,569	18,216	8,527	6,174	12,042	12,042
2010	33,981	33,751	13,088	12,858	20,893	20,893
2011	64,013	62,917	34,335	33,239	29,678	29,678
2012	173,790	174,068	51,343	51,621	122,447	122,447
2013	550,271	551,455	65,603	66,787	484,668	484,668
Total	842,624	840,407	172,896	170,679	669,728	669,728

*Korea Association of Pellet, 2013.

pellets in 2009. Sustained annual growth since 2009, South Korea produced 65,000 tons of pellets and imported 484,000 tons in 2013 m (Table 1).

If we look at production capacity and sales volume divided by facilities, 21 organizations produced pellets about 7 organizations, such as Jungbu center, Shinyoung PnP, Yangpyungsanrim association, Danyang Sanrim association, Pohang Sanrim association, Donghae Bio, Pyungtak Greeneco, etc, produced 38,499 tons of pellets in 2013. Wood and byproducts produced by Afforestation, deforestation and etc in South Korea was total of 6,400 km^3 and 3,400 km^3 was not used. Apart from 40% of unused 340 m^3 wood and byproducts which were not economical and were not possible to be collected technically, it is possible to produce about 1 million tons pellets if using/utilizing 200 km^3 (Table 2).

Transportation method

In order to solve the transportation method, it generally needs the information like followings. Firstly, quantity/numbers of supplies at origin (m), and each supplier's ability of producing products should be same quality for certain period of time. Secondly, number/quantity of demands at destination (n), and each demand volume should be same for certain period of time. The third, the transportation cost is constant per product unit.

Linear Programming Model

m

n

: Origin of supplier, : Destination of demand

S_i

: Affordable supplying capacity from origin of supplier.

D_i

: Transported volume of products required by destination of demand.

C_{ii}

: Transportation cost from origin of supplier to destination of demand per 1 product unit

x_{ii}

: Transportation volume which has to be delivered from origin of supplier to destination of demand.

In this model, total affordable supplying capacity from origin of $\sum S_i$ supplier from (m) and total and total $\sum D_i$ demand volume requested by (n) are same, it is called balanced model and it is called unbalanced model if not same. At the event of unbalanced model, it is necessary to make a balanced model to add postulated origin of supply or postulated destination of demand. Transportation problems like this can be explained with Fig. 1.

Model analysis for production type

In order to carry out analysis of reducing production cost of wood pellet, it is applied that basic production flow was set as shredding materials - dry - forming - packaging and operation time was 5 days (1 day 24 hours operating) and

Table 2. Domestic pellet production and sales

Division	Manufacturing facility			Output (t)	Consumption (t)
	Manufacturer	Production capacity (t)			
		Max	Real		
2013	National Forestry Cooperative Federation	12,480	7,800	9,050	8,855
	Shinyoung E&P	24,960	15,600	11,162	12,954
	National Forestry Cooperative Federation in Yangpyong	12,480	7,800	3,782	3,415
	National Forestry Cooperative Federation in Danyang	12,480	7,800	7,013	7,388
	National Forestry Cooperative Federation in Pohang	12,480	7,800	4,825	5,299
	Ildo Biotech	6,240	3,900	532	534
	Green eco	12,480	7,800	2,135	2,396
	Subtotal	93,600	58,500	38,499	40,841

*Korea Association of Pellet, 2013.

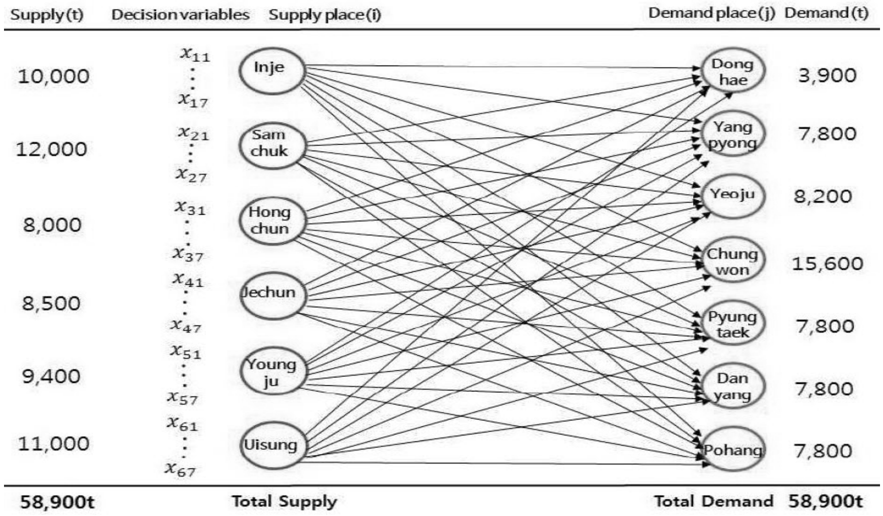

Fig. 1. Transportation network of pellet raw material.

data was applied using total of 36 months operation record data in actual factory (2011. 1-2013. 12). And comparative analysis had carried out with 4 different models considered the type of raw material, production size, etc.

The facility cost was set 3 billions Won based on 2 tons of producing size per hour, Model A has applied actual operating 3 years data of Jungbu center of National Forestry Cooperatives Federation (2011-2013). Model B was designed based on local forest cooperation Model A's raw material features had applied to Model B and additionally, power consumption cost, drying cost and labour cost had been applied to it. Model C used the pellet production system, which was the most economical producing 10 thousands tons (2 t/hr) per year and stable, based on Model B. Model D has set based on model C and applied 2 times more production size, which it produced 20 thousands tons of pellets, and the facility cost was 5 billions Won.

The study firstly analyzed related domestic and overseas SCM cases to build up a SCM, and it carried out the study as a basic stage to apply domestic pellet production SCM through reviewing general background and condition. In order to minimize transportation cost of pellets, transportation method of linear programming method had been used, it tended to suggest an effective production scheme for reducing production cost through carrying out analysis by production type.

Results and Discussion

Result of transportation method analysis

Vogel's approximation method (VAM) is one of well-known transportation methods in the literature that was investigated to obtain more efficient initial solutions. A variant of VAM was proposed by using total opportunity cost and regarding alternative allocation costs. To apply the VAM, we first compute for each row and column the penalty faced. A penalty cost is determined for each row (column) by subtracting the lowest transportation cell cost in the row (column) from the next lowest unit cell cost in the same row (column). Therefore, the penalty cost is row or column at least given the opportunity cost per unit costs that may arise not assigned to a space means. After obtaining the largest penalty cost penalty expenses row or column having to choose. Having a transport costs per unit of hung up on selected line or at least the volume of traffic and supply in Cell as possible within the limit given a lot of traffic volume. Allocated on the transport and adjust the supply and demand, supply or adjust the amount of discarded lines in zero or 10 is deleted, and demand for fever line is next excluded from the process of calculation. The penalty will not be deleted for the remaining panels with back and assess the additional cost allocation until we have no choice on the calculation of process repeated. These all rows and rows of supply and demand through a process all assigned or when they reach the initial solution. Evolved a initial solution result of the VAM (Vogel's approximation method), 7,800 tons in Cell (1, 2) Cell (1, 4) 2,200 tons, 390 tons (2, 1) in Cell, 181 tons in Cell (2, 3), (3, 3) in Cell, 100 tons and 100 tons, and (3 and 4) in Cell, Cell (3, 5) 780 tons, 185 tons in Cell (4, 4), (5, 4) in Cell7, 800 tons in Cell (5, 6) Cell (6.4) to 32 tons, about 16 tons, Cell (6, 7) 780 tons and been assigned to the 983,600 thousands Won the initial solution (Table 3).

Modified distribution method through the initial solution derived using derive optimum solution. It was appeared that 964,600 thousands Won was the best transportation costs as optimal solution. Comparing between the methods of Vogel 983,600 thousands Won the initial solution and the best saved by the modified distribution method of optimal solution 964,600 thousands, optimal solution showed less 190,100 thousands Won (Table 4).

Analysis result of optimal transportation network

Evolved optimal solution result derived from the VAM (Vogel's approximation method) is 964,600 thousands Won. And The optimal transportation network of each origin supply of raw materials, which are Injae, Samcheok, Hongcheon, Jecheon, Youngju, Uiseong, to demand destination, which are Donghae, Yangpyung, Cheongwon, Pyungtak, Dangyang and Pohang, is as follows (Fig. 2).

Injae supplies 7,800 tons to Yangpyeong and 2,200 tons Yeoju out of 10,000 tons. Samcheok supplies 3,900 tons to Donghae, 300 tons to Yeoju and 7,800 tons to Pohang out of 12,000 tons. Hongcheon who has to supply 8,000 tons supplies 5,300 tons to Yeoju and 2,700 tons to Pyungtak. Jecheon supplies 3,000 tons to Cheongwon and 5,500 tons to Pyungtak out of 8,500 tons. Youngju supplies 1,600 tons to Cheongwon and 7,800 tons to Danyang out of 9,400 tons. Lastly, Uiseong supplies whole 11,000 tons to Cheongwon. Therefore, the minimum transportation cost of total 58,500 tons is 964,600 thousands Won to transport each demand destination.

Fig. 3 briefly shows the optimal transportation network on map.

Table 3. Results of Vogel's approximation method (unit: thousand won, t)

	D1 (Donghae)	D2 (Yangpyong)	D3 (Yeoju)	D4 (Chungwon)	D5 (Pyungtaek)	D6 (Danyang)	D7 (Pohang)	Supply
S1 (Inje)	0.0	7,800.0	0.0	2,200.0	0.0	0.0	0.0	10,000.0
S2 (Samchuk)	3,900.0	0.0	8,100.0	0.0	0.0	0.0	0.0	12,000.0
S3 (Hongchun)	0.0	0.0	100.0	100.0	7800.0	0.0	0.0	8,000.0
S4 (Jechun)	0.0	0.0	0.0	8,500.0	0.0	0.0	0.0	8,500.0
S5 (Youngju)	0.0	0.0	0.0	1,600.0	0.0	7,800.0	0.0	9,400.0
S6 (Uisung)	0.0	0.0	0.0	3,200.0	0.0	0.0	7,800.0	11,000.0
Demand	3,900.0	7,800.0	8,200.0	15,600.0	7,800.0	7,800.0	7,800.0	58,900.0
Initial Solution				983,600.0				

Table 4. Results of modified allocation method (unit: thousand won, t)

	D1 (Donghae)	D2 (Yangpyong)	D3 (Yeoju)	D4 (Chungwon)	D5 (Pyungtaek)	D6 (Danyang)	D7 (Pohang)	Supply
S1 (Inje)	0.0	7800.0	2200.0	0.0	0.0	0.0	0.0	10000.0
S2 (Samchuk)	3900.0	0.0	300.0	0.0	0.0	0.0	7800.0	12000.0
S3 (Hongchun)	0.0	0.0	5700.0	0.0	2300.0	0.0	0.0	8000.0
S4 (Jechun)	0.0	0.0	0.0	3000.0	5500.0	0.0	0.0	8500.0
S5 (Youngju)	0.0	0.0	0.0	1600.0	0.0	7800.0	0.0	9400.0
S6 (Uisung)	0.0	0.0	0.0	11000.0	0.0	0.0	0.0	11000.0
Demand	3900.0	7800.0	8200.0	15600.0	7800.0	7800.0	7800.0	58900.0
Initial Solution				964,600.0				

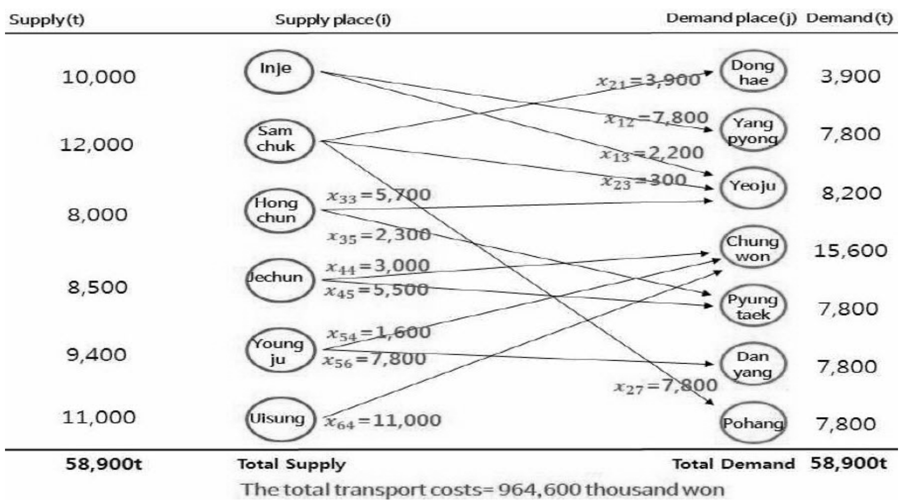

Fig. 2. Result of optimum transport network analysis.

Fig. 3. Constructing the optimum transportation network.

Model analysis result of production type

In order to each model (A, B, C, D) production cost, each item cost had been calculated. Additionally, model (E, F, G) production cost was calculated based on model D item cost and it was assumed that the production would extend 10,000 tons every year (Table 5).

Result which analyzes the impact on production costs is an annual production volume of pellet, the production cost tended to be reduced as annual pellets production size expanded, which showed that there was huge production cost reduction as 85,595 Won/t resulted from 325,701 Won/t to 240,106 Won/t with up to 20,000 t/y expansion. After it showed that there was trend of production cost reduction but the effect of production expansion size was considerably reduced.

In other words, it is expected that pellets production cost will be reduced about 17% as from 283,897 Won/t to 240,106 Won/t if pellets factory , which can produce 10,000 tons using afforestation as a raw material with 2 tons per hour capacity in South Korea, can produce 20,000 tons after expanding the production size 4 tons per hour capacity. Therefore it is considered that the production cost can be reduced a lot if expanding production size at the same time operation rate gets higher.

Transportation cost analysis result according to production volume

The analysis result of optimal transportation network of pellets raw material, the optimal transportation was 964,600 thousands Won. However the analysis result after making production model for reduction production cost, the production cost reduction trend was the maximum when higher operation rate result of 20,000 tons/y from the first volume of 8,233 tons/y. Therefore we compared pellets raw material transportation cost of model C as the optimal production system and model D which expanded the production size with twice bigger operation rate.

At first, the analysis carried out based on model C and the optimal transportation cost was 964,500 thousands Won.

Table 5. Results of each type of production model analysis (unit: won/t)

Model	A	B	C	D	E	F	G
Output	8,233t	8,000t	10,000t	20,000t	30,000t	40,000t	50,000t
Raw material	109,473	122,244	122,244	122,244	122,244	122,244	122,244
Labor	41,054	45,500	33,800	16,900	11,267	8,450	6,760
Expenses	118,077	131,445	109,915	89,374	82,818	79,540	77,574
*Electricity costs	20,044	22,892	22,892	22,892	22,892	22,892	22,892
*Drying costs	27,220	35,386	26,540	26,540	26,540	26,540	26,540
*Expendable costs	33,476	37,750	32,150	20,275	20,275	20,275	20,275
*Depreciation costs	28,342	29,167	23,333	16,667	11,111	8,333	6,667
*Ect costs	8,995	6,250	5,000	3,000	2,000	1,500	1,200
Administrative costs	27,334	26,512	17,938	11,588	10,925	10,593	10,394
Total production costs	295,938	325,701	283,897	240,106	227,254	220,827	216,972

Table 6. Optimal transportation cost of a model C (unit : thousand won, t)

	D1 (Donghae)	D2 (Yangpyong)	D3 (Yeoju)	D4 (Chungwon)	D5 (Pyungtaek)	D6 (Danyang)	D7 (Pohang)	Supply
S1 (Inje)	0.0	1,000.0	0.0	0.0	0.0	0.0	0.0	10,000.0
S2 (Samchuk)	0.0	0.0	2,400.0	0.0	0.0	600.0	9,000.0	12,000.0
S3 (Hongchun)	0.0	0.0	7,600.0	0.0	400.0	0.0	0.0	8,000.0
S4 (Jechun)	0.0	0.0	0.0	0.0	8,500.0	0.0	0.0	8,500.0
S5 (Youngju)	0.0	0.0	0.0	0.0	0.0	9,400.0	0.0	9,400.0
S6 (Uisung)	0.0	0.0	0.0	10,000.0	0.0	0.0	1,000.0	11,000.0
Demand	0.0	10,000.0	10,000.0	10,000.0	8,900.0	10,000.0	10,000.0	58,900.0
Initial Solution				964,500.0				

Table 7. Optimal transportation cost of a model D (unit: thousand won, t)

	D1 (Donghae)	D2 (Yangpyong)	D3 (Yeoju)	D4 (Chungwon)	D5 (Pyungtaek)	D6 (Danyang)	D7 (Pohang)	Supply
S1 (Inje)	0.0	1,000.0	0.0	0.0	0.0	0.0	0.0	10,000.0
S2 (Samchuk)	0.0	0.0	1,200.0	0.0	0.0	0.0	0.0	12,000.0
S3 (Hongchun)	0.0	0.0	8,000.0	0.0	0.0	0.0	0.0	8,000.0
S4 (Jechun)	0.0	0.0	0.0	8,500.0	0.0	0.0	0.0	8,500.0
S5 (Youngju)	0.0	0.0	0.0	500.0	0.0	8,900.0	0.0	9,400.0
S6 (Uisung)	0.0	0.0	0.0	11,000.0	0.0	0.0	0.0	11,000.0
Demand	0.0	10,000.0	20,000.0	20,000.0	0.0	8,900.0	0.0	58,900.0
Initial Solution				993,400.0				

Demand of Donghae showed 0 demand if 10,000 tons applied as a optimal production volume as model (Table 6).

The optimal transportation cost of pellet raw material when the production volume expanded up to 20,000 tons as model D (Table 6) was 993,400 thousands won, and Pohang, Pyungtak, Donghae demand was 0 after model D applied. The transportation cost was 28,900 thousands Won more when model D applied compared to model C (Table 7).

Comparing transportation cost with existing production volume and applied production volume of model C and model D showed 964,600 thousands Won, 964,500 thousands Won and 993,400 thousands Won and it did not make big differences ,which showed 16,377 Won, 16,375 Won and 16,866 Won, if it calculates a cost per ton.

Discussion

The study draw a schemes of effective production through building optimal transportation network and reducing pellets production cost.

It will be not only reducing pellets production cost but also understanding and managing South Korean SCM flow systematically if it can understand the whole process from origin supply to end destination and apply to production models. Furthermore, it will be considerably helpful to activate a market through building forest industry SCM if it doesn't set the limit to pellets and apply South Korean whole forest market.

Conclusions

The study have been carried out regarding pellets, which are recently taken a spotlight as one of the most outstanding eco-friendly energy source, for the basic step for market activation and managing SCM systematically through building forest industry SCM (Supply Chain Management). South Korean pellet market has been increased, but it is eventually unable to compete with imported pellets due to expensive facility cost and high production cost. Also considerable amounts of faulty pellets have been distributed in the market because it of lack of systematic distribution channel. Therefore, the study tries to contribute to building pellets SCM and activate a market through building opti-

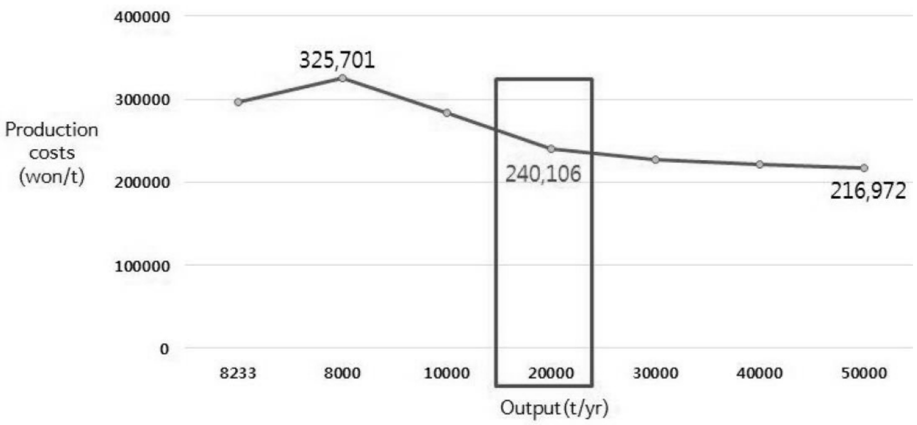

Fig. 4. Change according to the scale of production costs.

Fig. 5. Comparing the optimum transportation network in accordance with production.

mal transportation network, which helps to understand the process pellets raw material flow from origin supply to demand destination, and plan the production model to reduce pellets production cost.

The result after building the optimal pellets transportation network from 6 origin supply points to 7 demand destination points, the total transportation cost for each transporting points was 964,600 thousands Won.

Also, the result after analyzing each modes, which were designed for reducing pellets production cost and provided the effective pellets production, were reduced to 240,106 Won/t from 325,701 Won/t effected by trend of reducing production cost according to production size if the total annual production size expanded 20,000 tons from previous total annual production of 8,233 tons (Fig. 4). However it was very poor even though it showed the production cost reduction when production size expanded up to 50,000 tons.

The result after comparing the optimal transportation cost of pellets raw materials according to production volume showed that total transportation cost was 964,500 thousands Won applied by model C and 993,400 thousands Won applied by model D. The demand volume in Donghae became 0 when model C was applied and the demand volume in Pohang, Pyungtak and Donghae became 0 when model D was applied. So there were not much difference if redistributing supply volume according to effective production, an effective transportation will be able to be built applying transportation cost and production efficiency rate if supply production volume increase according to wood production increase. Also, it is understood that Donghae, Pohang, Pyungtak may need other origin supply or oversea supply rather than existing origin supplies (Fig. 5).

Therefore it is considered that transportation cost can be reduced and this will bring reduction of not only raw material cost of pellets but also total pellets production cost if the optimal transportation network is applied when origin supply, supply, volume, and distance according to production volume is considered and decided where and how much can be supplied in the case of the factory/supplier who produce pellets can be supplied of afforestation goods or by-products.

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