Drewno 2020, Vol. 63, No. 205
DOI: 10.12841/wood.1644-3985.274.02

Katarzyna Szewczyk, Krzysztof Polowy

PRODUCTION OF FUEL WOOD CHIPS AS AN EXAMPLE OF SUPPLY CHAIN REORGANISATION RESULTING FROM SOCIOECONOMIC CHANGES IN POLAND

An analysis was made of the production of fuel wood chips and associated logistics operations in the Wejherowo Forest District in the years 2000-2017. Detailed observations of the fuel chip harvesting process and an analysis of the supply chain were made in the context of socioeconomic changes. In addition, the total cost of production was calculated and the price of 1 m^3 of fuel chips in the years 2009-2017 was analysed. As a result of socioeconomic changes, seven variants of the forest fuel chip supply chain were observed in the years analysed. The unit production cost of forest fuel chips was 25 USD per m^3. The average price of 1 m^3 of forest fuel chips in the analysed period was 30 USD.

Keywords: supply chain, fuel wood chips, production, costs

Introduction

Until the end of the 1980s, all tasks related to forestry work in Polish state forests were conducted by internal organisational units of the State Forests National Forest Holding. The changing economic environment forced the State Forests to implement economic and organisational transformations. This involved mainly the privatisation of economic activities of the Forest Districts. Forestry work was to be commissioned to private companies through a system of contracts and tenders. The establishment of the private forestry sector was an integral part of this transformation, aimed at improving the economic efficiency of the State Forests organisational units [Kocel 2000, 2010, 2013a, 2013b, 2014; Łyp and Zychowicz 2007; Więsik and Wójcik 2008; Zastocki et al. 2012; Glazar and Polowy 2015]. Indeed, the takeover of forestry operations by private contractors caused a significant decrease in costs of forest production [Więsik 2000].

In the initial period of transformation most private firms were single-person (self-employed) entities. As a result of market forces, in the mid-1990s small

Katarzyna Szewczyk✉ (*katarzyna.szewczyk@up.poznan.pl*), Krzysztof Polowy (*krzysztof.polowy@up.poznan.pl*), Faculty of Forestry, Poznań University of Life Sciences, Poznań, Poland

firms were gradually eliminated due to their limited capabilities. Furthermore, larger companies increased the scope of their services and investments in modern equipment, which was more efficient, safer and better for the environment [Więsik 2000].

The rules on the contracting of forestry work to private entities altered significantly with Poland's accession to the European Union. This obliged the State Forests to implement the provisions of the Act of 29 January 2004 titled Public Procurement Law [Kocel 2013a; Glazar and Iwanicki 2016]. Tender, as the main form of commissioning of forestry work, led to strong competition between companies, in terms of both price and the quality of their operations [Kocel 2002]. The contracting of various tasks necessary for a company's own operations to specialised external units is generally known as outsourcing. In the case of tasks that are directly connected to the core operations of the company, it is called 'production outsourcing'. Entities realising successive phases of the manufacture of a final product and its distribution to the customer constitute the so-called 'supply chain'. Each link of the chain generates some added value. The sum of these values provides a final value for the customer. A proper distribution of tasks along units in a supply chain maximises the value for the customer, ensuring adequate competitiveness for individual companies and for the whole supply chain [Gołębiowski 2003].

The aim of this study was to evaluate changes in the forest fuel chip supply chain from a logistics perspective in the context of socioeconomic changes in Poland in the years 2000-2017, based on the example of the Wejherowo Forest District.

Materials and methods

In this study an analysis was made of forest fuel chip production and associated logistics operations in the Wejherowo Forest District in the years 2000-2017. Detailed observations of the fuel chip harvesting process and the supply chain were analysed in the context of socioeconomic changes. In accordance with the Polish Standard BN-76/9195-01, the total time of operations in the forest chip production process was determined as a multiple of 8-hour control shifts (T_{07}) (Fig 1).

In addition, the total cost of production was calculated based on the methods developed by Szramka et al. [2016].

The following assumptions were made in the calculation:

1. The machines were new. The number of hours previously worked was zero.
2. Machine purchases were financed from the company's own financial resources.
3. Machine purchase prices consisted of the net purchase price, including any additional purchase costs (transport and assembly costs).

<table>
<tr><td colspan="7">Time category</td></tr>
<tr><td>T_{08}</td><td>T_{07}</td><td>T_{04}</td><td>T_{02}</td><td>T_1</td><td colspan="2">Effective time</td></tr>
<tr><td>Control shift time</td><td>Total shift time</td><td>Working shift time</td><td rowspan="3">Operative active time</td><td rowspan="3">T_2</td><td rowspan="3">Subsidiary time</td><td>T_{21}</td></tr>
<tr><td rowspan="14"></td><td rowspan="11"></td><td rowspan="7"></td><td>T_{22}</td></tr>
<tr><td>T_{23}</td></tr>
<tr><td rowspan="3">T_3</td><td colspan="2" rowspan="3">Technical service time</td><td>T_{31}</td></tr>
<tr><td>T_{32}</td></tr>
<tr><td>T_{33}</td></tr>
<tr><td rowspan="2">T_4</td><td colspan="2" rowspan="2">Faults deletion time</td><td>T_{41}</td></tr>
<tr><td>T_{42}</td></tr>
<tr><td>T_5</td><td colspan="4">Rest time</td></tr>
<tr><td rowspan="2">T_6</td><td colspan="3" rowspan="2">Transport drive time</td><td>T_{61}</td></tr>
<tr><td>T_{62}</td></tr>
<tr><td>T_7</td><td colspan="4">Time of daily miantenance of accompanying machines</td></tr>
<tr><td rowspan="3">T_8</td><td colspan="4" rowspan="3">Loses of time from independent reasons on researched machine</td><td>T_{81}</td></tr>
<tr><td>T_{82}</td></tr>
<tr><td>T_{83}</td></tr>
</table>

Fig. 1. Classification of working time according to BN-76/9195-01 [Laurow 1999]

T_1 – effective time; T_2 – subsidiary time $T_2 = T_{21} + T_{22} + T_{23}$, T_{21} – turning back time, T_{22} – waste drive time in work-place, T_{23} – technological dead time; T_3 – maintenance time $T_3 = T_{31} + T_{32} + T_{33}$, T_{31} – daily maintenance time, T_{32} – machine preparation for work time, T_{33} – regulation time; T_4 – repair time $T_4 = T_{41} + T_{42}$, T_{41} – technological defects removal time, T_{42} – technical defects removal time; T_6 – transport drive time $T_6 = T_{61} + T_{62}$, T_{61} – drive time from berth to work-place and return, T_{62} – drive time between work-sites; T_8 – losses of time due to reasons independent from researched machine $T_8 = T_{81} + T_{82} + T_{83}$, T_{81} – losses of time from organizational reasons, T_{82} – losses of time from meteorological reasons, T_{83} – losses of time from other reasons.

4. Depreciation rate: for a chainsaw and chipper – 14%, increasing factor 1.4; for a horse and truck – 20%.
5. Insurance cost index: 2% – chainsaw and truck; 1% – chipper; fixed insurance for a horse: 286.57 USD (1 USD=3.8385 PLN, according to the NBP table of average exchange rates for 9 September 2016).
6. Deposit interest rate: 3%, capitalisation period: 1 month.
7. Repair cost index: 100% for a chainsaw and a chipper, 75% for a truck.

8. Horse feed: 782 USD per year.
9. Stable: 3804 USD per year.
10. Costs of veterinary services and horse-shoeing: 156 USD per year.
11. Oil and lubricant consumption indicator: for a chipper and a truck – 20% of the value of fuel consumption.
12. Price of gasoline/diesel – 0.91 USD per litre.
13. For a chainsaw: price of engine oil – 4.69 USD, engine oil consumption – 0.01 l/engine hour (e.h.), price of oil for the cutting system – 2.34 USD, consumption of oil for the cutting system – 0.3 l/e.h., petrol consumption – 0.5 l/e.h.
14. The cost of machine transportation was not included in the calculation.

The price of 1 m^3 of fuel chips in the years 2009-2017 was analysed based on information from 'Notifications of the best bid selection' for the supply of fuel chips to the F. Ceynowa Specialist Hospital in Wejherowo.

Results

In the years 2000-2008 the average quantity of fuel chips harvested in the Wejherowo Forest District was approx. 1500 m^3 per year, with the F. Ceynowa Specialist Hospital in Wejherowo being the only consumer. In 2009 the Forest District ceased to produce fuel chips, but continued to supply the material for chipping – poles and rods, mostly of Scots pine. The chipping material was harvested in Scots pine stands, on fresh mixed coniferous forest sites during thinning in age class II (20-40 years). The average dbh of harvested trees was 13 cm, and their average height was 13 m.

Chips were produced from poles and rods harvested in two variant operational processes. In the first variant (A) poles and rods were cut to the same length (4.5 m) and chipped. The other variant (B) was used for larger trees, where first pulpwood (length 2.4 m) was produced, and the rest of the tree was cut into poles and chipped.

The process of obtaining fuel chips was divided into the following operations: felling, delimbing and cross-cutting, manual extraction, extraction by horse, chipping, and haulage of chips. Harvesting was carried out by two teams consisting of a chainsaw operator and an assistant. The chainsaw operator felled the trees and performed delimbing and cross-cutting into specific types of log, while the assistant extracted the logs manually. The logs were placed alongside the extraction routes, cut by the chainsaw operator and then extracted by horse. Extraction was carried out by two teams consisting of an operator and a horse. The logs were then stacked alongside the forest road where the chipping operation took place. Produced chips were blown directly from the chipper into the hauling truck container and delivered to the customer. Chip transportation consisted of the following phases: driving loaded, unloading, and driving empty.

In one production cycle an average of 30 m^3 of chips and about 10 m^3 of pulpwood were harvested. The mean times of particular operations within one full production cycle were as follows:

- felling, delimbing, cross-cutting and manual extraction – three 8-hour shifts;
- extraction by horse (average distance 80 m) – 2.5 8-hour shifts;
- chipping and chip transport (average distance 5 km) – half of an 8-hour shift (chips were blown directly to the truck container during chipping).

Horse skidding could be carried out simultaneously with felling, delimbing, cross-cutting and manual extraction, but this was not always done.

The average time of one fuel chip production cycle under variants A and B is shown in Figure 2.

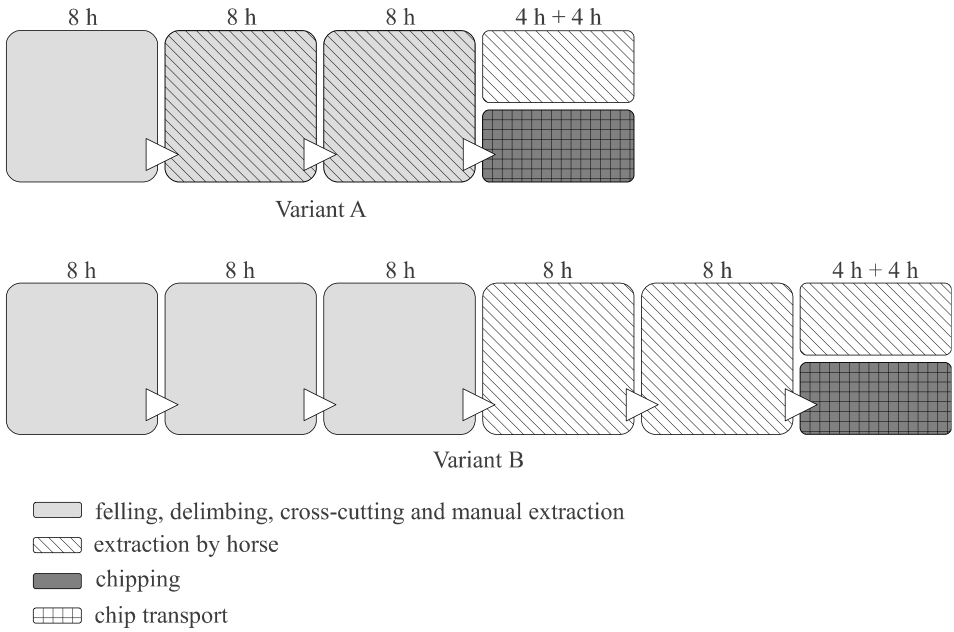


Fig. 2. Average time of one fuel chip production cycle under variants A and B

Initially, before the privatisation of forestry work, the supply chain of forest fuel chips in the Wejherowo Forest District consisted of only two links: the producer, namely the forest district; and the customer, the hospital heating plant (Fig. 3.I). All operations within the chain were carried out by the Forest District’s own employees and equipment.

In the course of privatisation, some tasks were contracted to external private companies. Work involving harvesting and extraction was the first to be outsourced (Fig. 3.II). The final stage of privatisation involved the commissioning of chipping and transport to private contractors (Fig. 3.III). Thus,

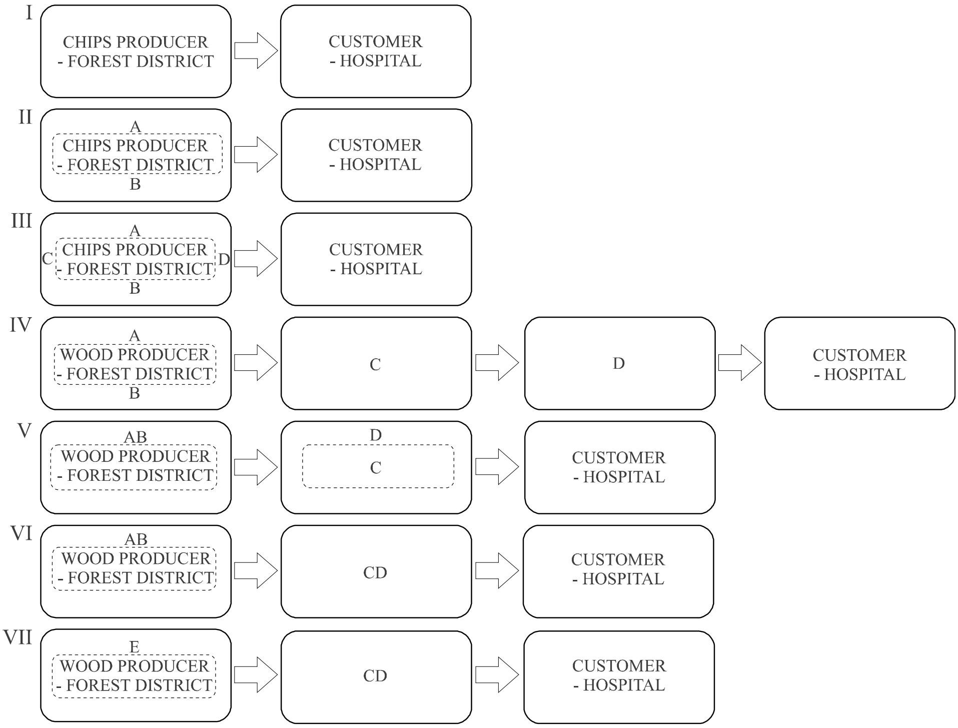


Fig. 3. Transformation of the forest fuel chip supply chain in the Wejherowo Forest District in the years 2000-2016

Variants I-VII; A – felling, delimbing, cross-cutting and manual extraction by service providers (SPs); B – horse or mechanical extraction by SPs; C – chipping by SPs; D – chip transport by SPs; AB – felling, delimbing, cross-cutting and manual extraction by SPs; CD – chipping and chip transport by SPs; E – felling, delimbing, cross-cutting and manual extraction by consortia of service providers.

a complete 'production outsourcing' was accomplished. At this stage, four units were involved in the production of forest fuel chips. In this study these units are denoted with the following letters:

- A – company carrying out felling, delimbing, cross-cutting and manual extraction
- B – company extracting wood by horse or mechanically
- C – company carrying out chipping
- D – chip transport company[1]

With time, this model of forest fuel chip production was also transformed. Smaller quantities of fuel chips were sold to the original customer – the hospital heating plant. Certain companies were interested in buying the chipping material

[1]The letter symbols used here (A-D) need not represent the number of companies involved in carrying out the tasks, e.g. harvesting and extraction were not done by the same company in all cycles. Tasks could be contracted to different companies.

(poles and rods) and chipping it to be sold to other customers. Some companies were interested in buying timber of better quality, also for chipping and sale. As a result, a new supply chain was formed (Fig. 3.IV). The new chain was longer – it included links C and D, which up to that time had been included in production outsourcing. The Forest District became a producer of the chipping material, rather than of the chips themselves.

As a consequence of market forces, weaker companies were gradually eliminated from the market. Larger and stronger firms survived, expanded, and invested in newer technologies. Modern equipment was safer, more efficient and more environmentally friendly. This resulted in new variants of the forest fuel supply chain (Fig. 3.V-VI).

A major change in the development of forest service companies came with Poland's accession to the European Union and the obligation of the State Forests to comply with the Act of 29 January 2004 titled Public Procurement Law. At that time forestry companies were typically small and unable to influence their market environment effectively. Forest Districts began to commission tasks in larger batches (packages) and it was difficult for smaller companies to meet the requirements of the tender terms of reference. This incentivised smaller firms to form consortia. In the case of the Wejherowo Forest District, the first consortium bid in a tender procedure for forest services in the year 2011. Since 2012 there have been two consortia working in the District. The current forest fuel chip supply chain is shown in Figure 3 as variant VII.

Table 1 shows examples of costs of particular operations within the forest fuel supply chain, divided into fixed and variable costs. Workers' remuneration was excluded from the analysis.

The cost of chainsaw work was estimated at 2 USD/h and the cost of horse extraction at 2.70 USD/h. Costs of using a Vermeer chipper with manual feeding and a transport truck were 29 USD/h and 36 USD/h respectively.

Table 2 presents the total cost of forest fuel chip production for an example production process. The total cost of producing 30 m^3 of forest fuel chips was estimated at 755 USD, which gives a unit cost of 25 USD per m^3.

The average price for 1 m^3 of forest fuel chips in the analysed period was 30 USD.

Discussion

The supply chain is primarily interpreted as a set of entities that are directly involved in the flow of products, services, finance and/or information from the supplier to the customer [Mentzer et al. 2001; Sieniawski and Porter 2012; Antonowicz 2016].

The ultimate goal of each supply chain is to reduce costs and ensure continuous improvement of service quality [Waściński 2014]. This principle is

Table 1. Average unit costs of particular operations in the forest fuel chip supply chain, divided into fixed and variable costs, excluding staff remuneration

	Felling, delimbing and cross-cutting	Extraction by horse	Chipping	Chip transport
Type of machine	Chainsaw 3.5 kW	Horse	Vermeer BC1800A 77 kW	Truck 235 kW
Net purchase price [USD*]	782	1954	41683	109418
Number of working hours/year	1000	2000	1500	1500
Fixed costs [USD/engine hour] including	0.19	2.20	6.57	18.27
Depreciation	0.15	0.13	5.45	14.59
Insurance	0.02	0.14	0.28	1.46
Opportunity costs	0.02	0.03	0.84	2.22
Cost of garage	–	1.90**	–	–
Variable costs [USD/engine hour]	1.78	0.47***	22.56	18.17
Spare parts and repair	0.57	–	4.63	10.94
Fuel, oil	1.21	–	17.93	7.23
Total	1.97	2.67	29.13	36.44

*1 USD=3.8385 PLN (according to the NBP table of average exchange rates for 9 September 2016).
**Cost of stable
***For a horse, variable costs included feed, veterinary costs and horseshoes

especially important in the supply chain of forest fuel, when profitability is oftentimes at risk [Hudson and Hudson 2000; Gunnarsson et al. 2004; Cambero and Sowlati 2014; Wolfsmayr and Rauch 2014]. In the market economy the basic criterion for evaluating market entities is the profit generated. This applies also to forestry. In order to improve the economic efficiency of the State Forests, forestry work has been outsourced to external companies.

According to Kocel [2013a], the best economic result was achieved by the privatisation of work in reforestation and afforestation. When selecting private companies to carry out forestry work, forest districts prefer bids with the lowest price, which leads to considerable savings. On the other hand, the prices offered are often insufficient to cover all of the private company's costs. High competition forces companies to lower their prices. In some cases this makes it

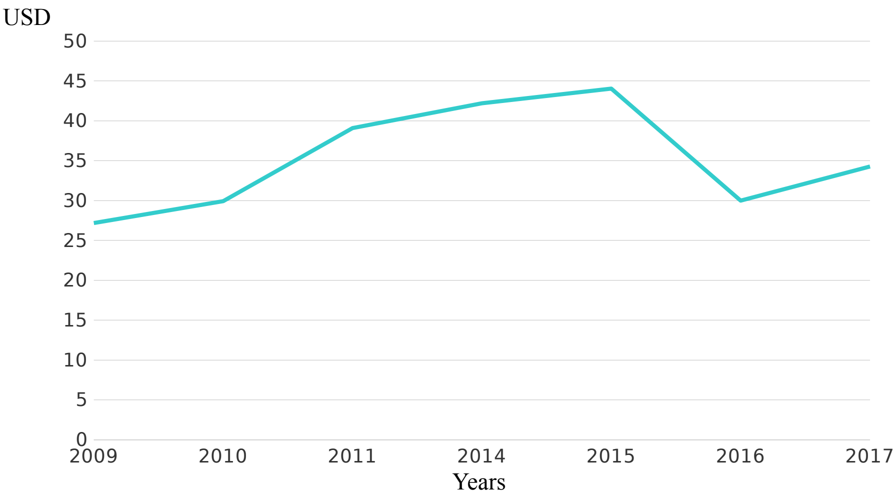
Table 2. Production costs of forest fuel chips, including cost of equipment and staff remuneration

Type of machine/Personnel	Work time [engine hour/hour]	Engine hour cost/gross hourly wage [USD]	Total costs [USD]
FELLING, DELIMBING, CROSS-CUTTING AND MANUAL EXTRACTION*			
Chainsaw	10	1.97	19.70
Chainsaw operator	48	3.91	187.68
Assistant	48	3.13	150.24
EXTRACTION BY HORSE*			
Horse	40	2.67	106.80
Horse operator	40	3.13	125.20
CHIPPING			
Chipper	2.5	29.13	72.82
Chipper operator	4	3.13	12.52
Assistant	4	3.13	12.52
CHIP TRANSPORT			
Truck	1.5	36.44	54.66
Truck driver	4	3.13	12.52
Total	–	–	754.66

*Personnel working time shown above consists of total working hours of two teams involved in production.

impossible to generate profits when operating within the boundaries of the law. Some companies attempt to ‘bend’ the regulations and create a ‘grey zone’. According to Kocel [2013a], in every year most of the workers active in reforestation and afforestation are not legally employed.

In times of increasing interest in renewable energy sources, the timber market is impacted by increasing demand for wood biomass for energy generation [Hudson and Hudson 2000; Laitila 2008; Tahvanainen and Anttila 2011; Kärhä 2011; Röser et al. 2011; Kaputa and Sucháň 2012; Ratajczak et al. 2012; Ratajczak and Bidzińska 2013; Murphy et al. 2014; Wolfsmayr and Rauch 2014; Drábek et al. 2015], including forest fuel chips. Initially in Poland organisational units of the State Forests were the only producers of fuel chips [Maciejewska 2005]. Later, certain companies became interested in purchasing the raw material for chipping and resale. As a result, forest districts switched from the role of producers of fuel chips to that of suppliers of the raw material. The outsourcing of chipping and transportation of chips to private companies allowed the forest districts to avoid costly and time-consuming operations. On the other hand, chipping and transporting companies usually offer more competitive prices.



1 USD = 3.8385 PLN (according to the NBP table of average exchange rates for 9 September 2016).

Fig. 4. Price offered per cubic meter in tenders for a continuous supply of fuel wood chips to the F. Ceynowa Specialist Hospital in Wejherowo in 2009-2017

The total production cost of forest fuel chips is strongly related to transport [Röser et al. 2011; Wolfsmayr and Rauch 2014] and the equipment used [Laitila 2008; Kärhä et al. 2011]. It includes mostly the operating costs of chipping machinery and remuneration of workers.

To determine the total costs of machine use, it is essential to know the maintenance costs and operating costs. Maintenance costs are classified as fixed costs and include depreciation, insurance, garage cost, scheduled maintenance costs, loan repayment or unpaid interest. Operating costs are classified as variable costs and include repair and spare parts, fuel, oil and lubricant.

The operating costs of machinery may be significantly reduced by employing cheaper and smaller machines, providing that their size is suitable for the task when their full potential is used [Glazar and Wojtkowiak 2009]. Correct estimation of the offer price by the contractor is essential for the smooth completion of work and for the economic stability of the company. It requires a comprehensive calculation of all costs, including labour, equipment operation and all required indirect taxes. Furthermore, additional costs resulting from the natural qualities of the forest, terrain conditions, climate, etc. should be taken into account [Asikainen et al. 2011]. On the other hand, from the commissioning entity's point of view, the work should be carried out in a timely manner, to a good quality and at the lowest price.

In practice, the offer price is the most important factor in the selection of bids. Forest districts prefer companies that offer the lowest prices, which may be insufficient to cover all costs, including employment costs. This situation forces forestry contractors to expand into other sectors, such as wood processing or trading in timber.

An important opportunity for the development of forestry contractors is provided by the possibility of forming consortia. Forestry companies are usually small and are not able to influence their market environment. The forest districts commission work in packages, which are usually rather large (1-3 packages per district), and small companies might not fulfil the requirements stated in the terms of reference for tender procedures. The formation of a consortium allows small companies to cooperate and submit a valid bid. For forestry contractors this means less competition in the market. Small companies often treat cooperation through consortia as an alternative to independent operations, or as an undesired circumstance in their economic relations with the State Forests [Kocel 2013a].

The number of companies paying attention to logistics and the improvement of logistic operations in order to keep their market position and gain a competitive advantage is increasing every year. Logistics is an effective instrument in innovation process management [Loučanova et al. 2016]. This applies also to the organisational units of the State Forests, because – apart from many non-productive functions (e.g. conservation, social functions) – their main goal is to supply the market with wood.

The example considered in this study, namely the forest fuel chip supply chain with all of its modifications, proves that informed logistic decisions can generate profits not only for the forest owner, but also for the participating contractors.

The main task of management within the State Forests, forestry contractors and timber merchants is to overcome the space–time gap between supply and demand. Wood should be delivered to buyers just when they need it. According to the definition of logistics, this should be in a timely manner, to the agreed place, in the quantity ordered, and with the agreed parameters relating to quality and dimensions [Moskalik 2006].

Supply chains are likely to undergo changes. Their users will expect flexibility, transparency, objectivity, and the integrity of the goods and services they order. These modifications will be evolutionary and will result from changes in the market environment as well as the need to adapt the supply chain. Such changes may also be seen as a source of competitive advantage. This may involve the creation of new organisational forms or business models of supply chain logistics, in the context of employing innovative technologies to achieve better efficiency [Windisch et al. 2013; Antonowicz 2016].

Conclusions

As a result of socioeconomic changes, seven variants of the forest fuel chip supply chain were observed in the years analysed.

Initially, before the privatisation of forestry work, the supply chain of forest fuel chips consisted of only two links: the producer, namely the forest district; and the customer, a hospital heating plant.

As a result of changes in the timber market, a new supply chain was formed. The new chain was longer, including two links (chipping and chip transport) which up to that time had been included in production outsourcing. The forest district became a producer of the chipping material, rather than of the chips themselves.

A precise analysis of the wood market with respect to the potential for selling wood of accepted quality at an accepted time and place can facilitate a decision-making process that would be expected to yield a financial gain. An efficient logistics system is crucial for proper response to market change.

Logistics processes have become an integral part of planning in every enterprise. By taking measures to utilise their own logistics infrastructure more efficiently, or by modifying their own logistics systems, companies may gain considerable savings and ensure a competitive advantage.

References

Antonowicz M. [2016]: Wyzwania logistyczne firm-elastyczne łańcuchy dostaw (Logistics challenges of companies – flexible supply chains). Studia Ekonomiczna. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach Nr 255: 215-229

Asikainen A., Röser D., Laitila J., Sikanen L. [2011]: Feasibility of the Nordic forest energy harvesting technology in Poland and Scotland. Biomass and Bioenergy 35 [11]: 4565-4569

Cambero C., Sowlati T. [2014]: Assessment and optimization of forest biomass supply chains from economic, social and environmental perspectives – A review of literature. Renewable and Sustainable Energy Reviews 36: 62-73

Drábek J., Jankovský M., Jankovský J. [2015]: New opportunities on the market with wood chips in central Slovakia. Proceedings of: Wood Processing and Furniture Manufacturing Challenges on the World Market. Wood-Based Energy Goes Global, 5-10 October 2015. Dubrovnik, Croatia: 61-68

Gołębiowski T. (ed.) [2003]: Marketing na rynku instytucjonalnym (Marketing in the Institutionalised Market). PWE, Warsaw, pp. 14-15

Glazar K., Iwanicki P. [2016]: Pozycja strategiczna przedsiębiorstwa sektora usług leśnych z obszaru RDLP w Poznaniu, Pile i Szczecinie (Strategic position of a forest service company in the Poznań, Piła and Szczecin RDSF). Sylwan 160 [1]: 11-20

Glazar K., Polowy K. [2015]: The organisational and legal forms of enterprises in forestry sector in selected state forests directorates. Acta Scientiarum Polonorum Silvarum Colendarum Ratio et Industria Lignaria 14 [1]: 15-30

Glazar K., Wojtkowiak R. [2009]: Koszty pracy maszyn leśnych (Costs of Forestry Machinery Operations). PIMR, Poznań

Gunnarsson H., Rönnqvist M., Lundgren J.T. [2004]: Supply chain modelling of forest fuel. European Journal of Operational Research 158 [1]: 103-123
Hudson B., Hudson B. [2000]: Wood fuel supply chain in the United Kingdom. New Zealand Journal of Forestry Science 30 [1-2]: 94-107
Kaputa V., Sucháň R. [2012]: Slovak Wood Biomass Market. Intercathedra 28/1: 24-30
Kärhä K. [2011]: Industrial supply chains and production machinery of forest chips in Finland. Biomass and Bioenergy 35 [8]: 3404-3413
Kärhä K., Jylhä P., Laitila J. [2011]: Integrated procurement of pulpwood and energy wood from early thinnings using whole-tree bundling. Biomass and Bioenergy 35 [8]: 3389--3396
Kocel J. [2000]: Prywatyzacja działalności gospodarczej nadleśnictw. Stan i rozwój prywatnego sektora usług leśnych. In: Prywatny sektor usługowy w leśnictwie. Stan i perspektywy rozwoju (Privatisation of Forest District Economic Activity. Current State and Development of Private Forest Service Sector. In: Private Sector in Forestry Services. Current State and Prospects for Development). Wyd. MTB Sawo, Tuchola: 19--29
Kocel J. [2002]: Stan i uwarunkowania rozwoju prywatnego sektora usług leśnych w Polsce (Current State and Determinants of Development in the Private Forest Service Sector in Poland). Prace Instytutu Badawczego Leśnictwa, seria A, 931: 6-25
Kocel J. [2010]: Prywatny sektor usług leśnych z perspektywy 20 lat (Private Forestry Services Sector – 20-year perspective). Forum leśne: Człowiek las drewno. Wyd. Ornatus, Poznań, 9-19
Kocel J. [2013a]: Firmy leśne w Polsce (Forest companies in Poland). CILP, Warsaw
Kocel J. [2013b]: Rola sektora usług leśnych w otoczeniu społeczno-ekonomicznym Lasów Państwowych (Private Service Sector in Socio-economic Environment of Polish State Forests). Poznańskie Towarzystwo Przyjaciół Nauk. Wydział Nauk Rolniczych i Leśnych. Forestry Letters 104: 23-33
Kocel J. [2014]: Prywatne przedsiębiorstwa leśne – stan obecny, bariery i możliwości rozwoju (Private Forest Service Companies – Current State, Threats and Potential for Development) [accessed 12.03.2015]. Panel Ekspertów „Rozwój". Lasy i gospodarka leśna jako instrumenty ekonomicznego i społecznego rozwoju kraju, Sękocin Stary. Available from: http://www.npl.ibles.pl/sites/default/files/referat/referat_j.kocel_.pdf
Laitila J. [2008]: Harvesting technology and the cost of fuel chips from early thinnings. Silva Fennica 42 [2]: 267-283
Loučanova E., Parobek J., Palus H., Kalamarova M. [2016]: Logistic as a part of innovation process. Acta Logistica 3 [1]: 1-4
Łyp K., Zychowicz W. [2007]: Funkcjonowanie nadleśnictwa w gospodarce rynkowej (Forest district in market economy). In: Technika i technologia w leśnictwie polskim (Technique and Technology in Polish Forestry). Wyd. SGGW, Warsaw: 180-183
Maciejewska K. [2005]: The operative labour consumption of technologies of fuel wood harvesting from improvement cuttings in pine stands. Acta Sci. Pol., Silvarum Colendarum Ratio at Industria Lignaria 4 [1]: 41-50
Mentzer J.T., DeWitt W., Keebler J.S., Min S., Nix N.W., Smith C.D., Zacharia Z.G. [2001]: Defining Supply Chain Management. Journal of Business Logistic Vol. 22, No. 2
Moskalik T. [2006]: Logistyka transportu drewna (Wood transport logistics). Forum leśne: Człowiek las drewno. Wyd. Ornatus, Poznań, 65-72
Murphy F., Devlin G., McDonnell K. [2014]: Forest biomass supply chains in Ireland: A life cycle assessment of GHG emissions and primary energy balances. Applied Energy, 116, 1-8

Ratajczak E., Bidzińska G. [2013]: Rynek biomasy drzewnej na cele energetyczne (Market of Woody Biomass for Energy). In: Biomasa leśna na cele energetyczne (Woody Biomass for Energy). IBL, Sękocin Stary

Ratajczak E., Szostak A., Bidzińska G., Herbeć M. [2012]: Demand for wood biomass for energy purposes in Poland by 2015. Drewno 55 [187]: 51-63

Röser D., Sikanen L., Asikainen A., Parikka H., Väätäinen K. [2011]: Productivity and cost of mechanized energy wood harvesting in Northern Scotland. Biomass and Bioenergy 35: 4570-4580

Sieniawski W., Porter B. [2012]: Zrównoważony łańcuch dostaw drewna na przykładzie wybranego zakładu (Sustainable Wood Supply Chain based on a selected sawmill). Studia i Materiały CEPL w Rogowie. R. 14. Zeszyt 32/3: 254-264

Szramka H., **Adamowicz K., Glazar K., Starosta-Grala M, Rutkowska A.** [2016]: Katalog kosztów minimalnych prac leśnych (Minimum costs of forest works). Wydawnictwo Uniwersytetu Przyrodniczego, Poznań

Tahvanainen T., Anttila P. [2011]: Supply chain cost analysis of long-distance transportation of energy wood in Finland. Biomass and Bioenergy 35 [8]: 3360-3375

Waściński T. [2014]: Procesy logistyczne w zarządzaniu łańcuchem dostaw (Logistics processes in supply chain management). Zeszyty Naukowe Uniwersytetu Przyrodniczo-Humanistycznego w Siedlcach, Administracja i Zarządzanie 30 [103]: 25-38

Więsik J. [2000]: Rozwój i wyposażenie techniczne prywatnych firm leśnych (Development and technical equipment of private forest companies). In: Prywatny sektor usługowy w leśnictwie. Stan i perspektywy rozwoju (Private Sector in Forestry Services. Current State and Prospects for Development) Wyd. MTB Sawo, Tuchola: 38-39

Więsik J., Wójcik K. [2008]: Wpływ mechanizacji na zatrudnienie robotników w firmach leśnych (Influence of mechanisation on employment of workers in forest companies) In: Tendencje i problemy techniki leśnej w warunkach leśnictwa wielofunkcyjnego (Trends and Problems of Forest Technology in Multifunctional Forestry). UP Poznań: 77-86

Windisch J., Röser D., Mola-Yudego B., Sikanen L., Asikainen A. [2013]: Business process mapping and discrete-event simulation of two forest biomass supply chains. Biomass and Bioenergy 56: 370-381

Wolfsmayr U.J., Rauch P. [2014]: The primary forest fuel supply chain: A literature review. Biomass and Bioenergy 60: 203-221

Zastocki D., Moskalik T., Sadowski J., Mokrzyński Ł., Dytkowski M. [2012]: Lokalne uwarunkowania rozwoju prywatnych firm leśnych na przykładzie wybranego nadleśnictwa (Local conditions for the development of private forest firms based on a selected forest district). Studia i Materiały CEPL w Rogowie. R. 14. Zeszyt 32/3: 231-237

List of standards

BN-76/9195-01 Maszyny rolnicze. Podział czasu pracy. Symbole i określenia (Agricultural machines. Working time distribution. Symbols and definitions)

Submission date: 10.07.2018

Online publication date: 15.05.2020