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VERIFICATION OF AN INNOVATIVE LOGISTICS-BASED COSTING MODEL FOR AGRICULTURAL ENTERPRISES IN A PROCESS APPROACH

Abstract:

This paper presents the main assumptions and functionalities of an innovative logistics-based costing model dedicated to agricultural enterprises. The model was verified in purposefully selected farms of various acreage engaged in crop or livestock production. The use of an innovative logistics-based costing model allowed to determine the basic logistics cost ratios both at a general level and in a process-based approach (by stages and by basic logistics processes), taking total/actual process costs into account. In livestock farms, the ratio of logistics costs to total costs was twice as high as in crop farms, and ranged from 30.4% to 42.9% of total costs. In crop farms, the corresponding ratio varied from 15.8% to 23.6%. The analysis of logistics costs by basic logistics processes shows that the largest difference in ratios between the farms was observed for warehousing processes. In livestock farms, the relevant ratio was three times higher than in crop farms.

Keywords:

logistics-based costing model, agricultural enterprises, model verification, process approach

JEL Classification: C81, M40, Q14

1. Introduction

Optimum decision making is among the core issues of corporate management. The key is to have the essential knowledge of processes, especially including their implementation costs. Logistics processes are among those which generate high costs, ranging from 10% to 40% of the value of goods sold (Skrodzka, 2007). Therefore, it is crucial to know these costs when making both micro- and macroeconomic decisions.

That knowledge is particularly sought after by enterprises who base their competitive strategy on cost leadership. Active in the initial stage of the food supply chain, agricultural enterprises are best placed to adopt that very strategy to compete in the market. However, in order to effectively support it, managers of such enterprises must solve multiple difficult problems. One of them is the absence of adequate measurement methods for process costs. Until recently, traditional methods for the determination of costs were good enough for that purpose. However, the information they provide has become insufficient because of the dynamic evolution of the immediate and wider business environment. The key changes include: increased competition, technological progress, increased process complexity, progress in IT, and change in external requirements (e.g. as to quantity, type or quality).

The above developments imply multiple changes, including in the nature of corporate operations, and reveal a multitude of new problems related to the measurement and adequate assessment of processes in economic and financial terms. The increase in the share of indirect costs in total production costs is a common occurrence (Kisperska-Moroń, 2006). On the one hand, process costs need to be accounted for on a comprehensive basis, but on the other, they are allocated to products and processes based on traditional methods. This may result in considerable distortions. The difficulties may be exacerbated depending on the number and type of products and processes handled by the enterprise. The above limitations make it difficult to analyze the multidimensional relationships between product costs, on one side, and processes implemented and resources consumed, one the other side.

That problem becomes even more acute when it comes to logistics costs because they are dispersed and difficult to identify in traditional accounting systems. This is all the more important since these costs play an increasing role in the entire value chain. The reasons for the above include the fact that in order to implement logistics processes, the company must own tangible assets in the form of buildings, warehouse structures, vehicles and other essential machinery and auxiliary equipment, including IT systems together with software. Current assets (in the form of stocks) are also used to a considerable extent and have a significant impact on financial performance (Christopher, 2005). In addition to these resource types, physical flows of materials, raw materials and products in the enterprise require the involvement of human resources, e.g. in transport, warehousing and process management activities. The above imply the generation of high labor costs (Nowicka-Skowron, 2000).

In agricultural enterprises, the specific features of agricultural production have a considerable impact on logistics processes. Based on a literature review (Kapusta, 2008; Klepacki 2011) and the author's own research (Wajszczuk, 2013), a series of characteristics may be identified which affect the logistics processes in these enterprises, namely: spatial nature of agricultural production; seasonality of production; strict compliance with work schedules; diversity of goods transported; large total weight of freight; unidirectional nature of agricultural transports, especially internal transports; short-haul transport (often on poor roads); and unsuitability of many agricultural products for transport and warehousing.

Considering the above characteristics, studies carried out by many scientific centers suggest that the share of logistics in general costs of agricultural holdings ranges quite broadly, depending on production profile, from around 23% to as much as 54% (Krysztofiak, 2010; Paulina and Timpanaro, 2012; Irigoyen, 2014; Pepliński, 2014; Wajszczuk, 2016). The key determinants of these costs are the production profile, field arrangement patterns, internal transport distances and the quality of storage facilities and means of transport. Therefore, already in 1913, Albrecht Thaer had a good reason to believe that *whether they want it or not, farms are transport undertakings* (Wolszczan, 1988), now a well-known saying.

It follows from the above that the economic performance of an enterprise is largely affected by its logistics system. Therefore, monitoring the costs of that system should become a key task for the management who should be adequately empowered with efficient, duly organized inventory and information systems based on applicable cost identification models. The role of these models should be to analyze and assess the functioning of the logistics system in the context of costs it generates.

Having the above in mind, the purpose of this paper is to present the main assumptions and functionalities of the proposed innovative logistics-based costing model, and to present the basic logistics cost ratios for agricultural enterprises, determined as a result of the model's validation in the context of agricultural business.

2. Material and methodology

The study was conducted in the marketing year[1] 2016/2017 in 21 purposefully selected Polish farms in the Wielkopolska region. Considering the area structure of local farms, the selected holdings were classified into three groups: (i) small farms, with up to 10 ha of AL[2], (ii) medium farms, with 10 to 20 ha of AL and (iii) large farms, beyond 20 ha of AL. Additionally, the farms surveyed were divided into two groups by core production activities in the global production structure[3]. See Table 1 for general characteristics of farms.

The survey provided the following detailed information on the processes implemented: (i) structure of processes at the supply, production and distribution stages (all tasks included), (ii) consumption of different resources (inputs of human labor, fixed and current assets and energy carriers).

The logistics cost ratios were determined based on a process approach: (i) by stage: costs of the supply stage (SC), production stage (PC) and distribution stage (DC); (ii) by basic logistics processes: costs related to physical flow of materials, raw materials, semi-finished products, finished products, machines, humans, etc. (CF), costs related to warehouse management (CW), costs related to information flow (CI) and ratios of logistics costs to total production costs for the whole farm.

Table 1. General characteristics of agricultural enterprises surveyed.

Specification	Enterprises surveyed					
	Main production profile: crops			Main production profile: livestock		
	Small	Medium	Large	Small	Medium	Large
Number of agricultural enterprises	4	3	4	2	3	5
Average farm area (ha)	8,3	15,8	34,3	8,9	16,2	36,7
Dominant production lines	Cereals	Cereals + rape	Sugar beet + cereals	Swine	Swine + bovine animals for fattening	Dairy cattle + swine

Source: own calculations.

[1] The marketing year is taken into consideration to identify all processes of crop and livestock production and the related inputs and costs. As regards most crops, the process starts in spring and/or autumn and ends the next summer.
[2] AL: agricultural land.
[3] Crop production is the core production activity if it represents over 65% in the company's global production mix. In turn, livestock production is the core production activity if it has a share from 55% to 60%.

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3. Findings

3.1. Main assumptions, structure and functionality of the model

The approach which consists in indirect cost allocation to processes and products is an innovative solution used in the proposed logistics-based costing model dedicated to agricultural enterprises (LBC-AE) which distinguishes it from previous models used in the context of agricultural businesses. The underpinning principle of this solution is that all indirect and direct costs are taken into account when calculating unit consumption costs of various enterprise resources. As a consequence, indirect costs (through the use of adequate ratios) are allocated to specific processes based on actual resource consumption rather than on allocation keys.

LBC-AE generates processed information which enable decision making in business areas where logistics play a key role, including: outsourcing; agricultural product quality assurance; flows of materials, finished products and information; land layout; sustainable development of agricultural enterprises.

Note that the proposed ratio and index system is different from other ones addressed in the literature as it takes into consideration the specific nature of agricultural enterprises and introduces some aspects of the assessment of logistics processes from the perspective of sustainable agricultural development.

LBC-AE is structured into 7 modules which consist of:

Module 1: identifying the processes to be covered by the logistics-based costing model for agricultural enterprises; assigning IDs to tasks.

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Module 2: identifying the resources required to implement the identified logistics processes in an agricultural enterprise.

Module 3: recording the consumption of resources in particular processes (process sheets).

Module 4: calculating the unit consumption costs of different resources used in relevant processes.

Module 5: calculating the implementation costs of logistics processes with the use of process-based equations.

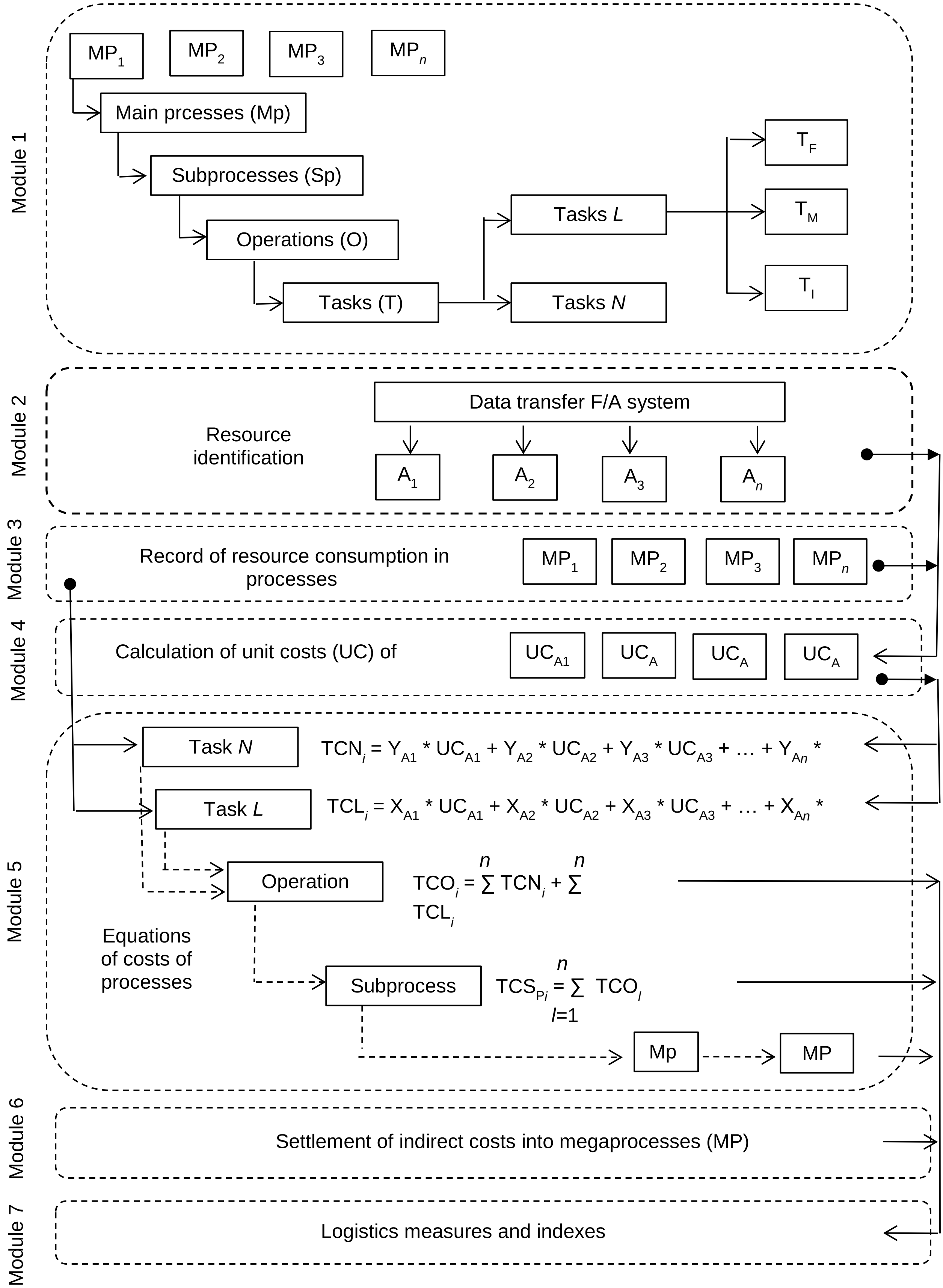
Module 6: allocating the indirect cost pool to specific megaprocesses.

Module 7: defining the logistical ratios and indexes.

The order of the modules listed above results from the logic underpinning the proposed model. The diagram reflecting that approach is shown in Figure 1.

The first module addresses the problem of identifying the processes to be used in the logistics-based costing model by emphasizing the essence and importance of the processed-based approach to enterprise management and the role of logistics in process coordination. The purpose of research covered by this module was to develop (using the process mapping method) proprietary reference models for business processes taking place in agricultural enterprises, so as to ensure better visibility of logistics processes.

The use of the process mapping method in the development of reference models enhanced the utility of the LBC-AE model for several reasons. Implementing that model will provide the enterprise with the following opportunities: (i) the employees will be empowered to understand and precisely know the structure of processes; note that according to worldwide research, innovation propositions are more likely to be accepted if the staff has a good understanding of it; (ii) streamlining the existing processes and eliminating the redundant ones; (iii) implementing the concept of process-based enterprise management; (iv) separating logistics processes from business processes.


Module 1
MP1
MP2
MP3
MPn
Main prcesses (Mp)
Subprocesses (Sp)
Operations (O)
Tasks (T)
Tasks L
Tasks N
TF
TM
TI
Module 2
Resource identification
Data transfer F/A system
A1
A2
A3
An
Module 3
Record of resource consumption in processes
MP1
MP2
MP3
MPn
Module 4
Calculation of unit costs (UC) of
UCA1
UCA
UCA
UCA
Module 5
Task N
TCNi = YA1 * UCA1 + YA2 * UCA2 + YA3 * UCA3 + … + YAn *
Task L
TCLi = XA1 * UCA1 + XA2 * UCA2 + XA3 * UCA3 + … + XAn *
Operation
TCOi = Σ TCNi + Σ TCLi
Equations of costs of processes
Subprocess
TCSPi = Σ TCOl
Mp
MP
Module 6
Settlement of indirect costs into megaprocesses (MP)
Module 7
Logistics measures and indexes

Legend:

Legend:

MP_1, …, MP_n – megaprocesses in an enterprise from 1 to *n*,

A_1, …, A_n – types of resources in an enterprise from 1 to *n*,

F/A system – financial and accounting system of an enterprise,

Tasks N – non-logistics tasks,

Tasks L – logistics tasks,

T_F – logistics tasks related with physical flow of materials, raw materials, semi-finished products, finished products, machines, humans, etc.,

T_W – logistics tasks related with warehouse management,

T_I – logistics tasks related with information flow,

UC_{A1},…, UC_{An} – unit costs of resource consumption from 1 to n,

Y_{A1}, …, Y_{An} – amount of resource consumption from 1 to n in a non-logistics task,

X_{A1}, …, X_{An} – amount of resource consumption from 1 to n in a logistics task,

TCN_i – total cost of implementation „*i”* of a non-logistics task,

TCL_i – total cost of implementation „*i”* of a logistics task,

TCO_i – total cost of implementation „*i”* of an operation,

TCS_{Pi} – total cost of implementation „*i”* of a subprocess,

Figure 1. The scheme of cost settlement in the LBC-AE model

Source: Author's own compilation.

The second module identifies and characterizes the resources of the agricultural enterprise which are required to implement the business process, with particular focus on the implementation of logistics processes. In that context, the author proposed its own classification by type of the logistics infrastructure characteristic of agricultural enterprises

Separating the logistics processes from business processes would be impossible without extending the model with adequate operational records, as presented in the third module. The author developed its own method for recording the consumption of resources in particular processes which allowed to extract logistics processes from the total pool of business processes. An entry to resource consumption records proposed in LBC-AE includes: (i) identification of the megaprocess aggregation level (main processes, sub-processes, actions and tasks); (ii) task deadline; (iii) type of resource consumed; (iv) measure of resource consumed; (v) number of units of resource consumed; (vi) task IDs (the *L* logistics tag and tags of basic logistics processes: T_F, T_W and T_I).

Module four provides the calculation methods for unit consumption costs of various enterprise resources used during the processes. The growing share of indirect costs in total production costs has become an increasingly wide-spread phenomenon. Therefore, legacy indirect cost allocation methods are no longer enough to provide a complete and—above all—undistorted result. To meet the growing requirements for complete information on process and product costs, LBC-AE relies on an innovative approach underpinned by the principle that all indirect and direct costs are taken into account when calculating unit consumption costs of various enterprise resources by determining the full amount of: (i) operating costs, in the case of technical infrastructure involved in the implementation of logistics processes; (ii) gross remuneration, in the case of human resources; (iii) material costs, in the case of using current assets. Therefore, the essence of the model's innovativeness is that costs are allocated based on actual consumption of resources in different processes.

Module five presents the algorithms developed for *cost equations of business processes* (including logistics processes). Equation algorithms reflect the consumed value of a resource in the process considered, which is the combined effect of two variables: (i) unit consumption cost of the resource (data generated in module four); (ii) quantity of resource consumed during the process (data retrieved from module three; the adequate consumption measure will be used depending on resource type).

The developed equation algorithms for business processes (including logistics processes) enable the generation of a series of output data on logistics costs and other process costs at various aggregation levels, thereby establishing a comprehensive information base on process costs incurred by the agricultural enterprise.

The procedure for determining process costs at various aggregation levels results from the logic behind the decomposition of megaprocesses. This means that task costs are calculated first, and are afterwards aggregated at subsequent levels, ultimately reaching the enterprise-wide level.

Figure 2 shows a diagram of the structure of linkage between megaprocess cost equations in LBC-AE. For the sake of clarity, the Figure shows only the selected links between equations in an effort to provide the best reflection of relationships and characteristics of links between costs generated at various aggregation levels.

In accordance with the diagram presented above, and with the use of previously defined process tags, the following costs are determined:

- costs of a non-logistic task (NC_T),
- costs of a logistic task (LC_T) which may relate to: (i) physical flow of materials, raw materials, semi-finished products, finished products (LC_{TF}) or (ii) warehousing materials, raw materials, semi-finished products, finished products (LC_{TW}) or (iii) information flow (LC_{TI}).

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In accordance with megaprocess reference models, individual tasks are identified at adequate stages of megaprocesses. This determines the allocation of costs to the provisioning, production or distribution stage, respectively. Therefore, the costs of tasks performed at each stage will be calculated with the following formulas:

A. Cost equation for a non-logistic task:

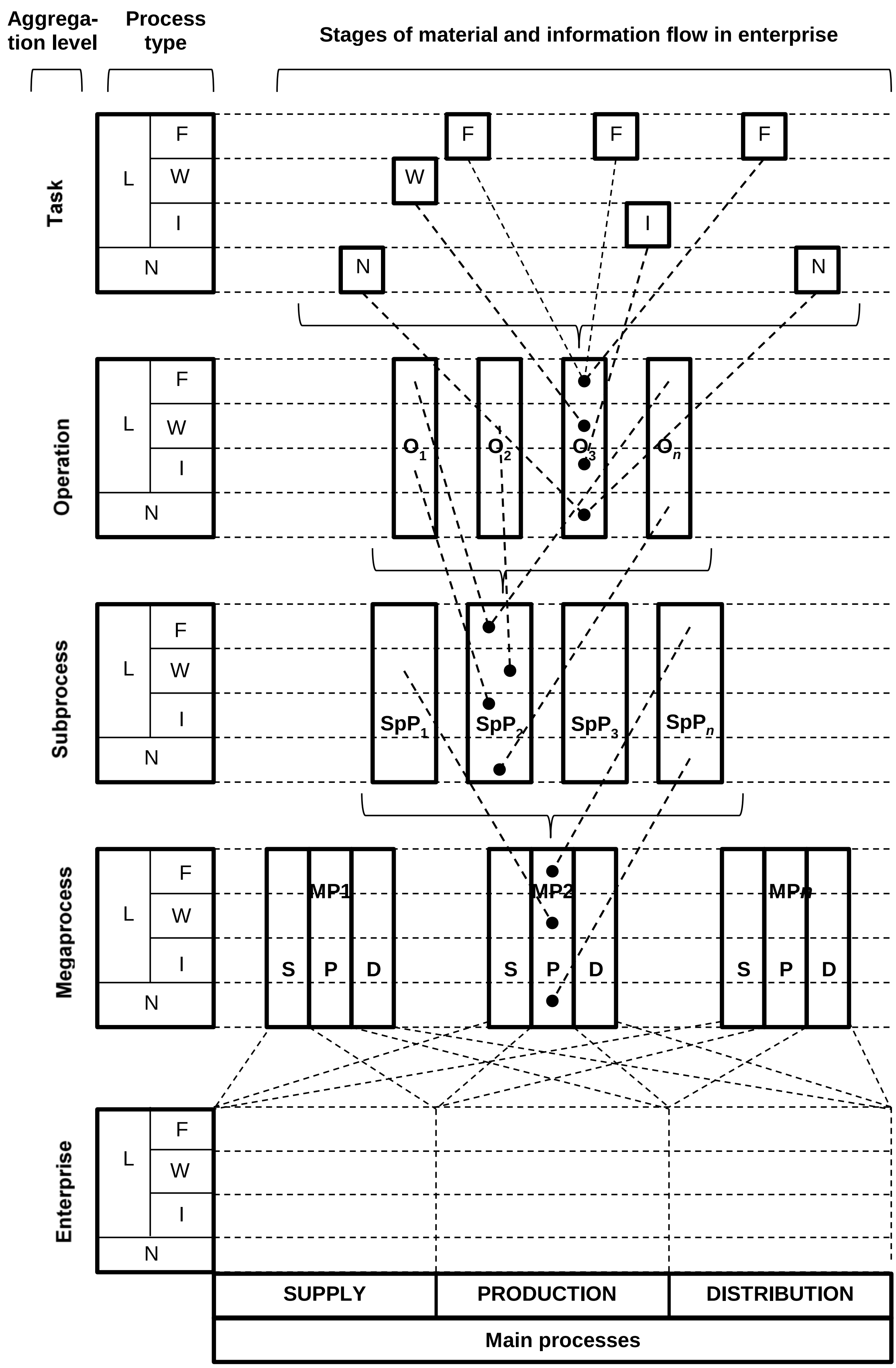
$$\mathbf{NC_{T\mathit{i}} = Y_{A1} * UC_{A1} + Y_{A2} * UC_{A2} + Y_{A3} * UC_{A3} + \ldots + Y_{A\mathit{n}} * UC_{A\mathit{n}}} \quad (1)$$

where:

NC_{Ti}: total cost of non-logistic task *i*,

Y_{A1}, …, Y_{An}: quantity of resources from 1 to *n* consumed within a non-logistic task,

UC_{A1},…, UC_{An}: unit consumption costs of resources from 1 to *n*.


Aggregation level
Process type
Stages of material and information flow in enterprise
Task
Operation
Subprocess
Megaprocess
Enterprise
L
F
W
I
N
O1
O2
O3
On
SpP1
SpP2
SpP3
SpPn
MP1
MP2
MPn
S
P
D
SUPPLY
PRODUCTION
DISTRIBUTION
Main processes

Legend:

MP_1, …, MP_n: enterprise megaproceses from 1 to *n*,

N: non-logistics processes; **L**: logistics processes,

F: logistics processes related to physical flow of materials, raw materials, semi-finished products, finished products, machines, humans etc.; **W**: logistics processes related to warehouse management,

I: logistics processes related to information flow,

SpP_1,…, SpP_n: sub-processes (from 1 to n) of the main production process; **O_1, …, O_n**: actions (from 1 to n) covered by subprocess PpP_2,; **S**: Supply (main process); **P**: production (main process); **D**: distribution (main process).

Figure 2. Structure of linkage between megaprocess cost equations in LBC-AE

Source: Author's own compilation.

B. In function of the tag assigned to a logistic task during identification, cost equations for logistic tasks take one of the following three forms:

$$LC_{TF} = X_{A1TF} * UC_{A1} + X_{A2TF} * UC_{A2} + + X_{A3TF} * UC_{A3} + \dots + X_{AnTF} * UC_{An} \quad (2)$$

$$LC_{TW} = X_{A1TW} * UC_{A1} + X_{A2TW} * UC_{A2} + X_{A3TW} * UC_{A3} + \dots + X_{AnTW} * UC_{An} \quad (3)$$

$$LC_{TI} = X_{A1TI} * UC_{A1} + X_{A2TI} * UC_{A2} + X_{A3TI} * UC_{A3} + \dots + X_{AnTI} * UC_{An} \quad (4)$$

where:

LC_{TF}: total cost of a logistics task related to physical flow of materials, raw materials, semi-finished products and finished products,

LC_{TW}: total cost of a logistics task related to warehousing of materials, raw materials, semi-finished products and finished products,

LC_{TI}: total cost of a logistics task related to information flow,

X_{A1TF}, …, X_{AnTF}: quantity of resources from 1 to *n* consumed within a logistics task related to physical flow of materials, raw materials, semi-finished products and finished products,

X_{A1TW}, …, X_{AnTW}: quantity of resources from 1 to *n* consumed within a logistics task related to warehousing of materials, raw materials, semi-finished products and finished products,

X_{A1TI}, …, X_{AnTI}: quantity of resources from 1 to *n* consumed within a logistics task related to information flow,

UC_{A1},…, UC_{An}: unit consumption costs of resources from 1 to *n*.

3.2. Verification of the model

The innovative logistics-based costing model presented above was used to determine the basic logistics cost ratios for agricultural enterprises, both at a general level and in a process-based approach (by stages and by basic logistics processes). The results are shown in Table 2.

An analysis of ratios of logistics costs to total costs compared between undertakings engaged in different production activities reveals a clear trend. Generally, in livestock farms of any size, the ratio of logistics costs to total costs was twice as high as in crop farms, and ranged from 30.4% to 42.9% of total costs. In crop farms, the corresponding ratio varied from 15.8% to 23.6%. The contributing factors are: (i) the daily delivery of green fodder to livestock buildings, including loading and unloading activities; (ii) the need to store concentrates and roughage for several months.

Table 2. Basic logistics cost ratios for agricultural enterprises.

Type of logistics costs	Enterprises surveyed											
	Core production activity: crops						Core production activity: livestock					
	Small		Medium		Large		Small		Medium		Large	
	PLN/ha	%	PLN/ha	%	PLN/ha	%	PLN/ha	%	PLN/ha	%	PLN/ha	%
Logistics cost ratios in a process approach (by stage)												
S	213.2	22.4	290.6	21.8	300.1	20.7	447.3	21.2	498.8	18.8	527.2	17.3
P	341.6	35.9	506.5	38.0	582.9	40.2	835.5	39.6	1180.5	44.5	1481.0	48.6
D	396.8	41.7	535.8	40.2	566.9	39.1	827.0	39.2	973.6	36.7	1039.1	34.1
Total	951.6	100.0	1332.9	100.0	1449.9	100.0	2109.8	100.0	2652.9	100.0	3047.3	100.0
Logistics cost ratios by basic logistics processes												
F	858.4	90.2	1191.6	89.4	1286.1	88.7	1820.8	86.3	2217.8	83.6	2431.7	79.8
W	78.0	8.2	117.3	8.8	139.2	9.6	246.8	11.7	384.7	14.5	545.5	17.9
I	15.2	1.6	24.0	1.8	24.6	1.7	42.2	2.0	50.4	1.9	70.1	2.3
Total	951.6	100.0	1332.9	100.0	1449.9	100.0	2109.8	100.0	2652.9	100.0	3047.3	100.0
Share of logistics costs in total production costs												
Total costs	6023.1	100.0	6287.4	100.0	6143.5	100.0	6940.0	100.0	7208.9	100.0	7103.3	100.0
Including logistics costs	951.6	15.8	1332.9	21.2	1449.9	23.6	2109.8	30.4	2652.9	36.8	3047.3	42.9

Source: own calculations.

The impact of factors listed above was reflected in the level of ratios calculated for basic logistics processes. In livestock farms, logistics cost ratios for *F* processes were twice as high as in crop farms. In turn, the difference in the level of ratios for *W* processes was even higher (with the level recorded by livestock farms being as much as three times that of crop farms).

The analysis of logistics costs by stage showed that the ratios for livestock farms were around twice as high as in crop farms in each stage. This is especially true for stage *P* where the ratios ranged from 835.5 PLN/ha to 1481,0 PLN/ha, and from 341.6 PLN/ha to 582.9 PLN/ha, respectively.

4. Conclusions

The use of an innovative logistics-based costing model allowed to determine the basic logistics cost ratios for agricultural enterprises both at a general level and in a process-based approach (by stages and by basic logistics processes), taking total/actual process costs into account.

In livestock farms, the ratio of logistics costs to total costs was twice as high as in crop farms.

The analysis of logistics costs by basic logistics processes shows that the largest difference in ratios between the farms was observed for warehousing processes. In livestock farms, the relevant ratio was three times higher than in crop farms.

In summary, considering the quality and scope of data it generates, the use of LBC-AE will allow to improve the efficiency of logistics in agricultural enterprises. The extent of efficiency improvement may be reflected in many operating areas of the company, from process enhancement through to a more effective utilization of resources, cost reduction, and improved customer experience.

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