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THE SELECTION OF TRANSPORTATION MEANS FOR TECHNOLOGICAL PROCESSES

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Abstract: *The article discusses the issue of selection of the technical measures and the means of transport to carry out the executive and transport operations transport infrastructure investment: the chains of suppliers on the example of transport task, in production - for example the building transport infrastructure investment and in the storage warehouse. The developed method allows to determine the construction schedule (determination of the order of operations performed optimal technical measures and optimal means of transport) with the optimal function criterion (cost / time). The simulations have shown that this method allows an unambiguous selection of the technical measures and means of transport (vehicles) to implement the particular technological operations at a given time/cost, taking into account the established constraints.*

Key words: *graph, schedule, technological process operation, technical measures, transport means*

1. Introduction

Market demand for transport services, consignors and customers as well as manufacturers enforces the proper selection of means of transportation to carry out transport processes. Today's market competition is based on a huge supply of carrier's services on the one hand and on the direction of producers, suppliers and customers on the other hand. The optimal choice of transportation permits allows to restrict the costs of transport tasks. It also allows to adjust the timing and frequency of deliveries in the accordance with customer expectations. This is important because the overall transportation costs are included into the total price of a given good where they make up between few and tens percent.

A proper assessment of the product design in its initial stage is essential for any investor or service schedule production (manufacturing or modernization on an asset). The possibility of making a choice of the best solution among many different concepts (called the initial project), in the initial stage of the transport infrastructure investment will help to protect investors against potential losses (time or money, or both). In order to choose the best solution investor can use the based on various criteria – time, cost, materials used, means of transport, technical means selection.

This article deals with the issues determining the choice of means of transportation for technological processes taking place in the chain/logistics systems and the implementation of transport infrastructure investment. However, the responsibility and the difficulties of choosing the best solution affects not only investor, but other parties involved in the construction of the site (carriers, manufacturers or suppliers, contractors, customers, etc.). In effect, the use of specific methods of operational research becomes necessary.

Implementation of technological processes transport infrastructure investment is complex and imposes important requirements. A consistent plan (schedule) of the transport infrastructure investment must take into account economic issues (outlays), the proper use of technical means and modes of transport and their material resources, as well as the duration of the transport infrastructure investment (including completion times for the various stages). This is why, the planning of the transport infrastructure investment should be preceded by the analysis of relevant technology for the delivery of individual operations of the transport infrastructure investment, selection of appropriate technologies for the technical means and modes of transport and their material resources and their availability.

We have to take into consideration that very often several alternative plans for the implementation of the transport infrastructure investment are prepared and each of them recommends the accomplishment with a different sequence of individual operations and the allocation of adequate resources (technical

and transportation). Among these plans there are some specific plans determined like e.g. the realization plan, according to which the transport infrastructure investment that takes into account preconceived plan of selected criteria is to be implemented.
Processes can be described as transport operations carried out by means of transportation and production operations (referred to in this Article regulations) carried out by sets of technical measures. These operations are recognized in TRANSPORT – supply chain (Fig. 1), in MANUFACTURING and SERVICES - within production systems, including the raw and semi-finished materials transport, other materials and goods used to produce new products (Fig. 2), the STORAGE – within production systems and manufacturing that has an impact on population as well as on the final consumption of finished products (Fig. 3) (Fijałkowski, 2003; Jacyna, 2009; Jacyna-Gołda, 2015; Kendra et al., 2013). Each arch on the presented chart will be represented by one transport operation, and its nodes will represent events corresponding to the operation commencement and its termination (Ambroziak, 2007; Ambroziak and Lewczuk, 2008).
It is known that technological processes are RESOURCES capital and time consuming.

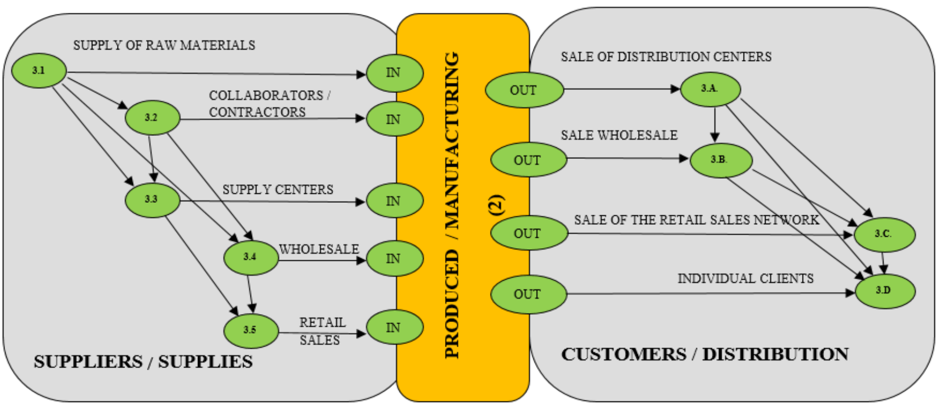


Fig. 1. Supply chain processes

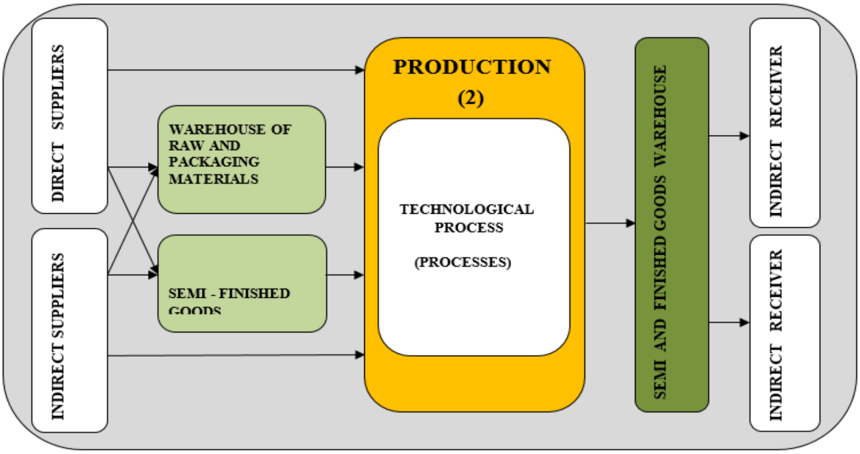


Fig. 2. Technological processes in manufacturing and services

The means of transport is dependent on many factors which can be divided into technical and economic.
Among the technical factors of selection means of transport to carry out transport operations can be divided into external, such as:
- the type of load (features and characteristics, susceptibility technical spatiality, quantity),
- type the task of lading, range (relation) carriage contracts between suppliers and customers,
- infrastructure of senders and recipients (roads, gates, squares, ramps, front works),
- road infrastructure,
- the course (use) of the vehicle,
- time of transport,
- the cost of transport

and internal, which can include:
- loading machine and method of execution of works cargo,
- workers, their qualifications,
- work organization,
- technical facilities.

In contrast, economic factors, selection of means of transport to carry out transport operations can be divided because of:
- the point of view of each of the participants involved in the implementation of transport operations from the standpoint of carriers (appropriate use of capacity / capacity of the vehicle, protection of property and the value of the cargo, as the lowest unit costs of transport),
- from the point of view of senders and recipients (behaviour characteristics of consumption and production of goods, minimizing transport costs while maintaining adequate quality transport service),
- point of view of manufacturers:
  - volume production needs (size of the supply of raw materials and packaging materials),
  - minimizing inventories of raw materials (short delivery time, the volume of deliveries, availability of suppliers / their production capacity),
  - the manner of delivery of raw materials and packaging (delivery direct and indirect),
  - the size of stores of raw materials (size and frequency of deliveries),
  - the performance of loading equipment at the input (raw materials and packaging) and output (finished products);
  - daily volume of deliveries and shipments of goods,
  - delivery just in time,
  - the time of delivery (from suppliers on demand material),
  - size of storage products,
  - how to implement the distribution of finished products (supplies direct and indirect),
  - contract customers (volume and frequency of shipments).

A tool for the right choice of means of transport for technological processes occurring in the supply chain is to plan the transport infrastructure investment.
Considered in this article venture involves the task of transport from the initial source to the end user in the supply chain (Figure 1) or from a specified point of supply to the designated distribution.

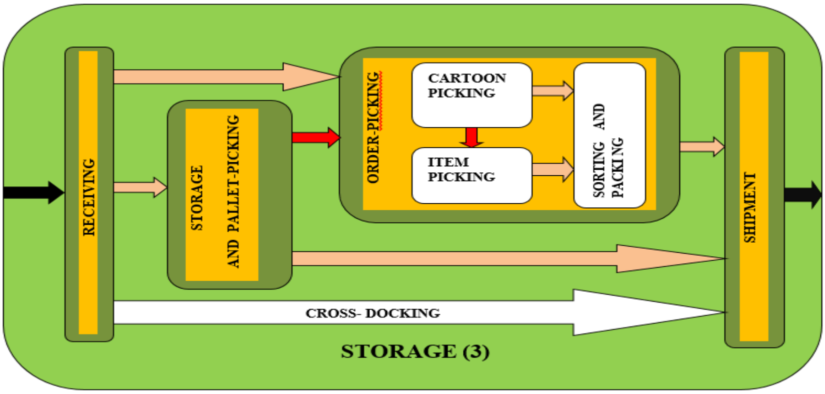


Fig. 3. Processes occurring in storage

Another link of the transport infrastructure investment is to process raw materials and intermediates in the production plants (production / manufacturing). Delivery of the finished product or intermediate can be carried out directly to the end user or through links indirect distribution network (distribution centres, warehouses and retail outlets).
A transport infrastructure investment plan shows (usually in graphic form) implementation of individual transport operations at a time, it presents the selection of appropriate means of transport and consumed by the corresponding material resources.
The plan should also take into account individual operations implementing transport infrastructure investments taking place within transshipment points (cents logistics, warehouses, retail outlets) and in the production plants. This realization enforcement operations has a direct impact on the choice of the means of transport.
The criterion for the selection of the optimal transport infrastructure investment implementation under test may be cost, time or rational use of means of transport under the given constraints (availability, capacity, capacity utilization rate, such as organizational constraints. EURO means of transport, etc.).
There is therefore a need for a method for the optimal selection of transport means for the implementation of transport operations.
In the literature there is no more publication - a new approach to solving the problem of optimal selection of means of transport to carry out transport operations (Love et al., 2014). Basis for discussion on these issues is found in the works of T. Ambroziak (Ambroziak, 2007; Ambroziak and Lewczuk, 2008) and are discussed in the works of S. Tkaczyk (Tkaczyk, 2014, 2015a, 2015b). In contrast, known methods of network analysis - CPM, PERT, GERT not solve the problem, since they are limited only to determine the critical path.

2. Problem research and test method

2.1. Selection of transport means in the supply chain

For the purposes of this article analysed the transport infrastructure investment has been divided into 3 parts, each of them dealt with separately – transport processes in supply chains, transport processes in production and transport processes in storage.

When considering transport processes in the supply chain (Fig. 1) intentionally omitted implementing the processes occurring in the handling points (assumed to be zero cost and transit time). In contrast, considering the processes taking place in production processes (Fig. 2) and storage (Fig. 3), takes into account the impact of regulations on the operation of transport operations.
However, only the simultaneous consideration of these three aspects can give an optimal solution (this issue will be analysed in the next stage of research the author) selection means of transport to carry examined technological processes occurring in the enterprise.
Graph G (Leszczyński, 1994; Pinedo, 2012), illustrating the structure of transport operations occurring in the logistics chain (Fig. 1) is designated as an example of the project to develop the transport sentences in the supply chain (Tkaczyk, 2015a) (each arc of the graph will be represented by the transport operation, and vertices – events corresponding to the facts start and termination of the operation).
For the purposes of this article as a transport task assumed carriage of cargo from the manufacturer (A) to the end customer (E). In order to optimize the selection of means of transport to carry out transport operations, a plan which takes into account the sequence of operations performed transport (precedence relationships) in the supply chain (Fig. 4).

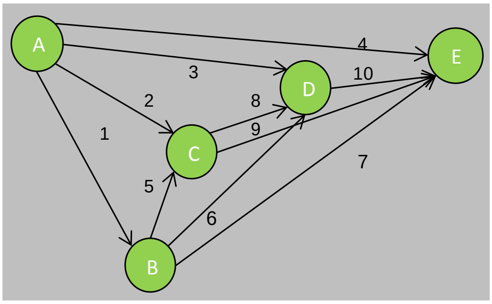


Fig. 4. Graph transport operations in the supply chain network

Table 1 shows the distances between points in the supply chain. On the basis of the adopted Graph transport operations in the supply chain (Fig. 4) was determined all available routes executing the transport infrastructure investment in question (Table 2), and each path may consist of one or more segments.

Table 1. Table distance between each node in the supply chain [km]

	A	B	C	D	E
A	0	150	250	300	300
B	x	0	100	200	300
C	x	x	0	100	200
D	x	x	x	0	100
E	x	x	x	x	0

Table 2. Routes acceptable task of transport

	T1	T2	T3	T4	T5	T6	T7	T8
AB	x	x	x	x	1	1	1	1
AC	x	x	1	1	x	x	x	x
AD	x	1	x	x	x	x	x	x
AE	1	x	x	x	x	x	x	x
BC	x	x	x	x	1	1	x	x
BD	x	x	x	x	x	x	1	x
BE	x	x	x	x	x	x	x	1
CD	x	x	1	x	1	x	x	x
CE	x	x	x	1	x	1	x	x
DE	x	1	1	x	1	x	1	x

The article assumes that the implementation of the transport task will be applied four types of transport (Table 3), varied due to the permissible total weight of the DMC and payload capacity (expressed in JLP).

Table 3. The list of available resources transportation

Number of means of transport	DMC [t]	the unit load pallet (pcs)
P1	4	6
P2	8	12
P3	12	18
P3	24	33

Among the costs generated during the implementation of a transport operation to analyse the selection of means of transport included only the cost of tolls, differentiated by class vehicle expressed EURO standards (Jacyna and Merkisz, 2014; Polish Council of Ministers, 2011). Taking into account the distances between each node (Table 1) were determined by the cost of tolls related to the implementation of the transport task.

Table 4. Potential allocation of means of transport to carry out transport operations

	A	B	C	D	E
A	x	P1, P2	P2, P3	P2, P3	P4
B	x	x	P2, P3	P2, P3	P4
C	x	x	x	P2, P3	P4
D	x	x	x	x	P4
E	x	x	x	x	x

Knowing Graph transport operation, considered the supply chain (Fig. 2), the allocation of transport for the implementation of individual operations (Table 4) and costs of individual transport operations (Table 5) can be determined graph realization transport task supply chain.

Table 5. Summary of cost of tolls for each section [zł]

	P1				P2				P3				P4			
	Euro2	Euro3	Euro4	Euro5	Euro2	Euro3	Euro4	Euro5	Euro2	Euro3	Euro4	Euro5	Euro2	Euro3	Euro4	Euro5
1 (A-B)	48	42	33	24	48	42	33	24	63	55,5	43,5	31,5	63	55,5	43,5	31,5
2 (A-C)	80	70	55	40	80	70	55	40	105	92,5	72,5	52,5	105	92,5	72,5	52,5
3 (A-D)	96	84	66	48	96	84	66	48	126	111	87	63	126	111	87	63
4 (A-E)	96	84	66	48	96	84	66	48	126	111	87	63	126	111	87	63
5 (B-C)	32	28	22	16	32	28	22	16	42	37	29	21	42	37	29	21
6 (B-D)	64	56	44	32	64	56	44	32	84	74	58	42	84	74	58	42
7 (B-E)	96	84	66	48	96	84	66	48	126	111	87	63	126	111	87	63
8 (C-D)	32	28	22	16	32	28	22	16	42	37	29	21	42	37	29	21
9 (C-E)	64	56	44	32	64	56	44	32	84	74	58	42	84	74	58	42
10 (D-E)	32	28	22	16	32	28	22	16	42	37	29	21	42	37	29	21

Graph realization takes into account any acceptable variation of the task of transport. Fig. 5 shows only a portion of the graph, showing the possibility of the maritime transport operation (for Route 1) different modes of transport. And so the operation transport section 1 (curve represents the transport operation - the first digit - is the number of segment) can be carried out using means of transport P1 and P2 (the number 2- potential number of means of transport), each of which meets the relevant EURO (number 3 - EURO standard the means of transport).

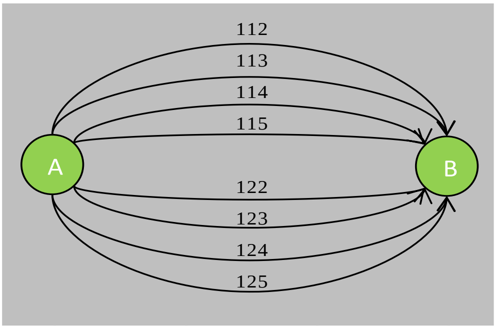


Fig. 5. Graph takes into account many aspects of the maritime transport operation

2.2. Selection of transport means in manufacturing processes

Graph G (Kendra et al., 2013; Love et al., 2014), illustrating the structure of the executive occurring in manufacturing (Fig. 2) will be designated for the transport infrastructure investment of the construction of the facility – a warehouse building (Tkaczyk, 2014). In pursuing construction of the facility must take a number of operations implementing a series of interrelated technological dependence. Transport operations, pre-operations executive, are intended to supply appropriate material resources for individual operations executive.

The scope and diversity of planned building works require the involvement of specialized technical equipment and early clarify its availability within the period provided for the implementation of individual operations associated with the construction warehouse. The list of operations implementing processes of the object shown in Table 6.

In order to plan the execution of works related to the construction of a storage facility is required to develop a plan defining the optimum sequence of operations performed regulations. With the list of operations regulations necessary to implement a particular transport infrastructure investment to be constructed, based on the knowledge of experts and its own experience of implementing the operation table indicating which ones immediately preceding the operation, and the ones following it (Table 6). Therefore, you can draw a graph of the operation process of implementing the construction of a warehouse building (Fig. 6).

The list of the administered sets of technical means used to carry out operations executive for the transport infrastructure investment in question is presented in table 7.

The construction works carried out by those adopted above sets of technical measures (technologies) forces the involvement of certain means of transport to pick up on the site of required material resources. The list of available resources to achieve supply transport are shown in Table 8.

Table 6. List implementing operations facility construction and operations prior to and subsequent regulations for the operation executive

Ord.	Number of operation	A description of the executive operations	Pre operations	Subsequent operations
1	m (1)	Levelling of land	0	m(2)
3	m (2)	Earthworks	m(1)	m(3), m(21)
4	m (3)	Foundations and foundations walls	m(2)	m(4)
5	m (4)	Insulation of vertical and horizontal ground	m(3)	m(5)
6	m (5)	External walls	m(4)	m(6), m(10)
7	m (6)	Partition walls	m(5)	m(7),m(11),m(13),m(14),m(15)
8	m (7)	Roof-construction and warming	m(6)	m(8)
9	m (8)	Roof- covering	m(7)	m(9)
10	m (9)	Guters	m(8)	m(20.2)

Ord.	Number of operation	A description of the executive operations	Pre operations	Subsequent operations
11	m (10)	Windows, exterior doors, gates	m(5)	m(20.1)
12	m (11)	Plumbing	m(6)	m(16.1)
13	m (12)	Installation of sanitary fittings	m(17)	m(18.1)
14	m (13)	Electrical installation	m(6)	m(16.2)
15	m (14)	IT networks, TV, alarms	m(6)	m(16.3)
16	m (15)	Central heating	m(6)	m(16.4)
17	m (16)	Internal Plasters	m(11),m(13),m(14),m(15)	m(17)
18	m (17)	Spout	m(16)	m(12),m(19)
19	m (18)	Painting works	m(12),m(19)	m(24.2)
20	m (19)	Intermal doors	m(17)	m(18.2)
21	m (20)	External plasters	m(20)	m(24.1)
22	m (21)	Fence	m(2)	m(22)
23	m (22)	sidewalks	m(21)	m(23)
24	m (23)	Lawns	m(22)	m(24.3)
24	m (24)	Technical reception	m(20),m(18),m(23)	0

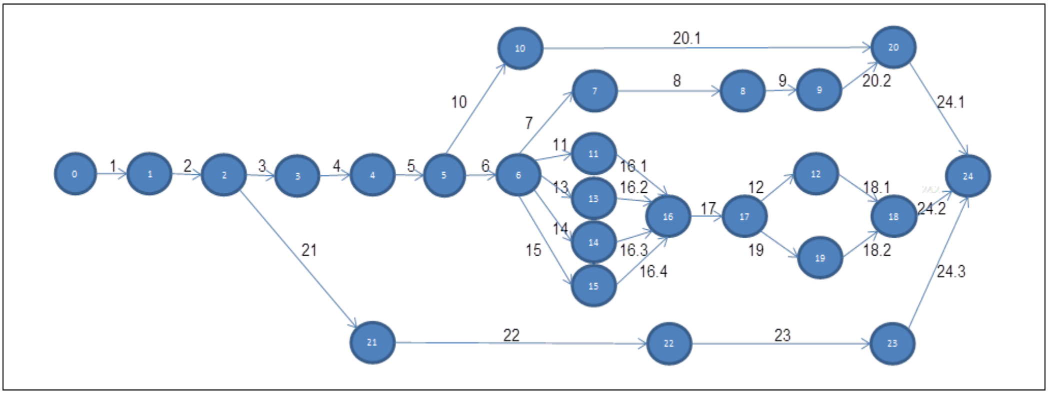


Fig. 6. Graph operations implementing the construction of a storage facility

Table 7. List the administered sets of technical means used in the construction of a storage facility

Ord.	A set number of technical measures	A description of technical measures
1	1	Construction laborers brigade – 4 werkers
2	2	Bulldozer
3	3	Excabator
4	4	Concrete mixer (9m3)
5	5	Werkers brigade, brick porotherm 44x25x25, U=0,3 W/m2K
6	6	Werkers brigade, poliuretan sandwich panel "250"
7	7	Roofers brigade
8	8	Carpenters brigade
9	9	Plumbers brigade
10	10	Electricians brigade
11	11	External fence company
12	12	External concretes company
13	13	External asphalts company
14	14	External horticultular company
15	15	Technical committee

Table 8. List of transportation available resources for the construction of a storage facility

Number of resource	Name of resource	Description of resource	Dimension [m/m]
1	ZT 1	Mixer car	x
2	ZT 2	specialized trailer	x
3	ZT 3	tractor + trailer 24 ton	2,50 /13,60
4	ZT 4	truck 12 ton	2,50 x 7,20
5	ZT 5	truck 6 ton	2,50 x 7,20
6	ZT 6	truck 2,0 ton	2,50 x 4,20
7	ZT 7	bus passenger	x
8	ZT 8	truck max 500 kg	1,00 x 1,40
9	ZT 9	Car	x
10	ZT 10	Asphalt set	x

Graf G (Fig. 6) illustrating the structure of all operations processes storage building construction, after taking into account:

- breaks down the operations of technological processes for implementing operations (related to the execution of construction works specified set of technical measures (technology) and transport operations (associated with delivery to the construction site material resources needed for the implementation of the operations of implementing certain means of transport),
- allocation sets the technical means to carry out operations implementing the process of constructing the warehouse building, knowing the sets of technical capacity and volume operations executive,
- allocation of means of transport to carry out transport operations building process storage building, knowing the efficiency of transport and the volume of transport operations

can be represented graphically- Knowing Graph (Fig. 7.).

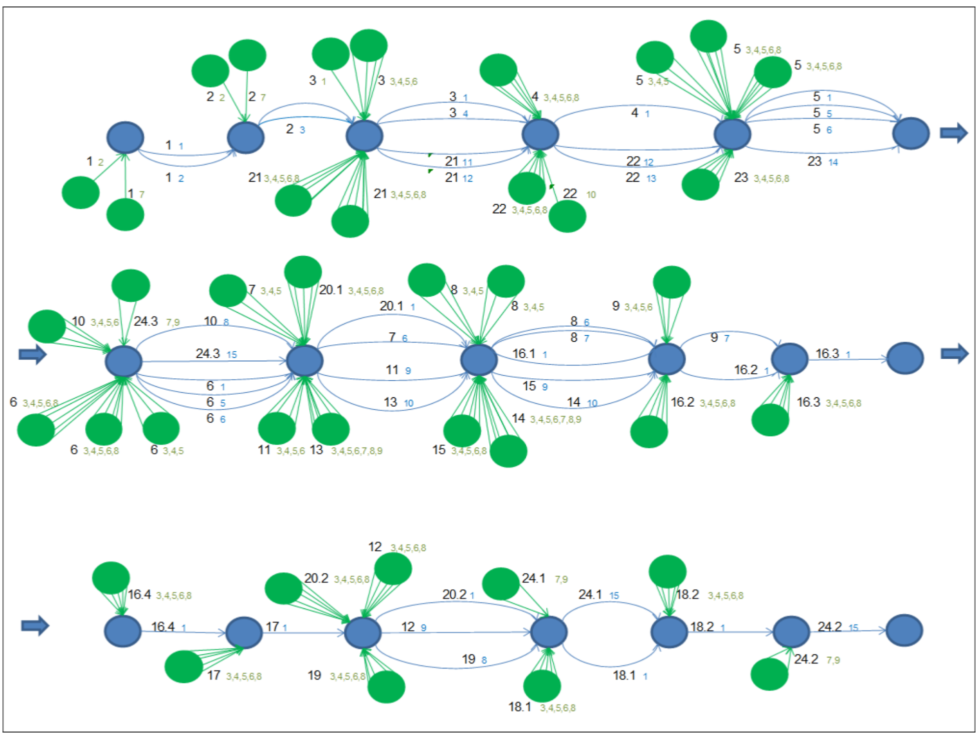


Fig. 7. Graph executive of building a storage facility taking into account not the use of means of transport (transport operations) and a set of technical measures (operations executive)

2.3. Selection of cash transport storage

Considering the processes occurring in storage (Fig. 3), we can proceed the same way as the processes occurring in manufacturing (2.2.). The difference will be only the use of means of transport. Vehicles will be replaced by an external means of handling that perform internal transport processes occurring within transshipment points. In contrast, implementing operations are related to storage and picking (picking cardboard, completion piecing, storage and packaging).

3. Plan for selection means of transport

Adopted in article form of writing and recording characteristics determining the choice of means of transport plans for the implementation of technological processes allow for the formulation of a wide variety of optimization tasks.

Formulated the following tasks vary adopted optimization criterion function and accepted the restrictions, depending on what the real situation of decision-making are mapped.

For the purposes of this study were isolated several types of tasks related to Single-optimization technology selection execution of operations implementing technological process:

- single-task optimization technology choices to minimize the duration of the operation of the technological process of implementing a fixed number of technical means,
- single-task optimization technology choices to minimize the duration of the technological process of implementing operations with a limited number of technical means,
- single – task optimization technology choices to minimize the cost of implementing the operation of the technological process,
- single-task optimization technology choices to minimize the cost of implementing the operation of the technological process by reducing the number of technical means.

Similarly, you can formulate tasks related to the Single-optimization technology selection execution of transport operations process:

- single-task optimization technology choices to minimize the duration of the transport operations of the technological process for a fixed number of means of transport,
- single-task optimization technology choices to minimize the duration of the transport operations of the technological process with a limited number of means of transport,
- single-task optimization technology choices to minimize the cost of the transport operations of the technological process,
- single-task optimization technology choices to minimize the cost of the transport operations of the technological process by reducing the number of means of transport.

Knowing records related tasks Single-optimization technology selection and implementation of operations executive transport operations of the technological process can be formulated tasks for the whole process, assuming that it consists of both executive operations and transport operations.

Therefore, by analogy we extracted several types of tasks related to Single-optimization technology choices implement the whole process:

- single-task optimization technology choices to minimize the duration of the technological process for a fixed number of technical measures and means of transport,
- single-task optimization technology choices to minimize the duration of the technological process with a limited number of technical measures and means of transport,
- single-task optimization technology choices to minimize the cost of implementation (of the whole) process technology
- single-task optimization technology choices to minimize the cost of the technological process by reducing the number of technical measures and means of transport.

For the transport infrastructure investment in question, for the purposes of this article, solved using a computer program LINGO (Lingo, 2002). Single-problem of determining a plan of functions criterion, which is the minimum/maximum cost of the transport infrastructure investment.

On the basis of the adopted graphs – for transport operations occurring in the supply chain (Fig. 4) and for implementing operations and transport operations occurring in production processes (Fig. 7) taking into account:

- list of operations executive
- a list of the administered set of technical measures and their efficiency and volume,
- allocation sets of technical means for individual operations implementing the technological process,

- volume and cost of individual operations executive
- a list of transport operations,
- a list of available resources and their transport performance and volume
- allocation of means of transport to individual transport operations of the technological process,
- volume and cost of individual transport operations

obtained the plan selection of means of transport for achieving these examples, taking into account as a function of criterion cost of the transport infrastructure investment in question.

The function reaches the minimum criterion taking into account the following system limitations. Analytical form of individual constraints (presented below) can be interpreted as follows:

Ad 1° condition priming operation,

Ad 2° condition Diversity exploit kits technical means,

Ad 3° condition Diversity exploitation of means of transport,

Ad 4° condition need all operations,

Ad 5° taken into account when determining the schedule will be the starting point for the implementation of transport operations and implementing operations processes,

Ad 6° appointed will be the timetable for the implementation of operations processes that will not be exceeded intensity of consumption of material resources for a set of technical measures,

Ad 7° appointed will be the timetable for the implementation of operations processes that will not be exceeded intensity of consumption of material resources for means of transport,

Ad 8° all operations executive will be assigned an appropriate set of technical measures,

Ad 9° all transport operations will be allocated the appropriate means of transport.

1°. $\boldsymbol{tt}(f) - \boldsymbol{tt}_{min}(f) \geq 0$

2°. $\overline{\overline{z(k,f,s) \cap z(l,f,s)}} \cdot \overline{\overline{\boldsymbol{T}(k,f) \cap \boldsymbol{T}(l,f)}} = 0; \qquad k, l \in \boldsymbol{K}(f), \quad k \neq l, \quad s \in \boldsymbol{S}$

3°. $\overline{\overline{z(k',f,p) \cap z(l',f,p)}} \cdot \overline{\overline{\boldsymbol{T}(k',f) \cap \boldsymbol{T}(l',f)}} = 0; \qquad k', l' \in \boldsymbol{K'}(f), \quad k' \neq l', \quad p \in \boldsymbol{P}$

4°. $\boldsymbol{M}(f) = \bigcup_{g=1}^{I^*(f)} \boldsymbol{M}^g(f), \qquad M^g \cap M^{g'} = \varnothing; \qquad g, g' = \overline{1,I}^*, \quad g^1 g'$

5°. $T_{pocz}\{(k,f), (k',f)\} = \{t(k,f); t(k',f)\}, \qquad k \in \boldsymbol{K}(f), \qquad k' \in \boldsymbol{K'}(f)$

6°. $\lambda_z(f, t, tt(k,f), \boldsymbol{S}(f)) \leq \lambda_z(f,z,t)^{max}$ for everyone $t \in \langle T_{pocz}(f), T^*(f) \rangle, \quad z \in \boldsymbol{Z},$

7°. $\lambda_z(f, t, tt(k',f), \boldsymbol{P}(f)) \leq \lambda_z(f,z,t)^{max}$ for everyone $t \in \langle T_{pocz}(f), T^*(f) \rangle, \quad z \in \boldsymbol{Z},$

8°. $$t''(k,f) = t'(k,f) + \frac{Q(k,f)}{\sum_{s \in N((k,f),s)} w(k,f,s)\, l(k,f,s)}; \qquad k \in \boldsymbol{K}(f)$$

9°. $$t''(k',f) = t'(k',f) + \frac{Q(k',f)}{\sum_{p \in N((k',f),p)} w(k',f,p)\, l(k',f,p)}; \qquad k' \in \boldsymbol{K'}(f)$$

wherein:

function criterion is formulated on the basis of the considerations set out in an earlier chapter of this work,

k – the executive operation (step processes),

k' – the transport operation (step processes),

l – the number of means,

w – performance standards,

Q – the volume of operations,

N(k, f, s) – set of numbers of technical means used to carry out this operation k-executive f-this graph technology,

N(k', f, p) – the set of numbers means of transport used to carry out this operation k'-transport f-this graph technology.

$$\min_{f\in \boldsymbol{F}} \min_{\boldsymbol{tt}(f),\boldsymbol{S}(f)\in \boldsymbol{PLAN}(f)} \min_{\boldsymbol{tt}(f),\boldsymbol{P}(f)\in \boldsymbol{PLAN}(f)} \left\{ \int_{T_{pocz}(f)}^{T^*(f)} \left\{ \begin{array}{l} \rho\sum_{s=1}^{S} c_j(s)\, e\left(s,f,t,tt(f),\boldsymbol{S}(f)\right)+\sum_{z=1}^{Z} c_j(z)\,\lambda_z\left(z,f,t,tt(f),\boldsymbol{S}(f)\right)+ \\ +\sum_{s=1}^{S} c_g(s)\, e\left(s,f,t,tt(f),\boldsymbol{S}(f)\right)+\rho\sum_{p=1}^{P} c_j(p)\, e\left(p,f,t,tt(f),\boldsymbol{S}(f)\right)+ \\ +\sum_{z=1}^{Z} c_j(z)\,\lambda_z\left(z,f,t,tt(f),\boldsymbol{P}(f)\right)+\sum_{p=1}^{P} c_g(p)\, e\left(p,f,t,tt(f),\boldsymbol{P}(f)\right) \end{array} \right\} dt \right\}$$

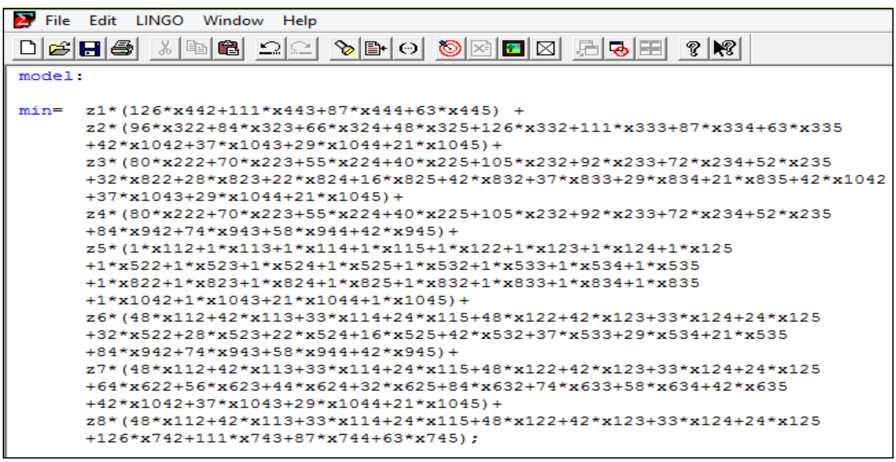
wherein:

f – number of graph G,
$\boldsymbol{tt}$(f) – set of the commencement of implementation of individual operations in the graph f,
PLAN(f) – plan for all operations of technological processes illustrated in the graph f,
$T_{pocz}(f)$, $T^*(f)$ – pre-defined moments: the start and completion of the transport operation processes mapped graph technology,
s – set number of technical measures (s-th set of technical measures),
$c_j(s)$ – the unit cost of operation of s-this set of technical measures,
$c_g(s)$ – man-of-the cost of this set of technical measures,
p – number of means of transport (p-th mode of transport),
$c_j(p)$ – the unit cost of operation of p-this set of means of transport,
$c_g(p)$ – man-of-the cost of this set of means of transport,
e – the number of operating (at a time t),
z – number of-this resource material,
λ_z – intensity of consumption in-this resource material.

4. Optimal cost of development

It proposes a model designation minimize the costs of the transport task implemented to LINGO (Fig. 8) has offered a solution to minimize the cost of the transport task (Fig. 9). A solution is achieved specifying the minimum cost for the model in question (Fig. 9). as shown in graphic form (Fig. 10). But for the present transport infrastructure investment, construction of a storage facility (point 2.2.), using a computer program LINGO (Lingo, 2002) sets the agenda for transport operations due to minimizing the cost of implementation of the f-this transport infrastructure investment.

It proposes a model designation minimize the costs of the transport task that once implemented to LINGO (Fig. 11) has offered a solution to minimize the cost of the transport task (Fig. 12).




```
model:

min=   z1*(126*x442+111*x443+87*x444+63*x445) +
       z2*(96*x322+84*x323+66*x324+48*x325+126*x332+111*x333+87*x334+63*x335
       +42*x1042+37*x1043+29*x1044+21*x1045)+
       z3*(80*x222+70*x223+55*x224+40*x225+105*x232+92*x233+72*x234+52*x235
       +32*x822+28*x823+22*x824+16*x825+42*x832+37*x833+29*x834+21*x835+42*x1042
       +37*x1043+29*x1044+21*x1045)+
       z4*(80*x222+70*x223+55*x224+40*x225+105*x232+92*x233+72*x234+52*x235
       +84*x942+74*x943+58*x944+42*x945)+
       z5*(1*x112+1*x113+1*x114+1*x115+1*x122+1*x123+1*x124+1*x125
       +1*x522+1*x523+1*x524+1*x525+1*x532+1*x533+1*x534+1*x535
       +1*x822+1*x823+1*x824+1*x825+1*x832+1*x833+1*x834+1*x835
       +1*x1042+1*x1043+21*x1044+1*x1045)+
       z6*(48*x112+42*x113+33*x114+24*x115+48*x122+42*x123+33*x124+24*x125
       +32*x522+28*x523+22*x524+16*x525+42*x532+37*x533+29*x534+21*x535
       +84*x942+74*x943+58*x944+42*x945)+
       z7*(48*x112+42*x113+33*x114+24*x115+48*x122+42*x123+33*x124+24*x125
       +64*x622+56*x623+44*x624+32*x625+84*x632+74*x633+58*x634+42*x635
       +42*x1042+37*x1043+29*x1044+21*x1045)+
       z8*(48*x112+42*x113+33*x114+24*x115+48*x122+42*x123+33*x124+24*x125
       +126*x742+111*x743+87*x744+63*x745);
```

Fig. 8. The model optimization task selection means of transport for the transport task

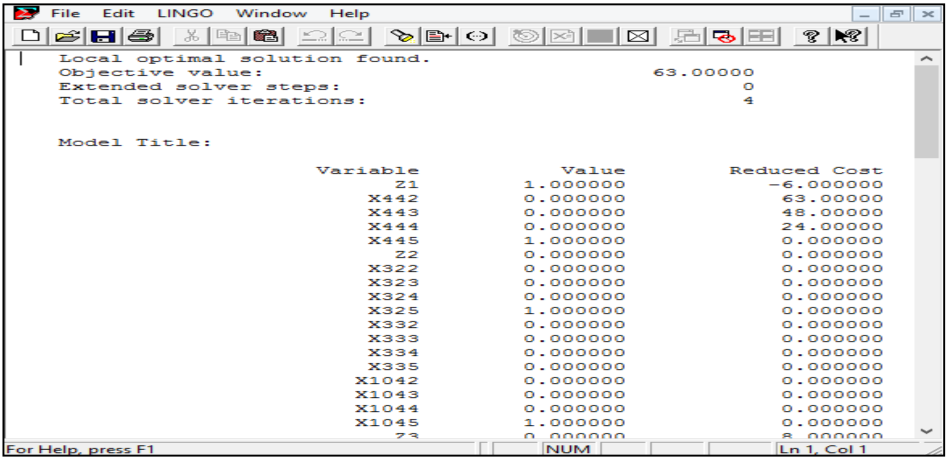


Fig. 9. Termination optimization task selection means of transport for the transport task

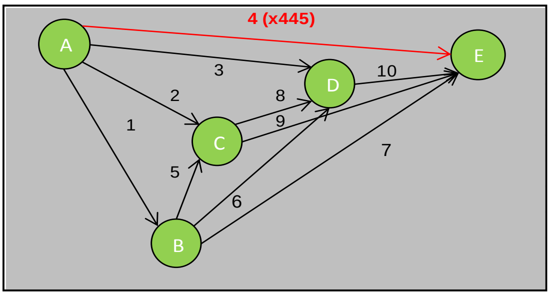


Fig. 10. The character graphics solution selection means of transport for the transport task

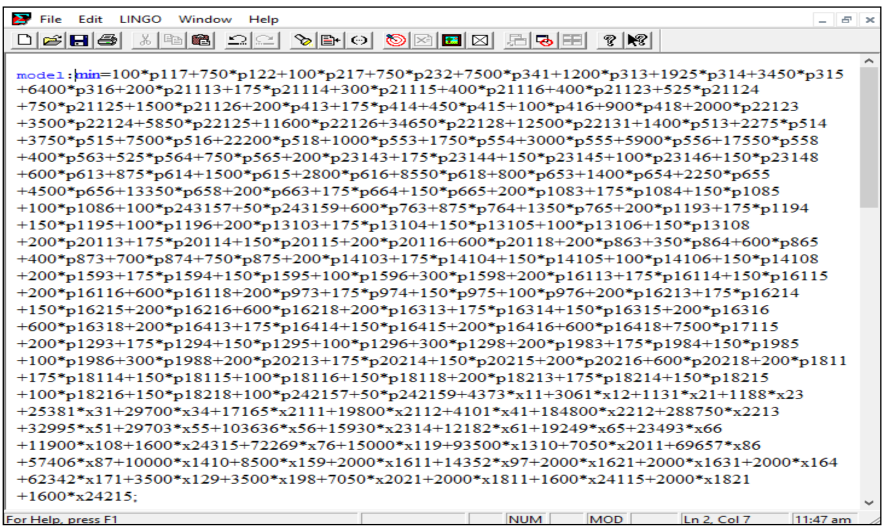


Fig. 11. Model task optimization transport infrastructure investment to build a storage building

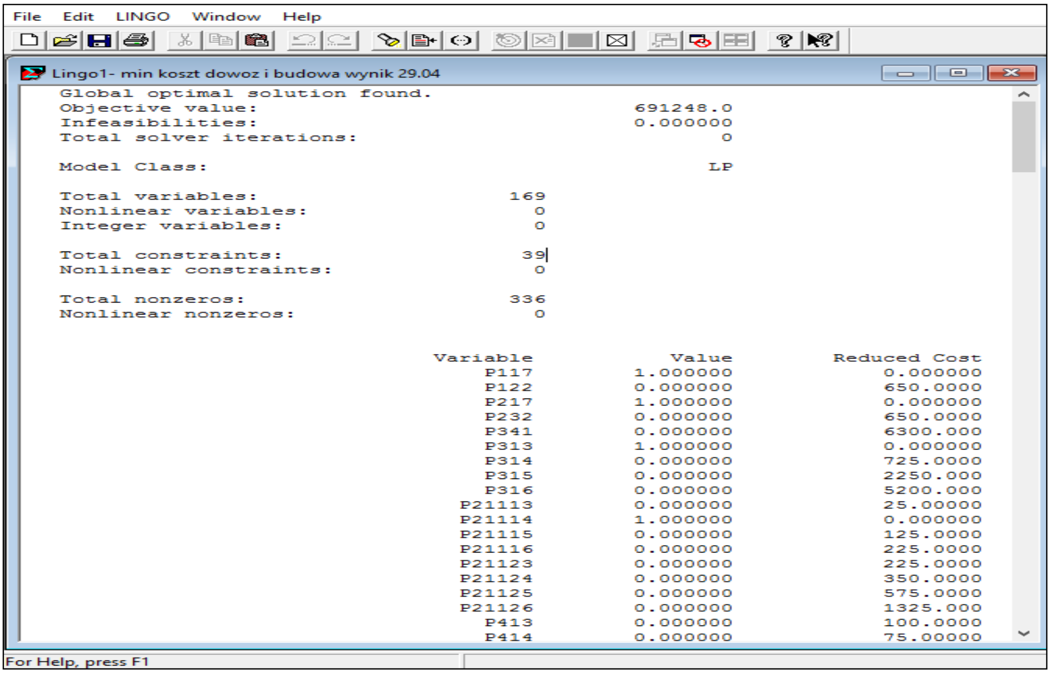


Fig. 12. Solution of the Problem of optimization transport infrastructure investment to build a storage building

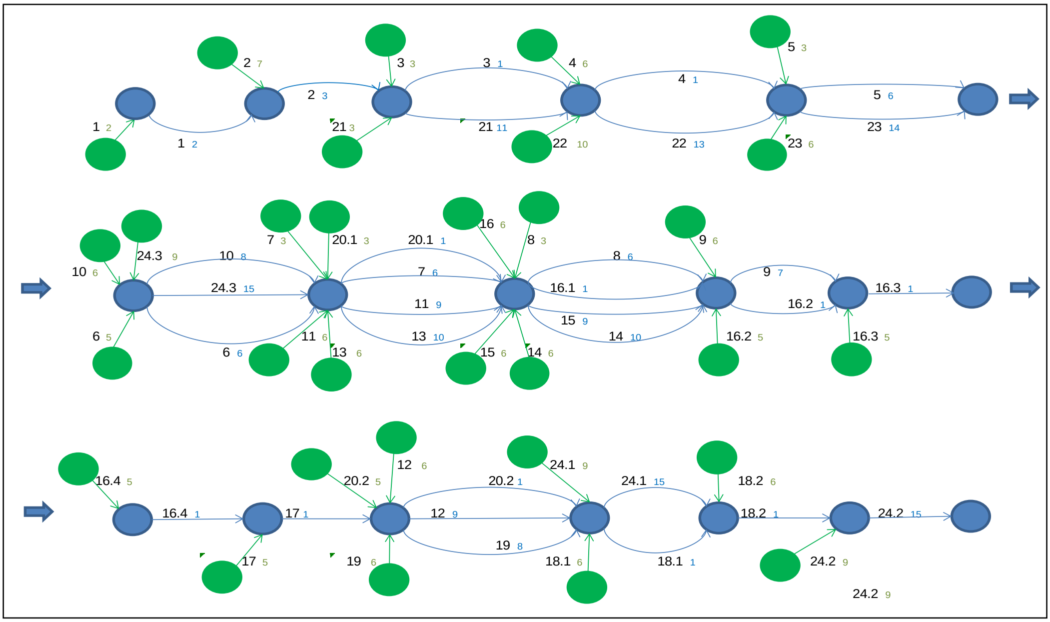


Fig. 13. The character graphics solution selection means of transport for the construction of a storage facility

Same as for the determination of minimizing the cost of the task transport (2.1), with the use of the computer program LINGO solution is achieved specifying the minimum cost for the model in question, which is presented graphically in Fig. 13.

5. Summary

Analyzed in the article the problem of choice of means of transport based on two embodiments of the transport task - in the supply chain and on the construction of a warehouse building.

The developed method uses a computer program LINGO thus allows the determination of such a plan (specifying the order of execution of transport operations using optimal means of transport) for which the total cost of the process is optimal.

Simulations showed that the Single-solving task of determining a plan of functions criterion, which is the minimum or the maximum cost of the transport infrastructure investment can be determined cost of transport task.

In consideration for the purposes of this paper example (supply chain) obtained for minimal cost routing T1 and amounted to K min = 63,00zł, while the maximum cost was obtained for the route T5 and amounted to K max = 453,00zł.

However, in the example of the realization of facility construction costs amounted to Cumin = 691 248 PLN and K max = 983 891 PLN (the minimum and maximum cost of carrying out the operations executive amounted to 676 623 zł and 886 391 zł, and for transport operations 14 625 zł and 97 500 zł). By introducing the calculations further restrictions were actually transport companies (fit up camp in the enterprise – its payload or capacity, standard EURO vehicle, axles, speed, technical, combustion, etc.) Can be used forth in Article tool (method) for optimal selection means of transport carrying real transport tasks that occur on the transport market

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