Logistics Facilities Designing Method – a Study of a Procedure for Logistics Facilities Designing and Its *OL09* Software Implementation

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Abstract

The paper describes the new logistics facilities designing method, which includes e.g. the procedure for logistics facilities designing and the procedure for optimisation of functional and spatial areas. Some information is given on implementation of the new designing method into the designing software *OL09*. In case of testing the *OL09* software's correctness, the verification of implemented logistics facilities designing procedure has been prepared and described. The verification was done in a way of a case study. As a result, some indicators and rates were compared. It was done using a weight method. While working on a method and implementing it into software, some theoretical and practical aspects connected to the problem were identified. Those aspects are mentioned in the paper's conclusion.

1. Introduction

In the literature review of the problem, a critical review of logistics facilities designing methods, developed in recent decades, has been done. As a result of making the critical review of designing methods it was decided to develop a new logistic facilities designing method. The developed method was expanded to include additional evaluation indicators and optimisation procedure.

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In addition, it was decided to prepare computer-supported designing tool (*OL09*) based on the new designing method, in the form of software. This software provides strong support for designing procedures.

An implementation in a form of a computer tool makes it possible to prepare a complete logistics facility design. Preparation of such a tool is difficult because of the quantity of tasks, which have to be completed for this purpose. Usually computer-supported designing tools are limited only to some selected parts of logistics facility (or group of logistics (or group of logistics facilities) or to a computer-supported simulation and visualisation researches of logistics facility.

Additionally, the optimisation procedure of the spatial and functional design was prepared. In practice, optimal sizes of the building blocks and areas only for one, pre-defined designing object can be defined. Too many parameters are involved for a 'global' optimisation to be realised. Therefore it was decided that a problem of sub-optimisation of functional and spatial areas in logistics facilities should be considered. Details of the procedure for optimisation of functional and spatial areas are not discussed in the paper. Comprehensive discussion of the designing method and its implementation in a computer software package allowed distinguishing a number of theoretical and functional aspects of the problem. It is specifically described in the summary of the paper. In addition, in the summary there were given, in a precise manner, the possible directions of further researches on the problem of logistic facilities designing method.

2. Identification of the Subject Matter in Literature

As far as logistics facilities designing methods are concerned there were identified 16 designing methods. They are, by the name of methods' creators, methods of:
 1. Heskett, Glaskowsky, Ivie,
 2. Apple,
 3. Firth, Apple, Denham, Hall, Inglis, Saipe,
 4. Hatton,
 5. Mulcahy,
 6. Oxley,
 7. Fijalkowski,
 8. Korzen,
 9. Govindaraj, Blanco, Bodner, Goetschalckx, McGinnis, Sharp,
10. Rouwenhorst,
11. Rowley,
12. Rushton, Oxley, Croucher,
13. Bodner, Govindaraj, Karathur, Zerangue, McGinnis,
14. Hassan,

15. Waters,
16. Rushton, Croucher, Baker.

The critical review of the literature proved that most of the proposed designing methods are schematic (e.g. methods No.: 3., 4., 9., 13.). Some of methods designing steps are not in logical order (e.g. methods No.: 1., 2., 6., 11., 12., 16.). There is also lack of uniformity and lack of interaction between designing steps as far as some methods are concerned. There are also some other defects of designing methods, for example: lack of a possibility of order-picking area designing (e.g. methods No.: 1., 14.), a fact that methods do not treat the whole designing problem (e.g. methods No.: 1., 2., 6., 10., 15.) and finally a fact that some methods seem to be functional specifications rather than designing methods (e.g. method No.: 5.).

Both in scientific journals and academic books, many differences in designing methods appear. Methods are results of different authors' points of view on the design process.

There are also advantages of these methods, which were included into the new method presented in this paper, e.g. an idea of simulation in designing process.

According to the authors of the report *Warehouse design: A structured approach* (2009) there is still lack of solid theoretical basis for logistics facilities designing methods, [2]. As far as mentioned methods are concerned, the most comprehensive is method by Fijalkowski J. (Korzen method - year of publication: 1998 - seems to be similar to Fijalkowski method - year of publication: 1995). The method contains many kinds of aspects. There are groups of aspects such as: technological, economic and organizational. There are not only aspects related to storage technology, examining the components of a project in terms of functional and spatial. Apart from them, it also shows the organizational issues, financial aspects, and insists on a comprehensive assessment stage for all obtained variants. None of the other methods (except for the method by Korzen) has proposed such a rich compilation of individual elements of the project as in Fijalkowski method. Due to the complexity of the Fijalkowski warehouses designing method it was decided, after implementing some changes in original method, to prepare a computer tool supporting the logistics facilities designing: *OL09* software. It should be noted that this method is labour and time consuming. It requires long and careful calculations. A logistics facility designer's work can be greatly accelerated by using advanced software. The purpose of this software is not to exclude a designer of the designing process. The designer must make many decisions on their own, regardless of whether he uses a computer tool or not. The first important and rational aspect of using of a computer tool is the ability to quickly design a number of a design's variants. Another important fact for the support is preparing relatively fast design calculations. The third reasonable aspect is to present results in an illustrative manner, facilitating communication between a designer of a logistics facility and a principal.

3. Graphical Description of the Logistics Facilities Designing Method

It was decided to prepare a computer tool supporting the logistics facilities designing: *OL09* software. *OL09* software was the last stage of the research project. First there had to be the logistics facilities designing method prepared – a method based on the method by Fijalkowski enriched with a few new designing steps. To develop the mentioned compilation of the existing method and its enrichment, a graphical description of the logistics facilities designing method had to be done. It was done with a specific modelling language: *IDEF0*.

IDEF (*Integration Definition for Function Modelling*) is a modelling methodology for describing manufacturing functions, which offers a functional modelling language for the analysis, development, reengineering, and integration of information systems, business processes or software engineering analysis.

In order to build a functional model for computer-aided designing tool *OL09*, *IDEF0* graphical notation rules were used. This was done for the reason that the *IDEF0* allows to prepare a graphic documentation describing a set of interrelated activities that occur in the logistics facilities designing steps. Documentation is an important contribution to the implementation of *OL09* software. *IDEF0* is part of the *IDEF* family of modelling languages in the field of software engineering, [26].

While the functional flow block diagram is used to show the functional flow of a product, *IDEF0* is used to show data flow (here: designing steps inputs and outputs), system (here: method) control, and the functional flow of lifecycle processes (here: designing steps after-effects).

These are graphical notations, which consist of graphic symbols and diagrams. Rules for *IDEF0* are simple, consistent and logical, clearly defining the tasks posed by data processing. It provides rigorous and precise description and promotes consistency of usage and interpretation. Detailed parts of fragments of the graphical model, as an example of formalising idea, are shown in Figures 1-4. (the graphical model consists of 40 diagrams, therefore it is not possible to show them all). It is not coincidence that these diagrams were chosen in the paper to be shown. Each following figure inherits characteristics from the previous one (attention should be paid to symbol in Figures 1-4).

4. The Model of Logistics Facilities Designing Procedure

A model of a computer-supported designing is a physical model and is focused on an implementation of software. The implementation represents software binary code and software's architecture.

The scheme of the model of computer-supported logistics facilities designing in a general form is shown in Fig. 5. This is an abbreviated form of the method's model
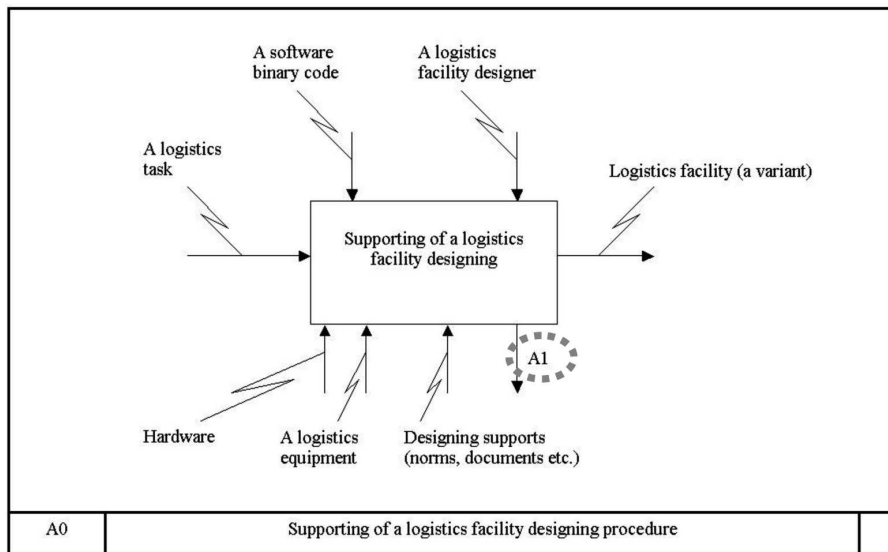
Fig. 1. Part of the graphical model of logistic facilities designing method: supporting of a logistics facility designing procedure
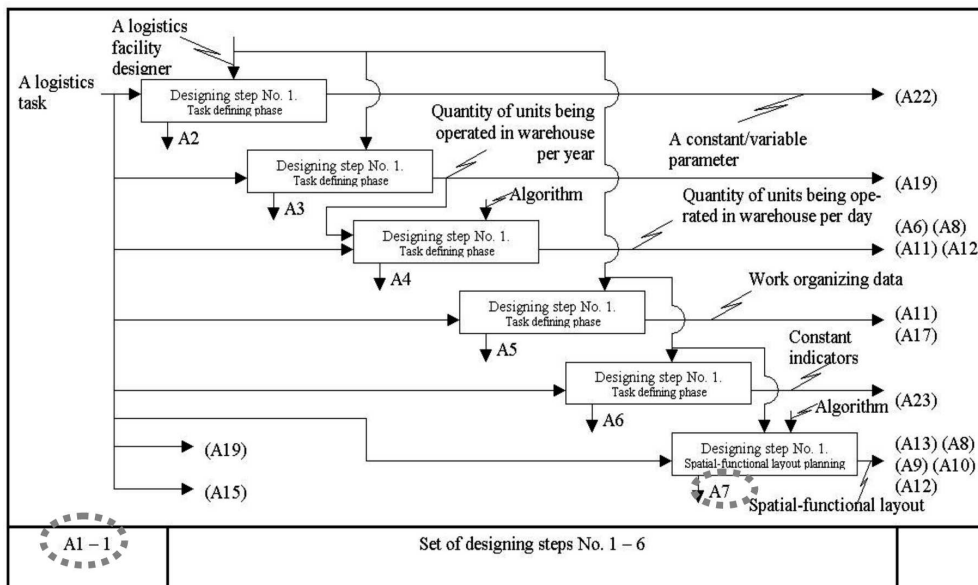

Fig. 2. Part of the functional model of logistic facilities designing method: set of designing steps No. 1 – 6; the diagram inherits from A0

which was done with *IDEF0* methodology – as it was mentioned, the functional model consists of 40 diagrams therefore it is not possible to show them all.
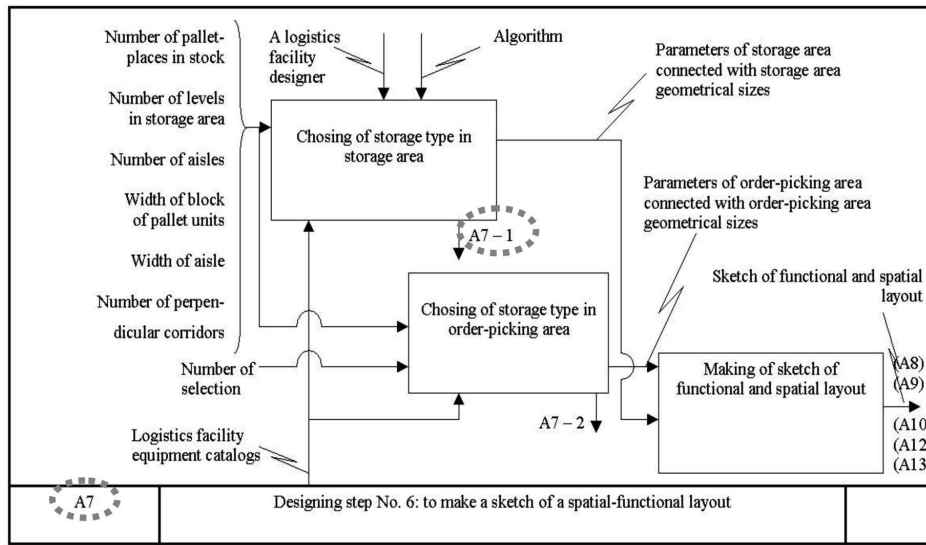
Fig. 3. Part of the functional model of logistic facilities designing method: designing step No. 6; the diagram inherits from A1 – 1
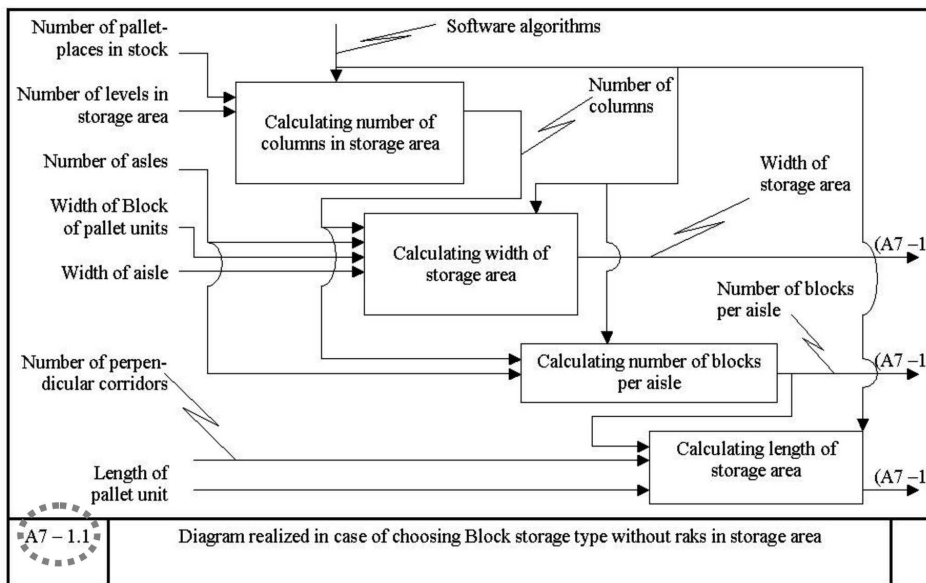

Fig. 4. Part of the functional model of logistic facilities designing method: the design diagram for designing step No. 6. (*Sketch of a Spatial-functional Layout module*); the diagram inherits from A7

In the model of logistics facilities designing **method** are included:
– system functions modelling,
– the input data (assumptions),

- the **procedure for logistics facilities designing** (computer-supported logistics facilities designing procedure):
  - ○ *Task Defining* module,
  - ○ *Solution Design* – group of modules,
  - ○ *Solution Variant Evaluation* module,
- the **procedure for optimisation of functional and spatial areas**,
- output data (for each of *n* variants).

It must be particularly emphasized that the method consists of 2 main procedures, as it was mentioned before.

Each of the mentioned modules (or group of modules) has assigned algorithms, which are parts of the logistics facilities designing procedure.

A complex variants evaluation is not an integral part of the model. Nevertheless it has been included in order to identify opportunities for designing method development.
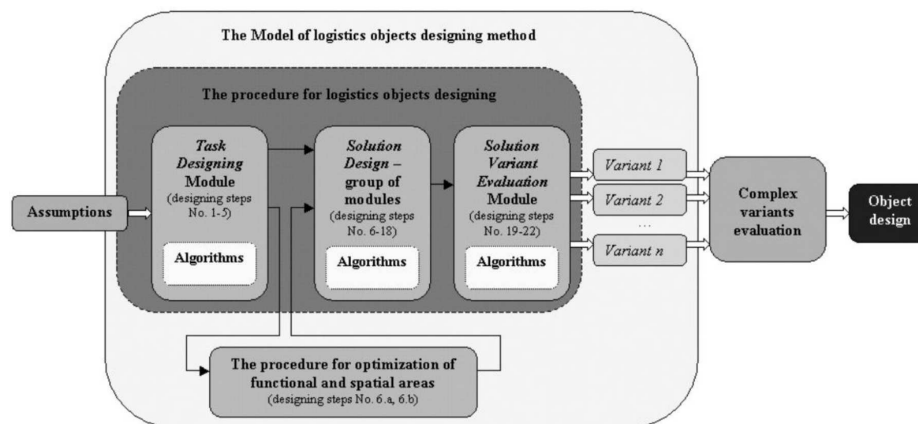

Fig. 5. Scheme of the model of logistics facilities designing method (general view on the software's architecture)

5. The Procedure for Logistics Facilities Designing

The procedure for logistics facilities designing consists of 3 phases:
- task defining,
- solution designing,
- solution evaluation.

It must be mentioned that designing steps marked with bold (below) are those, in which changes were made in relation to the 'original' method (understood as the method by Fijalkowski) or those which did not occur in the 'original' method. The reasons of changes are mentioned below, after designing steps are given.

The composition of the task-defining phase includes the following steps:
– designing step No. 1: to choose designing parameters which can be variable in various variants and to define a range of parameters changeability,
– designing step No. 2: to define a structure of supplies (outer inputs) and shipments (outer outputs) outside of a logistics facility,
– designing step No. 3: to define a structure of internal inputs and outputs,
– designing step No. 4: to identify data connected with work organization in logistics facility,
– designing step No. 5: to identify parameters of evaluation.

The composition of the solution designing phase includes the following steps:
– designing step No. 6: to make a sketch of a spatial-functional layout,
– **designing step No. 6a: to use spatial optimisation tool,**[1]
– **designing step No. 6b: to calculate a minimal capital spending coefficient and a logistics facility space balancing coefficient,**
– designing step No. 7: to prepare description of the material-flow processes and information-flow processes in a logistics facility,
– designing step No. 8: to make a plot of a flow of materials and information on a logistics facility layout,
– designing step No. 9: to identify, to describe materials (or information) points of origin and materials (or information) destination points,
– designing step No. 10: to define quantity of units (materials and information) which flow on the routes between points mentioned in designing step No. 9 and to define a schedule of processes realised on these routes,
– **designing step No. 11: to define geometric and technical parameters of routes,**
– **designing step No. 12: to prepare material-flows or information-flows documentation and transport cycles documentation,**
– **designing step No. 13: to calculate the durations of each transport cycle (or other processes),**
– **designing step No. 14: to define operating parameters and elementary costs for resources of transport and elementary costs of human labour for workers,**
– designing step No. 15: to calculate a daily labour-intensity of material-flow processes realised by equipment, a daily reduced labour-intensity of material-flow processes realised by workers, a daily reduced labour-intensity of information-flow processes realised by equipment and a daily reduced labour-intensity of information-flow processes realised by workers,
– designing step No. 16: to calculate a reduced number of resources and workers,
– designing step No. 17: to draft organization of work,
– designing step No. 18: to calculate logistics facility's capital spending and annual

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[1] designing steps No. 6a and No. 6b are not discussed in the article, see [14]

operational costs (for building, resources and workers) and indicators such as: an investment rate, a costs rate and a cost of material-flow of one unit rate.

The composition of the solution evaluation phase includes the following steps:

– designing step No. 19: to calculate a reduced labour-intensive of resources, equipment and workers, a reduced number of resources and a reduced number of employees,

– **designing step No. 20: to calculate indicators: a real-efficiency utilization coefficient and a cost-efficiency utilization coefficient,**

– **designing step No. 21: to calculate a daily physical activity of employees,**

– **designing step No. 22: to compare, to evaluate and to make a complex variants evaluation and to choose the best logistics facility design variant.**

Designing steps No. 6a and No. 6b are optional steps for designing step No. 6. Authors of the paper [3] reached the conclusion that analytic designing is not enough. At the same time a logistics facility – after making an analytic design of it – should be treated as a simulation object. It was proved in previous papers [15, 16]. Therefore it was decided to prepare optimisation tool that is based on the simulation idea. Simulation here is a part of optimisation in the research project. It helps to generate a lot of variants in relatively fast way. Therefore the part of simulation in software is narrowed. It is narrowed to calculation and plotting a proper drawing. The optimisation procedure of the spatial and functional design was prepared. The optimisation of the logistics facilities geometry is taken into account due to the fact that many other design issues depend on the geometrical parameters.

The conclusion is that designing step No. 6 was enriched with the optional designing steps of optimisation of functional and spatial areas.

Moreover some changes were proposed in the order of the procedure for logistics facilities designing.

The first change concerns designing steps No. 11 and No. 12. Originally designing step No. 12 preceded designing step No. 11. The change was done because geometric and technical parameters of routes (distances – length, height, and width) have to be defined first. Then a designer can define material-flows or information-flows documentation and transport cycles documentation. That is because he or she has to generate an idea which routes (between points of origin and destination points) would be taken by a means of transport with a load (that is connected with material-flow especially).

The second change concerns designing steps No. 13 and No. 14. Originally designing step No. 14 preceded designing step No. 13. The change was done because calculations of the duration of each transport cycle is a part of transport cycles documentation, which is done in designing steps No. 12. The procedure for logistics facilities designing should be as heuristic as it is possible (obviously with exception of feedbacks when needed).

There are proposed calculations of some new indicators (as designing step No. 20.): a real-efficiency utilization coefficient and a cost-efficiency utilization coefficient. The new indicators are pre-defined in [7].

The order of designing steps No. 21 and No. 22 is changed because of the fact that designing step No. 20 was inserted into the procedure.

6. Computer-Supported Procedure of Logistics Facilities Designing – a Computer Software *OL09*

The prepared software helps to design a part of the logistic system. This part of logistics system is a logistics facility. The software is based on the logistics facilities technological designing model (functional model). The model has been developed in the form of 40 diagrams. These diagrams are elements (unpublished in the paper except for 4 diagrams, Figures 1-4) of the model shown in Fig. 5. The model is the result of reinterpretation, and further implementation, of 21 designing steps method developed by Fijalkowski J., [5, 6]. 21-steps method has been upgraded with adding some designing steps such as designing step No. 6a, designing step No. 6b and designing step No. 20 (plus some changes mentioned in previous part of the paper).

It should be noted that not all designing steps could be fully supported by the software. Involving the designer – very important within each of designing steps – is an essential requirement in these steps.

The prepared software is a computer tool of a dialog-type.

The procedure for logistics facilities designing is divided into three phases:
– *A task defining* – phase, which involves logistics task defining [5, 6] and assumptions defining,
– *A solution designing* – phase, which involves logistics task solving (includes technical calculations, organizational schedule and economic calculations of material flow processes) which is finished with creating one independent variant of logistics facility design,
– *A variant evaluation* – phase, which involves variant's evaluation (which includes calculation of the evaluation parameters).

Similar sections (phases) were used in the software. *OL09* software consists of three sections: *Task Defining*, *Solution Design* and *Solution Variant Evaluation*.

Taking into account mentioned sections, the software consists of the following modules:
– *Task Defining*,
– A group of modules - *Solution Design*:
   ○ *Spatial-functional Layout Calculations,*
   ○ *Sketch of a Spatial-functional Layout,*
   ○ *Output Data for a Spatial-functional Layout,*
   ○ *Origin and Destination Points,*
   ○ *Material-flows Chart,*
   ○ *Transport Cycles, parts I-III,*
   ○ *Quantitative Parameters,*

      ○ *Capital Spending and Costs,*
      ○ *A Real-efficiency Utilization Coefficient and A Cost-efficiency Utilization Coefficient,*
– *Solution Variant Evaluation,*
– *Optimisation of Functional and Spatial Areas* (the module is not discussed in the paper).

Task Defining module is based on the following steps of the logistics facilities designing procedure: from No. 1 to No. 5 (Figure 6).

Modules: *Spatial-functional Layout Calculations* and *Sketch of a Spatial-functional Layout* support realisation of designing step No. 6 (Figure 6). The first module helps to prepare spatial arrangement in logistics facility which includes selection of a type of storage in storage area, a type of storage in order-picking area, a number of levels in pallet rack storage in storage area, a number of aisles in storage area, a number of perpendicular corridors in storage area, a number of levels in pallet rack storage in order-picking area, a number of aisles in order-picking area, a number of perpendicular corridors in order-picking area. The second module enables to prepare sketches of logistics facility space. It is 2 dimensions module. It should be noted that there are optional designing steps such as No. 6a and 6b, which are a base for optimisation of functional and spatial areas (the module *Optimisation of Functional and Spatial areas* is not discussed in the paper).

Designing step No. 7 (Fig. 6) has a descriptive character therefore it is not implemented in the software.

Output Data for a Spatial-functional Layout module summarizes the preliminary designing phase. At the same time at this level, a preliminary verification of a variant is being realised. Some restrictions are checked. These restrictions are connected with maximal permissible logistics facility area and its maximal permissible height.

Material-flows Chart module is based on designing step No. 8 (Fig. 3).

Origin and Destination Points module is based on the following designing steps of the logistics facilities designing procedure: from No. 9 to No. 11 (Fig. 6).

Modules *Transport Cycles, part I-III* are based on the designing steps No. 12 and No. 13 (Fig. 6).

Quantitative parameters module is based on the designing steps No. 15 and No. 16 (Fig. 6).

Capital Spending and Costs module is based on the following steps of logistics facilities designing procedure: No. 14, No. 17, No. 18 (Fig. 6).

A Real-efficiency Utilization Coefficient and A Cost-efficiency Utilization Coefficient module is based on designing step No. 20 (Fig. 6).

Solution Variant Evaluation module is based on the following steps of logistics facilities designing procedure: No. 19, No. 21 (Fig. 6).

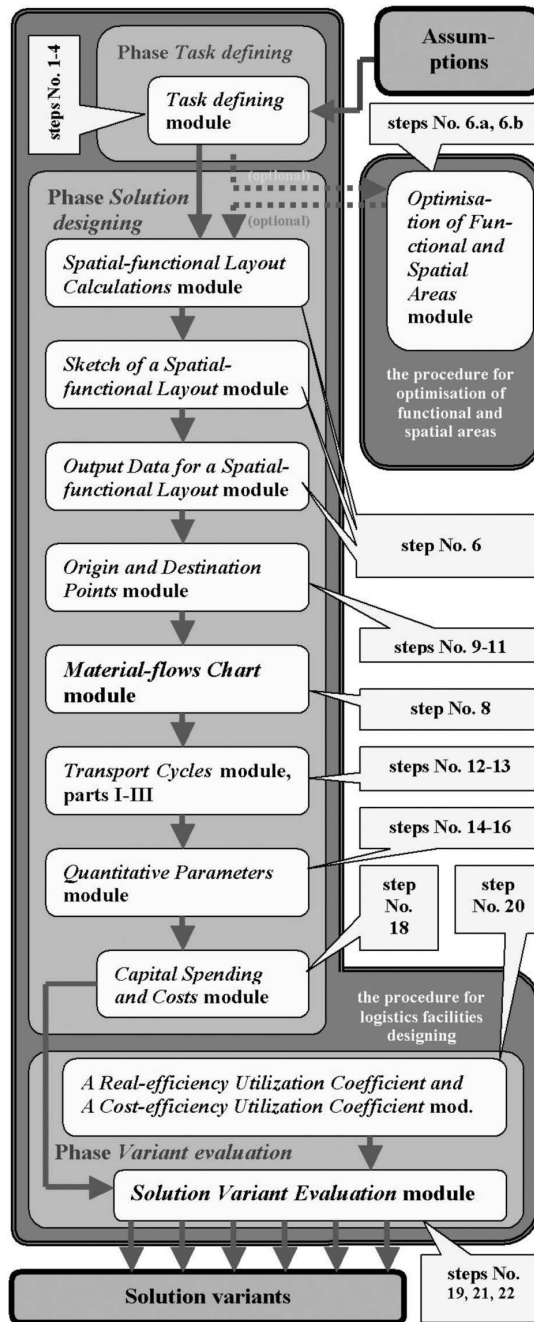Designing step No. 22 (Fig. 6) is not a subject of software.

Fig. 6. The scheme of conducting *OL09* software with the relations between designing steps and
modules of *OL09* software

7. The Verification of the Logistics Facilities Designing Procedure

The implementation of logistics facilities designing procedure was verified on the example of a warehouse designed in two ways. At first, a warehouse was designed without the usage of computer support. This solution is described as analytic solution, [14]. As the second stage, a warehouse was designed, for the same input values, with using *OL09* software, [14]. Two variants were generated in solution with using *OL09* software. The results of both solutions (with and without using *OL09* software) are provided to verify the method and its computer implementation.

Input data in the research are fictitious. However, an effort was made to base data on actual warehouse finance market situation (PLN – Polish currency). Obviously, input data are the same for each solution. Input data are specified in Table 1.

Table 1

Technologic data (input data) for warehouse design

Parameter	Value
Quantity of units being operated in warehouse per year [pgu/year][2]	129 000
Norm factor of storage	20
Quantity of working days per year [days]	285
Storage rotation	15
Number of pallet-places in stock [pps][3]	8 600
Assortment	468
Accumulations factor on entrance	1.24
Accumulations factor on exit	1.54
Medium filling percentage of pallet	0.54
Order-picking factor	0.67
Medium structure of pallet with load unit after order-picking process	10×4[4]
Work time factor	0.80
Warehouse permissible surface [m^2]	8 000
Warehouse permissible height [m]	12

The sketch of a warehouse layout in analytic solution is described in Fig. 7. The selected type of storage in storage area in case of this solution is: *storage in rows in a warehouse rack with using front-side forklift truck*. The selected type of storage in order-picking area in case of this solution is: *storage in rows on warehouse' floor*. An input value of *a number of levels in pallet rack storage in storage area* is: 6. An input value of *a number of aisles in storage area* is: 9. An input value of *a number*

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[2] pgu/year – **p**allet with **g**oods **u**nit per year

[3] pps – **p**allet **p**lace**s** unit which informs about number of places for pallet storage

[4] *w* x *p* – *w* is the number of lines on the order-picking list and *p* is the number of goods per one line

of perpendicular corridors in storage area is: 1. An input value of *a number of levels in pallet rack storage in order-picking area* is: 1. An input value of *a number of aisles in order-picking area* is: 3. An input value of *a number of perpendicular corridors in order-picking area* is: 1.
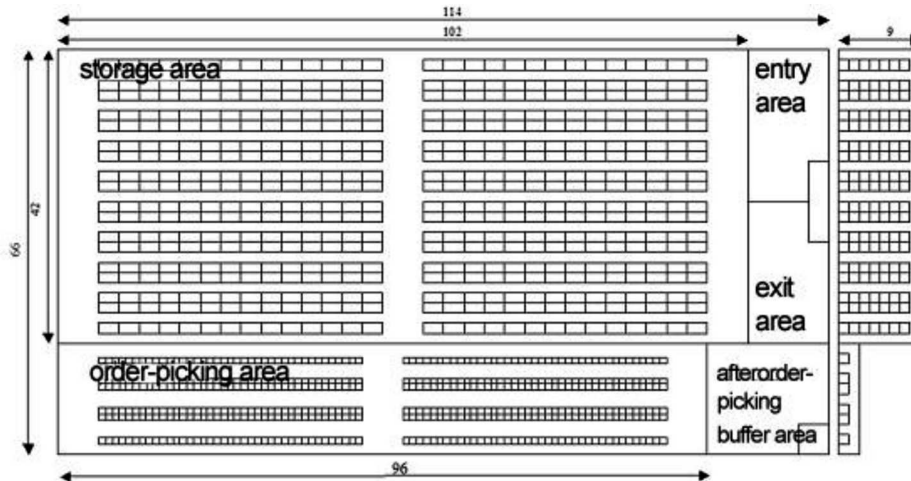
Fig. 7. The sketch of a warehouse layout in analytic solution; the top view on the left side of the figure and the cross section view on the right side of the figure
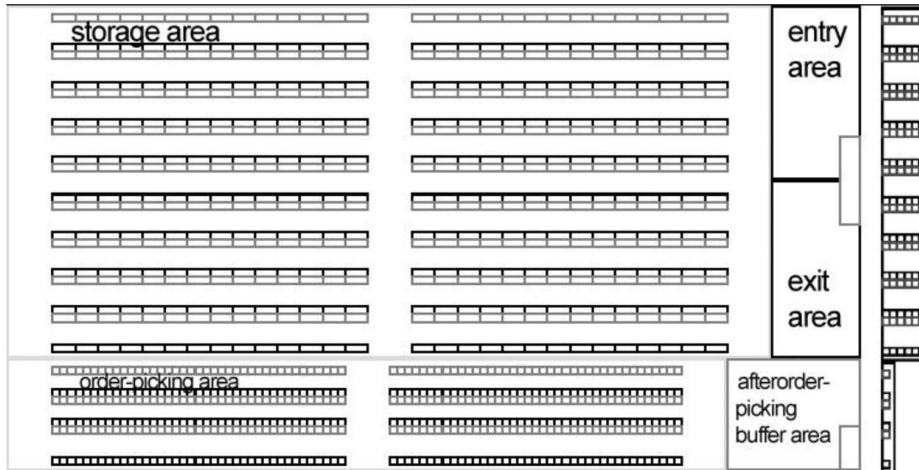
Fig. 8. The sketch of a warehouse layout in solution with using *OL09* software – variant No. 1; the top view on the left side of the figure and the cross section view on the right side of the figure

The outputs for this solution are in Table 2. in the column No. 2.

As it can be seen there are not any values in case of indicators such as: a logistics facility space-balancing coefficient, a minimal capital-spending coefficient. The

reason is that the mentioned indicators are a part of the procedure for optimisation of functional and spatial areas, which were not used, in analytical solution. The same situation is in case of solution with using *OL09* software – variant No. 1. The aim of not using the procedure for optimisation of functional and spatial areas was to generate a comparable solution to analytic solution. It turns out that comparative results are different for the two types of solutions although the differences are not substantial. It is discussed further in the paper.

The sketches of warehouse layout in solutions with using *OL09* software are generated by the software's module *Sketch of a Spatial-functional Layout*.

The sketch of a warehouse layout prepared in case of variant No. 1. can be found in Figure 8. The selected type of storage in storage area in case of this solution is: *storage in rows in a warehouse rack with using front-side forklift truck*. The selected type of storage in order-picking area in case of this solution is: *storage in rows on warehouse' floor*. An input value of *a number of levels in pallet rack storage in storage area* is: 6. An input value of *a number of aisles in storage area* is: 9. An input value of *a number of perpendicular corridors in storage area* is: 1. An input value of *a number of levels in pallet rack storage in order-picking area* is: 1. An input value of *a number of aisles in order-picking area* is: 3. An input value of *a number of perpendicular corridors in order-picking area* is: 1.
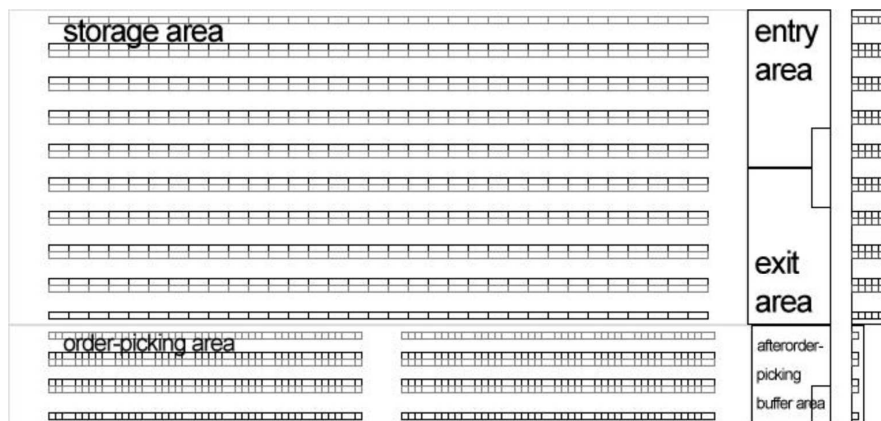

Fig. 9. The sketch of a warehouse layout in solution with using *OL09* software – variant No. 2;
the top view on the left side of the figure and the cross section view on the right side of the figure

The sketch of a warehouse layout prepared in case of variant No. 2. can be found in Fig. 9. The selected type of storage in storage area in case of this solution is: *storage in rows in a warehouse rack with using front-side forklift truck*. The selected type of storage in order-picking area in case of this solution is: *storage in rows on warehouse' floor*. An input value of *a number of levels in pallet rack storage in storage area* is: 5. An input value of *a number of aisles in storage area* is: 9. An input value of *a number of perpendicular corridors in storage area* is: 0. An input

value of *a number of levels in pallet rack storage in order-picking area* is: 1. An input value of *a number of aisles in order-picking area* is: 3. An input value of *a number of perpendicular corridors in order-picking area* is: 1.

The variant No. 1 of the solution with using of *OL09* software was done without using the procedure for optimisation of functional and spatial areas. The aim of not using this procedure was to generate comparable solution (the variant No. 1.) to analytic solution. Therefore it was possible to evaluate whether the software's binary code is done properly.

It turns out that comparative results (Table 2) are different for the two types of solutions (the analytic solution *versus* the variant No. 1 solution) although the differences are not substantial.

Table 2

Output parameters calculated for the verification of the logistics facilities designing procedure; analytic solution and *OL09* solutions comparison

Name of parameter	Analytic solution	Solutions with using *OL09* software – variants	
		Var. No. 1	**Var. No. 2**
1	*2*	*3*	*4*
Capital spending [PLN]	29 117 120,00	28 827 120,00	25 589 620,00
Annual operational costs [PLN/year]	7 006 960,75	6 707 762,14	5 632 112,76
An investment rate [PLN/pps[5]]	3 385,71	3 351,99	2 975,54
A costs rate	0,67	0,68	0,77
A cost of material-flow of one unit rate [PLN/pgu[6]]	54,32	52,00	43,66
A daily labour-intensity of warehouse processes	250,58	250,58	170,94
A daily labour-intensity of material-flow processes realised by equipment	65,93	61,10	64,53
A daily reduced labour-intensity of material-flow processes realised by workers	103,20	97,60	111,50
Number of equipment by type W1/3/7/12[7]	18/11/10/18	17/10/9/18	18/9/5/18
Number of workers by category L1/2/3/4[8]	36/22/20/36	34/20/18/36	36/18/10/36
A logistics facility space balancing coefficient	–	–	0,5
A minimal capital spending coefficient	–	–	0,145

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[5] pps – pallet places unit which informs about number of places for pallet storage

[6] pgu – pallet with goods unit

[7] Symbols of equipment types correspond to numbers used in *OL09* software: W1 – guided forklift truck, W3 – front forklift truck, with stationary mast, counterbalanced, three-wheeled, W7 – front-side forklift truck, with rotating-sliding type of forks, three-wheeled, W12 – battery horizontal picker.

[8] Similarly to [7], these are symbols of workers cathegories correspond to numbers used in *OL09* software, e.g. L1 works on W1, L2 works on W3 etc.

These differences are due to more accurate calculations in case of the *OL09* software usage. Round numbers in the computer tool are limited only to the computational power of a computer. Therefore, it provides an accurate value of considered parameters. A kind of anxiety may be caused by different numbers of lift-trucks of the same type or numbers of employees of the same category. In the solution in which *OL09* software assisted these are lower. Oversizing of parameters in warehouse designing is a danger; therefore, additional number of lift-trucks obtained in analytic solution could reach high value of the reserve value of work. Therefore, additional number of lift-trucks could be useless which means: *they could have no work to do*. It is well known that in such a situation it is better to buy another lift-truck later than 'suffer' the consequences of oversizing at the designing stage, especially of the financial aspect – as it is well known, prices of warehouse equipment can be really high.

An investment rate (Table 2) needs special explanation. Its value in solution with using the software (the variant No. 1. solution) has been calculated as higher compared to analytic one. The reason for this is that the software calculated a smaller number of pallet places required in the warehouse, so according to the equation it obtained higher value. One can think that values of an investment rate are quite high in case of obtained results. What mostly influences on that fact are high prices of means of transport (as forklift-trucks of different types), other devices or machines, warehouse infrastructure *et cetera*. Therefore a value of an investment can be high.

Table 3

Weight method used for the verification of the logistics facilities designing procedure

Evaluation criterion		Analytic solution		Solutions with using *OL09* software - variants			
Criterion name	Criterion weight			Var. No. 1		Var. No. 2	
		Mark	Points	Mark	Points	Mark	Points
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Capital spending [PLN]	16	3	48	2	32	0	0
Annual operational costs [PLN/year]	14	3	42	2	28	0	0
An investment rate [PLN/pps]	10	3	30	2	20	0	0
A costs rate	10	0	0	1	10	3	30
A cost of material-flow of one unit rate [PLN/pgu]	11	3	33	2	22	0	0
A daily labour-intensity of warehouse processes	15	2	30	2	30	0	0
A reduced number of equipment	12	2	24	0	0	1	12
A reduced number of workers	12	1	12	0	0	3	36
Counted points	**100**		**219**		**142**		**78**
Preferred sequence of variants			**3**		**2**		**1**

Generally it can be accepted that values of all indicators and rates in the analytic solution *versus* the variant No. 1. solution are similar. In view of these explanations the verification is believed to be rewarding.

8. Conclusion

Beside the indicators and rates comparison (Table 2) an effort was made to compare all solutions. It has been done with using the *weight method*, [5]. In the weight method there are attributed criterion weights for every of evaluation criteria. For each solution marks are given (from 0 for the best value of evaluation criterion to 5 for the worst one). Marks and criterion weights are multiplied for each evaluation criterion and then counted within one type of solution. The less score of summed multiplies is, the better for realisation the solution is. As a result a preferred sequence of variants is defined. It turns out that the best solution for realisation is the solution with using *OL09* software and the procedure for optimisation of functional and spatial areas.

The paper presents briefly the way of preparing implementation of logistics facilities designing procedure (a part of logistics facilities designing method). Implementation was made in the form of software – a package of modules. It gives strong possibilities for practical usage in logistics facilities designing. Implementing of the procedure (as a part of method) was the priority of research.

While working on the software some theoretical and practical aspects connected to the problem were identified.

Some main theoretical aspects are described below.

The first one is logistics facilities designing issue graphic model and its analysis - the usage of graphic notation. *Integration Definition for Function Modelling (IDEF0)* allowed preparing graphic description documentation of a set of interrelated activities occurring in facilities designing.

The second one is assessment of designing method based on existing methods and the fact that a decision was made to redefine existing methods with addition of some designing steps and enrichment with the procedure for optimisation of functional and spatial areas (enrichment designing step No. 6 with the optional designing steps of sub-optimisation of functional and spatial areas, changing the order of designing steps No. 11 and 12, No. 13 and 14, adding new indicators, [7]).

And last but not the least, an effort was made to elaborate on a proposition of mathematical formulas for calculations connected with logistics facility geometry. Formulas were prepared as a function of, [14]:
–   selected type of storage in storage area,
–   selected type of storage in order-picking area,
–   a number of levels in pallet rack storage in storage area,
–   a number of aisles in storage area,
–   a number of perpendicular corridors in storage area,

– a number of levels in pallet rack storage in order-picking area,
– a number of aisles in order-picking area,
– a number of perpendicular corridors in order-picking area,
– and other.

Among the practical aspects there are identified such as the following:
– the graphical module in computer software (2D module),
– the optimisation module (not discussed in the article), [14],
– the instruction for using software,
– obtaining variant solutions with using the software (freeing the designer from the painstaking work, repetitive tasks such as calculations, drawing sketches of logistics facilities layout, etc).

There is still a requirement for software development and further research. There are demands to:
– increase the flexibility of computer software by implementing other types of spatial systems and types of storage,
– extend the software by making a module of sub-areas in storage area for different types of units,
– make preparation of a complex variants evaluation module for comparing different variants of the same facility design; this module would become the first step on the way of preparing database of designing indicators values (a strongly welcome database).

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