METHOD FOR ELABORATION OF OPTIMAL STORAGE STRUCTURE

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Abstract: The paper shows a design conception for an existing warehouse elaborated for a forwarding and warehousing company. The conception can be applied to define an optimal storage structure based on a given warehouse floor area and available forecasts relating to types and volume of loading units (LU) to be stored. The LUs are coming in shipping containers, which should be managed as a unit and stored in a same place (in blocks) because these will be delivered together. Because of it the first phase of the design is the determination of optimal block dimensions in case of different types of loading units, aisle width and aisle directions. The study shows 4 possible alternatives for storage structure and blocks arrangement. Longitudinal and transversal aisle arrangements were taken into consideration in both of buildings of the warehouse. Authors elaborated 7 parameters relating to maximal storage capacity, maximal utilization of floor area and volume to compare the different structure alternatives and define the optimal storage structure.

Keywords: warehouse design, optimal storage structure

1. Introduction

Recently new storage methods are implemented at the production companies due to the application of advanced manufacturing technologies and globalization. The result of this tendency is that companies concentrate on the main activities, the other additional activities are outsourced. One of these additional activities is the storage of components and finished goods from point of view of production companies. This activity is completed in form of general warehousing and storage. This tendency causes the intensification of general warehousing and storage activities. The increasing demand for warehousing activity results the increasing of number of companies that provide these services. Most of transport companies have to improve the field of activities to keep and improve the competitive position, so these companies have to achieve general warehousing and storage activity beyond transportation. Our paper shows the warehouse design conception for an existing warehouse operated by a forwarding and warehousing company, which conception is suitable to define an optimal storage structure for case of a given warehouse floor area.

2. Design concepts

The aim of warehouse planning is the formation of possible storage structure alternatives for a given warehouse floor area and define an optimal structure.
The possible objective functions to be taken into consideration are the followings:

- minimal investigation cost,

- minimal operation cost,
- maximal specific storage capacity,
- maximal utilization of floor area and space,
- minimal length of material flow,
- maximal utilization of human and equipment resource, etc.

The task of the planner is to define the weight of importance of fulfillment of objectives during the design.

3. Method for storage structure design

Our study is based on a warehouse management project completed for a Hungarian forwarding and warehousing company. The task is the elaboration of an optimal storage structure of existing warehouse buildings (Figure 1.) taking the floor area, high of the building and dimension of loading units (LU) into consideration. The aim of the design is the formation of a storage structure to realize an optimal utilization of floor area and space in case of a forecasted types and volumes of loading units.

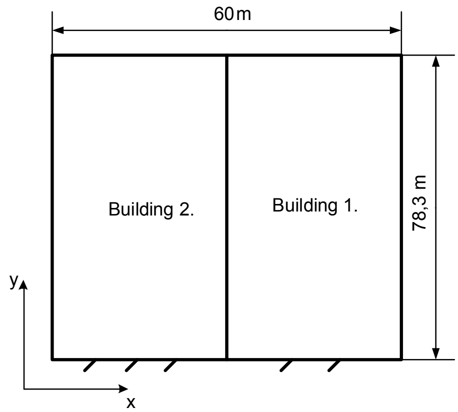


Figure 1. Warehouse layout

3.1. Properties of loading units to be stored

Two buildings will be used for storage of products of two companies (A, B), but unfortunately the forecasts are available only for products of company A. In the next part of our study we only focus on the storage demands of company A. The loading units of company A can be divided into 5 groups.
The LUs are coming in shipping containers. 24-26 pieces of LUs which area is 1000x1200 mm, 30 pieces of LUs which area is 800x1100 mm are included in a shipping container. The LUs arriving in a container should be managed as a unit and stored in a same place (in a block) because these will be delivered together.

Table 1. Forecast relating to loading units of company A

Storage type of LUs		Dimension [mm]	Number of LUs [pieces]
Without racking	LU 1.	1000x1200x1400	1430
	LU 2.	1000x1200x1900	650
	LU 3.	1000x1200x900	130
	LU 4.	800x1100x1200	390
In racking system	LU 5.	1000x1200x2100	200

3.2. Determination of optimal block dimensions

The first phase of design is the determination of optimal block dimensions in case of different types of loading units which not require racking storage.
Possible alternatives for storage of Loading Units are shown in Figure 2-5.

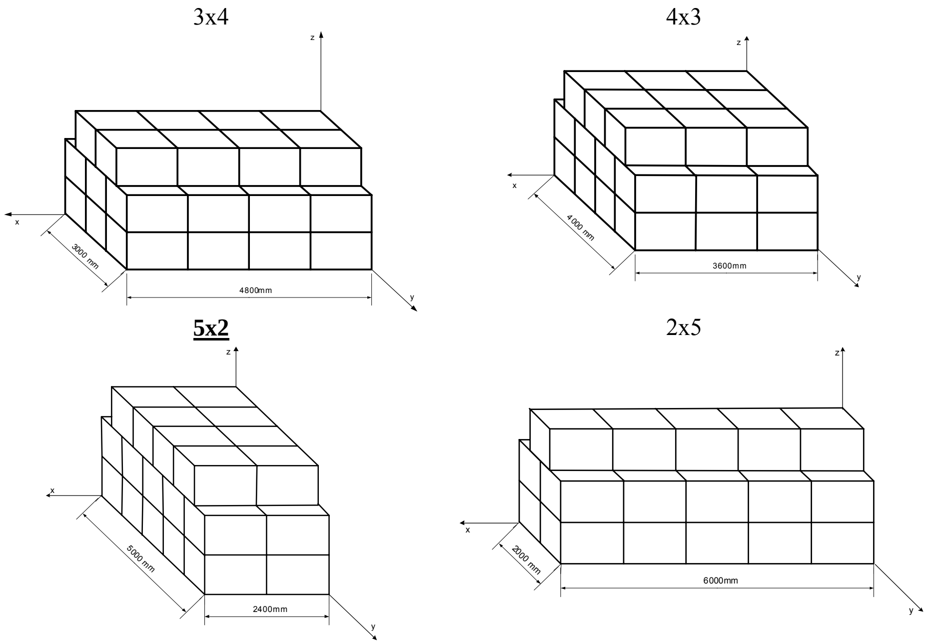


Figure 2. Possible alternatives for storage of LU 1 (maximal stacking height is 3 pieces)

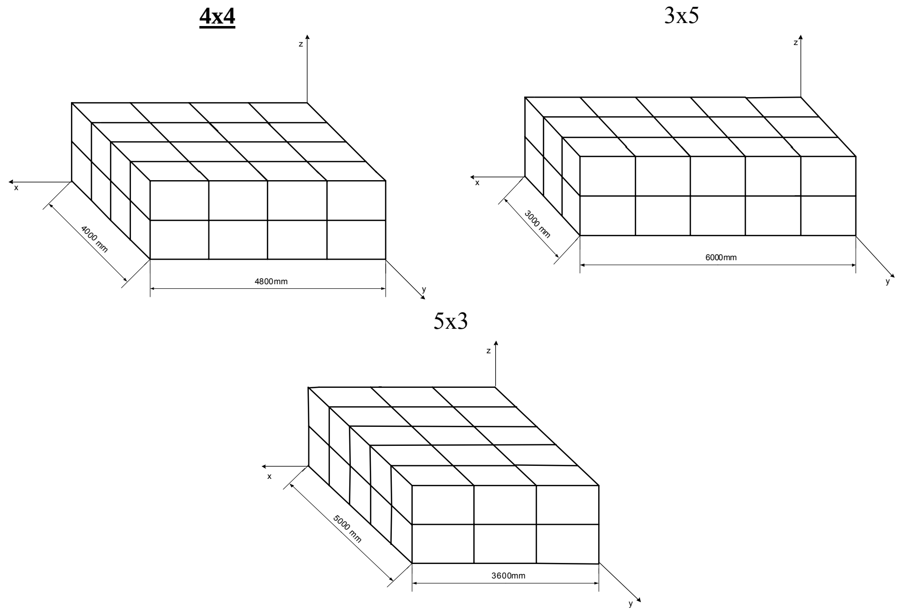


Figure 3. Possible alternatives for storage of LU 2 (maximal stacking height is 2 pieces)

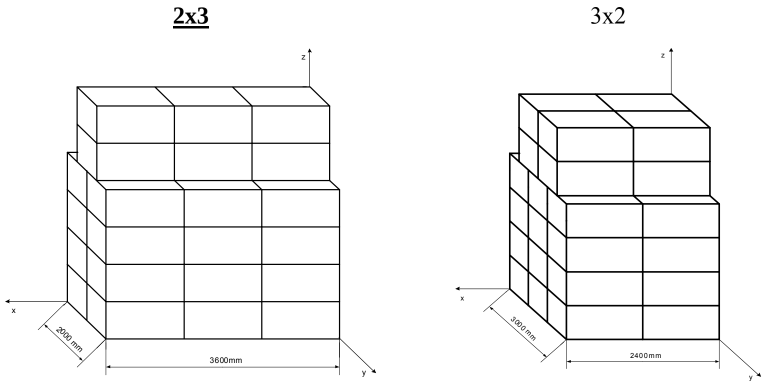


Figure 4. Possible alternatives for storage of LU 3
(maximal stacking height is 6 pieces)

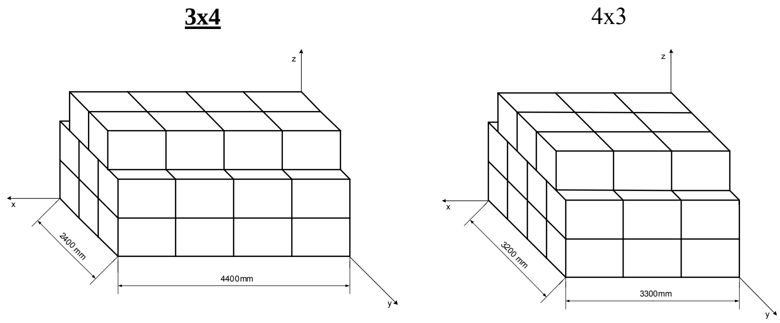


Figure 5. Possible alternatives for storage of LU 4
(maximal stacking height is 3 pieces)

The optimal block dimensions in case of different types of loading units (underlined numbers) were defined by comparison of alternatives based on the following parameters:

- maximal number of LUs in a block,
- maximal area utilization (minimal area consumption).

4. Formation of storage structures

The main object of the design is a maximal utilization of buildings, taking into consideration that the same type of LUs should be located in the same buildings. Figure 6. shows possible alternatives for building 1-2 and combinations of these. We elaborated 8 possible alternatives for storage structure in our R+D project, but in this paper we show only the half of it because of the page limit.

In our paper we analyse the situation when one type of LUs are located together in one building, LU1 and LU2 are in building 2, LU3-LU5 are in building 1. In building 2 we analysed the longitudinal aisles arrangement, in case of building 1 both of transversal and longitudinal aisles arrangement were examined. Storage of LU5 requires racking system which was taken into consideration during the formation of storage structure (width of the rack is 2,7 meter).

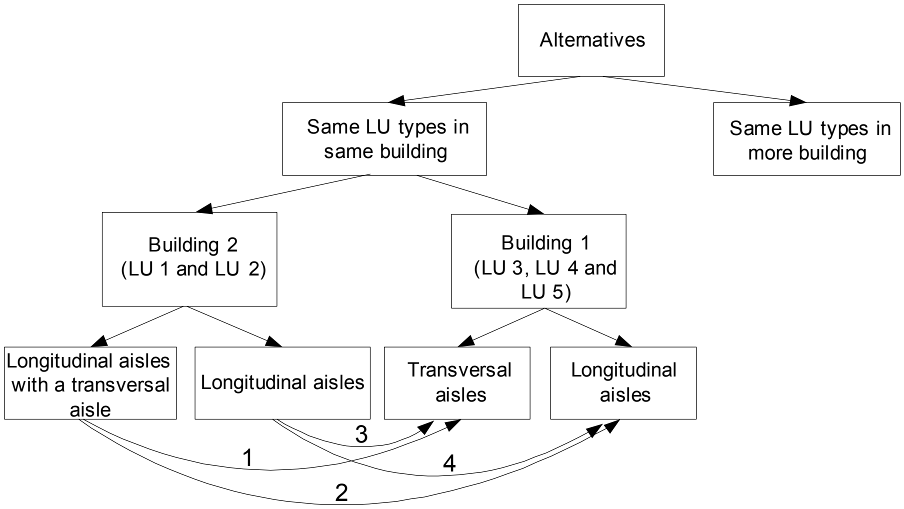
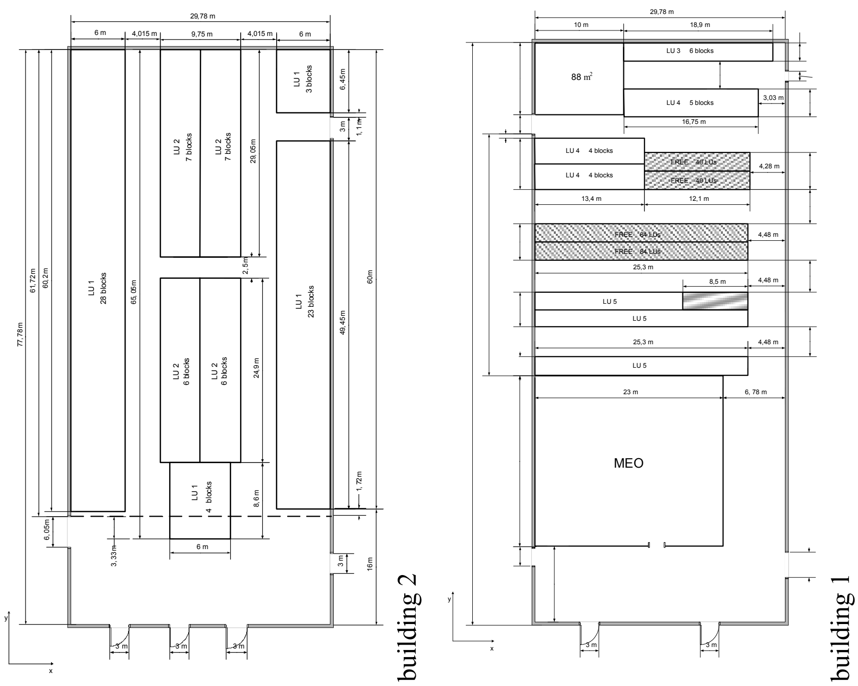
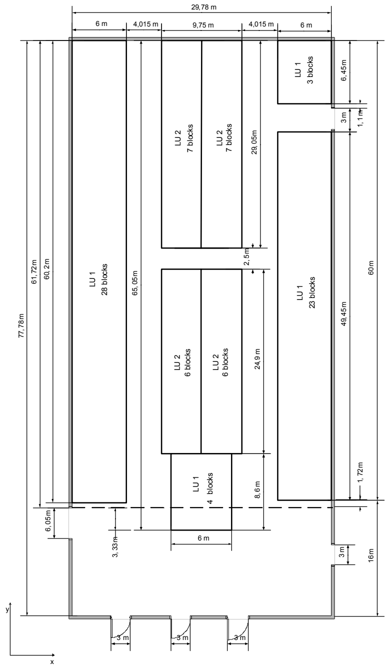


Figure 6. Alternatives for storage structure combinations

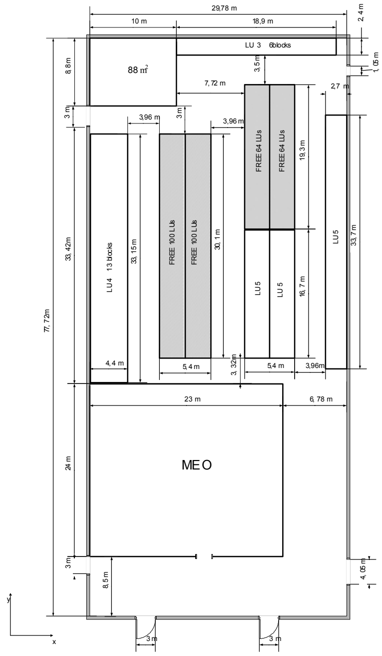
4.1. First alternative



4.2. Second alternative

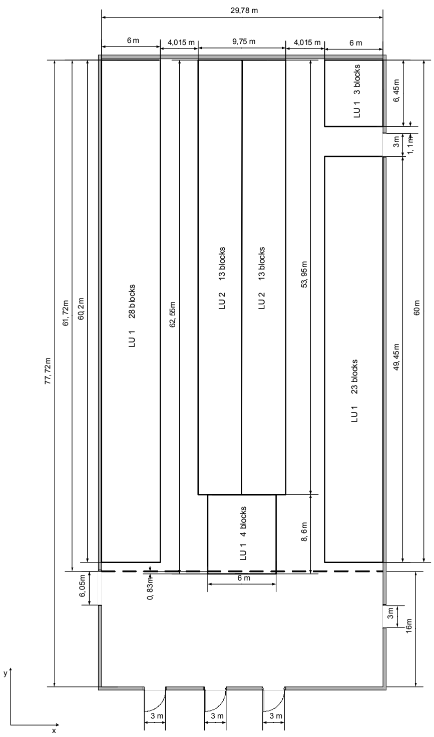


building 2

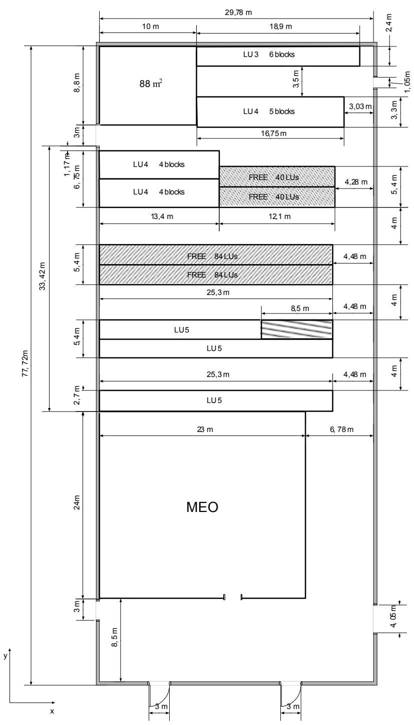


building 1

4.3. Third alternative

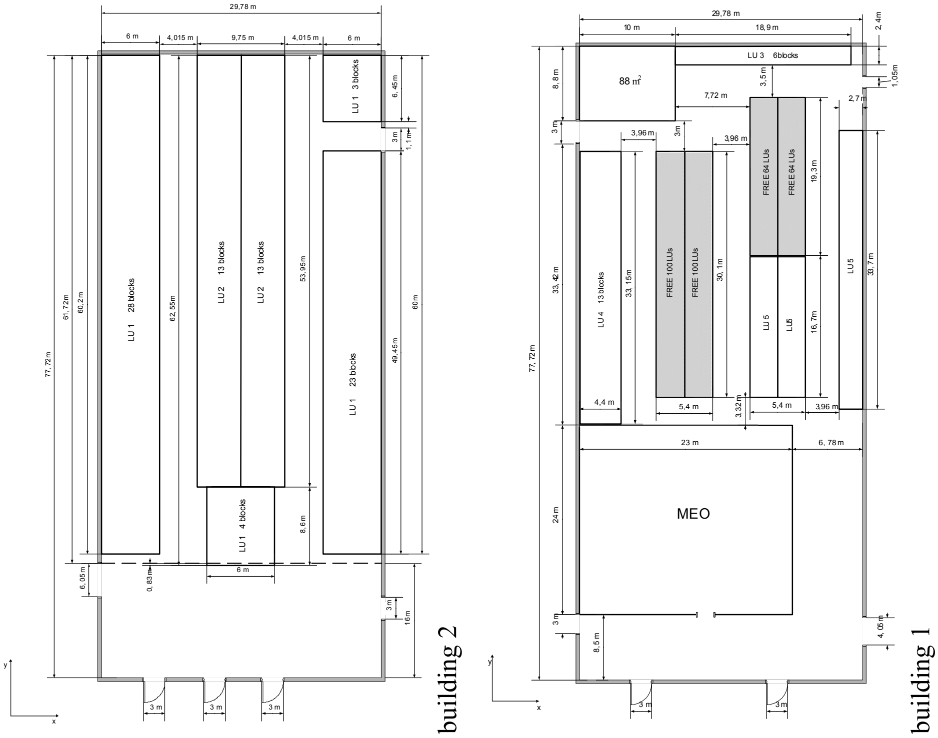


building 2



building 1

4.4. Fourth alternative



5. Comparison of alternatives

Utilization factors should be elaborated to define the optimal warehouse arrangement. Comparison of different structure alternatives was based on the following aspects: maximal storage capacity, maximal utilization of floor area and space.

Utilization of floor area (α_k) can be calculated:

$$\alpha_k = A_{fk} / A_t \cdot 100 \ [\%], \qquad (1)$$

where

A_{fk} – area used for storage in case of the k^{th} alternative [m^2]:

$$A_{fk} = L_{fxk} \cdot L_{fyk},$$

L_{fxk} – length of useful area in direction x in case of the k^{th} alternative [m],
L_{fyk} – length of useful area in direction y in case of the k^{th} alternative [m],

A_t – total warehouse area [m^2]:

$$A_t = L_{tx} \cdot L_{ty},$$

L_{tx} – length of warehouse in direction x [m],
L_{ty} – length of warehouse in direction y [m],
k – identification of different alternatives.

Ratio of useful storage area and total storage area (α_k^{ht}):

$$\alpha_k^{ht} = A_{hk} / A_t \cdot 100 \ [\%], \quad (2)$$

where

A_{hk} – useful storage area in case of the k^{th} alternative [m^2]:

$$A_{hk} = A_f - (T_{fk} + T_{etk}),$$

T_{fk} – total area of aisles in case of the k^{th} alternative [m^2],
T_{etk} – area of preparation place in case of the k^{th} alternative [m^2].

Ratio of useful storage area and area used for storage (α_k^{hf}):

$$\alpha_k^{hf} = A_{hk} / A_{fk} \cdot 100 \ [\%], \quad (3)$$

Utilization of warehouse volume (β_k) can be calculated:

$$\underline{\beta_k} = V_{fk} / V_t \cdot 100 \ [\%], \quad (4)$$

where:

V_{fk} – volume used for storage in case of the k^{th} alternative [m^3],
V_t – total warehouse volume [m^3].

Ratio of useful storage volume and total warehouse volume (β_k^{ht}):

$$\beta_k^{ht} = V_{hk} \ / \ V_t \cdot 100 \ [\%], \quad (5)$$

where

V_{hk} – useful storage volume in case of the k^{th} alternative [m^3].

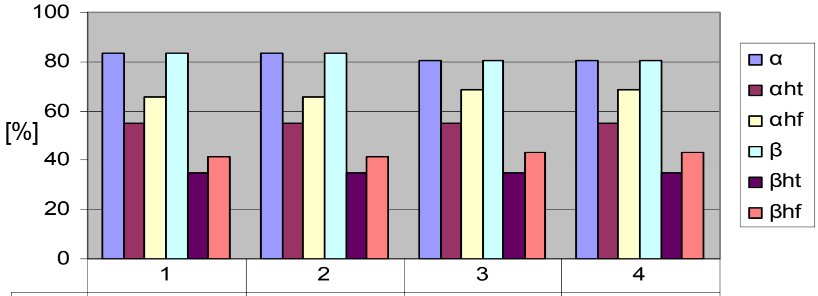
Ratio of useful storage volume and volume used for storage (β_k^{hf}):

$$\beta_k^{hf} = V_{hk} \ / \ V_{fk} \cdot 100 \ [\%], \quad (6)$$

6. Analysis of alternatives 1-4.

Figure 7. shows the above mentioned utilization factors relating to different alternatives. Based on the floor area and volume utilizations (α, β) the alternatives 1. and 2., based on factors α^{hf} and β^{hf} the alternatives 3. and 4. are more advantageous. However it can be seen that there is a small differences between the values of each parameter in case of different alternatives. Values of α^{ht} and β^{ht} are the same in case of all alternatives.

Figure 8. shows the total number of LUs which can be stored in the two buildings in case of different alternatives. This total value is the sum of pieces of LU1-LU5.



	1	2	3	4
α	83,68	83,68	80,48	80,48
αht	55,05	55,05	55,05	55,05
αhf	65,77	65,77	68,41	68,41
β	83,68	83,68	80,48	80,48
βht	34,78	34,78	34,78	34,78
βhf	41,58	41,58	43,24	43,24

Figure 7. Utilization factors relating to alternatives 1-4 [%]

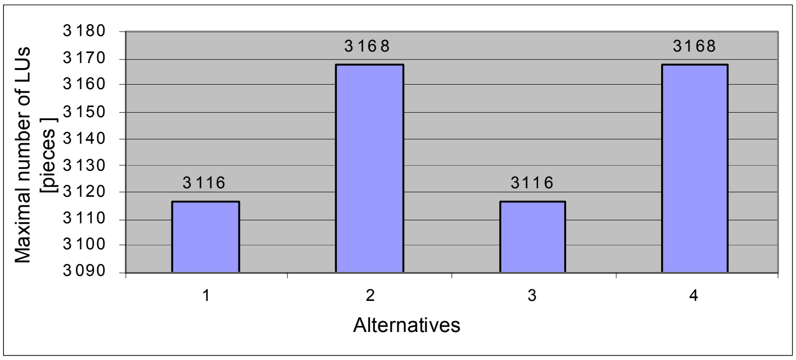


Figure 8. Total number of LUs in building 1-2.

Based on results it can be seen that the alternative 2 and 4 are the most advantageous from the point of view of storage capacity.

The primer objective from the point of view of the warehouse owner is the maximization of pieces of LUs which can be stored in the warehouse, the maximal area and volume utilization of the warehouse is only a secondary aim (if there is no significant differences between the alternatives, as in our case). Based on the analysis the alternative 2 and 4 are the suggested variation for optimal warehouse structure. After the finishing of the research project the subscriber company approved our results and started to use our suggestions relating to optimal warehouse structure.

7. Summary

The paper shows a design conception for an existing warehouse elaborated for a forwarding and warehousing company. The conception can be applied to define an optimal storage structure based on a given warehouse floor area and available forecasts relating to types and volume of loading units (LU) to be stored. The LUs are coming in shipping containers, which should be managed as a unit and stored in a same place (in blocks) because these will be delivered together. Because of it the first phase of the design is the determination of optimal block dimensions in case of different types of loading units, aisle width and aisle directions. The study shows 4 possible alternatives for storage structure and blocks arrangement. Longitudinal and transversal aisle arrangements were taken into consideration in both of buildings of the warehouse. Authors elaborated 7 parameters relating to maximal storage capacity, maximal utilization of floor area and volume to compare the different structure alternatives and define the optimal storage structure.

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