# THE INFLUENCE OF DISTANCE CALCULATION ON THE LOCATION OF CENTRAL WEREHOUSE

M.Sc. Herić M.[1], Associate Prof. Topčić A. PhD.[1], Associate Prof. Cerjaković E. PhD.[1], Assistant Prof. Lovrić S. PhD.[1]
Faculty of Mechanical Engineering – Tuzla, University of Tuzla, Bosnia and Herzegovina [1]

muhamed.heric@untz.ba

**Abstract:** *Choosing the right warehouse location is very important question which should be considered with great care, because it has a direct influence on the operating cost. For solving this problem many methods are on disposal. According to the way of determination of new warehouse location these methods can be divided in two groups': qualitative methods and quantitative methods. Quantitative methods are often used in practice from the reason greater objectivity and possibility to analyse obtained results. Most often used methods are: gravity method, load distance method, Weber problem and many others. For calculating of distance in the load distance method two approaches are in use rectilinear distance and Euclidean distance. Neither one of these two approaches credibly describes transport routes because they not taken into consideration any physical obstacles that might occur between potential warehouse locations. With the goal to determine the influence of distance calculation on the result of the load distance method, choice analysis of optimal location of warehouse for retail stores, shops in the urban area was performed and presented.*

**Keywords**: LOGISTICS, MATERIAL FLOW, WAREHOUSING, LOCATION, TRANSPORT COST

## 1. Introduction

Warehouse is an inevitable part of logistic chain and without it binding of production, transport and consumption would not be possible. The purpose of the warehouse is best visible in retail stores which one have variable and unpredictable demand for goods, and the request for warehouse service is often issued during the working time of retail stores and it have to be fulfilled quickly. In contrary the shelves of retail stores will be empty and the customer will go to other retail stores. It is quite clear that the warehouse cannot be near to all of users of warehouse services, and it is also quite clear that their needs will better satisfied if the warehouse is able to respond as soon as possible. Placing the warehouse on location which will provide good services for all users is of crucial importance.

For solving of this problem many methods are on disposal. According to the way of determination of new warehouse location these methods can be divided in two groups': qualitative methods and quantitative methods. Qualitative methods are based on analysis of specific number of key factors which are important for choosing of warehouse location. Every one of those factors are analytically evaluated in form of points. The number of points, for every specific key factor, is determined by the analyst which is in charge for solving the problem of new warehouse location. The analyst determine these points subjectively in accordance with personal considerations. It is quite clear that some other analyst can evaluate same location differently which ultimately can lead to the selection of another warehouse location. These methods can be used for choosing the final warehouse location or they can be used in initial stage of determination of warehouse location for reducing of number of potential locations from which optimal warehouse location will be chosen with some other method. Quantitative methods used for solving the problem of warehouse location are methods that use clearly defined analytical indicators. These analytical indicators are: distance, transport cost, amount of transported material, investment cost, etc. Quantitative methods for solving the problem of warehouse location that are primary based on transport cost are used when relatively large transport costs are expected, i.e. when the transport distances are long [1]. Some of these methods are: *canter of gravity*, *load distance*, *Weber's* problem, *Launhardt graphical method*, *Rockstroh method*, *northwest angle method*, etc.

## 2. Load distance method

*Load distance* method is approach for determining warehouse location based on analysis of distance between two location and amount of cargo transported between them. The goal of this method is to find location which will minimize the amount of cargo transported between warehouse and warehouse users and at the same time ensure the decrease of transport cost. In this way the load distance method, alongside spacious distance takes in consideration the amount of transported cargo as an equally important factor. By applying the *load distance* method, a numerical value is obtained that represents the sum of products of the users distance from the given warehouse location and the amount of transported load between them. Numerical value is marked as *LD*, according to the name of this method "*Load Distance*" and according to [2] it is calculated as:

$$LD_j = \sum_{i=1}^{n} D_{ij} \times W_i \quad (1)$$

, where are:

$LD_j$ - numerical value of *load distance* method
$D_{ij}$ - distance between *i* and *j* warehouse location
$W_i$ - amount of transported cargo from *i* location

As it can be seen from the equation (1), value of $LD_j$ is determined by the distance between two location and by the amount of cargo transported between them [3]. Distance $D_{ij}$ can be calculated as length of hypotenuse of imaginary triangle, which is formed by *x* and y coordinates of two locations, as is presented on Figure 1, where locations are shown and imaginary triangles which they form. Above mentioned distance is known as *Euclidean distance* and it can be calculated as [2],[4],[5]:

$$D_{ij} = \sqrt{(x_i - X_j)^2 + (y_i - Y_j)^2} \quad (2)$$

The $D_{ij}$ distance can be calculated as *rectilinear distance* between two points with 90[°]turn [3],[6],[7] i.e. the distance presents the sum of the lengths of cathetus, Figure 1.

$$D_{ij} = |x_i - X_j| + |y_i - Y_j| \quad (3)$$

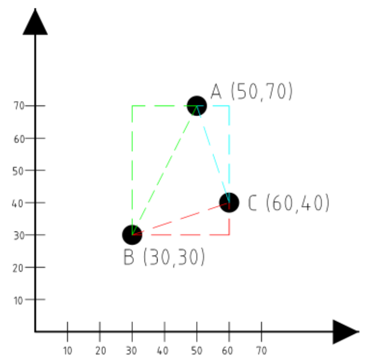


***Fig. 1** Position of potential warehouse locations*

Cargo or load $W_i$ represents the amount of transported material and it is determined by demand of specific location for specific type of goods, and it can be expressed through number of transport cycles or number of transported units form proposed location of warehouse to the *i* location of user of warehouse services.

The decision for warehouse location is made by comparison of *LD* values for proposed locations and the optimal location is the one with lowest *LD* value. As it can be seen form equation (1) *LD* is in direct dependence from amount of transported material and distance $D_{ij}$. Distance determination ways are shown in equation (2) and (3). From those equations it can be seen that these two ways do not describe credibly realistic state of the transport paths nor do they take into account any physical obstacles that may occur between the two potential locations.

## *3. Determining of central warehouse location on specific example*

To show the impact of distance $D_{ij}$ determining methods on to the choice of the central warehouse location using the *load distance* method, in this paper is presented concrete example of determination of potential location of warehouse for chain of retail objects in the urban area. Presented locations of retail objects are users of warehouse service and they are also potential locations where the central warehouse could be positioned next to the retail facilities.

During the calculation of *LD* value for all the users of central warehouse services it is assumed that the transport intensity $W_i$ is constant. Although this assumption does not correspond to realistic conditions, this allows clear determination of the dependence of the method of calculating the $D_{ij}$ distance on the selection of the location of central warehouse.

The arrangement of the users of central warehouse services for which is necessary to determinate an adequate central warehouse location is required is presented in Figure 2.a. The service users are assigned by the names A, B, C, etc. For the given locations of the users of the central warehouse service, their position are determined by *x* and *y* coordinates, that were used for determination of the respective distance $D_{ij}$.

By analising of equations (2) and (3) for determining of $D_{ij}$ it can be concluded that is not important where the center of coordinate system is placed as long as the distance between the points are unchanged, with the condition that all the location of warehouse users are placed in same quadrant of coordinate system. By applying of these limitations, the coordinates for each given location i.e. the point were determined, Figure 2.b. The coordinates of users of central warehouse services are non-dimensional values because they are in function of the image resolution according to which they are determined.

Based on the obtained coordinates, the distance $D_{ij}$ was calculated in both pre-presented ways, using a constant value for $W_i$ with the aim of neutralizing of its influence on the choice of location of central warehouse.

The results of calculation of the *LD* values for arrangement of the users of central warehouse services presented on Figure 2 are shown on the Figure 3, where can be seen that the location *D* is optimal location when the distance is calculated by *Euclidean distance*, and by applying *rectilinear distance* calculation location *H* is optimal choice for new central warehouse location. In both cases in those optimal locations of the central warehouse, factor *LD* has the lowest value. But the question is still remains, which location is optimal for central warehouse *D* or *H*

Although using the *rectangular* and *Euclidean* approach of the distance determination allows us to calculate the *LD* and determine the location of the central warehouse in accordance with the set criteria, the way of calculating of the distance $D_{ij}$ can significantly deviate from the real conditions, as can be seen on the Figure 4. Based on the foregoing, it can be concluded that by applying of real distance for the same conditions, the *load distance* method could give different results.

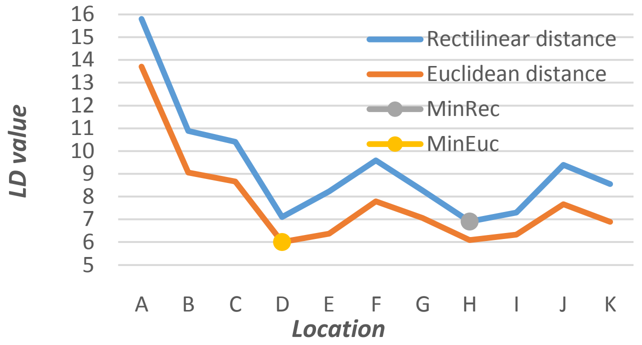


***Fig. 3*** *Comparison of the results for Euclidean and rectilinear distance calculation in load distance method.*

With the aim to analyse the influence of the way of determining the distance between the potential locations of the central warehouse and the users of warehouse services on the results of *load distance* method, the same positions of users of central warehouse services are used as in previous example, Figure 2.

The real distance are determined using the *Google maps* software for all location as it is shown on the Figure 4.c. For determined distances, calculation of the *LD* values was performed in accordance with the previously presented methodology. The results of that calculation are presented in the Table 1. Based on the obtained values, there is an obvious deviation from the results obtained in the previous two cases as can be seen on the Figure 5.

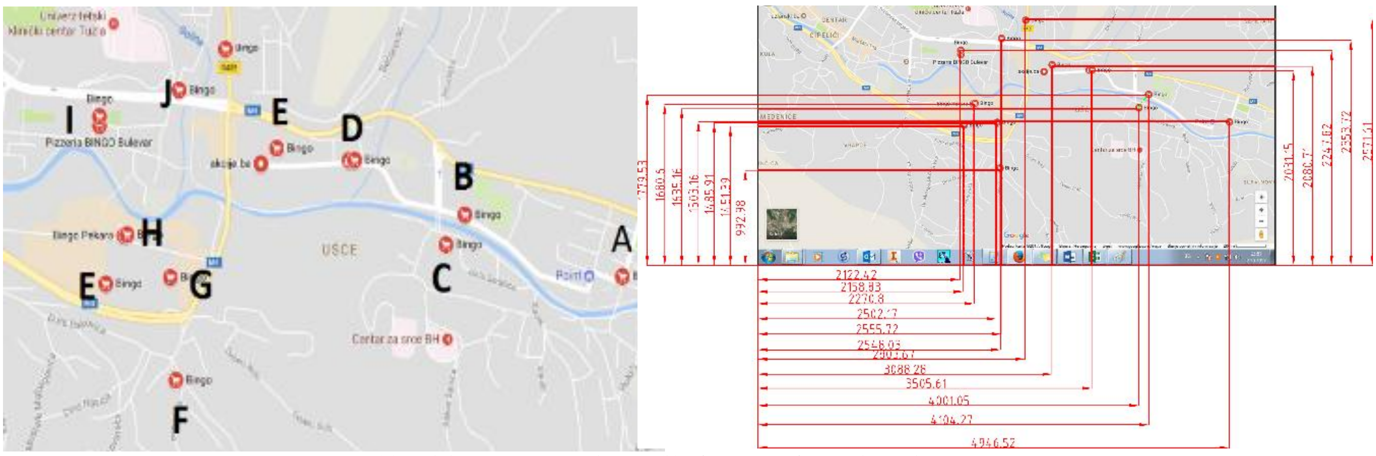


***Fig. 2*** *Position (a) and determining coordinates (b) of "users" of central warehouse services - clients..*

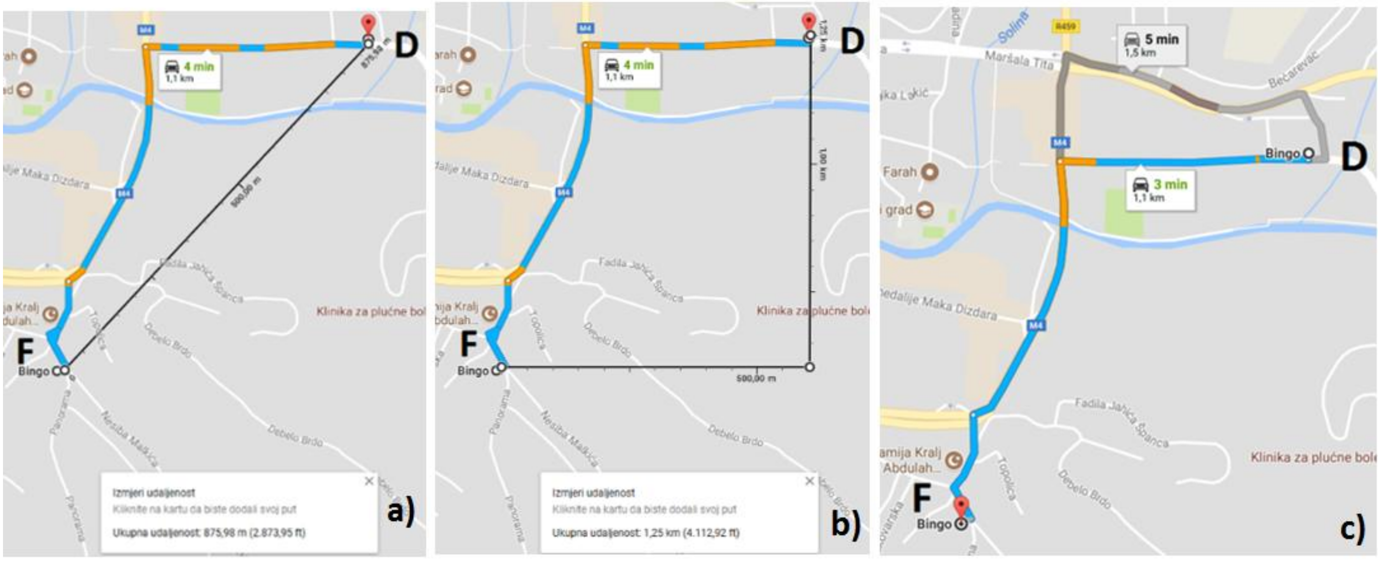


***Fig. 4** Different ways to determine $D_{ij}$ distance between two potential locations: a) Euclidean distance: $D_{ij}$ =0,875 [km], b) rectilinear distance: $D_{ij}$ =1,25 [km], c) real distance determined by transport routes: $D_{ij}$ =1,1 [km].*

Using the first two approaches location *D* was the optimal location of the central warehouse with the minimum *LD* value for *Euclidian* distance calculation, and location *H* when *rectangular* distance calculation was applied. However, when real values of distances defined by "real" transport routes determined by *Google Maps* are used, the optimal location of the central warehouse with a minimum value of *LD* is the location *E*. In this case, the total distance that the transport vehicles will cross if location *D* is selected instead of location *E* is 2.85 [*km*], and if the location *H* is selected instead of *E* location the total distance that the transport vehicles will cross is 3,01 [*km*]. The resulting deviations certainly do not represent a small and negligible distance which the transport vehicles will cross, which ultimately creates the prerequisites for lowering the total transport costs.

## 4. Conclusion

The cost of transport is a very important item in the business of a company, and it can often be the one of items that secures market competitiveness, which is particularly evident in consumer products, products of low weight but with large volume, etc. Choosing wrong warehouse location can lead to decrease of income, and eventually to reduction of the market competitiveness. Many methods have been developed with the purpose to determine optimal warehouse location, and every of hem have it good and bad sides as well as area of application. What is common to all those methods is that they use the same or similar mathematical algorithm to determine distances between the potential warehouse locations. One of the methods used for determining new warehouse location is *load distance* method. *Load distance* method is very simple to use and it don't have complicated mathematical procedure which would require a high degree of knowledge and experience for its usage.

The paper presents the approach by which load distance method sests the optimal location of warehouse, as well as the ways to determine coordinates of potential locations of warehouse using available software such as *Google maps* and any of the 2D Design software such as *Solid Edge 2D* , *BabaCad*, *nanoCAD*, etc.

By analyzing of mathematical equations for determination of the distance between potential warehouse locations it have been noticed that resulting distances do not credibly describes transport routes as they are in reality, neither do the take in to consideration any physical obstacles that might occur between two locations. Specifically, in the example of usage of *Euclidean* equation for calculation of distances, the resulting distances i.e. transport routes are the shortest possible, that is more appropriate to air transport. By usage of *rectilinear* equation for calculation of distances the resulting distances, i.e. transport routes can been presented in the form of two straight lines intersecting at 90[°] who connects two potential warehouse locations, and this distance is slightly longer than the calculated *Euclidean* distance. Applying of these two approaches for calculation of the distances in some cases can results in different values of calculated distances for the *load distance* method, which additionally increases the distrust in its application.

The real transport routes, used for movement of transport vehicles, are consisted from a series of changes of directions that further increases the distance between two locations. It should also be taken in to consideration that all roads that are easy to use for movement of light transport vehicles do not provide same conditions for movement of heavy transport vehicles.

***Table 1**: Determining the optimal warehouse location by applying load distance method using real distance.*

| | | Real distance [*km*] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Location** | $W_i$ | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** | **K** |
| **A** | 1 | 0 | 0,65 | 0,85 | 1,1 | 1,4 | 2,6 | 2,6 | 2,5 | 2,5 | 2,2 | 3,4 |
| **B** | 1 | 0,65 | 0 | 0,24 | 0,45 | 0,7 | 1,6 | 1,6 | 1,8 | 1,8 | 1,6 | 2,4 |
| **C** | 1 | 0,85 | 0,24 | 0 | 0,45 | 0,75 | 1,6 | 1,6 | 1,8 | 1,8 | 1,6 | 2,4 |
| **D** | 1 | 1,1 | 0,45 | 0,45 | 0 | 0,35 | 1,5 | 1,2 | 1,4 | 1,4 | 1,1 | 2,7 |
| **E** | 1 | 1,4 | 0,7 | 0,75 | 0,35 | 0 | 0,85 | 0,9 | 0,8 | 0,8 | 0,85 | 1,7 |
| **F** | 1 | 2,6 | 1,6 | 1,6 | 1,5 | 0,85 | 0 | 0,8 | 0,7 | 0,7 | 1,6 | 1,1 |
| **G** | 1 | 2,6 | 1,6 | 1,6 | 1,2 | 0,6 | 0,8 | 0 | 0,3 | 0,1 | 1,4 | 1,4 |
| **H** | 1 | 2,5 | 1,8 | 1,8 | 1,4 | 0,8 | 0,7 | 0,3 | 0 | 0,21 | 1,3 | 1 |
| **I** | 1 | 2,5 | 1,8 | 1,8 | 1,4 | 0,8 | 0,7 | 0,1 | 0,21 | 0 | 1,1 | 1 |
| **J** | 1 | 2,2 | 1,6 | 1,6 | 1,1 | 0,85 | 1,6 | 1,4 | 1,3 | 1,1 | 0 | 0,35 |
| **K** | 1 | 3,4 | 2,4 | 2,4 | 2,7 | 1,7 | 1,1 | 1,4 | 1 | 1 | 0,35 | 0 |
| **LD** | | **19,8** | **12,84** | **13,09** | **11,65** | **<u>8,8</u>** | **13,05** | **11,9** | **11,81** | **11,41** | **13,1** | **17,45** |

On the example presented on the Figure 3.c, it can be seen that from point *D* to point *F* there are two routes, the first one with the distance of 1.1 [*km*] and the second one with 1.5 [*km*]. Assuming that the movement of transport vehicles is forbidden through the first shorter transport route then the transport vehicles must take second longer route.

Figure 4.c shows the procedure for determining the real distance between two locations, which results in the actual path that the transport vehicles will make with real distance value, as well as with the possibility of taking into account traffic restrictions for certain types of the vehicles

The Figure 5 shows the results of implementation of *load distance* method for all three distance calculation approaches for the same settings as they are presented on the Figure 2. Given to the fact that the calculated *Euclidean* and *rectilinear* distance $D_{ij}$ have different values, the resulting value of the *LD* coefficient is also different, which ultimately leads to suggestions of different warehouse locations. On the other hand, by usage of real distances in calculation, results in location that differs from the optimum location obtained by application of *rectangular* or *Euclidean* distance. By applying of real distances, calculated results are credible and they cannot be throw in doubt. As a matter of fact, an obtained results i.e. distances corresponds to the actual situation on the ground, and the approach of determining of real distances between potential locations is a lot simpler than the measuring of the coordinates and calculation of the *Euclidean* and *rectangular* distances.

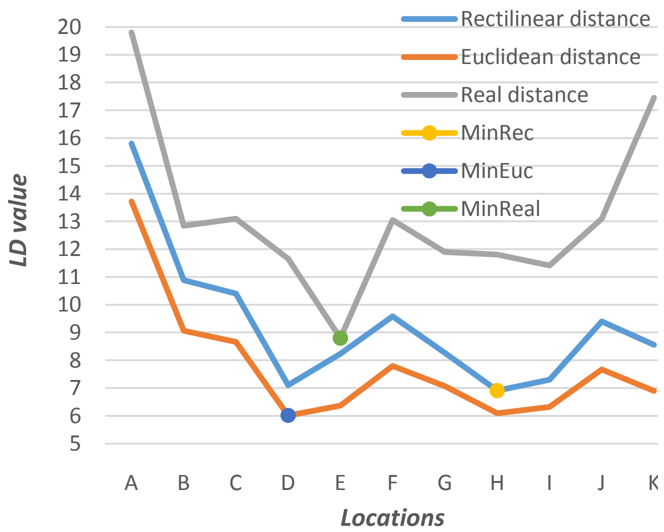


***Fig. 5*** *Comparison of the results for load distance method for all three approaches of distance calculations.*

## *5. Literature*

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