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Analysis of the optimal location of new facilities within a production section

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Abstract. *In this paper the location of the warehouse of finished products and technical inspection post in the new space of a section for an industrial enterprise, intended for the processing of new products is proposed. This will be done according to several conditions imposed by the company's management. This was done using the Facility Location and Layout module of the WinQSB program, using two problem types: Facility Location and Functional Layout. The first type of problem was used for the location of the two new production units, and the second for the verification, using the CRAFT method, of the spatial location of the production units.*

Keywords: *optimisation, rectilinear distance, Euclidean distance, objective function, initial emplacement*

1. Introduction

Today, in order to face global competition, the industry needs to focus on computer science and technology. In this regard, industrial firms that focus on shortening the production cycle and also on the quality of the manufactured products will face the challenges of the market, adapting quickly to the needs and expectations of customers. To do this, however, he must respond promptly to rapid changes in technology, to turn to high-performance production systems, which lead to an increase in productivity and an improvement in quality, and at the same time to a significant decrease in costs [1]. Based on these considerations, in this paper we will analyse the problem of siting new production units.

Localization problems form a broad class of mathematical optimization problems [9]. The location decision is strategic, long-term and non-repetitive. For this reason, this type of decision must be taken with great care, as the lack of good and thorough site planning from the outset leads to ongoing operational problems in the future and can be a constant source of higher costs [5].

In this paper the location of the warehouse of finished products (WFP) and technical inspection post (TIP) in the new space in a section of an industrial enterprise, intended for the processing of new products is proposed and the optimal solution has been obtained.

Two essential conditions imposed by the management of the company are set out [1]:

• The new location is aimed at the decommissioning of a space in a production station, where there are the necessary facilities to ensure the energy supply of the machines.

• In the new location will be used existing equipment (noted U1-U22), coming from the decommissioning of two production halls within the company.

The working regime of the workshop is 5 days/week, 2 shifts/day, 8 hours/shift.

Table 1 shows the main products to be maded in the refurbished section.

Table 1. Manufacturing schedule

No. crt.	Product name	Volume production [pieces/year]
1.	Threaded bolt 1	352
2.	Threaded bolt 2	2304
3.	Threaded bolt	128
4.	Bolt	128
5.	Fitting 1	2200
6.	Fitting 2	2200
7.	Nozzle	4400
8.	Nut	4400
9.	Fixing bush	24960
10.	Buffer	24960
11.	Coupling GS type A PN 160 PN 160	2200
12.	Coupling GS type B PN 160 PN 160	2200

The organization of a production line for these parts must be carried out using the machines available from two production sites of the enterprise, due to the restriction of the previous manufacturing profile.

Following the design of the production system, it was concluded that it is composed of three manufacturing cells and that it was dimensioned using the method based on the detailed layout of machinery, furniture and workplaces developed in Autodesk inventor (Figure 1), observing the normalized location distances and the normalized width of the traffic lanes (Figure 2).

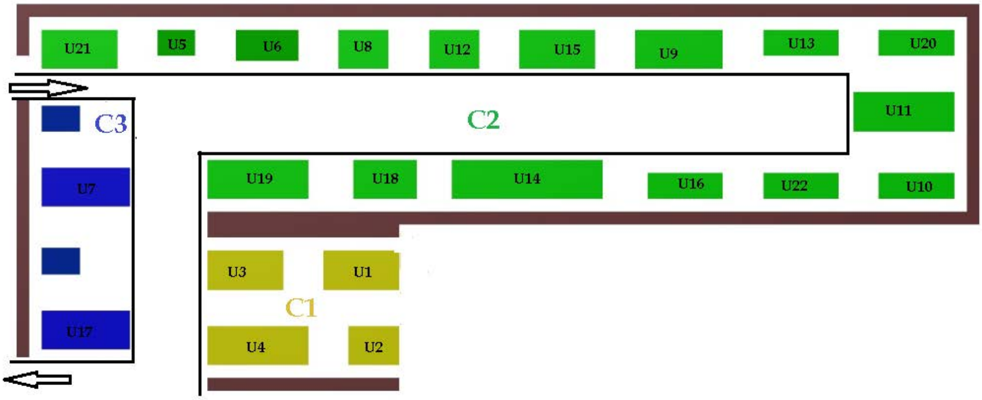

Figure 1. 2D Placement
Source: [1], pg.218

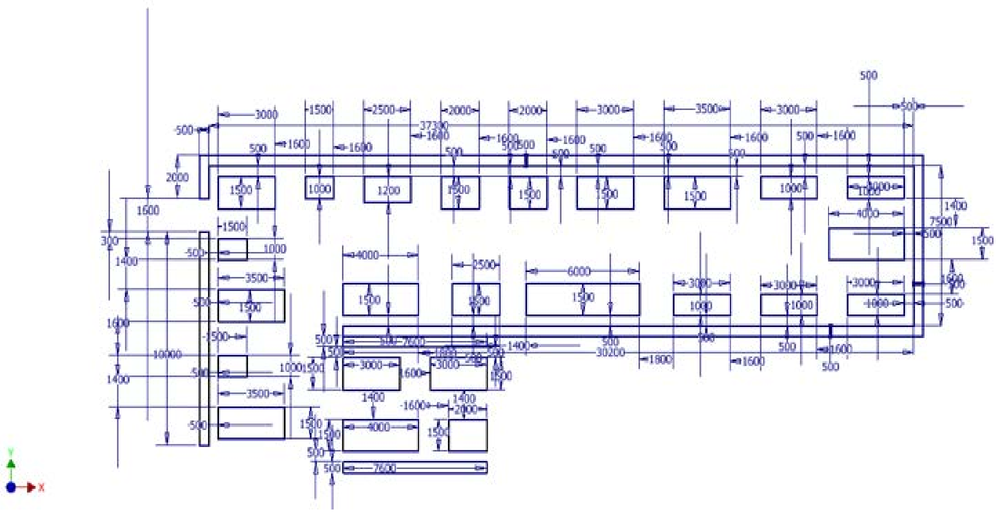

Figure 2. Detailed 2D location
Source: [1], pg. 260

2. Input data

Based on the known data of the study, namely:

1. workshop working regime;
2. the time rules of each product;
3. volume of production;
4. distribution of parts per production cells;
5. the location of the three manufacturing cells;
6. possible locations for WFP and TIP,

we calculate the amount of products executed by each manufacturing cell per day. This brings us to the following results:

• Cell C1, parts are manufactured: Threaded bolt 1, threaded bolt 2, threaded bolt and bolt– 12 pcs/day, toward the TIP post, then WFP;

• Cell C2, the following marks are executed: fitting 1, fitting 2, nozzle, nut, fixing bush and buffer – 265 pcs/day, of which 56 (fitting 1, fitting 2, nozzle and nut) go to cell C3, and 209 (fixing bush and buffer) to station TIP, then WFP;

• Cell C3 – 18 pcs/day (coupling GS type A PN 160 and coupling GS type B PN 160), to TIP post, then WFP.

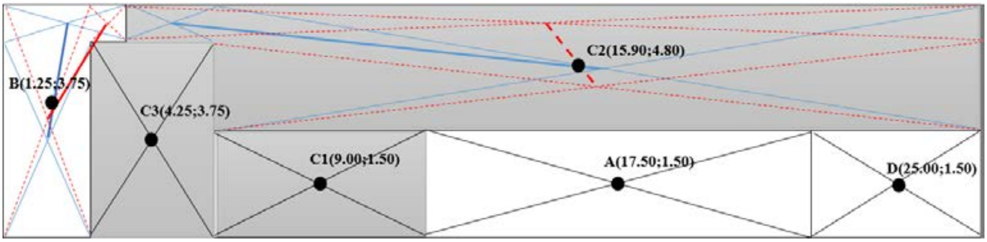

Figure 3. Possible locations for WFP and TIP

There are two possible locations: A(17.50; 1.50) and B(1.25; 3.75), and for TIP – B(1.25; 3.75) and D(25.00; 1.50). Starting from the data presented above, we determine the coordinates of the point in the hall where we need to place the WFP.

3. Results

Changing the location of the production units must take into account the fact that the total area of the redeveloped section cannot be changed, but the way the units are located relative to one another can be changed [3].

The QSB program package uses three types of distance measurement models, namely: Rectilinear, Euclidean and squared Euclidean.

09-13-2022	New Facility	X Axis	Y Axis	New Facility	X Axis	Y Axis
1	WFP	15.90	4.80	WFP	15.89	4.80
Total	Flow to&from	New Location	= 239	Flow to&from	New Location	= 239
Total	Cost to&from	New Location	= 373.50	Cost to&from	New Location	= 307.36
(by	Rectilinear	Distance)		Euclidian	Distance)	

Figure 4. The optimal solution offered by WinQSB
for rectilinear and Euclidean distance

It is noted in fig.4. that WFP and production cell C2 have the same location.

Summary of Optimal Location for Amariei 0

09-13-2022	New Facility	X Axis	Y Axis
1	WFP	14.68	4.46
Total	Flow to&from	New Location	= 239
Total	Cost to&from	New Location	= 2,854.80
(by	Squared	Euclidian	Distance)

Figure 5. The optimal solution offered by WinQSB
for the squared Euclidean distance

Nor is the optimal solution for the squared Euclidean distance (Figure 5) better than the other solutions found. For this reason we take into account the two possible locations for WFP, namely points A(17.50; 1.50) and B(1.25; 3.75), and the results are shown in Figures 6 and 7.

09-13-2022	New Facility	X Axis	Y Axis	New Facility	X Axis	Y Axis	New Facility	X Axis	Y Axis
1	WFP	17.50	1.50	WFP	17.50	1.50	WFP	17.50	1.50
Total	Flow to&from	New Location	= 239	Flow to&from	New Location	= 239	Flow to&from	New Location	= 239
Total	Cost to&from	New Location	= 1,382.60	Cost to&from	New Location	= 1,107.67	Cost to&from	New Location	= 6,856.18
(by	Rectilinear	Distance)		Euclidian	Distance)		Squared	Euclidian	Distance)

Figure 6. Results related to point A, in synthetic form

09-13-2022	New Facility	X Axis	Y Axis	New Facility	X Axis	Y Axis	New Facility	X Axis	Y Axis
1	WFP	1.25	3.75	WFP	1.25	3.75	WFP	1.25	3.75
Total	Flow to&from	New Location	= 239	Flow to&from	New Location	= 239	Flow to&from	New Location	= 239
Total	Cost to&from	New Location	= 3,477.80	Cost to&from	New Location	= 3,225.04	Cost to&from	New Location	= 46,058.14
(by	Rectilinear	Distance)		Euclidian	Distance)		Squared	Euclidian	Distance)

Figure 7. Results related to point B, in synthetic form

From the solution provided by the WinQSB software (Figure 6 and Figure 7), the total costs are different depending on the model used for measuring distances.

As the total cost of transport is lower in the Euclidean model than in the rectilinear model, this is considered the optimal solution in the case of location in point A.

Table 2. Results obtained at both possible WFP locations

Model for measuring distance	Coordinate		Total cost	Point
	x	y		
Rectilinear	17.50	1.50	1382.60	A
Euclidean	**17.50**	**1.50**	**1107.67**	
Squared euclidean	17.50	1.50	6856.18	
Rectilinear	1.25	3.75	3477.80	B
Euclidean	1.25	3.75	3225.04	
Squared euclidean	1.25	3.75	46058.14	

Then proceed with the location of the technical inspection post (TIP), taking into account the results previously obtained, i.e. the location of the WFP at point A(17.50, 1.50). The first possible location for TIP is at point B(1.25; 3.75) and the results obtained are given in Figure 8 and the second possible location is at point D(25.00; 1.50), with the results shown in Figure 9.

09-13-2022	New Facility	X Axis	Y Axis
1	WFP	17.50	1.50
2	TIP	1.25	3.75
Total	Flow to&from	New Location	= 534
Total	Cost to&from	New Location	= 6,683.30
(by	Rectilinear	Distance)	

09-13-2022	New Facility	X Axis	Y Axis
1	WFP	17.50	1.50
2	TIP	1.25	3.75
Total	Flow to&from	New Location	= 534
Total	Cost to&from	New Location	= 5,850.98
(by	Euclidian	Distance)	

Figure 8. Results in synthetic form for points A (for WFP) and B (for TIP)

09-13-2022	New Facility	X Axis	Y Axis
1	WFP	17.50	1.50
2	TIP	25	1.50
Total	Flow to&from	New Location	= 534
Total	Cost to&from	New Location	= 3,869.50
(by	Rectilinear	Distance)	

09-13-2022	New Facility	X Axis	Y Axis
1	WFP	17.50	1.50
2	TIP	25	1.50
Total	Flow to&from	New Location	= 534
Total	Cost to&from	New Location	= 3,442.24
(by	Euclidian	Distance)	

Figure 9. Results in synthetic form for points A (for WFP) and D (for TIP)

It can be seen from the results obtained and summarized in Tables 2 and 3 that the optimal location of the WFP is at point A(17.50; 1.50), and for TIP, for the point D(25.00; 1.50). The graphical representation of the optimal solution is shown in Figure 10.

Table 3. The results obtained at both possible points of placement of the TIP post

Model for measuring distance	**Coordinate for TIP**		**Coordinate for WFP**		**Total cost**
	x	**y**	x	y	
Rectilinear	1.25	3.75	17.50	1.50	6683.30
Euclidean	1.25	3.75	17.50	1.50	5850.98
Rectilinear	25.00	1.50	17.50	1.50	3869.50
Euclidean	25.00	1.50	17.50	1.50	3442.24

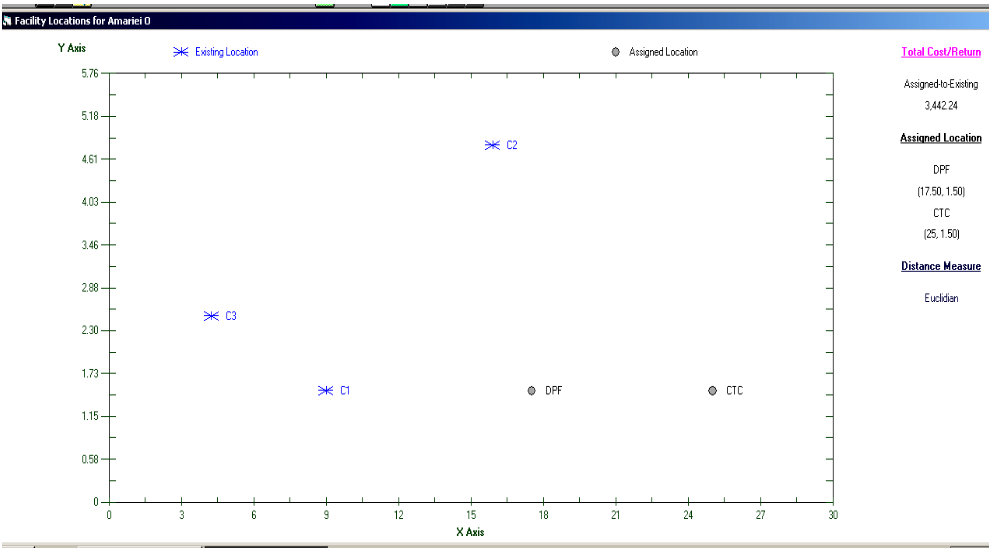

Figure 10. Results in graphic form

4. Verification of the obtained solution

Further we check whether the solution obtained is optimal or can be improved. For this purpose we have several options for problem solving, namely [6]: improvement by exchanging 2 departments, improvement by exchanging 3 departments, improvement by exchanging 2 then 3 departments, improvement by exchanging 3 then 2 departments, evaluation the initial layout only.

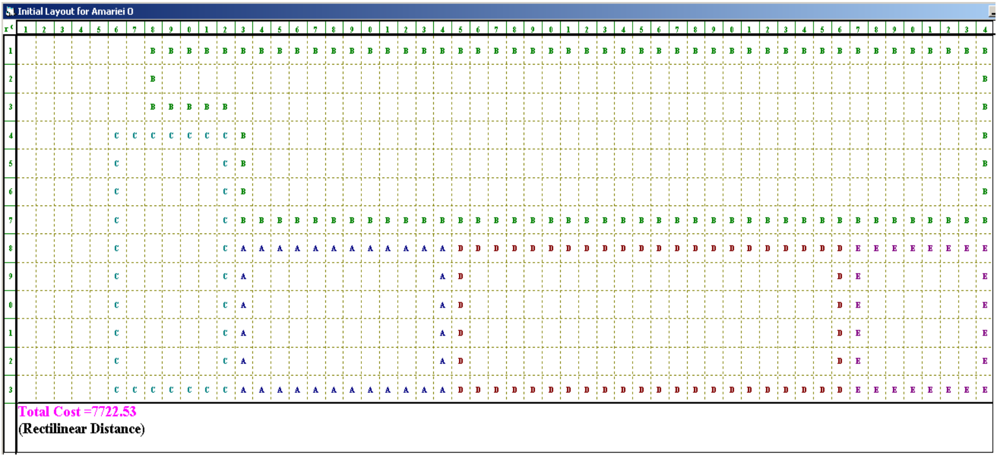

Figure 11. Initial solution

The starting solution (the initial solution) is that obtained in section 3 and is plotted in Figure 11. The total cost is double, because when entering the data into the program, specifically when entering the number of lines in the affected area, we could not enter six and a half lines and then we doubled the number of columns, so that all the values that will appear next will be double.

The location of the units after accessing the options offered by the program are shown in Figures 12÷15.

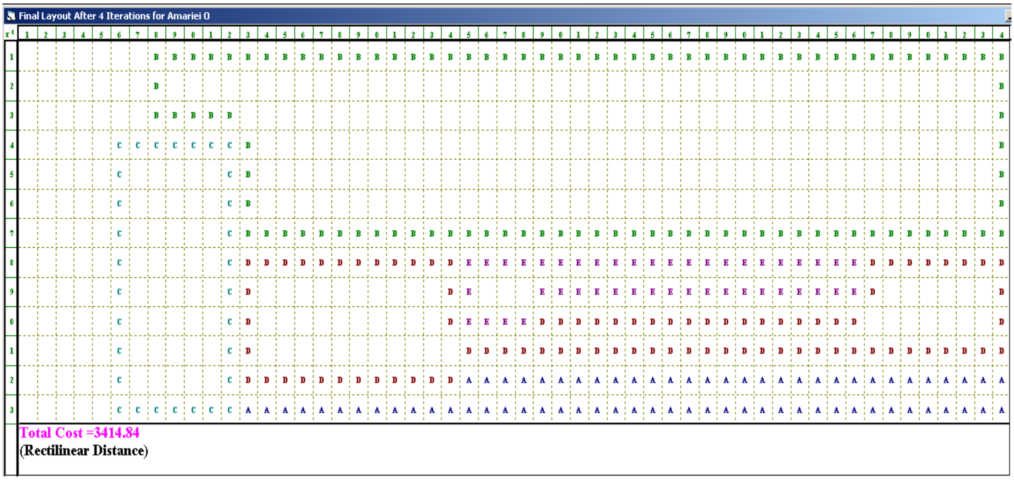

Figure 12. “Improvement by exchanging 2 departments” option

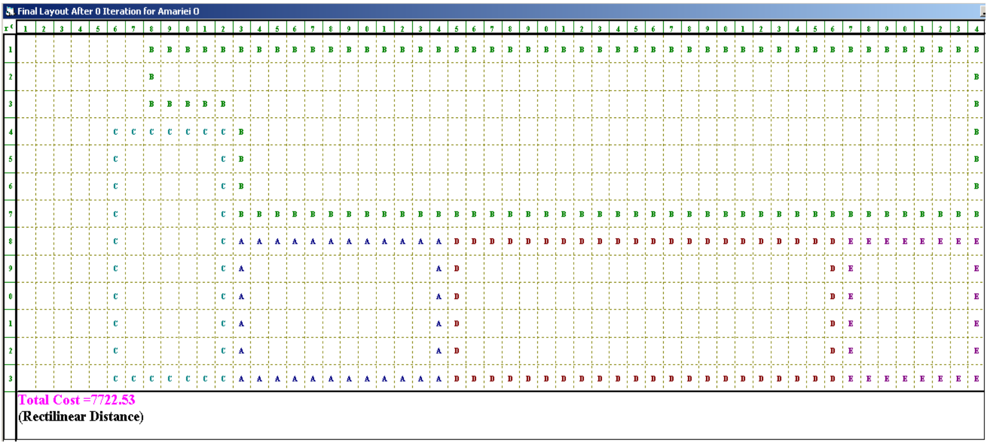

Figure 13. "Improvement by exchanging 3 departments" option

The location obtained from the permutation of two units (fig.13) is identical to the solution we started from (fig.11) and also the other three options are identical, but with a lower objective function value of 3414,84 (actual cost - 1707.42), which denotes an improvement in the previous location.

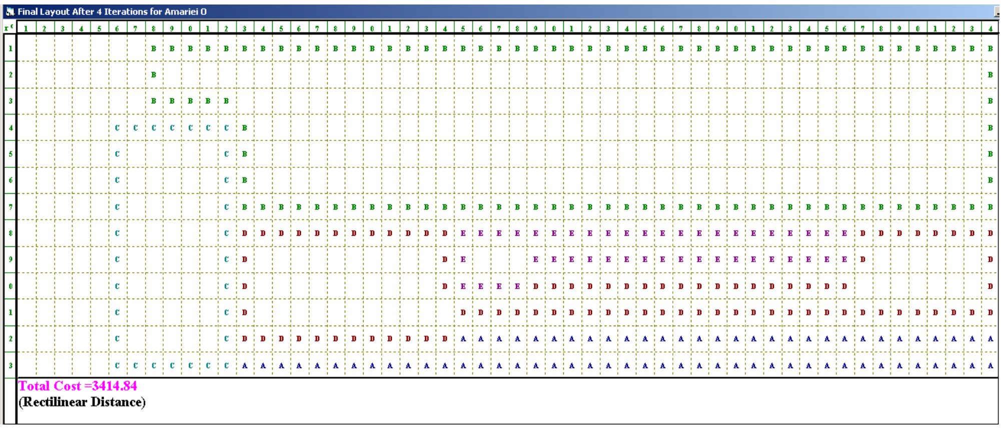

Figure 14. "Improvement by exchanging 2 then 3 departments" option

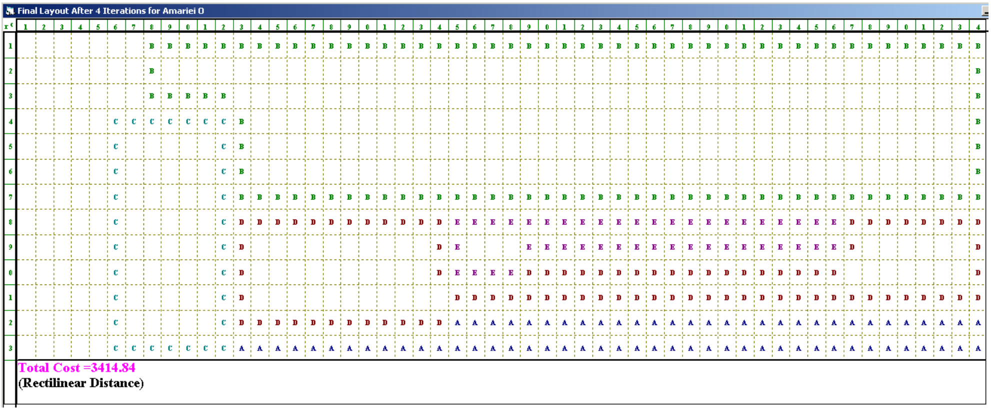

Figure 15. "Improvement by exchanging 3 then 2 departments" option

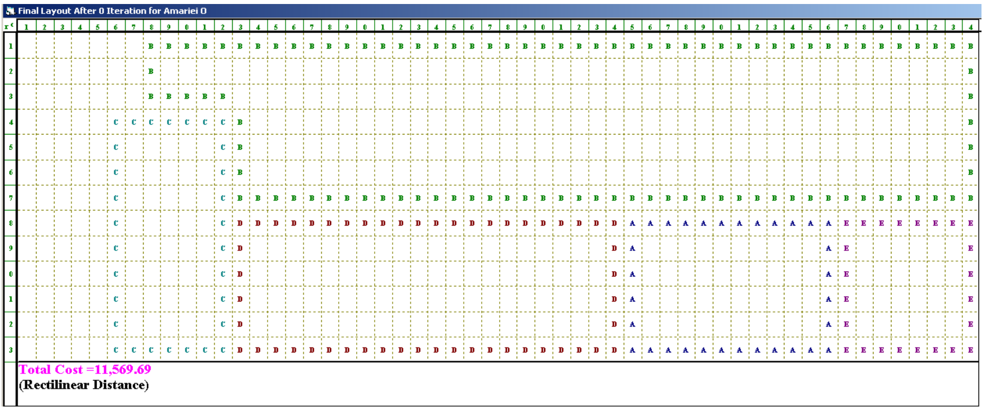

Figure 16. Adjusted location 1

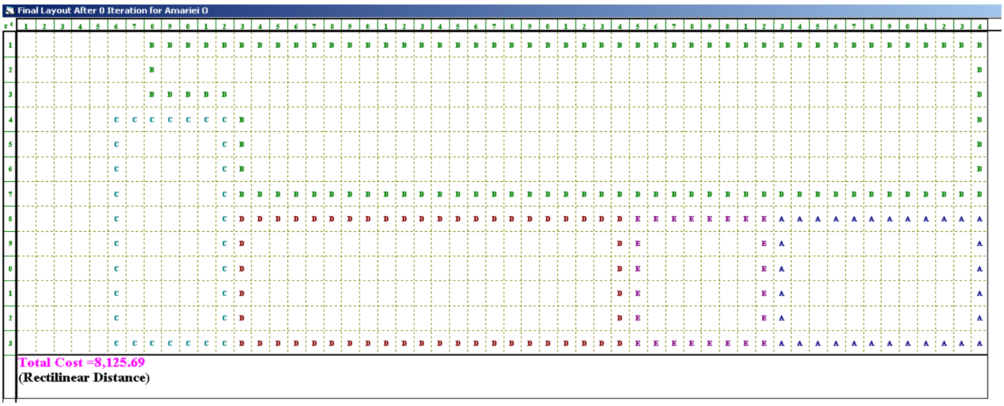

Figure 17. Adjusted location 2

5. Conclusion

The WinQSB program cannot take into account a predefined form of the units to be placed, but it allocates a certain area to them [1]. These sites generated by the program shall be harmonized with the form of the units to be located. These theoretical sites (fig.12, fig.14-15) are the basis of the final site. If C1 units with WFP and TIP are swapped, but provided that the shape of each unit is taken into account, we obtain locations with much higher objective function values (fig.16-17) than in the case of the initial location.

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