SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2020
ORGANIZATION AND MANAGEMENT SERIES NO. 142

EFFICIENCY ASSESSMENT OF THE USE OF BLOCH-SCHMIGALLA TRIANGULAR METHOD TO IMPROVE THE FUNCTIONING OF COMMERCIAL INDUSTRY ENTERPRISE

Bożena SKOTNICKA-ZASADZIEŃ[1*], Grzegorz SOWIŃSKI[2]

[1] Silesian University of Technology, Faculty of Organization and Management, Zabrze; Bozena.Skotnicka@polsl.pl, ORCID: 0000-0003-1717-304X
[2] Silesian University of Technology, Faculty of Organization and Management, Zabrze
* Correspondence author

Purpose: In order to maintain the highest possible quality of services, more and more often the enterprises make use of proven optimization methods that allow them to maintain competitiveness on the market. One of these methods is spatial placement of workstations that influences the functioning of enterprises. There are many techniques of placing workstations, depending on the business activity run by the company.
Design/methodology/approach: This article presents the use of Bloch-Schmigalla triangular method to improve the placement of office workstations in a commercial industry enterprise. The method used allowed to improve the functioning of the company by shortening the time for forwarding of all documents and information.
Findings: The use of Bloch-Schmigalla triangular method allowed for quick placement of workstations, new placement of workstations. As a result, the workstations will not be as loaded and specific tasks will be performed faster. The time saved can be used to complete other tasks. Thanks to Bloch-Schmigalla triangular method, the distances between the workstations are equal. Before, the distances between several of the workstations were greater than in the case of other ones.
Research limitations/implications: The major limitation of the paper is that it is based on one case of an. In the future, it will be necessary to conduct studies in more organizations so as to find out if the same result can be achieved.
Originality/ value: The article concerned the use of the Bloch-Schmigalli method to improve the positioning of office spaces in a commercial industry company. Until now, this method has not been used to improve the quality of work in office positions.

Keywords: Bloch-Schmigalla triangular method, quality, effectiveness, enterprise.

Category of the paper: Research paper.

1. Introduction

At the beginning of the 1950s, the methods of special of working methods begun to develop. Earlier, till the end of the 1940s, the issues of spatial work organization were discussed within the traditional research on working methods. The development of this area was initiated by W. Bloch, who published a method, according to which objects are placed on a network of equilateral triangles. This method can be used for both production processes, as well as administration and office processes.

The optimization methods, to which the Bloch-Schmigalla triangular method belongs, allow to develop a workstations placement scheme on networks of rectangles (or squares) and triangles, where the normative distances between workstations, the distance between machines and transport routes, as well as building construction elements are taken into account.

Bloch-Schmigalla triangular method is a technique developed by W. Bloch in the 1950s. In 1968, it was modified and developed by H. Schmigalla. The core of this method is a placement of working stations on a network of equilateral triangles. “This methods assumes certain simplifications:

– actual sizes of workstations are being skipped,
– distances between all pairs of neighboring objects are the same and equal to the network module,
– the placed objects must be of the same or similar size” (Stabryła, Trzcieniecki, 1986).

More and more often, this method is being called the **Bloch-Schmigalla equilateral triangular method**. It is used to optimize the present placement of workstations or to design their location in a completely new place. It is assumed, that the placement of workstations is optimal when the size of goal function, being the product of the flow rate of any factor with a distance of its movement, is minimal (Pasternak, 2005). It can be expressed with the use of the following formula: It can be expressed with the use of the following formula:

$$Q = \sum_{i=1}^{n} \sum_{j=1}^{n} S_{ij} * L_{(m)ij} \rightarrow \min \tag{1}$$

where:

Q – summary value of workstations load,
n – the number of workstations being placed,
i, j – placed objects,
$m_{(i)}$ – placement of i-th object,
$m_{(i)}$ – placement of j-th object,
S_{ij} – ij-th element of load matrix of workstations,
$L_{m(ij)}$ – the distance between to workstations where the objects “i” and “j” are placed.

The starting point for the calculation is to determine the number of all N objects and their links. The obtained matrix is transformed and the S_{ij} element is selected, that points to a pair of workstations with the strongest linkage. These workstations are placed in the center of the network. If there are several such pairs, the one with the greatest linkage with other objects must be selected. Then, the placement of other objects is decided – in order from the greatest number of linkages with objects that were already placed in the network. If the object being placed is linked with only one object, it is placed in its direct vicinity. If not – a place where the sum of links with the already placed objects is minimal is being chosen.

The correct placement of workstations with the use of Bloch-Schmigalla triangular method has the following benefits for the enterprise:

– Shortening of the production cycle and the decrease of the costs by reducing, for example, unnecessary movements.
– Facilitation of supervision and control over process due to it being harder to misplace materials.
– Easier introduction of changes to the facility functioning.
– Maximization of production volume and services rendered by the enterprise thanks to better use of resources, as well as production and service space.
– Strengthening of the sense of employee unity.
– Maintenance of the proper level of products and services quality (Muhlemann, Oakland, Lockyer, 1995, p. 180).

Placement of workstations is possible almost everywhere, both in production enterprises, as well as in commercial companies, where the employees perform their duties at desks – such an enterprise was described in this project.

This article presents the use of Bloch-Schmigalla triangular method to improve the placement of office workstations in a commercial industry enterprise.

2. Research problem analysis

In the analyzed enterprise of commercial industry, the employees perform their duties at office workstations. Due to its size and shape, the department where they work (commercial and logistic department in the Silesian voivodeship) resembles a large hall. This gives ample opportunities to organize the new placement of workstations. Currently, the desks are placed in 4 rows, 4 office workstations in each row. This is presented in Figure 1.

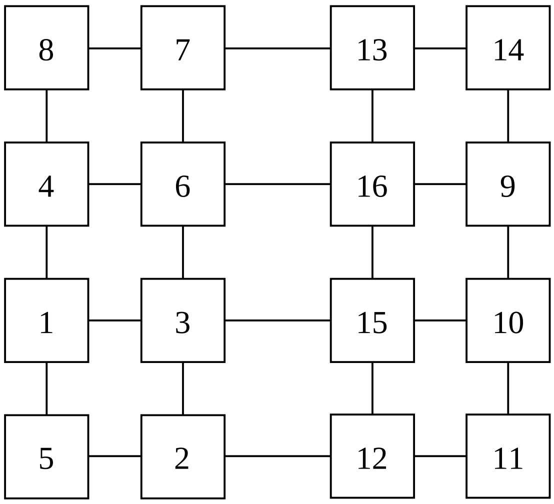

Figure 1. The current arrangement of the workstations in the commercial industry enterprise.

The current arrangement, as presented in Figure 1, may resemble the placement of workstations with the use of CORELAP method. As a result, it is possible to calculate the distance between the workstations – presented in Table 1. It is only a visual resemblance. The last personnel changes resulted in the fact that the new employees were given the free desks – not always taking into account if this will be optimal in terms of the speed of document and information flow. Additionally, the distances between the workstations are not equal. Therefore, research was started to improve the placement of workstations in the studied enterprise.

Table 1.
Distance between workstations in the current arrangement

Workstation	Scope of information flow															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	X	1.41	1	1	1	1.41	2.24	2	4.12	4	4.12	3.16	3.61	4.47	3	3.16
2		X	1	2.24	1	2	3	3.16	3.61	3.16	3	2	3.61	4.24	2.24	2.83
3			X	1.41	1.41	1	2	2.24	3.16	3	3.16	2.24	2.83	3.61	2	2.24
4				X	2	1	1.41	1	4	4.12	4.47	3.61	3.16	4.12	3.16	3
5					X	2.24	3.16	3	4.47	4.12	4	3	4.24	5	3.16	3.61
6						X	1	1.41	3	3.16	3.61	2.83	2.24	3.16	2.24	2
7							X	1	3.16	3.61	4.24	3.61	2	3	2.83	2.24
8								X	4.12	4.47	5	4.24	3	4	3.61	3.16
9									X	1	2	2.24	1.41	1	1.41	1
10										X	1	1.41	2.24	2	1	1.41
11											X	1	3.16	3	1.41	2.24
12												X	3	3.16	1	2
13													X	1	2	1
14														X	2.24	1.41
15															X	1
16																X

As it can be seen in Table 1, the distances between the workstations are non-measurable. It is an additional difficulty when calculating the goal function.

3. Research problem solution

In the analyzed enterprise, the Bloch-Schmigalla triangular method was used to solve the described problem, as it does not take into account the size of the workstations. In the studied enterprise, all desk are of the same size; additionally, having such a number of workstations, both the calculations, as well as the scheme of arranging subsequent workstations, are easier and the non-measurable values in the goal function are not present.

To begin the workstations placement, first, we need to know the scope of information and documents flow between the employees. For that purpose, for 10 subsequent days, the employees were filling in control check-list presented in Figure 2, and at the end of the day they entered the number of information flow and the number of workstations. In the research, the following persons were not included: President of the Management Board, warehouse workers and drivers, due to the performed functions.

KARTA KONTROLNA PRACOWNIKA ....

(Wpisać swój kod)

Proszę o uzupełnienie poniższej karty.
Przez najbliższych 10 dni roboczych proszę wpisywać, ile przekazał Pan/Pani dokumentów innym pracownikom każdego dnia.

	Dzień roboczy										
Kod pracownika	1	2	3	4	5	6	7	8	9	10	Razem

Dziękuję za wypełnienie i poświęcenie czasu.

Numer stanowiska: ……………

Figure 2. Employee's control check-list that the personnel was asked to fill in.

Once all control check-lists were collected and the values were calculated, the scope of documents flow was presented in Table 2.

Table 2.
Scope of information flow in the commercial industry enterprise

Workstation	Scope of information flow															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	X	55	72	107	36	0	0	0	0	0	0	0	0	0	159	104
2	33	X	61	85	48	0	0	0	0	0	0	0	0	0	82	93
3	56	23	X	73	54	0	0	0	0	0	0	0	0	0	71	47
4	135	93	96	X	27	0	0	0	0	0	0	0	0	0	63	66
5	44	60	38	15	X	0	0	0	0	0	0	0	0	0	45	57
6	0	0	0	0	0	X	65	82	0	0	0	0	0	0	81	125
7	0	0	0	0	0	53	X	76	0	0	0	0	0	0	102	88
8	0	0	0	0	0	111	92	X	0	0	0	0	0	0	55	79
9	0	0	0	0	0	0	0	0	X	97	61	117	82	108	105	88
10	0	0	0	0	0	0	0	0	69	X	89	41	128	54	72	129
11	0	0	0	0	0	0	0	0	47	68	X	33	18	79	63	68
12	0	0	0	0	0	0	0	0	80	62	38	X	57	22	51	105
13	0	0	0	0	0	0	0	0	52	103	54	37	X	46	42	74
14	0	0	0	0	0	0	0	0	88	67	52	43	28	X	36	58
15	102	94	68	83	39	81	106	56	135	101	47	62	29	54	X	77
16	127	87	62	65	38	104	121	89	73	84	51	129	73	35	71	X

Next, the values for subsequent links must be summed up.

Table 3.
Scope of information flow after summing up the values for mutual links in the commercial industry enterprise

Workstation	Scope of information flow															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	X	88	128	242	80	0	0	0	0	0	0	0	0	0	**261**	231
2		X	84	178	108	0	0	0	0	0	0	0	0	0	176	180
3			X	169	92	0	0	0	0	0	0	0	0	0	139	109
4				X	42	0	0	0	0	0	0	0	0	0	146	131
5					X	0	0	0	0	0	0	0	0	0	84	95
6						X	118	193	0	0	0	0	0	0	162	229
7							X	168	0	0	0	0	0	0	208	209
8								X	0	0	0	0	0	0	111	168
9									X	166	108	197	134	196	240	161
10										X	157	103	231	121	173	213
11											X	71	72	131	110	119
12												X	94	65	113	234
13													X	74	71	147
14														X	90	93
15															X	148
16																X

Knowing the distances between the workstations and the scope of document flows between then, on the basis of Table 1 and 3, the goal function could be calculated by summing the products of distances and flows between all workstations:

Q = 1.41*88 + 128 + 242 + 80 + 3*261 + 3.16*231 + 84 + 2.24*178 + 108 + 2.24*176 + 2.83*180 + 1.41*169 + 1.41*92 + 2*139 + 2.24*109 + 2*42 + 3.16*146 + 3*131 + 3.16*84 + 3*95 + 118 + 1.41*193 + 2.24*162 + 2*229 + 168 + 2.83*208 + 2.24*209 + 3.61*111 + 3.16*168 + 166 + 2*108 + 2.24*197 + 1.41*134 + 196 + 1.41*240 + 161 + 157 + 1.41*103 + 2.24*231 + 2*121 + 173 + 1.41*213 + 71 + 3.16*72 + 3*131 + 1.41*110 + 2.24*119 + 3*94 + 3.16*65 + 113 + 2*234 + 74 + 2*71 + 147 + 2.24*90 + 1.41*93 + 148 = **15595.7.**

As it can be seen in Table 3, the strongest linkage is between the workstations no. 1 and 15. Now a table (Table 4) can be drawn up, that allows to determine in what order the subsequent workstations are to be placed – similarly as in Tables 2 and 3.

Table 4.
Values of linkages between the workstations

Workstation	2	3	4	5	6	7	8	9	10	11	12	13	14	16
1	88	128	242	80	0	0	0	0	0	0	0	0	0	231
15	176	139	146	84	162	208	111	240	173	110	113	71	90	148
∑	264	267	**388**	164	162	208	111	240	173	110	113	71	90	379
4	178	169	---	42	0	0	0	0	0	0	0	0	0	131
∑	442	436	---	206	162	208	111	240	173	110	113	71	90	**510**
16	180	109	---	95	229	209	168	161	213	119	234	147	93	---
∑	**622**	545	---	301	391	417	279	401	386	229	347	218	183	---
2	---	84	---	108	0	0	0	0	0	0	0	0	0	---
∑	---	**629**	---	409	391	417	279	401	386	229	347	218	183	---
3	---	---	---	92	0	0	0	0	0	0	0	0	0	---
∑	---	---	---	**501**	391	417	279	401	386	229	347	218	183	---
5	---	---	---	---	0	0	0	0	0	0	0	0	0	---
∑	---	---	---	---	391	**417**	279	401	386	229	347	218	183	---
7	---	---	---	---	118	---	168	0	0	0	0	0	0	---
∑	---	---	---	---	**509**	---	447	401	386	229	347	218	183	---
6	---	---	---	---	---	---	193	0	0	0	0	0	0	---
∑	---	---	---	---	---	---	**640**	401	386	229	347	218	183	---
8	---	---	---	---	---	---	---	0	0	0	0	0	0	---
∑	---	---	---	---	---	---	---	**401**	386	229	347	218	183	---
9	---	---	---	---	---	---	---	---	166	108	197	134	196	---
∑	---	---	---	---	---	---	---	---	**552**	337	544	352	379	---
10	---	---	---	---	---	---	---	---	---	157	103	231	121	---
∑	---	---	---	---	---	---	---	---	---	494	**647**	583	500	---
12	---	---	---	---	---	---	---	---	---	71	---	94	65	---
∑	---	---	---	---	---	---	---	---	---	565	---	**677**	565	---
13	---	---	---	---	---	---	---	---	---	72	---	---	74	---
∑	---	---	---	---	---	---	---	---	---	637	---	---	**639**	---
14	---	---	---	---	---	---	---	---	---	79	---	---	---	---
∑	---	---	---	---	---	---	---	---	---	**716**	---	---	---	---

In accordance with table 4, the workstations should be placed as follows: 1, 15, 4, 16, 2, 3, 5, 7, 6, 8, 9, 10, 12, 13, 14, 11.

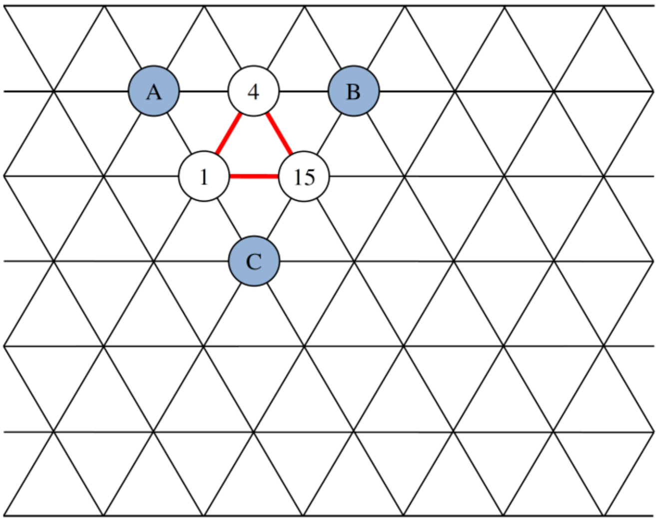

Figure 3. Placement of workstations no. 1, 15 and 4 on the equilateral triangles network and possible placement of workstation 16.

After placing the first three workstations no. 1, 15 and 4, the goal function value in accordance with formula (1) equals: **Q = 261 + 388 = 649.**

Table 5.
Scope of flows of workstation no. 16, as compared with other workstations

	Amount of work		
Workstation	**A**	**B**	**C**
Node			
1	231	462	231
15	296	148	148
4	131	131	262
Total	658	741	**641**

In line with Table 5, the next workstation, that is no. 16, will be placed in point C.

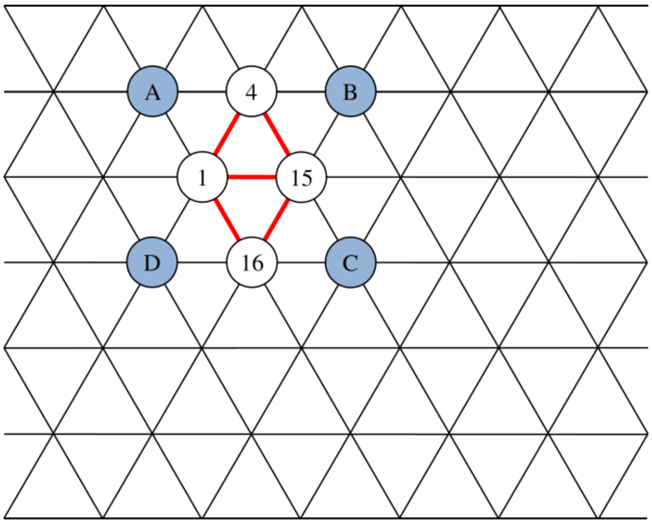

Figure 4. Placement of workstation no. 16 on the equilateral triangles network and possible placement of workstation no. 2.

Once the workstation no. 16 has been placed in the vicinity of workstations no. 1 and 15, the goal function equals: **Q = 649 + 641 = 1290.**

Table 6.
Scope of flows of workstation no. 2, as compared with other workstations

	Amount of work			
Workstation	**A**	**B**	**C**	**D**
Node				
1	88	176	176	88
15	352	176	176	352
4	178	178	356	356
16	360	360	180	180
Total	978	890	**888**	976

In line with Table 6, the next workstation, that is no. 2, will be placed in point C.

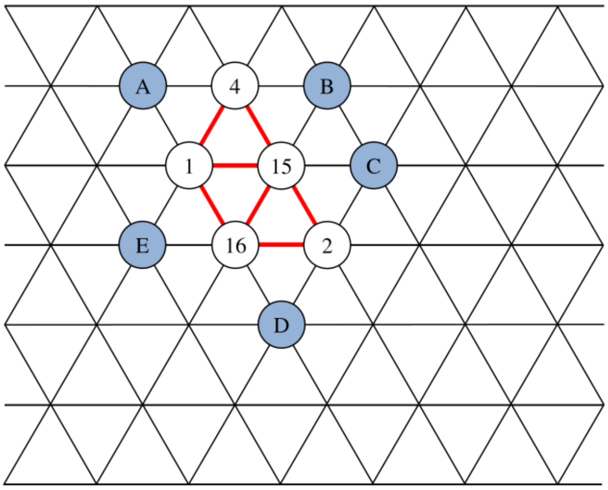

Figure 5. Placement of workstation no. 2 on the equilateral triangles network and possible placement of workstation no. 3.

Once the workstation no. 2 has been placed in the vicinity of workstations no. 15 and 16, the goal function equals: **Q = 1290 + 888 = 2178.**

Table 7.
Scope of flows of workstation no. 3, as compared with other workstations

	Amount of work				
Workstation	**A**	**B**	**C**	**D**	**E**
Node					
1	128	256	256	256	256
15	278	139	139	278	278
4	169	169	338	507	507
16	218	218	218	109	109
2	252	168	84	84	168
Total	1045	**950**	1035	1234	1318

In line with Table 7, the next workstation, that is no. 3, will be placed in point B.

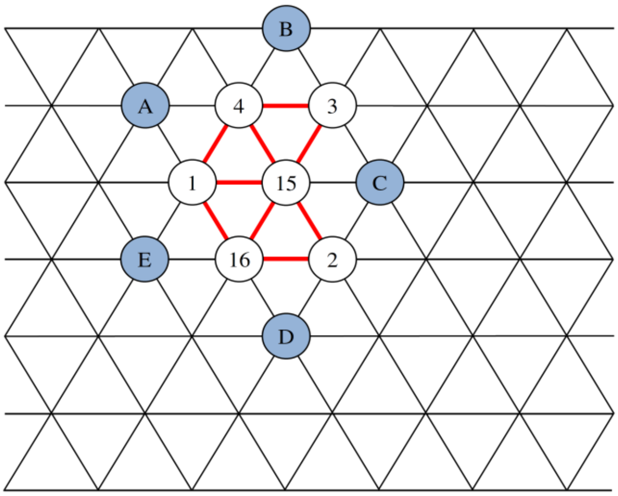

Figure 6. Placement of workstation no. 3 on the equilateral triangles network and possible placement of workstation no. 5.

Once the workstation no. 3 has been placed in the vicinity of workstations no. 4 and 15, the goal function equals: **Q = 2178 + 950 = 3128.**

Table 8.
Scope of flows of workstation no. 5, as compared with other workstations

	Amount of work				
Workstation	**A**	**B**	**C**	**D**	**E**
Node					
1	80	160	160	160	80
15	168	168	84	168	168
4	42	42	84	126	84
16	190	285	190	95	95
2	324	324	108	108	216
3	184	92	92	276	276
Total	988	1071	**718**	933	919

In line with Table 8, the next workstation, that is no. 5, will be placed in point C.

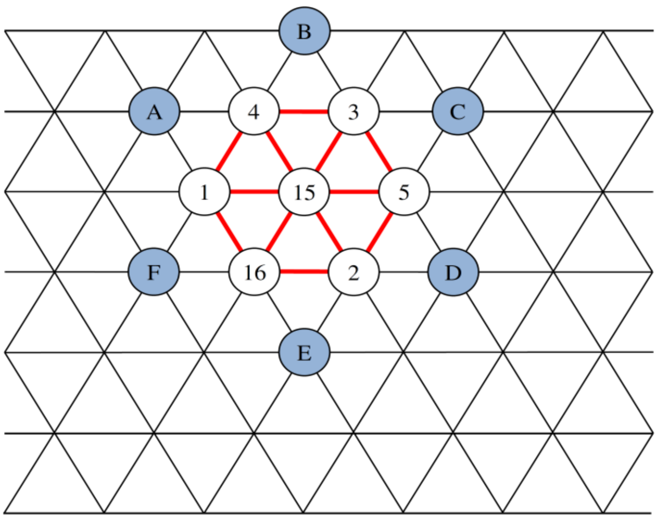

Figure 7. Placement of workstation no. 5 on the equilateral triangles network and possible placement of workstation no. 7.

Once the workstation no. 5 has been placed in the vicinity of workstations no. 2.3 and 15, the goal function equals: **Q = 3128 + 718 = 3846.**

Table 9.
Scope of flows of workstation no. 7, as compared with other workstations

	Amount of work					
Workstation	**A**	**B**	**C**	**D**	**E**	**F**
Node						
1	0	0	0	0	0	0
15	416	416	416	416	416	416
4	0	0	0	0	0	0
16	418	627	627	418	209	209
2	0	0	0	0	0	0
3	0	0	0	0	0	0
5	0	0	0	0	0	0
Total	834	1043	1043	834	**625**	**625**

In line with table 9, the subsequent workstation no. 7 can be placed in point E or F. In line with the rule described in an example in chapter 1.2.1, it can be any point. Therefore, point F is being chosen.

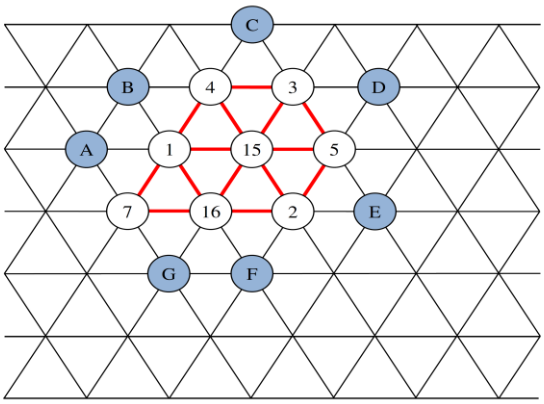

Figure 8. Placement of workstation no. 7 on the equilateral triangles network and possible placement of workstation no. 6.

Once the workstation no. 7 has been placed in the vicinity of workstations no. 1 and 16, the goal function equals: **Q = 3846 + 625 = 4471.**

Table 10.
Scope of flows of workstation no. 6, as compared with other workstations

	Amount of work						
Workstation	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Node							
1	0	0	0	0	0	0	0
15	324	324	324	324	324	324	324
4	0	0	0	0	0	0	0
16	458	458	687	687	458	229	229
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
7	118	236	354	472	354	236	118
Total	900	1018	1365	1483	1136	789	**671**

In line with Table 10, the next workstation, that is no. 6, will be placed in point G.

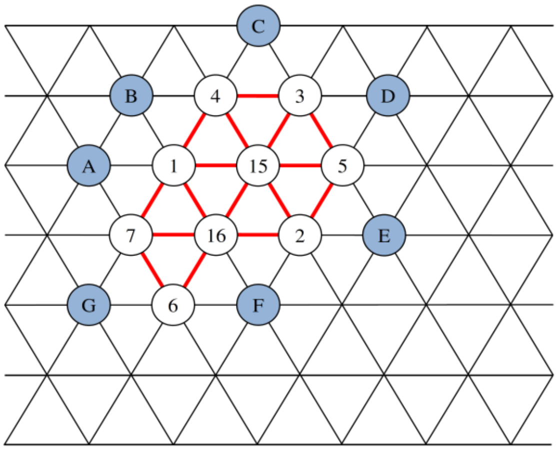

Figure 9. Placement of workstation no. 6 on the equilateral triangles network and possible placement of workstation no. 8.

Once the workstation no. 6 has been placed in the vicinity of workstations no. 7 and 16, the goal function equals: **Q = 4471 + 671 = 5142.**

Table 10.
Scope of flows of workstation no. 8, as compared with other workstations

	Amount of work						
Workstation	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Node							
1	0	0	0	0	0	0	0
15	222	222	222	222	222	222	333
4	0	0	0	0	0	0	0
16	336	336	504	504	336	168	336
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
7	168	336	504	672	504	336	168
6	386	579	772	772	579	193	193
Total	1112	1473	2002	2170	1641	**919**	1030

In line with Table 10, the next workstation, that is no. 6, will be placed in point G.

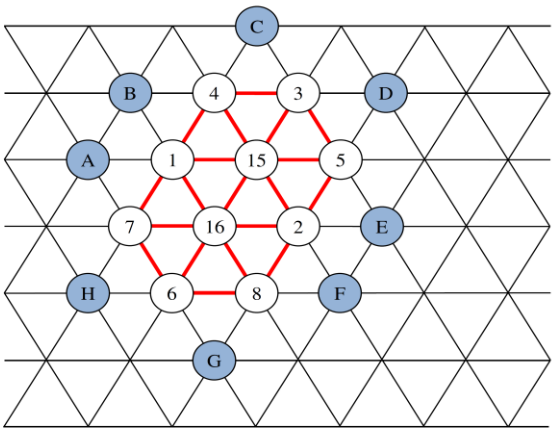

Figure 10. Placement of workstation no. 8 on the equilateral triangles network and possible placement of workstation no. 9.

Once the workstation no. 8 has been placed in the vicinity of workstations no. 2, 6 and 16, the goal function equals: **Q = 5142 + 919 = 6061.**

Table 11.
Scope of flows of workstation no. 9, as compared with other workstations

	Amount of work							
Workstation	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Node								
1	0	0	0	0	0	0	0	0
15	480	480	480	480	480	480	720	720
4	0	0	0	0	0	0	0	0
16	322	322	483	483	322	322	322	322
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
Total	**802**	**802**	963	963	**802**	**802**	1042	1042

In line with Table 11, the next workstation, that is no. 9, can be placed in points A, B, E, F. Point F is being chosen.

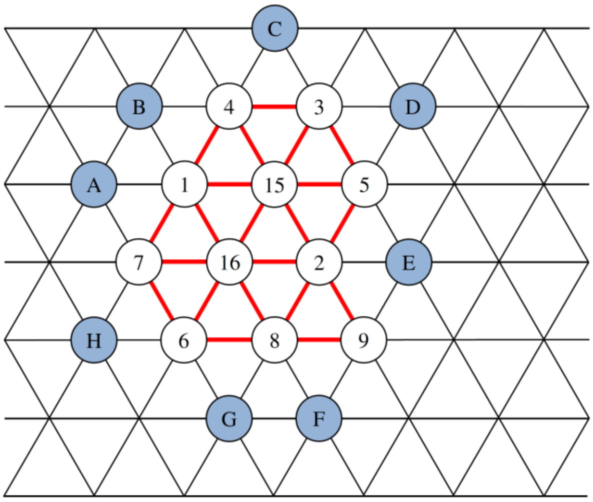

Figure 11. Placement of workstation no. 9 on the equilateral triangles network and possible placement of workstation no. 10.

Once the workstation no. 9 was placed in the vicinity of workstations no. 2 and 8, the goal function equals: **Q = 6061 + 802 = 6863.**

Table 12.
Scope of flows of workstation no. 10, as compared with other workstations

	Amount of work							
Workstation	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Node								
1	0	0	0	0	0	0	0	0
15	346	346	346	346	346	519	519	519
4	0	0	0	0	0	0	0	0
16	426	426	639	639	426	426	426	426

Cont. table 12.

2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	664	664	664	498	166	166	332	498
Total	1436	1436	1649	1483	**938**	1111	1277	1443

In line with Table 12, the next workstation, that is no. 10, will be placed in point E.

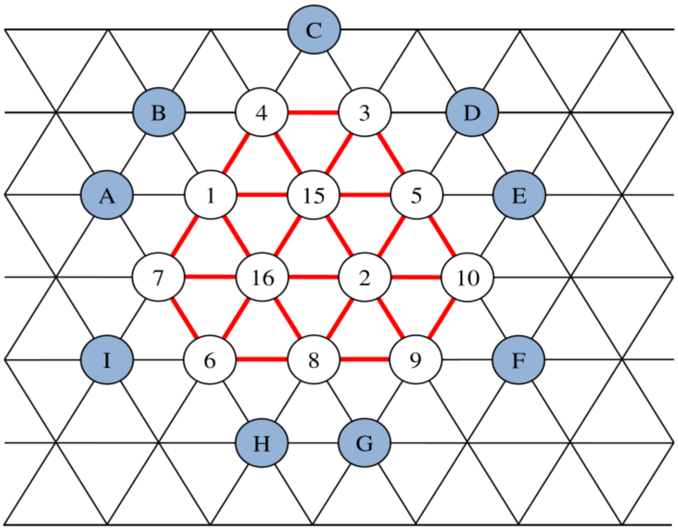

Figure 12. Placement of workstation no. 10 on the equilateral triangles network and possible placement of workstation no. 12.

Once the workstation no. 10 has been placed in the vicinity of workstations no. 2, 5 and 9, the goal function equals: **Q = 6863 + 938 = 7801.**

Table 13.
Scope of flows of workstation no. 12, as compared with other workstations

	Amount of work								
Workstation	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Node									
1	0	0	0	0	0	0	0	0	0
15	226	226	226	226	226	339	339	339	339
4	0	0	0	0	0	0	0	0	0
16	468	468	702	702	702	702	468	468	468
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	788	788	788	591	394	197	197	394	591
10	412	412	309	206	103	103	206	309	412
Total	1894	1894	2025	1725	1425	1341	**1210**	1510	1810

In line with Table 13, the next workstation, that is no. 12, will be placed in point G.

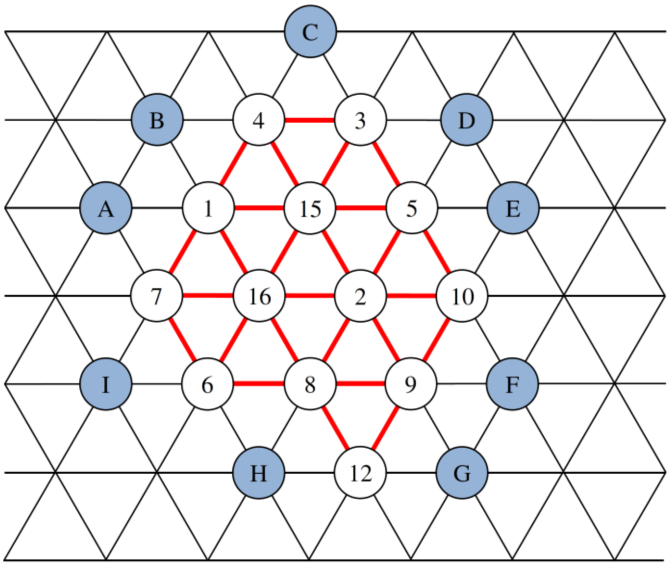

Figure 13. Placement of workstation no. 12 on the equilateral triangles network and possible placement of workstation no. 13.

Once the workstation no. 12 has been placed in the vicinity of workstations no. 8 and 9, the goal function equals: **Q = 7801 + 1210 = 9011.**

Table 14.
Scope of flows of workstation no. 13, as compared with other workstations

	Amount of work								
Workstation	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Node									
1	0	0	0	0	0	0	0	0	0
15	142	142	142	142	142	213	213	213	213
4	0	0	0	0	0	0	0	0	0
16	294	294	441	441	441	441	441	294	294
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	536	536	536	402	268	134	134	268	402
10	924	924	693	462	231	231	462	693	924
12	376	376	470	376	282	188	94	94	282
Total	2272	2272	2282	1823	1364	**1207**	1344	1562	2115

In line with Table 14, the next workstation, that is no. 13, will be placed in point F.

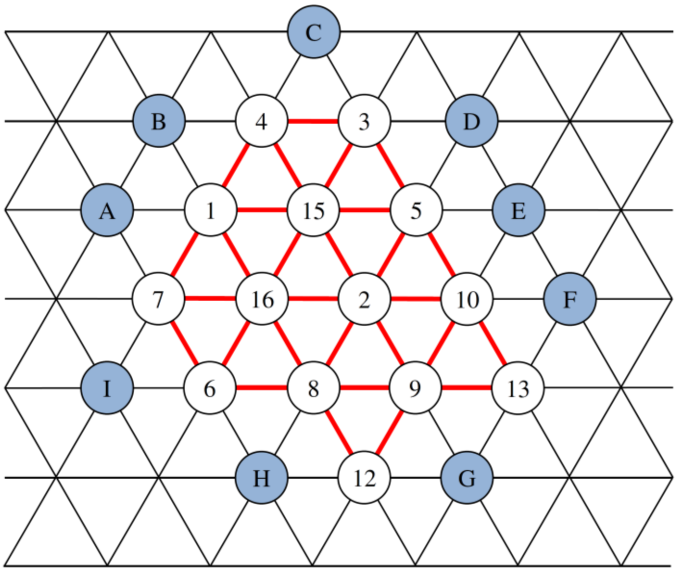

Figure 14. Placement of workstation no. 13 on the equilateral triangles network and possible placement of workstation no. 14.

Once the workstation no. 13 has been placed in the vicinity of workstations no. 9 and 10, the goal function equals: **Q = 9011 + 1207 = 10218.**

Table 15.
Scope of flows of workstation no. 14, as compared with other workstations

	Amount of work								
Workstation	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Node									
1	0	0	0	0	0	0	0	0	0
15	180	180	180	180	180	270	270	270	270
4	0	0	0	0	0	0	0	0	0
16	186	186	279	279	279	279	279	186	186
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	784	784	784	588	392	392	196	392	588
10	484	484	363	242	121	121	242	363	484
12	260	260	325	260	195	195	65	65	195
13	370	370	296	222	148	74	74	222	296
Total	2264	2264	2227	1771	1315	1331	**1126**	1498	2019

In line with Table 15, the next workstation, that is no. 14, will be placed in point G.

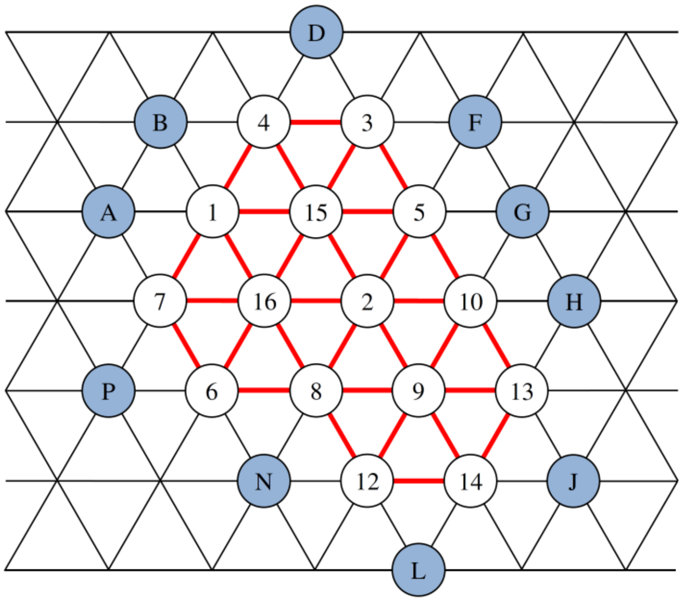

Figure 15. Placement of workstation no. 14 on the equilateral triangles network and possible placement of workstation no. 11.

Once the workstation no. 14 has been placed in the vicinity of workstations no. 9, 12 and 13, the goal function equals: **Q = 10218 + 1126 = 11344.**

Table 16.
Scope of flows of workstation no. 11, as compared with other workstations

	Amount of work									
Workstation	**A**	**B**	**D**	**F**	**G**	**H**	**J**	**L**	**N**	**P**
Node										
1	0	0	0	0	0	0	0	0	0	0
15	220	220	220	220	220	330	440	440	330	330
4	0	0	0	0	0	0	0	0	0	0
16	238	238	357	357	357	357	476	357	238	238
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0
9	432	432	432	324	216	216	216	216	216	324
10	628	628	471	314	157	157	314	471	471	628
12	284	284	355	284	213	213	142	71	71	213
13	360	360	288	216	144	72	72	144	216	288
14	655	655	655	524	393	262	131	131	262	524
Total	2817	2817	2778	2239	1700	**1607**	1791	1830	1804	2545

In line with Table 16, the next workstation, that is no. 11, will be placed in point H.

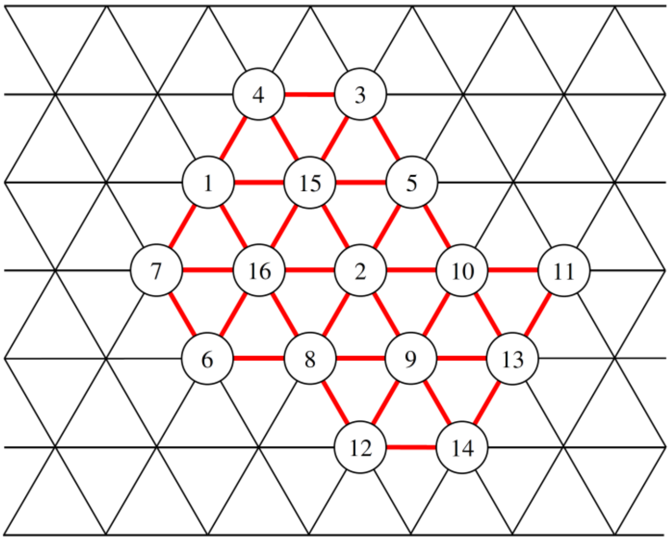

Figure 16. The final arrangement of the workstations in the commercial industry enterprise with the use of Bloch-Schmigalla triangular method.

Once all workstations were placed on the equilateral triangles network in line with Bloch-Schmigalla triangular method, the goal function equals: **Q = 11344 + 1607 = 12951.**

The goal function value, once all workstations were placed in line with Bloch-Schmigalla triangular method, decreased by 2,644.7 units, as compared with the original placement of workstations.

4. Conclusions

On the basis of the analysis carried out, with the use of Bloch-Schmigalla triangular method, the following results can be presented:

- The use of Bloch–Schmigalla triangular method allowed for quick placement of workstations.
- New placement of workstations decreased the value of goal function by 2,644.7 units. As a result, the workstations will not be as loaded and specific tasks will be performed faster. The time saved can be used to complete other tasks.
- Thanks to Bloch-Schmigalla triangular method, the distances between the workstations are equal. Before, the distances between several of the workstations were greater than in the case of other ones.
- Bloch-Schmigalla triangular method can present several possible solutions. In this case, workstations 7 and 9 have more than one possible placement. As a result, the final placement of workstations can differ slightly from the one presented, but the value of goal function will still be the same.
- The new arrangement allows for easy and quick placement of a potential new workstation in the vicinity of the other ones.

Acknowledgements

This paper was financed from the resources of the Silesian University of Technology, project no. BK-235/ROZ-1/2020 (13/010/BK_20/0042).

References

1. Bieniok, H. et al. (2004). *Metody sprawnego zarządzania. Planowanie, organizowanie, motywowanie, kontrola*. Warszawa: Ploacet, p. 60.
2. Korzeń, Z. (1999). *Logistyczne systemy transportu bliskiego i magazynowania, Projektowanie, Modelowanie, Zarządzanie. T. II*. Poznań: Instytut Logistyki i Magazynowania, p. 47.
3. Lis, S., and Santarek, K. (1980). *Projektowanie Rozmieszczenia Stanowisk Roboczych*. Warszawa: PWN, pp. 130-131, 138-139.
4. Martyniak, Z. (1999). *Metody organizacji i zarządzania*. Kraków: Wydawnictwo Akademii Ekonomicznej, pp. 122-123.
5. Matusek, M. (2012). Doskonalenie przepływu materiałów w U-kształtnej linii montażu. *Zeszyty Naukowe Politechniki Śląskiej, seria: Organizacja i Zarządzanie, 60*, p. 193.
6. Mikołajczyk, Z. (1995). *Techniki organizatorskie w rozwiązywaniu problemów zarządzania*. Warszawa: PWN, pp. 289-290.
7. Muhlemann, A.P., Oakland, J.S., and Lockyer, K.G. (1995). *Zarządzanie. Produkcja i Usługi*. Warszawa: PWN, p. 180.
8. Pająk, E., Klimkiewicz, M., and Kosieradzka, A. (2014). *Zarządzanie produkcją i usługami*. Warszawa: PWE, p. 140.
9. Pasternak, K. (2005). *Zarys zarządzania produkcją*. Warszawa: PWE, pp. 147-148, 156.
10. Stabryła, A., and Trzcieniecki, J. (Eds.) (1986). *Organizacja i zarządzanie. Zarys problematyki*. Kraków: Akademia Ekonomiczna, pp. 376-377, 384-385, 390, 392.
11. Strojek-Filus, M., Krynke, M., and Zasadzień, M. (2018). *Wybrane aspekty funkcjonowania przedsiębiorstwa – koszty, konkurencyjność, jakość*. Gliwice: Wydawnictwo P.A. NOVA.
12. Wolniak, R., Skotnicka-Zasadzień, B., and Gembalska-Kwiecień, A. (2018). *Identification of bottlenecks and analysis of the state before applying lean management*. 12th International Conference Quality Production Improvement – QPI 2018, Zaborze near Myszków, Poland, June 18-20, 2018 [online]. R. Ulewicz, and B. Hadzima (eds.). Les Ulis: EDP Sciences, (pdf file), art. 01001, pp. 1-6.

13. Zasadzień, M., Wolniak, R., and Skotnicka-Zasadzień, B. (2017). Doskonalenie procesu produkcji worków foliowych przy wykorzystaniu wybranych metod i narzędzi inżynierii jakości. In: B. Skotnicka-Zasadzień (Ed.), *Systemy. Wspomagania. Inżynierii. Produkcji. Sposoby i środki doskonalenia produktów i usług na wybranych przykładach*, *6(8)*, pp. 37-48.
14. Zielecki, W., and Sęp, J. (2014). *Wspomaganie projektowania linii produkcyjnych U-kształtnych metodą programowania sieciowego*. Opole: Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, pp. 682-683.
15. Zimniewicz, K. (2009). *Współczesne Koncepcje i Metody Zarządzania*. Warszawa: PWE, pp. 65-66.