

An integrated approach for facilities planning by ELECTRE method

E M Y Elbishari¹, M H F Al Hazza¹, E Y T Adesta¹, Nur Salihah Binti Abdul Rahman¹

¹Department of Manufacturing and Materials Engineering, International Islamic University Malaysia (IIUM), Jalan Gombak, 53100 Kuala Lumpur, Malaysia

Email: mauataz@iium.edu.my

Abstract. Facility planning is concerned with the design, layout, and accommodation of people, machines and activities of a system. Most of the researchers try to investigate the production area layout and the related facilities. However, few of them try to investigate the relationship between the production space and its relationship with service departments. The aim of this research is to integrate different approaches in order to evaluate, analyse and select the best facilities planning method that able to explain the relationship between the production area and other supporting departments and its effect on human efforts. To achieve the objective of this research two different approaches have been integrated: Apple's layout procedure as one of the effective tools in planning factories, ELECTRE method as one of the Multi Criteria Decision Making methods (MCDM) to minimize the risk of getting poor facilities planning. Dalia industries have been selected as a case study to implement our integration the factory have been divided two main different area: the whole facility (layout A), and the manufacturing area (layout B). This article will be concerned with the manufacturing area layout (Layout B). After analysing the data gathered, the manufacturing area was divided into 10 activities. There are five factors that the alternative were compared upon which are: Inter department satisfactory level, total distance travelled for workers, total distance travelled for the product, total time travelled for the workers, and total time travelled for the product. Three different layout alternatives have been developed in addition to the original layouts. Apple's layout procedure was used to study and evaluate the different alternatives layouts, the study and evaluation of the layouts was done by calculating scores for each of the factors. After obtaining the scores from evaluating the layouts, ELECTRE method was used to compare the proposed alternatives with each other and with the existing layout; ELECTRE compares the alternatives based on their concordance and discordance indices. The alternatives were ranked from best to worst where regarding to the layouts concerned with the manufacturing area B.4 is the best alternative.

1. Introduction

In today's modern age, technology made the process of developing new products from the initial stages of designing until the final stages of assembly more efficient. This paved the way for personalized, custom products to satisfy the various demands. In order to remain competitive, firms had to increase the variety while maintaining high volume to meet the changing demands of the markets. A facility layout problem (FLP) usually compromises with the placing of machines,



departments, transportation flow in a layout area objective to maximize the production rate of the system. The majority of the FLP use flow relationship between machines to reduce the material handling costs and increasing the machines utilization. According to Tompkins [1], material handling costs can account for 20–30% of total production costs. A FLP can be defined as one which aims to place the resources or departments in optimal locations which are essential for running a successful production system within the available space. The relationship between the facility layout in production area have been analysed by different researchers [2-5]. Many of them used the artificial intelligent methods such as genetic algorithm [6-7], simulation annealing method [8-9], and others used particle swarm [11-12]. However, very few researchers tried to investigate and analyse the effect of service and supporting departments on the work efficiency and the human efforts. Maximizing the efficiency of the factory layout usually is evaluated by the material handling system and the human efforts to have a smooth flow of the raw material, work in progress and final products and the needs of the human and manpower. This will increase the cost dependency on the distances between the different locations of machines, cells and other departments in the manufacturing systems. Therefore, the most used factor in facility layout design is the flow–distance metric based on weighted average between the material transferred and the distance travelled. However, material handling process for materials such as the raw material, semi-finished products and final products are affected directly by many factors such as manufacturing flexibility, work force capacity, lead-time, handling cost and efficiency of material flow. Therefore, facility layout design based on the flow–distance is insufficient. Selecting of the handling method and equipment based on factory layout during the design phase of the manufacturing system is one of the main complicated tasks that may affect the production rate and shortening the time to market of the products.

2. Methodology

To achieve the goal of this article a ELECTRE method [13] as one of multi criteria decision-making (MCDM) approach have been used to compare a number of alternatives for manufacturing facility layout. ELECTRE has supported by using apple's procedure [14]. In this research, apple's procedure has been customised to fit with the requirement of the case study: Dalia Industries, the steps of apple's procedure are shown in figure 1.

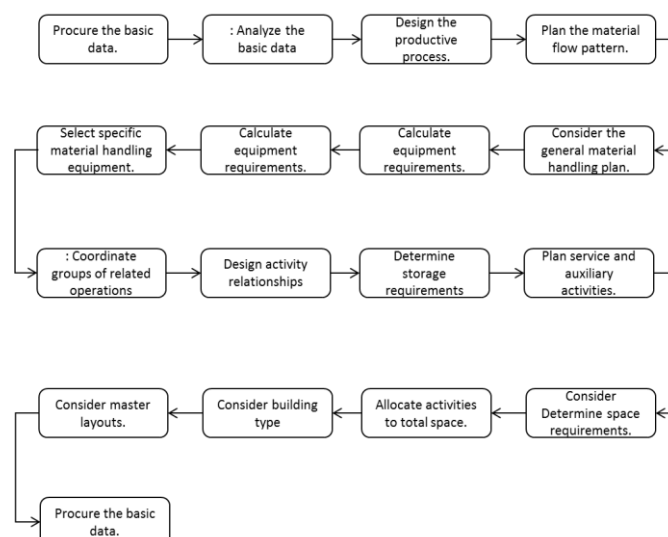


Figure 1. Apple's layout procedure steps

ELECTRE is a method for multi criteria decision making which was developed in France. ELECTRE is an acronym for elimination and choice translating algorithm. Given a set of alternatives on K objectives, this algorithm seeks to reduce the size of the non-dominated set. The k objectives all

have a set of weights that is determined by the decision maker. The fundamental idea of the ELECTRE technique is that alternatives can be eliminated which are dominated by other alternatives to a specified degree. There are two indices used in this method to determine advantages and disadvantages of one alternative to the other ones, which are:

1. Concordance index: This measures relative advantages.
2. Discordance index: This measures relative disadvantages.

Figure 2 shows the steps that are followed to complete the ELECTRE method and obtain the ranking result which is the goal of using this multi criteria decision making method. [15]

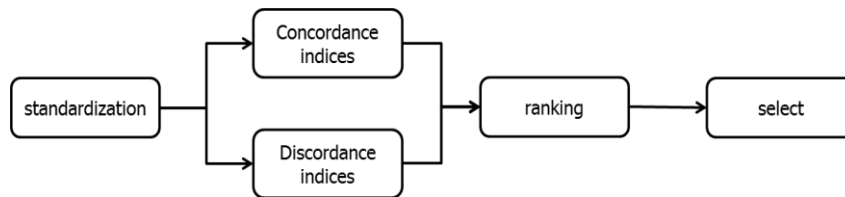


Figure 2. ELECTRE method steps

3. Results and Discussion

This section presents the results achieved from the integration of apples procedure and ELECTRE method. From data collected in Dalia industry the facility was divided into two layouts the first layout is considered with the whole facility which include management offices and utilities and the rest of the departments in Dalia Industries, this layout will be known as “Layout A”, the second layout is considered with the manufacturing area itself and the utilities considered in manufacturing and fabricating the product and is labelled as “Layout B”. The layouts for the facility will be known as “Layout A”, and the manufacturing area layout will be known as “Layout B” with “B.1” being the original layout and “Layout B.2,B.3,B.4” will be the alternative layouts. Layouts A.1 and B.1 are shown in figure 3.

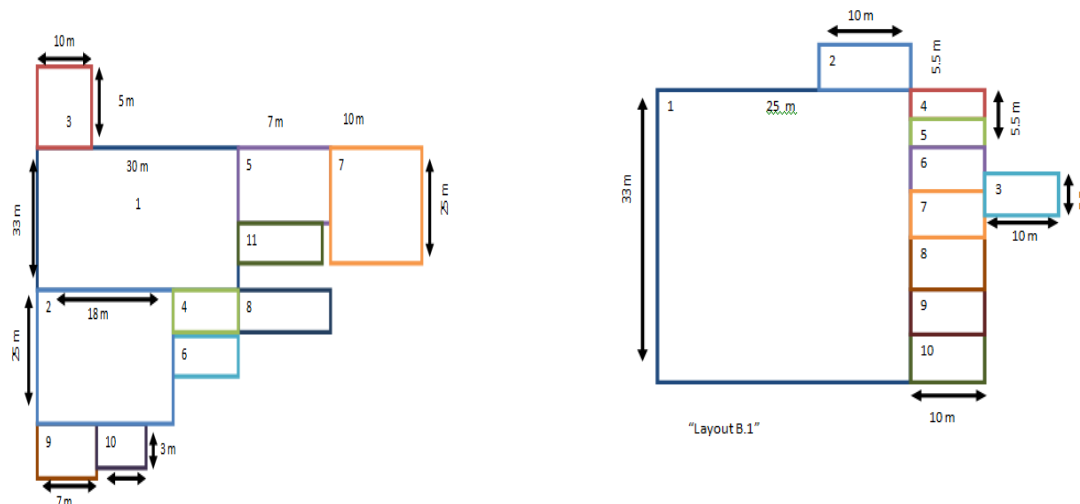


Figure 3. Original Layouts

Figure 4 presents the alternatives for the manufacturing area layout the figure shows there alternative layouts B.2, B.3, and B.4.

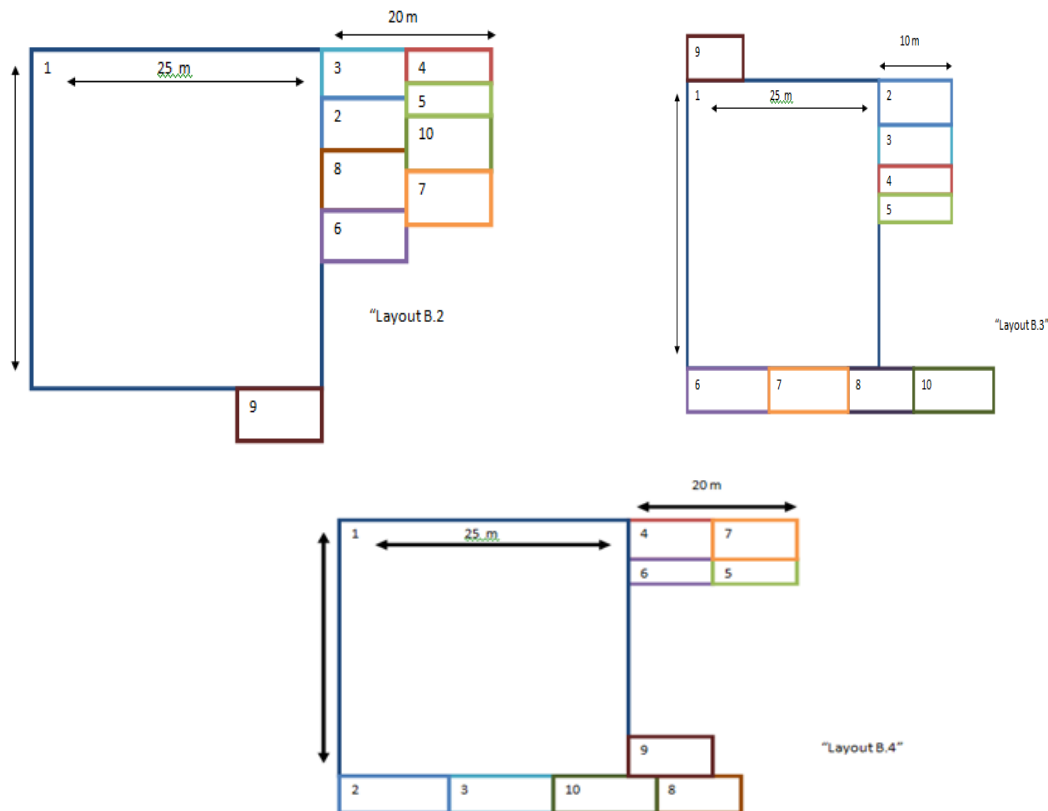


Figure 4. Alternative Layouts

Steps of the apples procedure will be inducted to analyze existing layouts and there produced alternatives. The evaluation of the alternative layouts will be compared based on each of the criteria's which are (Inter department satisfactory level, distance and time travelled for both the product and the workers), the result of these chapters will then be used as inputs ELECTRE method which will be used to compare the alternatives factoring in all the criteria's and coming up with a hierarchy evaluating the alternatives. Finally, a simulation have been conducted using delmia quest software to analyses the production rate and utilization for the manufacturing processes. Layouts were compared based on a number of factors starting with the inter department satisfactory level, which in it the layouts design were evaluated and checked for how many of the important relations were satisfied which are (A relations, and E relations), and checked if any of the undesirable relations (X relations) were found in the layouts. Table 1 summarizes the score of each layout in the Inter department relation satisfactory Level factor.

Table 1. Score for each layout in the inter department satisfactory level "Layout B"

	B.1	B.2	B.3	B.4
A Relations	9	9	6	6
E Relations	3	7	5	5
X Relations	-2	0	-2	0
Score	10	16	9	11

The second factor is the total distance travelled for the workers, this was checked by calculating a specified route travelled by workers, and since the layouts are different but conclude the same

departments the total distance could be calculated for each layout. Table 2 summarizes the score of each layout in the distance traveled for workers.

Table 2. Score of each layout in distance traveled for workers “Layout B”

Layout	B.1	B.2	B.3	B.4
Score	133.5 m	145 m	172 m	163.5 m

The next factor was total time travelled for workers, which used the total distance travelled and divided by the average worker speed to conclude the time travelled by workers in each layout. Table 3 summarizes the score of each layout in the time traveled for workers.

Table 3. Score of each layout in time traveled for workers “Layout B”

Layout	B.1	B.2	B.3	B.4
Score	47.7 sec	51.8 sec	61.4 sec	58.4 sec

The forth factor was the total distance travelled for the product this was checked by calculating a specified route that the product travels in, and since the layouts are different but conclude the same departments the total distance could be calculated for each layout. Table 4 summarizes the score of each layout in the distance travelled for product.

Table 4. Score of each layout in distance traveled for the product “Layout B”

Layout	B.1	B.2	B.3	B.4
Score	140 m	140 m	135 m	100 m

The final factor considered was total time travelled for the product, which used the total distance travelled and divided by the average product transfer speed to conclude the time travelled by the product in each layout. Table 5 summarizes the score of each layout in the time traveled for product

Table 5. Score of each layout in time traveled for the product

Layout	B.1	B.2	B.3	B.4
Score	84 sec	84 sec	81 sec	60 sec

After comparing between them based on each criteria we will proceed with the multi-criteria decision making tool that was chosen which is ELECTRE I. Table 6 shows the score of each layout based on each score.

Table 6. Summarized scores for the manufacturing area layouts “Layout B”

Layout	Inter department relation satisfactory Level	Distance traveled “Product”	Time traveled “Product”	Distance traveled “Workers”	Time traveled “Workers”
B.1	11	133.5	47.7	140	84
B.2	16	145	51.8	140	84
B.3	9	172	61.4	135	81
B.4	11	163.5	58.4	100	60

From table 6, it can be conclude the best layout based on each of the factors, in regards for the first factory, which is, inter department satisfactory level layout B.2. The layout obtained the highest score, for the total distance traveled and total time traveled for the workers layout B.1 has the lowest measurements which indicates it is the best layout based on those two factors. Finally, for the total distance and total time traveled for the workers layout B.2 obtained the lowest measurement, which indicates it has the best score in these two factors.

The standardized scores for the manufacturing area layout B is concluded in table 7.

Table 7. Standardized scores for the manufacturing area layouts “Layout B”

Layout	S1	S2	S3	S4	S5
B.1	0.43	1	1	0	0
B.2	1	0.3	0.3	0.5	0.5
B.3	0	0	0	0.875	0.875
B.4	0.29	0.78	0.78	1	1

Figure 5 compares between the different standardized scores as bar chart for the manufacturing area facility layouts “Layout B

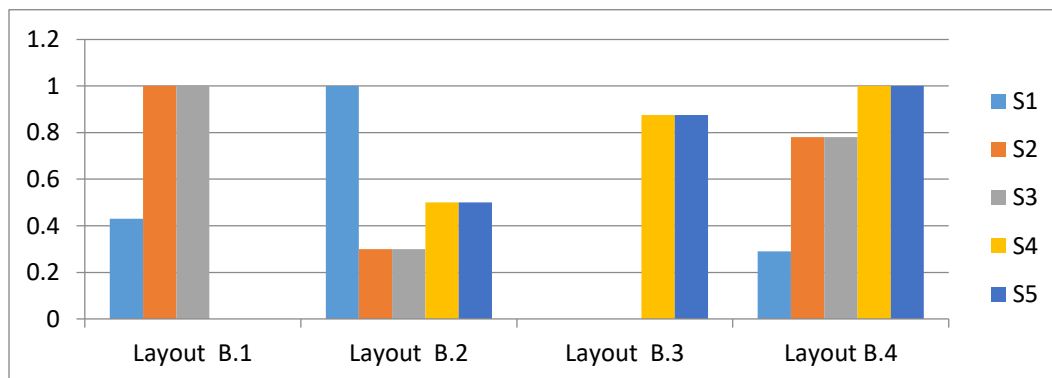


Figure 5. Bar chart for the manufacturing area facility layouts “Layout B”

After standardizing the numbers to a range between 0-1 you proceed to determine the concordance and discordance indices [16] by following the equation (1) and equation (2), respectively:

$$\text{Concordance index } C(A,B) = \frac{\sum (W= + .5 W-) / \sum (W= + W+ W-)}{\quad} \quad (1)$$

$$\text{Discordance index } D(A,B) = \text{Max } \{ [ZB_k - ZA_t] / [Z''_k - Z-k] \} \quad (2)$$

Table 8 and 9 show the concordance and discordance indices for both layouts layout A, and layout B.

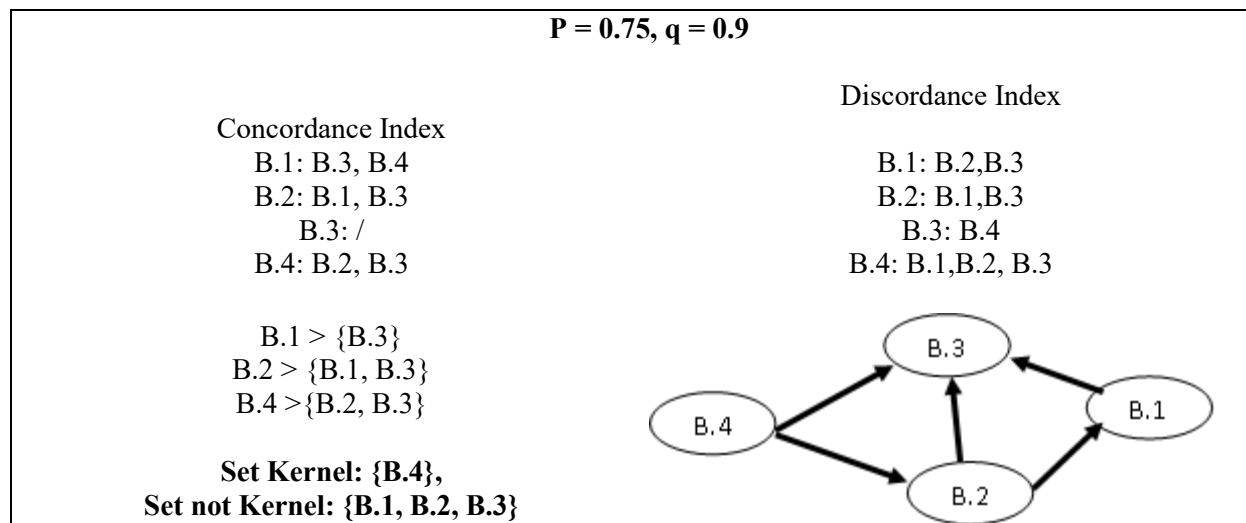
Table 8. Concordance indices for the manufacturing area layouts “Layout B”

C	B.1	B.2	B.3	B.4
B.1	-	0.4	0.6	0.6
B.2	0.6	-	0.6	0.2
B.3	0.4	0.4	-	0
B.4	0.4	0.8	1	-

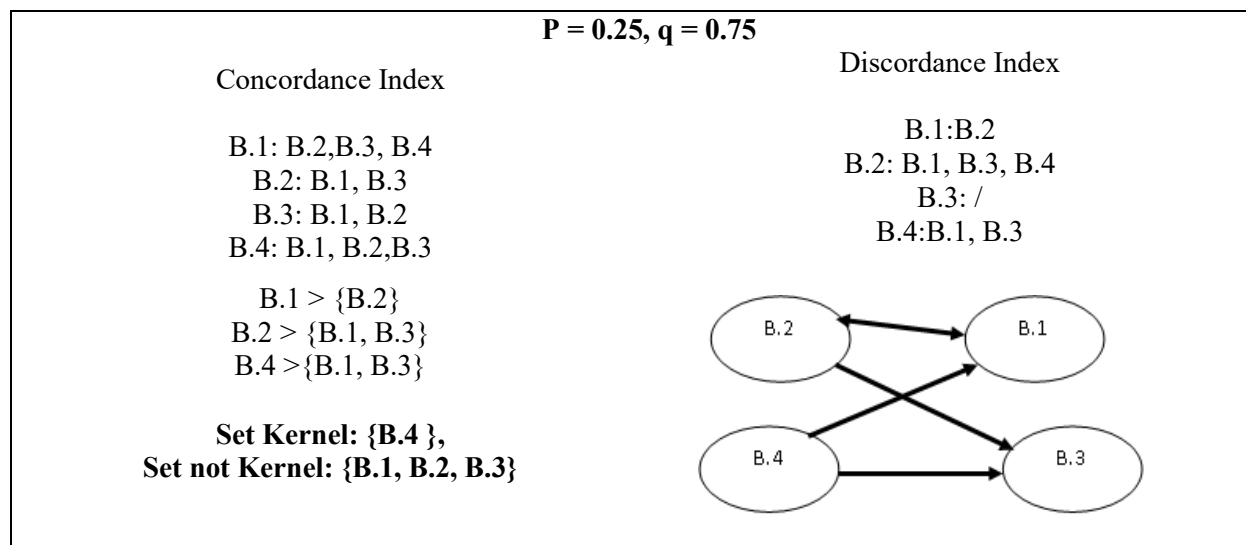
Table 9. Discordance indices for the manufacturing area layouts “Layout B”

D	B.1	B.2	B.3	B.4
B.1	-	0.57	0.875	1
B.2	0.7	-	0.375	0.5
B.3	1	1	-	0.78
B.4	0.22	0.71	0	-

For “p” and “q” the values which have been used are as follows (0.25, 0.75, 0.9). In the drawing the arrows go from the layout that is the dominant to the dominated layout.

**Figure 6.** Concordance Index, Discordance Index for p = 0.75 and q = 0.9

As shown in figure 6 above, we can see that layout B.1 dominates layout B.3 while B.2 dominates layouts B.1 and B.3, and B.4 dominates B.2 and B.3.

**Figure 7.** Concordance Index, Discordance Index for P = 0.25, q = 0.75

As shown in figure 7 above, we can see that layout B.1 dominates B.2 while B.2 itself dominates layouts B.1 and B.3, and B.4 dominates B.1 and B.3.

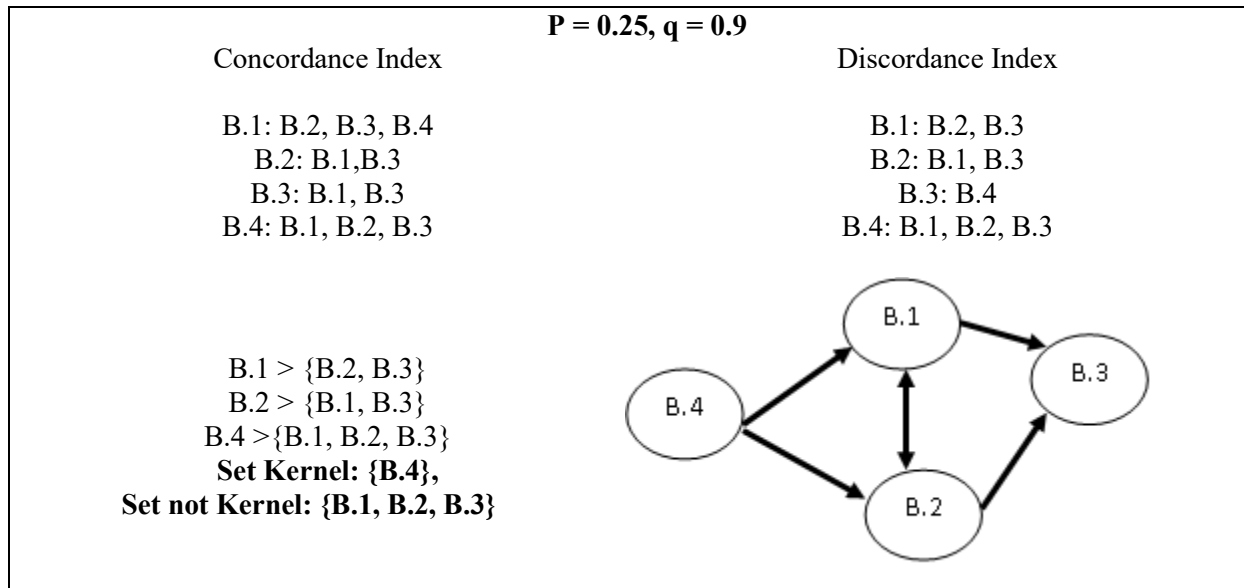


Figure 8. Concordance Index, Discordance Index for **P = 0.25, q = 0.9**

As shown in figure 8 above, we can see that layout B.1 dominates both layouts B.2 and B.3 while B.2 dominates layouts B.1 and B.3, and B.4 dominates B.1, B.2 and B.3.

4. Conclusion

As a result of apple's layout procedure a number of block layouts were developed for the whole facility (layout A) and for the manufacturing area (Layout B), the layouts were evaluated based on five different factors separately which were (inter department satisfactory level, total distance and time travelled for both the workers and the products). After comparing the layouts based on each factor ELECTRE was used as a multi-criteria decision making method to compare the layouts using all of the factors, the result of comparisons is shown below from the best layout to the worst. To conclude, the dominant and dominated layouts depends on the values of "p" and "q" different values were used for both limits, and as a result the layout that dominated the most, and was least dominated by will be at the top of the ranking. As conclusion, the best layout alternative for manufacturing area was layout "B.4 as shown in Table 10.

Table 10. Layouts ranking

	Layout B
1.	B.4
2.	B.2
3.	B.1
4.	B.3

References

- [1] Tompkins J A 2003 *Facilities planning* (New York: John)
- [2] Hungerländer P and Rendl F 2013 *Comput Optim Appl.* **55** 1-20.
- [3] Kothari R and Ghosh D 2014 *J. Heuristics* **20** 125-142
- [4] Anjos M F, Fischer A and Hungerländer, P. 2016 *Operations Research Proc.* (Springer

- International Publishing) p. 17-23
- [5] Allahyari M Z and Azab A 2017 *Computational Optimization in Engineering-Paradigms and Applications* (InTech)
 - [6] Mak K L, Wong Y S and Chan F T S 1998 *Computer Integrated Manufacturing Systems* **11** 113-127
 - [8] McKendall A R, Shang J and Kuppusamy S 2006 *Computers and Operations Research* **33** 2431-2444.
 - [9] Mavridou T D and Pardalos P M 1997 *Computational optimization and Applications* **7** 111-126
 - [11] Samarghandi H, Taabayan P and Jahantigh F F 2010 *Computers and Industrial Engineering* **58** 529-534.
 - [12] Kulturel-Konak S and Konak A 2011 *Engineering Optimization* **43** 1263-1287
 - [13] Roy B. 1991 *Theory and decision* **31** 49-73
 - [14] Meyers F E 2005 *Manufacturing Facilities Design and Material Handling* (Pearson Education)
 - [15] Hugonnard J C and Roy B 1982 *Cahiers Scientifiques de la Revue Transports*
 - [16] Benayoun R, Roy B and Sussman B 1966 ELECTRE: Une méthode pour guider le choix en présence de points de vue multiples. Note de travail 49, SEMA-METRA International, Direction Scientifique, 1966.