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Workshop Layout by the Method of Vote and Comparison to the Average Ranks Method

Maha Akbib, Ouafae Baida, Abdelouahid Lyhyaoui, Abdellatif Ghacham Amrani and Abdelfettah Sedqui

Abstract

The problem of workshop layout was highly considered in literature and several methods, which are widely used nowadays, were proposed namely: the method of links, the average ranks method, the method of the anteriorities, the method of the nearness.

The machine layout problem seeks to find the optimal arrangement of machines within each cell.

We will contribute to the resolution of this problem by proposing a new method. To do so, we will adapt a vote method as this of Schulze for the setting-up of the workshop. Then, we will compare its results to those of the average ranks method.

These methods will be applied to data which are results of our previous works. These data are the families of manufacturing sequences obtained thanks to the classification method of manufacturing sequences based on the language theory.

Keywords: workshop layout, schulze method, ranking, comparison

1. Introduction

Several methods arise from the society or are bio-inspired. The vote in political elections in favor of the favorite candidates is one of them. The vote takes place when a group has to unite preferences to make a global decision. Unfortunately, it is not always easy to make a single choice when we arrange preferences of many voters. The methods of vote designate every type of process that allows making this choice. An enormous number of vote methods exists; we distinguish generally three big families of electoral systems:

- The first one includes the systems of exhaustive ballot, govern by the logic of "the winner gains everything", in other words the candidate or the list of candidates arrived first is the only one represented.
- The second groups the systems of proportional ballot, which try hard to attribute representatives to all the political formations according to their respective results.
- Finally the family of the mixed ballots which includes all the electoral systems combining the effects of the systems stemming from the two other families.

The most used system is the one of the exhaustive ballot, but there are also situations in which we could ask the voters to give a complete ranking of a number of alternatives, as in a survey of marketing. The theory of the vote became an object of university study at the time of the French Revolution (O'Connor & Robertson, 2002). Jean-Charles de Borda (Borda, 1791) proposed an election method of the members of the Academy of Science. His system was disputed by the marquis de Condorcet, who proposes rather the method of comparison by pairs which he had conceived (Marquis de Condorcet, 1785). And which is the basis of methods of multicriteria decision (on ranking).

While Condorcet and Borda are generally considered as the founding fathers of the theory of the vote, recent researches showed that the philosopher Ramon Llull had discovered at the same time the method Borda and a method which satisfies the criteria of Condorcet in the XIIIth century. The manuscripts in which

he described these methods had been forgotten by the history, until their rediscovery in 2001 (Hägele & Pukelsheim, 2001). In 1958, Duncan Black built a method which mixed the methods of Condorcet and Borda. Namely, the winner in the method Black will be the Condorcet winner, unless he doesn't exist, then, the winner Borda will be chosen (Ratliff, 2002).

The works of the Marquis de Condorcet inspired F. Marcotorchino and P. Michaud to create the relational analysis in 1977. It is a theory based on the relational representation (comparison by pairs) of various variables and on the optimization under linear constraints of the criterion of Condorcet. The relational analysis allowed having theoretical advances and consequent practices.

The method of Condorcet presents a paradox. Condorcet shows how the majority vote can lead to a non-transitive, in particular cyclic collective preference.

The Schulze method allows solving most of the conflicts generated by the paradox of Condorcet. The Schulze method is a voting system developed in 1997 by Markus Schulze who chooses a simple winner in a vote with classification of the candidates. The method can be also used to create winners' ordered list. If a candidate wins all his duels during the confrontations by pairs with the other candidates (winner of Condorcet), the Schulze method guarantees that this candidate will win. Because of this property, the Schulze method is, by definition, a method of Condorcet. Contrary to the methods Borda and alternative vote of Ware for example, who can choose another winner than the winner of Condorcet. The Schulze method (Schulze, s.d.) allows resolving most of the conflicts generated by the paradox of Condorcet but does not guarantee a unique winner. We will use this method to obtain an order of the machines in a cell (layout).

Many heuristics were proposed for the resolution of the Schulze method. The most important heuristics are the path heuristic and the Schwartz set heuristic. In spite of their very different aspect, they give quite the same result.

We are going to choose the Schwartz set heuristic because the path heuristic considers the candidates not listed as placed after the others and with the same preference degree. And this condition can falsify our results when we consider the not existing machines in a sequence as placed after the others.

2. The proposed method

We are going to apply the Schulze method to the data of cells stemming from the sequences classification (Akbib, et al., 2013) with the aim of finding the effective layout of every cell. The Schulze method will allow creating an order of machines susceptible of minimizing the intra-cells movements. We consider the products' manufacturing sequences as the voters' ballots which contain the ranking of the candidates according to their preferences.

2.1 The Schulze method with the Schwartz set heuristic

With the concept of Schwartz set, the Schulze method can be described in a very concise way (Schulze, s.d.).

2.1.1 The Schwartz set

The definition of a Schwartz set, as used in the Schulze method, is as follows:

- An unbeaten set is a set of candidates of whom none is beaten by anyone outside that set.
- An innermost unbeaten set is an unbeaten set that doesn't contain a smaller unbeaten set.
- The Schwartz set is the set of candidates who are in innermost unbeaten sets.

2.1.2 Procedure

The voters cast their ballots by ranking the candidates according to their preferences, just like for any other Condorcet election.

The Schulze method uses Condorcet pairwise matchups between the candidates and a winner is chosen in each of the matchups. We establish then a balanced directed graph: summits are the candidates. If the candidate X confronted with the candidate Y wins n confrontations and loses p and if $n > p$, we create an arc of X towards Y balanced by " $n - p$ ". This method is comparable to the method Prométhée with n : positive flow, and p : negative flow.

From there, the Schulze method operates as follows to select a winner (or create a ranked list):

- Calculate the Schwartz set based only on undropped defeats.
- If there are no defeats among the members of that set then they (plural in the case of a tie) win and the count ends.
- Otherwise, drop the weakest defeat among the candidates of that set. Go to 1.

2.2 Application of the Schulze method to the workshop layout

We are going to use the Schulze method with the aim of creating an ordered list of the winners (in our case machines). In our previous work (Akbib, et al., 2013), we proposed a new approach based on the language theory for product family grouping according to their manufacturing sequences. This approach uses linear sequences of the manufacturing products which are assimilated to the words of a language. We have chosen the Levenhstein distance for sequence classification. And we have obtained four families of products (tables 1.a, 1.b, 1.c, 1.d).

Sequences	Sequences	Sequences	Sequences
S1: TEHKSF	S5: TDCHKEF	S13: ACPEHK	S24:AEGHKF
S2: TCHKF	S6: TCIHKMEF	S20: ABHKL	S25: ACHKF
S3: TDCHKF	S9: TDCHKLEF	S22: ACHKLF	S29: ABK
S4: TCGHK	S10: TDCHKLEF	S23: ACHKF	S31:ACHKEF

Tab. 1.a: Elements of the family F1

Sequences	Sequences
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S11 :ABPEHIKM

S17 :ADPEGKJNRQ

S16 :ADPEGKJN

S19 :ABKMGIJN

Tab 1.b: Elements of the family F2

Sequences

Sequences

S12:ACPEHKLMOJRQSN

S15:ACPEHKMORQN

S14:ADPEHKLSMOQN

Tab. 1.c: Elements of the family F3

Sequences

Sequences

Sequences

S7:TCHKMUQFN

S21:AEHKSMIQFN

S28:ADHKLEMIQFN

S8:TCHKMUQFN

S26:ABHKMIQFN

S30:ABHKLMIFN

S18:AEKLIHFN

S27:ADHKLEMIQFN

Tab. 1.d: Elements of the family F4

Every family designates a production cell. We will apply the Schulze method on these families in order to find the cells layout. We will consider the products' manufacturing sequences as the voters' ballots and the quantities of products as the number of voters. The ordered quantities of products are illustrated by table 2:

Workshop Layout by the Method of Vote and Comparison

Products	Average of the quantity /Week	Products	Average of the quantity /Week	Products	Average of the quantity /Week
P1	60	P11	65	P21	60
P2	55	P12	70	P22	55
P3	60	P13	60	P23	65
P4	55	P14	70	P24	60
P5	60	P15	65	P25	50
P6	65	P16	60	P26	55
P7	60	P17	60	P27	65
P8	60	P18	60	P28	55
P9	55	P19	65	P29	55
P10	50	P20	60	P30	50
				P31	60

Tab. 2: The ordered quantities of the families' products

2.2.1 Family F1

We make the confrontations by pairs (table 3):

	d[*],A]	d[*],B]	d[*],C]	d[*],D]	d[*],E]	d[*],F]	d[*],G]	d[*],H]	d[*],I]	d[*],K]	d[*],L]	d[*],M]	d[*],P]	d[*],S]	d[*],T]
d[A,*]		115	290	0	180	290	60	410	0	465	115	0	60	0	0
d[B,*]	0		0	0	0	0	60	0	115	60	0	0	0	0	0
d[C,*]	0	0		0	350	575	55	690	65	690	160	65	60	0	0
d[D,*]	0	0	225		165	225	0	225	0	225	105	0	0	0	0
d[E,*]	0	0	0	0		410	60	180	0	180	0	0	0	60	0
d[F,*]	0	0	0	0	0		0	0	0	0	0	0	0	0	0
d[G,*]	0	0	0	0	0	60		115	0	115	0	0	0	0	0
d[H,*]	0	0	0	0	290	695	0		0	870	220	65	0	60	0
d[I,*]	0	0	0	0	65	65	0	65		65	0	65	0	0	0
d[K,*]	0	0	0	0	290	695	0	0	0		220	65	0	60	0
d[L,*]	0	0	0	0	105	160	0	0	0	0		0	0	0	0
d[M,*]	0	0	0	0	65	65	0	0	0	0	0		0	0	0
d[P,*]	0	0	0	0	60	0	0	60	0	60	0	0		0	0
d[S,*]	0	0	0	0	0	60	0	0	0	0	0	0	0		0
d[T,*]	0	0	400	225	290	405	55	460	65	460	105	65	0	60	

Tab 3: Confrontations by pairs of the family F1

We constitute the directed graph of the duels (figure 1).

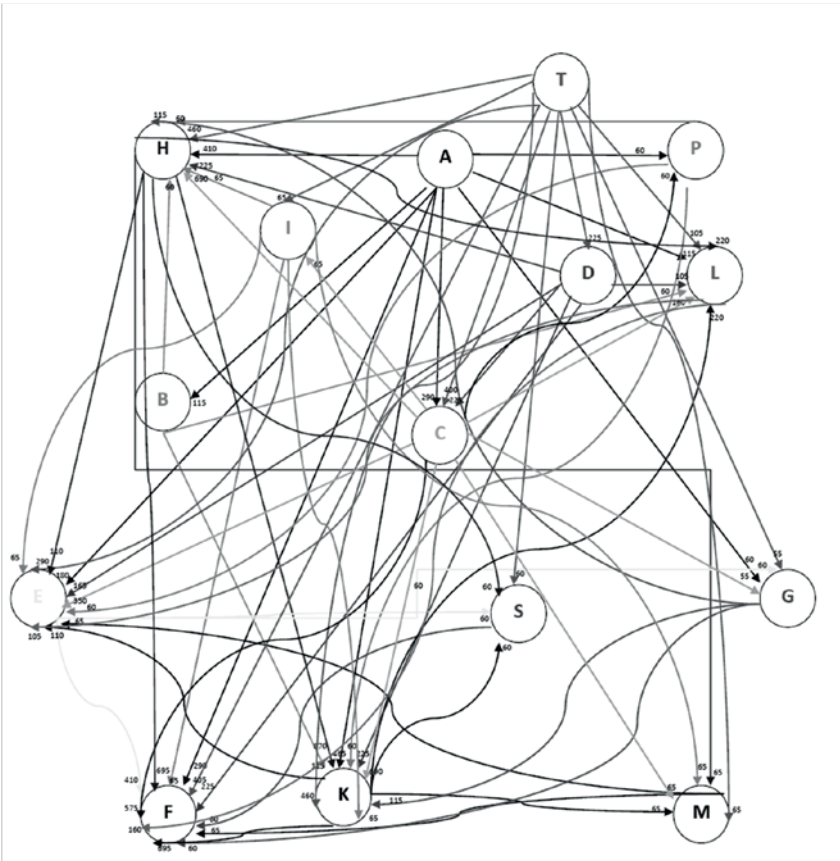


Fig. 1: The directed graph of the duels for the family F1

The Schwartz set is constituted by the set {A,T}. The candidates A and T are then the first winners. So both machines will be positioned in parallel.

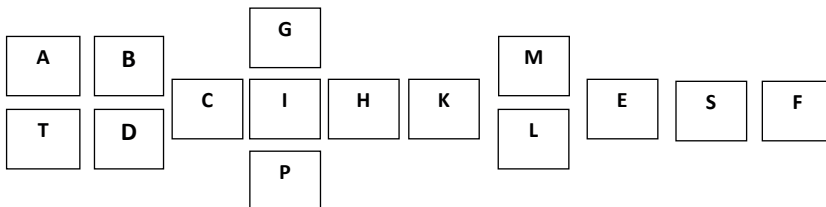
After a candidate wins, we eliminate him to find the 2nd winner (the one who will win if the first winner does not exist anymore).

If we do not find a winner, we eliminate the arc of the smallest defeat.

We repeat the application of the heuristic until we obtain an order of the machines.

For the first family, and consequently, the first cell, the layout will be as follows (figure 2):

Fig. 2: Layout of the first cell (family F1)



2.2.2 Family F2

We make the confrontations by pairs (table 4):

	d[*A]	d[*B]	d[*D]	d[*E]	d[*G]	d[*H]	d[*I]	d[*J]	d[*K]	d[*M]	d[*N]	d[*P]	d[*Q]	d[*R]
d[A,*]		130	120	185	185	65	130	185	250	130	185	185	60	60
d[B,*]	0		0	65	65	65	130	65	130	130	65	65	0	0
d[D,*]	0	0		120	120	0	0	120	120	0	120	120	60	60
d[E,*]	0	0	0		120	65	65	120	185	65	120	0	60	60
d[G,*]	0	0	0	0		0	65	185	120	0	185	0	60	60
d[H,*]	0	0	0	0	0		65	0	65	65	0	0	0	0
d[I,*]	0	0	0	0	0	0		65	65	65	65	0	0	0
d[J,*]	0	0	0	0	0	0	0		0	0	185	0	60	60
d[K,*]	0	0	0	0	65	0	65	185		130	185	0	60	60
d[M,*]	0	0	0	0	65	0	65	65	0		65	0	0	0
d[N,*]	0	0	0	0	0	0	0	0	0	0		0	60	60
d[P,*]	0	0	0	185	120	65	65	120	185	65	120		60	60
d[Q,*]	0	0	0	0	0	0	0	0	0	0	0	0		0
d[R,*]	0	0	0	0	0	0	0	0	0	0	0	0	60	

Tab. 4: Confrontations by pairs of the family F2

We constitute the directed graph of the duels (figure 3).

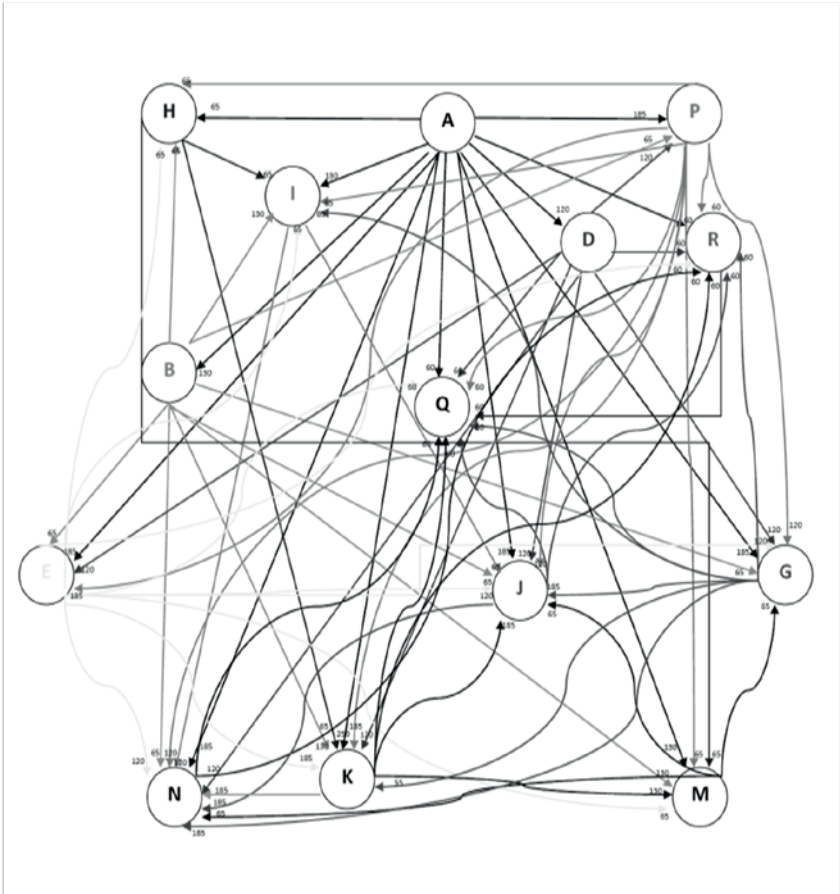


Fig. 3: The directed graph of the duels for the family F2

The Schwartz set is then constituted by the singleton $\{A\}$. The candidate A is then the first winner. We repeat the application of the heuristic until we obtain an order of the machines.

For the second family, and consequently, the second cell, the layout will be as follows (figure 4):

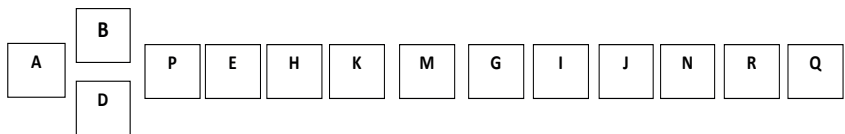


Fig. 4: Layout of the second cell (family F2)

2.2.3 Family F3

We make the confrontations by pairs (table 5):

	d[*A]	d[*C]	d[*D]	d[*E]	d[*H]	d[*J]	d[*K]	d[*L]	d[*M]	d[*N]	d[*O]	d[*P]	d[*Q]	d[*R]	d[*S]
d[A,*]		135	70	205	205	70	205	140	205	205	205	205	205	135	140
d[C,*]	0		0	135	135	70	135	70	135	135	135	135	135	135	70
d[D,*]	0	0		70	70	0	70	70	70	70	70	70	70	0	70
d[E,*]	0	0	0		205	70	205	140	205	205	205	0	205	135	140
d[H,*]	0	0	0	0		70	205	140	205	205	205	0	205	135	140
d[J,*]	0	0	0	0	0		0	0	70	0	0	70	70	70	
d[K,*]	0	0	0	0	0	70		140	205	205	205	0	205	135	140
d[L,*]	0	0	0	0	0	70	0		140	140	140	0	140	70	140
d[M,*]	0	0	0	0	0	70	0	0		205	205	0	205	135	70
d[N,*]	0	0	0	0	0	0	0	0	0		0	0	0	0	0
d[O,*]	0	0	0	0	0	70	0	0	0	205		0	205	135	70
d[P,*]	0	0	0	205	205	70	205	140	205	205	205		205	135	140
d[Q,*]	0	0	0	0	0	0	0	0	205	0	0	0		0	70
d[R,*]	0	0	0	0	0	0	0	0	135	0	0	135	0		70
d[S,*]	0	0	0	0	0	0	0	0	70	140	70	0	70	0	

Tab. 5: Confrontations by pairs of the family F3

We constitute the directed graph of the duels (figure 5).

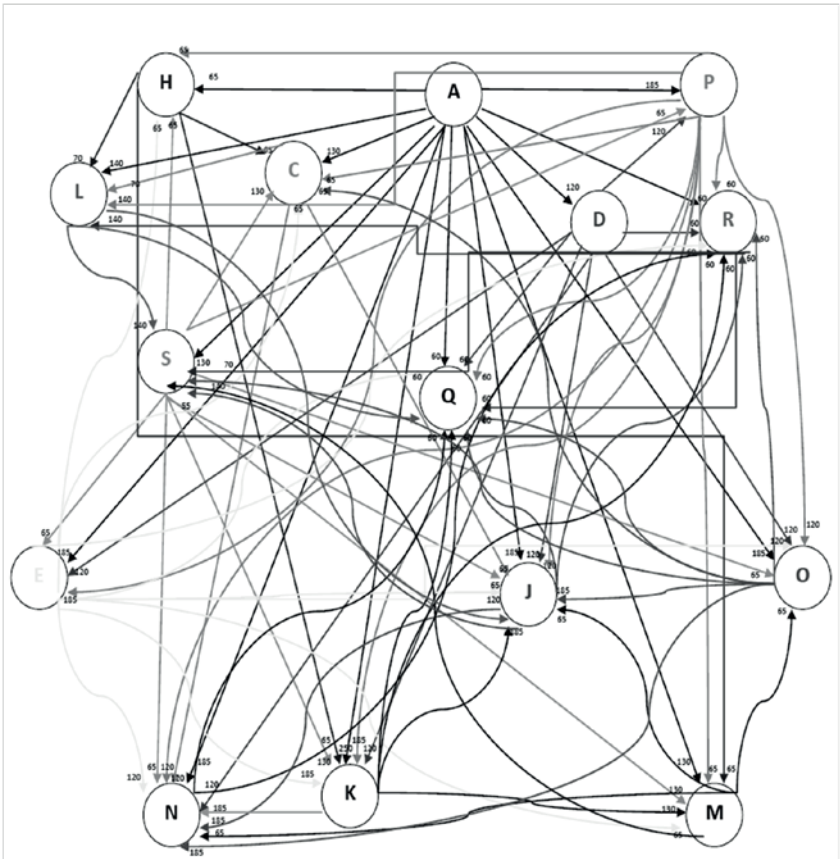


Fig. 5: The directed graph of the duels for the family F3

The Schwartz set is then constituted by the singleton {A}. The candidate (machine) A is then the first winner. We repeat the application of the heuristic until we obtain an order of the machines.

For the third family, and consequently, the third cell, the layout will be as follows (figure 6):

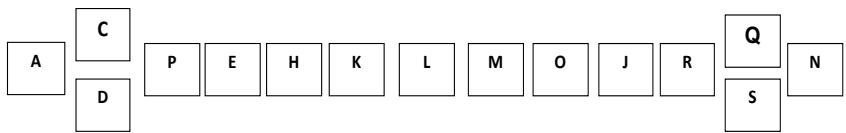


Fig. 6: Layout of the third cell (family F3)

2.2.4 Family F4

We make the confrontations by pairs (table 6):

	d[*],A]	d[*],B]	d[*],C]	d[*],D]	d[*],E]	d[*],F]	d[*],H]	d[*],I]	d[*],K]	d[*],L]	d[*],M]	d[*],N]	d[*],Q]	d[*],S]	d[*],T]	d[*],U]
d[A,*]		105	0	120	240	345	345	345	345	230	285	345	235	60	0	0
d[B,*]	0		0	0	0	105	105	105	105	50	105	105	55	0	0	0
d[C,*]	0	0		0	0	120	120	0	120	0	120	120	120	0	0	120
d[D,*]	0	0	0		120	120	120	120	120	120	120	120	120	0	0	0
d[E,*]	0	0	0	0		240	120	240	120	60	180	240	180	60	0	0
d[F,*]	0	0	0	0	0		0	0	0	0	0	465	0	0	0	0
d[H,*]	0	0	0	0	120	465		285	405	170	405	465	355	60	0	120
d[I,*]	0	0	0	0	0	345	60		0	0	0	345	235	0	0	0
d[K,*]	0	0	0	0	120	465	60	345		230	405	465	355	60	0	120
d[L,*]	0	0	0	0	120	230	60	230	0		170	170	120	0	0	0
d[M,*]	0	0	0	0	0	405	0	285	0	0		405	355	0	0	120
d[N,*]	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0
d[Q,*]	0	0	0	0	0	355	0	0	0	0	0	355		0	0	0
d[S,*]	0	0	0	0	0	60	0	60	0	0	60	60	60		0	0
d[T,*]	0	0	120	0	0	120	120	0	120	0	120	120	120	0		120
d[U,*]	0	0	0	0	0	120	0	0	0	0	0	120	120	0	0	

Tab. 6: Confrontations by pairs of the family F4

We constitute the directed graph of the duels (figure 7).

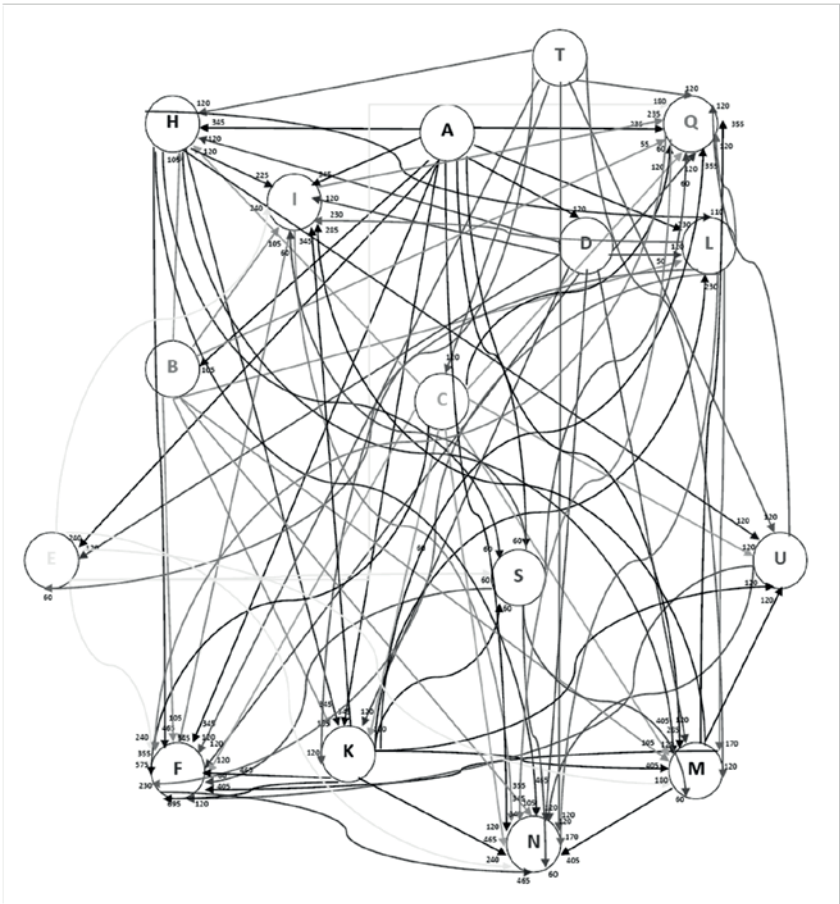


Fig. 7: The directed graph of the duels for the family F4

The Schwartz set is then constituted by the set $\{A, T\}$. The candidates A and T are then the winners. So both machines will be positioned in parallel. We repeat the application of the heuristic until we obtain an order of the machines.

For the forth family, and consequently, the forth cell, the layout will be as follows (figure 8):

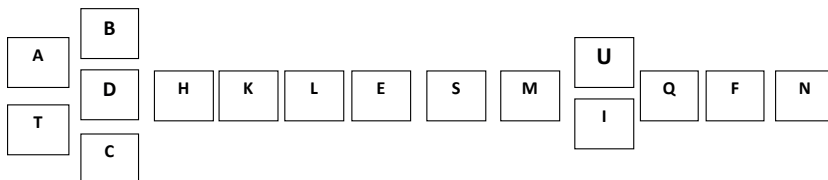


Fig. 8: Layout of the fourth cell (family F4)

3. Comparison of the Schulze method to the average ranks method

We are going to compare our workshop layout, obtained by the use of the Schulze method, to the one obtained by using the average ranks method.

3.1 Results of the application of the average ranks method

The average ranks method uses individual rankings to derive an overall ranking (Brazdil & Soares, 2000). This is a simple ranking method, inspired by Friedman's M statistic (Neave & Worthington, 1992).

The average ranks and the corresponding ranking of all the families are presented in tables 7, 8, 9 and 10.

	A	B	C	D	E	F	G	H	I	K	L	M	P	S	T
S1					2	6		3		4				5	1
S2			2			5		3		4					1
S3			3	2		6		4		5					1
S4			2				3	4		5					1
S5			3	2	6	7		4		5					1
S6			2		7	8		4	3	5		6			1
S9			3	2	7	8		4		5	6				1
S10			3	2	7	8		4		5	6				1
S13	1		2		4			5		6			3		
S20	1	2						3		4	5				
S22	1		2			6		3		4	5				
S23	1		2			5		3		4					
S24	1				2	6	3	4		5					
S25	1		2			5		3		4					
S29	1	2								3					
S31	1		2		5	6		3		4					
Total ranks	8	4	28	8	40	76	6	54	3	72	22	6	3	5	8
Nb of ranks	8	2	12	4	8	12	2	15	1	16	4	1	1	1	8
Average ranks	1	2	2,3	2	5	6,3	3	3,6	3	4,5	5,5	6	3	5	1
Ranking	1	3	5	3	11	15	6	9	6	10	13	14	6	11	1

Tab 7: Ranking of the machines in the family F1

	A	C	D	E	H	J	K	L	M	N	O	P	Q	R	S
S12	10	20		40	50	100	60	70	80	140	90	30	120	110	130
S14	10		20	40	50		60	70	90	120	100	30	110		80
S15	10	20		40	50		60		70	110	80	30	100	90	
Total ranks	30	40	20	120	150	100	180	140	240	370	270	90	330	200	210
Nb of ranks	3	2	1	3	3	1	3	2	3	3	3	3	3	2	2
Average ranks	10	20	20	40	50	100	60	70	80	123	90	30	110	100	105
Ranking	1	2	2	5	6	11	7	8	9	15	10	4	14	11	13

Tab. 8: Ranking of the machines in the family F2

	A	B	D	E	G	H	I	J	K	M	N	P	Q	R
S11	10	20		40		50	60		70	80		30		
S16	10		20	40	50			70	60		80	30		
S17	10		20	40	50			70	60		80	30	100	90
S19	10	20			50		60	70	30	40	80			
Total ranks	40	40	40	120	150	50	120	210	220	120	240	90	100	90
Nb of ranks	4	2	2	3	3	1	2	3	4	2	3	3	1	1
Average ranks	10	20	20	40	50	50	60	70	55	60	80	30	100	90
Ranking	1	2	2	5	6	6	9	11	8	9	12	4	14	13

Tab 9: Ranking of the machines in the family F3

	A	B	C	D	E	F	H	I	K	L	M	N	Q	S	T	U
S7			20			80	30		40		50	90	70		10	60
S8			20			80	30		40		50	90	70		10	60
S18	10				20	70	60	50	30	40		80				
S21	10				20	90	30	70	40		60	100	80	50		
S26	10	20				80	30	60	40		50	90	70			
S27	10			20	60	100	30	80	40	50	70	110	90			
S28	10			20	60	100	30	80	40	50	70	110	90			
S30	10	20				80	30	70	40	50	60	90				
Total ranks	60	40	40	40	160	680	270	410	310	190	410	760	470	50	20	120
Nb of ranks	6	2	2	2	4	8	8	6	8	4	7	8	6	1	2	2
Average ranks	10	20	20	20	40	85	34	68	39	48	59	95	78	50	10	60
Ranking	1	3	3	3	8	15	6	13	7	9	11	16	14	10	1	12

Tab. 10: Ranking of the machines in the family F4

According to these results, the layouts would be as follows:

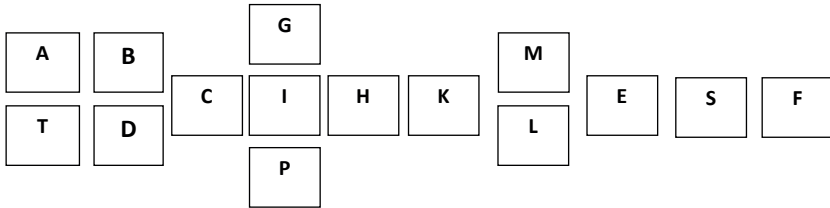


Fig. 9: Layout of the first cell by the average ranks method (family F1)

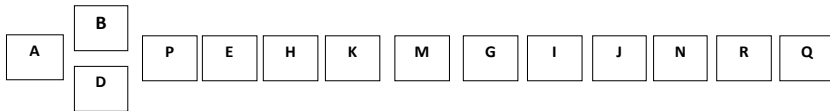


Fig. 10: Layout of the second cell by the average ranks method (family F2)

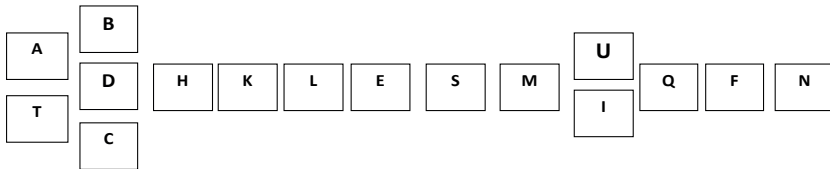


Fig. 11: Layout of the third cell by the average ranks method (family F3)

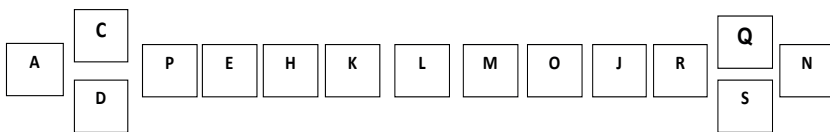


Fig. 12: Layout of the fourth cell by the average ranks method (family F4)

3.2 Comparison

We notice some differences between the results of the two methods. These differences are due to that the average ranks method is compensatory.

We can say that the result of the Schulze method is better because this method takes into account the quantity of products being moved from one machine to another. This means, it minimizes the intra-cell movements. For example, in the family F4, and by applying the Schulze method, machine L precedes machine E, opposing to the result of average ranks method. And if we go back to the products in this family and to their ordered quantities, we will see that the flow is higher from L to E:

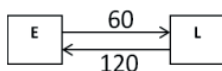


Fig. 13: flow of products between machines E and L in family F4

4. Conclusion

In this paper, we have proposed a new method for solving intra-cell layout problem. The Schulze method is a voting method that we had applied to the workshop layout problem. We have chosen the Schwartz set heuristic to resolute the Schulze method.

We have assimilated the products' manufacturing sequences to the voters' ballots and the ordered quantities of products to the number of voters.

The Schulze method gave us better results compared to those of the average ranks method because it takes into account the quantity of products being moved from one machine to another. This method allowed us to create an order of machines susceptible of minimizing the intra-cells movements.

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