American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-6, Issue-5, pp-72-85
www.ajer.org
Research Paper Open Access

The Effect of Parts Similarities on Machine Set-up Cost using Group Technology

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Abstract: *One of the major challenges in manufacturing of parts is on how to keep the price of the products as low as possible and at the same time shortening the time of the production cycle. Group similarities brings solutions in reduction of set-up cost and saves time and effort in setting up an operations for a group of similar parts instead of treating each part individually.This paper analyses the relationship between group similarity index of parts within the group and the associated machine set-up cost to see how this can reduce the manufacturing the cost of the product. A model was applied for thirty different components manufactured by lathe machine and grouped into similar parts and at the same time for computing similarity indices.A statistical analysis was also carried out to ascertain the correlation between them.*

Keywords: *Group technology, Similarity indices, Production cost, Product design, Set-up time*

I. INTRODUCTION

In the demanding competitive environment of the global economy, the continued existence of even the most well-established world class manufacturers depends on the ability to constantly improve quality of the product while reducing costs.A typical company makes thousands of different parts, in many different batch sizes, using a variety of different manufacturing operations, processes and technologies. It is beyond the capability of human mind to comprehend and manipulate such vast amounts of detailed data. Though, people still need to make decisions regarding how to run a manufacturing company and succeed in today‘s competitive environment locally and foreign markets. The pressures on management continue to increase as global competition drives the need for producing a greater variety of high quality products, in smaller lot sizes and at lower costs (Tim, 2013).As the demands increases continuously, the level of complexity present in a manufacturing environment becomes very high. Manufacturing systems must be able to manufacture products with low production costs and high quality as quickly as possible in order to deliver the products to customers in time (Kranton R. E.,2008; Hortonworks, 2014). In addition, the systems should be able to adjust or respond quickly to changes in product design and product demand without major investment. To achieve such purpose, there is need for both strategy and a tool that can be used to achieve such a purpose. Therefore, this paper presents the effects of group similarities on the machine set-up cost of the manufacturing product.

Manufacturing systems must be able tomanufacture products with low production costs and high quality as quickly as possible in order to deliver the products to customers in time (Douglas E.T., Stanley W. G. 2014; Anderson J., Chemical D., 2009). In addition, the systems should be able to adjust or respond quickly to changes in product design and product demand without major investment.

II. GROUP TECHNOLOGY (GT)

Group technology**,** although being used inthe manufacturing environment since late 1950s, is still drawing much attention from manufacturers and researchers because of its many applications for boosting productivity (Kamal et al., 2014). More generally, Group Technology can be considered a theory of management based on the principles that “similar things should be done similarly” (Askin, 1993). However, with respect to manufacturing, GT could be defined as a manufacturing philosophy in which similar parts are identified and grouped together to take advantage of their similarities in design and production (Mikell, 2008). The principle of group technology is to divide the manufacturing system into small groups or cells, each cell specializing in the production of a part family called cellular manufacturing (Hassan et al., 1998). Also, each machine cell is designed to produce a given part family or a limited collection of part families.

Part family is a collection of parts that are similar either in terms of their geometric shape and size or through their processing steps which are required in manufacturing operations. There are always differences among parts within a family may be different, but their similarities are close enough to merit their inclusion as members of the part family.There are three general methods for solving part families grouping (Pearson Education 2008; Odu, 2017). These include:

- Visual inspection - uses best judgment to group parts into appropriate families based on the parts or photos of the parts;
- Parts classification and coding - identifying similarities and differences among parts relating them by means of coding scheme, and
- Production flow analysis – using information contained on the analysis of sequence of operation(routes) that parts go through during fabrication. Parts that go through common operations are grouped into parts families.

From a machining perspective, however, other characteristics can also define a family. Consider parts that you can

- hold in the same fixture
- run with variations on the same program
- make using the same type of operations
- cut with the same set of tools.

Sometimes it is hard to see these common characteristics, but once you do, you can use them to boost production by reducing setup and changeover time, minimize programming effort, or improve other aspects of your process.Parts made by the same processes and tooling might not look the same, but the operations performed will determine a family. This implies that there is no changing out tooling between parts.

In general, GT simplifies and standardizes. The approach to simplify, standardizes, and internalize through repetition produces efficiency. Parts fixtures are developed and used in work center especiallyonly on a family of similar parts. Tooling may be stored locally since parts will always be processed through the same machines. Tool changes may be required due to tool wear only, not part changeovers (e.g. a press may have a generic fixture that can hold all the parts in a family without any change or simply by changing a part specific insert secured by a single screw. Hence setup time is reduced, and tooling cost is reduced. It is possible to show that if setup time is reduced, also the throughput time and the set-up cost for the system is reduced by the same percentage, in order to reduce complexity and achieveeconomies of scale effects in batch manufacturing (Askin and Standridge, 1993). There are two different approaches noticeable in past literature in order to form part families, first is Production Flow Analysis (PFA) which deals with processing requirements, operational sequences, and operational time of the parts on the machines (Charles-Owaba, 1981, Tamal et al., 2011). While the second approach is the classification and coding system which deals on predefined coding schemes to process several attributes of parts such as geometrical shapes, materials, design features and functional requirements etc. Several CC systems have been developed e.g. Opitz (Opitz, 1970) and DCLASS (Gallagher and Knight, 1985).This paper focuses on adopting the second approach developed by Opitz - classification and coding (CC) system, a methodology which organizes similar entities into groups (classification) and then assigns a symbolic code to these entities (coding) in order to facilitate information retrieval (Kamal et al., 2014).

III. GROUPING OF PARTS AND GROUP SIMILARITY INDEX

In computing the group similarity indices for classification of various parts, consider the model developed form previous workon the development of a model for computing similarity indices (Odu, 2017), which is expressed as:

For N groups, the overall within group similarity is given as

$$H = \frac{\sum H_k}{N}$$

where H is the within group similarity index of all parts in GT system andH$_K$has been defined as follows:

$$H_k = \frac{\sum_{i=1}^{n_k} \sum_{j=1}^{n_k - 1} R_{ij}}{n_k (n_k - 1)} \quad ; \qquad i, j \in g_k \text{ and } i \neq j$$

where $0 \le R_{ij} \le 1$; the following equation also holds $0.0 \le H_k, H \le 1.0$

where H_k is the similarity index of parts within group k and n_k is the number of parts in group k

g_k is a set of parts in group k,

But, $$R_{ij} = \frac{\overline{D}^{t}_{ij\alpha}\,\overline{D}_{ij\alpha}}{\overline{D}^{t}_{io\alpha}\,\overline{D}_{io\alpha}}$$

where R_{ij} isthe similarity index of parts i and j

while $$\overline{D}_{ij\alpha} = \begin{cases} 1 & \textit{if i and j are similar in shape in design characteristics } \alpha \\ 0 & \end{cases}$$

And $\overline{D}_{io\alpha} = 1 \forall \alpha$ while t means transpose
where

$$\overline{D}_{(1)} = \begin{Bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{Bmatrix}$$

The similarity state vector with relevant design characteristics, D_{ij} which represent the state of similarity or dissimilarity of part i and j respect to characteristic α .

3.1 Machine Set-up Cost

There is always a cost associated for every machine part being processed. The following section throws more light on how this can be achieved.

3.2Machine and its Set-up Tasks

Discrete parts processing machines is selected and have it carefully studied by an experienced operator. A number of parts to be processed on the machine are gathered and the machine set-up task for each part identified. A total of 30 distinct parts were chosen for the study.

An experienced operator was observed for some days and the following tasks were recorded:
1. Set-up chuck on headstock
2. Teardown chuck on headstock
3. Set-up cutting tool on tool post
4. Teardown centre on tailstock
5. Set-up centre on tailstock
6. Teardown centre on tailstock
7. Set-up cutting tool on tailstock
8. Teardown cutting tool on tailstock
9. Set up taper turning attachment
10. Adjust taper turning attachment
11. Adjust speed
12. Adjust depth of cut
13. Adjust feed
14. Adjust thread cutting levers
15. Set–up work piece (Disc type) on chuck
16. Teardown work piece (Disc type) on chuck
17. Set – up work piece (shaft type) on chuck and centre
18. Teardown work piece (shaft type) on chuck and centre
19. Adjust tailstock
20. Adjust cutting tool on tool post
21. Adjust cutting fluid

3.3Machine Set-up Time Data Collection

To collect the set-up time data a centre lathe machine located in the technical support unit of the faculty of technology, of the University of Ibadan, Nigeria is chosen. It has a bed length of 1.5 metres, with a motor power of 3 Horsepower and four ranges of speeds: 58-1200, 40-800, 85-1700 and 125-2500 revolution.

Using time study procedure, the standard time required to perform each set-up task was determined and presented in Table 1. The standard time to set-up the machine for each part is then determined independent of other parts. Assuming that part i is being processed next to part j, the sequence-dependent tasks to be accomplished are again identified and the standard time determined. This is repeated until the sequence-dependent matrix is formed. The same procedure is repeated for several problems required for different sets of parts.

Table 1 Time Study Result

S/No	Set-up tasks	Standard time
1.	Set-up chuck on Headstock	0.78
2.	Teardown chuck on headstock	1.15
3.	Set –up cutting tool on tool post	0.53
4.	Teardown cutting tool on tool post	0.29
5.	Set-up centre on tailstock	0.22
6.	Teardown centre on Tailstock	0.23
7.	Set-up cutting tool on tailstock	0.72
8.	Teardown cutting tool on tailstock	0.47
9.	Set-up taper turning attachment (Swiveling of compound slide)	0.85
10.	Adjust Taper turning attachment	0.77
11.	Set-up work piece (Disc type) on chuck	0.23
12.	Teardown work piece (Disc type) on chuck	0.20
13.	Set-up work piece (shaft type) on chuck and centre	0.68
14.	Teardown Workpiece (shaft type) on chuck and centre	0.51
15.	Adjust Tailstock	0.12
16.	Adjust cutting tool on tool post	0.96
17.	Adjust speed	0.33
18.	Adjust depth of cut	0.35
19.	Adjust feed	0.69
20.	Adjust thread cutting gear levers	0.74
21.	Adjust cutting fluid	0.20

Table 2 Coding System Based on Part Design Characteristics

Digit 1		Digit 2		Digit 3		Digit 4		Digit 5		Digit 6		Digit 7	
Overall shape		Overall size		Operation		Dimension of Feature		Surface finish		Tolerance		Material type	
0	Non-rotational	0	Disc type	0	Boring	0	$L/D \leq 0.5$	0	High quality finish <50μm	0	± 0.01 - 0.3	0	Cast iron
1	Rotational	1	Shaft	1	Drilling	1	$0.5 < L/D < 3$	1	Low quality fir >50μm	1	± 0.35 - 0.5	1	Mild steel
				2	Turning	2	$L/D \geq 3$			2	± 0.55 - 09.5	2	Steel
				3	Knurling					3	± 1.00 above	3	Aluminium
				4	Reaming							4	Copper alloy
												5	Brass

(Source: Odu, 2017)

IV. DATA ANALYSIS

To investigate the issue earlier raised, there is need to compute the set-up cost of each group within the system in setting up the machine using the optimizing technique. Based on these sequences, the value of the machine set-up cost for various grouping was determined.

A list of thirty different parts was presented in Table 3 showing the parts' characteristics and the required coded number as indicated in Table 4 was evaluated using the coding system based on the parts' characteristics (see Table 2). Thirty different parts were grouped into various groups with a maximum number of groups of eightwith five problems as presented in Table 5. The similarity for part i and j was computed as shown in Appendix A and was therefore used in computing the similarity index, of each part as presented in Table 6. In order to achieve the objective earlier stated in the previous section, five different values of the within group similarity indices and the corresponding set-up cost was determined and presented in Table 6. The machine set-up cost was determined using the optimizing technique as shown in appendix C for each number of groups in the system.

Table 3: Parts to be processed on a center lathe showing parts characteristics

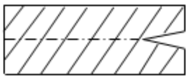
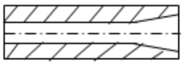
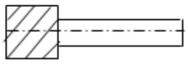
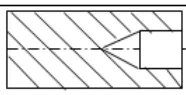
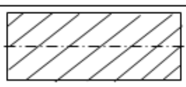
Part Drawing No.		Characteristics of parts							Code	No. off
		1	2	3	4	5	6	7		
1		Rotational	Disc type	Boring	L=150 O.D.=60 I.D.=55	12μ mm	±0.25	Mild steel	1001101	2
2		Rotational	Disc type	Centre drilling	L=175 Dia=60 C.D.with $\varphi 10$ by 90	24μ mm	±0.25	Mild steel	1011101	2
3		Rotational	Disc type	Straight turning with chamfering	L=200 Dia=60 3 by 45° Chamfer	60μmm	±0.25	Mild steel	1021201	2
4		Rotational	Disc type	Counter boring	L=200 Dia=60 C'bore to $\varphi 54$ by 10 deep	12μmm	±0.25	Mild steel	1001101	2
5		Rotational	Disc type	Counter sinking	L=150 O.D.=58 I.D.=51	12μmm	±0.25	Mild steel	1011101	2
6		Rotational	Disc type	Knurling	L=200 96 deep		±0.25	Mild steel	1030001	2
7		Rotational	Disc type	Drilling	L=200 O.D.=85 Drill $\phi 20$ by 50 deep	24μmm	±0.25	Mild steel	1011101	1
8		Rotational	Disc type	Facing	Face both ends to 180	40μmm	±0.25	Mild steel	1021101	2

Table 4: Coded parts

Parts No.	1	2	3	4	5	6	7
1	1	0	0	1	1	0	1
2	1	0	0	1	1	0	1
3	1	0	1	1	1	0	1
4	1	0	1	1	1	0	1
5	1	0	2	1	2	0	1
6	1	0	2	1	2	0	1
7	1	0	0	1	1	0	1
8	1	0	0	1	1	0	1
9	1	0	1	1	1	0	1
10	1	0	1	1	1	0	1
11	1	0	3	0	0	0	1
12	1	0	3	0	0	0	1
13	1	0	1	1	1	0	1
14	1	0	1	1	1	0	1
15	1	0	2	1	1	0	1
16	1	0	2	1	1	0	1
17	1	0	4	1	1	0	1
18	1	0	4	1	1	0	1
19	1	0	2	1	1	0	1
20	1	0	2	1	1	0	1
21	1	1	2	2	1	0	1
22	1	1	2	2	1	0	1
23	1	0	1	1	1	0	1
24	1	1	2	2	1	0	1
25	1	1	2	2	1	0	1
26	1	0	2	1	1	0	1
27	1	1	2	2	1	0	1
28	1	1	2	2	1	0	1
29	1	0	2	1	2	0	1
30	1	0	2	1	2	0	1

where each of the digits is represented below:

1. Overall shape   2. Overall size   3. Operation   4. Dimension of feature
5. Surface finish   6. Tolerance   7. Material type

Disc type: $\frac{L}{D} \leq 3$; Shaft type: $\frac{L}{D} > 3$

Table 5: Parts Grouping

No. of Groups	S/No	Problem 1	Problem 2	Problem 3	Problem 4	Problem 5
		Parts in				
2	1	21, 22,, 24, 25, 27, 28	11, 14, 1, 21, 22, 24, 2, 3, 5, 6	4, 5, 6, 7, 11, 12, 28, 29, 30, 18, 24, 27	21, 22, 24, 26, 23, 16, 15, 25, 27, 28, 13, 14	10, 3, 4, 9, 20, 17, 18, 5, 6, 11, 12, 29, 30
	2	10, 3, 4, 9, 13, 14, 23, 17, 18, 26, 15, 16, 19, 20, 5, 6, 29, 30, 11, 12, 1, 2, 7, 8	4, 7, 10, 12, 13, 17, 18, 19, 15, 20, 23, 25, 26, 29, 30, 27, 28, 8, 9, 16	2, 8, 1, 10, 13, 14, 17, 18, 15, 16, 19, 20, 21, 22, 23, 25, 26, 3, 9	29, 30, 1, 2, 3, 7, 8, 4, 9, 10, 5, 17, 18, 11, 12, 6, 19, 20	1, 2, 7, 8, 13, 14, 15, 16, 19, 21, 22, 23, 24, 25, 26, 27, 28
3	1	11, 12	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23	1, 2, 3, 4, 17, 18, 29, 30, 11, 12	23, 21, 22, 27, 28, 26, 24, 20, 25	11, 12, 21, 22, 24, 23, 25
	2	10, 3, 4, 9, 13, 14, 23, 7, 8, 26, 16, 19, 20, 17, 18, 5, 6, 29, 30, 1, 2	2, 4, 6, 8, 10, 12, 14, 16, 25, 27, 29	5, 6, 7, 8, 21, 22, 27, 28, 19, 20	29, 30, 18, 19, 16, 15	3, 8, 4, 10, 9, 14, 15, 17, 18, 20, 21
	3	21, 22, 24, 25, 27, 28	18, 20, 22, 24, 26, 28, 30	9, 10, 13, 14, 15, 16, 23, 24, 25, 26	3, 1, 2, 5, 6, 14, 13, 4, 4, 8, 10, 11, 12, 9, 7, 17	1, 2, 26, 27, 28, 29, 30, 7, 5, 6, 13, 19
4	1	29, 30	29, 30, 18, 19, 16, 15	29, 30, 7, 5, 6, 13, 19, 1, 2, 26	23, 21, 22, 27, 28, 26, 24, 20, 25	11, 14, 1, 21, 22, 24, 2, 3, 5, 6
	2	10, 3, 4, 9, 13, 14, 23, 7, 8, 26, 15, 16, 19, 20, 17, 18, 5, 6, 1, 2	11, 12, 21, 22, 24, 23, 25	21, 22, 24, 25, 27, 28	29, 30, 18, 19, 16, 15	15, 18, 30, 19, 16, 29
	3	21, 22, 24, 25, 27, 28	3, 8, 5, 6, 9, 14, 17	9, 10, 13, 14, 15, 16, 23	11, 12, 5, 6, 9, 10	4, 7, 8, 12, 13
	4	11, 12	4, 1, 2, 7, 10, 13, 20, 26, 27, 28	3, 4, 8, 11, 12, 17, 18, 20	1, 2, 3, 4, 7, 8, 13, 14, 17	9, 10, 17, 20, 23, 25, 26, 27, 28
5	1	17, 18	4, 1, 2, 7, 10, 13	21, 22, 24, 25, 27	15, 16, 18, 19, 29, 30	23, 21, 22, 27, 28, 26, 24 20, 25
	2	10, 3, 4, 9, 13, 14, 23, 7, 8, 26, 15, 16, 19, 20, 1, 2	29, 30, 18, 19, 16, 15	9, 10, 13, 14, 15, 16, 23	20, 21, 22, 23, 24, 26, 27, 28	3, 8, 5, 6, 9, 14, 17
	3	21, 22, 24, 25, 27, 28	3, 8, 5, 6, 9, 14, 17	10, 11, 12, 13, 14, 17, 25	11, 12	10, 1, 2, 4, 6, 21, 22
	4	11, 12	20, 21 22, 23, 26, 27, 28	1, 2, 5, 6, 7	5, 5, 8, 9	13, 29, 15, 30
	5	5, 29, 30, 6	11, 12, 24, 25	3, 4, 8, 11, 12, 17, 18, 20	1, 2, 3, 4, 7, 8, 13, 14, 17	9, 10, 17, 20, 23, 25, 26, 27, 28
6	1	17, 18	5, 7, 29, 30	5, 6, 29, 30	19, 20, 3, 4, 9, 10, 13, 14, 26, 15, 23, 16	20, 19
	2	10, 23, 26, 7, 16, 15, 8, 1, 2, 13, 3, 9, 4, 14	11, 12, 20, 13, 14, 17, 18	23, 21, 22, 27, 28, 26, 24, 20, 25	5, 29, 30, 6	10, 23, 26, 7, 16, 15, 8, 27, 28
	3	21, 24, 25, 27, 28, 22	10, 1, 2, 4, 6, 21, 22	16, 18, 19	1, 2, 7, 8	1, 2, 13, 3, 9, 4, 14
	4	11, 12	23, 8, 9, 15, 16, 27	11, 12, 13, 14, 15	17, 18, 21, 22, 24, 25	11, 12
	5	5, 29, 30, 6	3, 19, 23, 28	7, 8, 17, 1, 2, 3, 4	27, 28	5, 29, 30, 6, 21, 22, 24, 25
	6	20, 19	24, 25, 26	9, 10	11, 12	17, 18
7	1	1, 2	25, 27, 28, 23	7, 8, 9	23, 10, 13, 26, 16, 15	26, 23, 24, 25, 27, 28
	2	7, 8	11, 12, 17, 18	19, 20, 4	14, 1, 2, 9	4, 10, 19, 13, 14, 16, 3, 9
	3	21, 24, 25, 27, 28, 22	19, 20, 3, 4, 9, 10, 13, 14, 21, 24	1, 2, 3, 6	17, 18, 21	7, 8
	4	11, 12	5, 29, 30	11, 12, 17, 18	25, 27, 28, 12, 19, 20	11, 12
	5	5, 29, 30, 6	6, 7, 8, 15	5, 29, 30, 23, 24	29, 30, 24, 22	17, 18, 21, 22, 15, 20
	6	19, 20, 3, 4, 9, 10, 13, 14, 26, 15, 23, 16	1, 2, 16	16, 21, 25, 27, 28, 22, 15	5, 6, 7, 8	1, 2
	7	17, 18	22, 26	10, 13, 14, 26	11, 3, 4	5, 29, 6, 30
8	1	12, 11	19, 20, 3, 4, 9	27, 28, 29, 30	17, 18	5, 29, 30, 6

	2	1, 2	7, 8, 6	7, 24, 25, 8	22, 23, 26, 24	1, 2
	3	21, 24, 25, 27, 28, 22	1, 2	5, 6	3, 5, 6, 9, 10	19, 20, 23, 26, 25, 27
	4	5, 6	5, 29, 30	17, 18, 19, 20	11, 12	3, 4, 10, 13, 15, 16, 9
	5	29, 30	22, 27, 28	3, 4, 10, 13, 26, 16	13, 15, 19, 20, 14	17, 18
	6	17, 18	21, 16, 24, 25	14, 15	25, 27, 21	21, 22, 24, 28
	7	7, 8	11, 12, 17, 18	9, 1, 2, 21, 22	29, 30	11, 12, 14
	8	23, 3, 4, 10, 26, 16, 9, 14, 19, 20, 15	10, 13, 14, 26, 15, 23	11, 12, 23	28, 1, 2, 4, 7, 16, 8	7, 8

Table 6: Within Group Similarity Index and Set-up Cost

S/N	Similarity Index	Set-up Cost	Number of Groups
1	0.88	39.54	
2	0.7761	41.99	2
3	0.7301	42.05	
4	0.707	43.78	
5	0.7009	49.31	
1	0.9473	45.33	
2	0.7383	55.16	
3	0.7619	53.45	3
4	0.8263	49.7	
5	0.7126	61.53	
1	0.9641	44.34	
2	0.7448	64.96	4
3	0.8623	53.53	
4	0.822	56.3	
5	0.7674	60.09	
1	0.9776	53.28	
2	0.8004	67.28	
3	0.8531	65.21	5
4	0.7594	72.16	
5	0.8681	61.95	
1	0.9827	56.34	
2	0.7755	76.77	
3	0.8892	69.08	6
4	0.9485	60.4	
5	0.9121	66.71	
1	0.9889	64.12	
2	0.8223	74.53	
3	0.8544	70.76	7
4	0.7813	78.17	
5	0.9288	67.29	
1	0.9903	68.24	
2	0.9002	73.32	8
3	0.819	79.72	
4	0.9115	71.93	
5	0.9298	70.34	

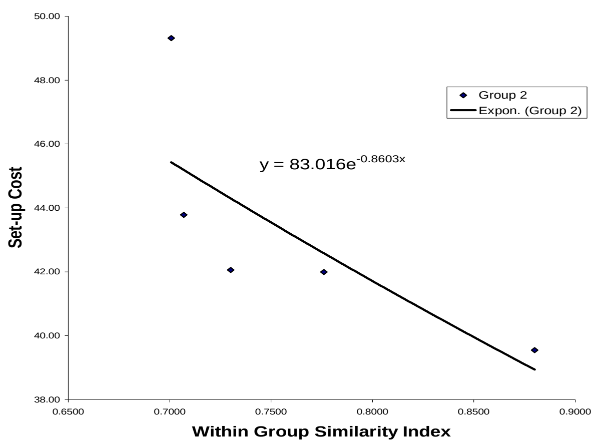


Fig. 1(a) Exponential graph of group similarity index against set-up cost for group 2

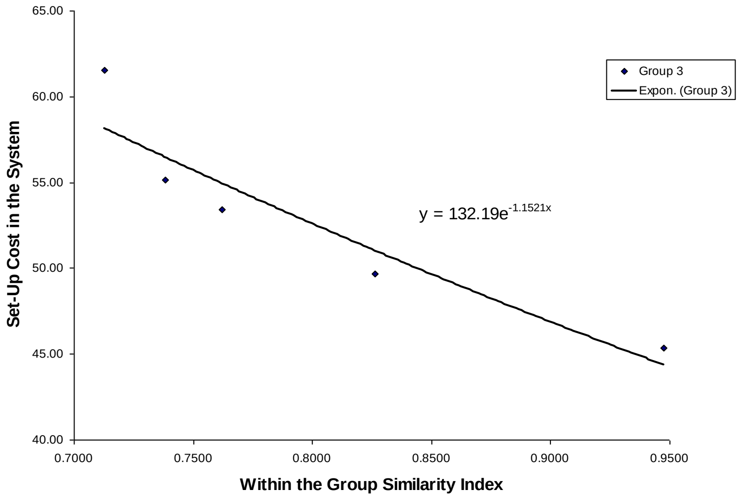


Fig. 1(b) Exponential graph of group similarity index against set-up cost for group 3

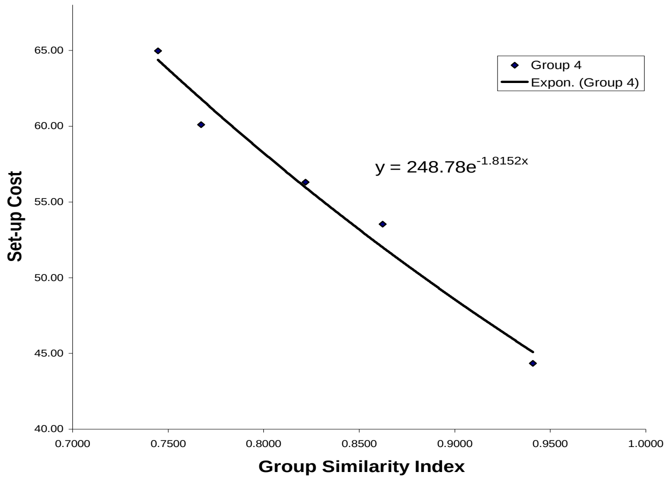


Fig. 1(c) Exponential graph of group similarity index against set-up cost for group 4

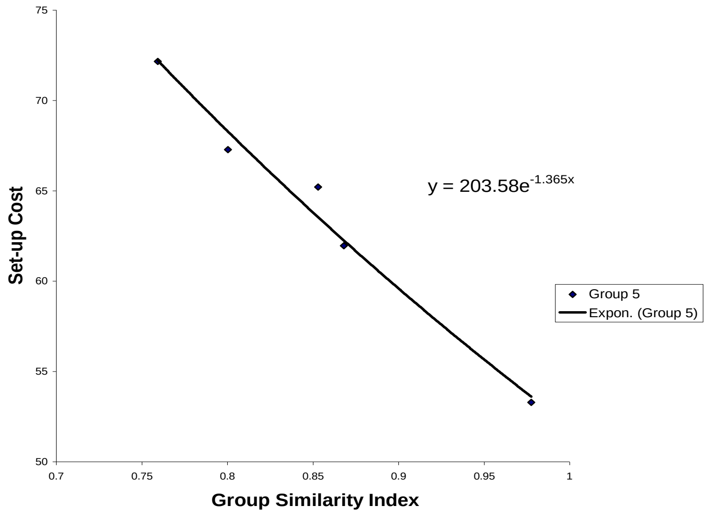


Fig. 1(d) Exponential graph of group similarity index against set-up cost for group 5

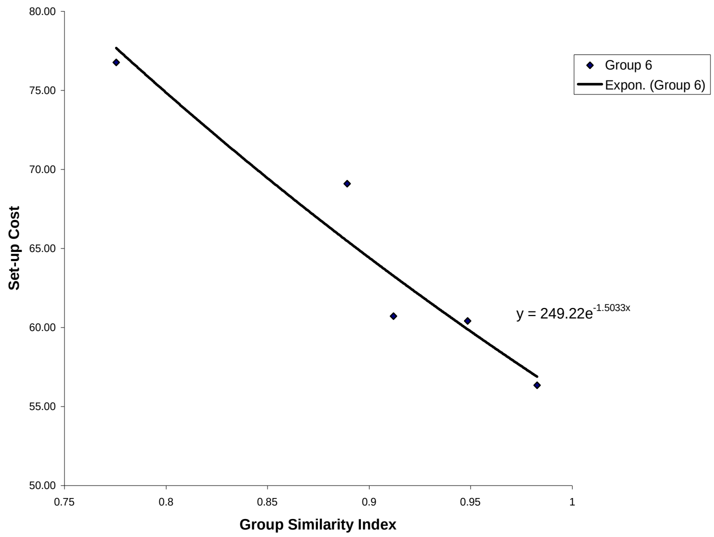


Fig. 1(e) Exponential graph of group similarity index against set-up cost for group 6

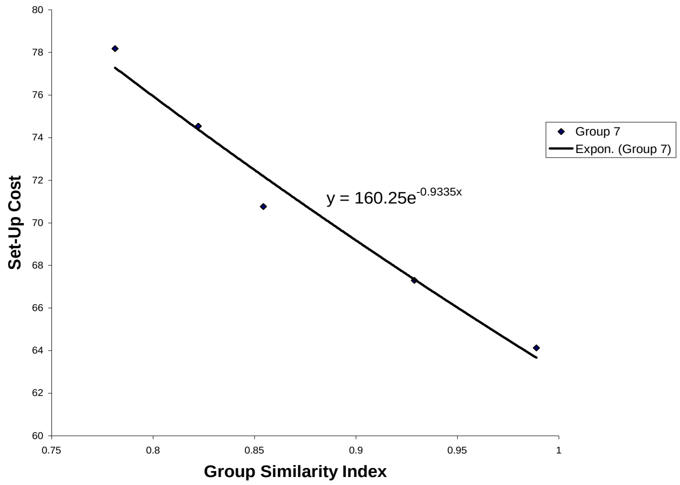


Fig. 1(f) Exponential graph of group similarity index against set-up cost for group 7

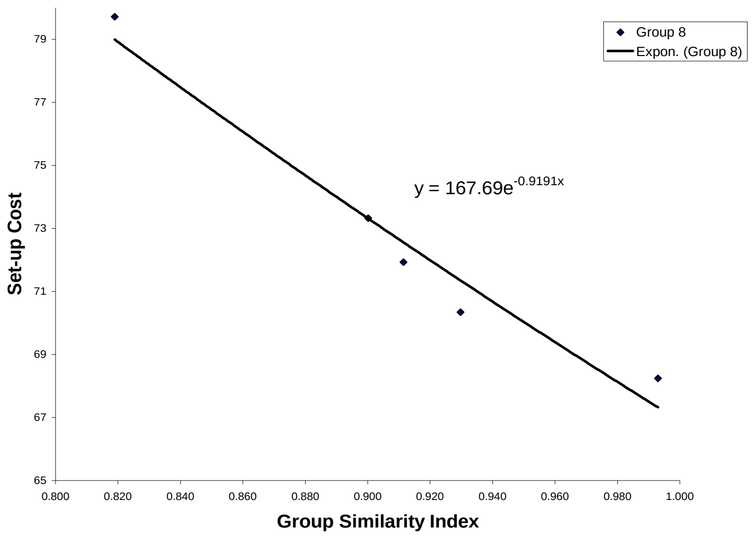


Fig. 1(g) Exponential graph of group similarity index against set-up cost for group 8

V. RESULTS AND DISCUSSIONS

The results presented in Table 6 shows the summary of all the groups involved between the group similarity and the machine set-up cost. A thorough investigation shows that when the number of groups is equal to two, the within group similarity index is 0.88 as the best index value this group can achieve. It also shows that at higher index value, the set-up cost is lower as compared to a lower index value.

In addition, investigation also shows that as the number of group increases, the group similarity index approaches one (0.9903) as indicated when the number of groups is eight. Parts in each group are similar in design characteristics and manufacturing processes required to produce them. This means that group 4 to 8 can be regarded as a better grouping, which brings about a reduction in machine set-up cost as shown in Table 6. Also, in Fig. 1 shows theexponential graphs between the within group similarity and machine set-up cost. A critical look at group 2 and 3 indicates that the predicted value is far from the observed value which shows the grouping is poor compare to group 4 to 8 as shown in the Fig. 1(c) to Fig. 1(g).

VI. CONCLUSION

In this paper an attempt was made to identify parts' relevant parameters for designing similarity indices and was used for computing group similarity indices. A coding system based on Optiz coding in design characteristics was adopted for thirty parts that can be manufactured on a lathe machine, the parts were grouped using the coding system.

A group machine set-up cost was computed from the machine set-up time obtained from the standard time to perform twenty-one machine set-up tasks. If the cost of performing a job for a period of time is quantified, then the total cost of carrying out the job can be determined. Based on these, it was observed that as the number of group increases, the set-up cost reduces, therefore saving time and effort in setting up the machine operation.

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Appendix A: Similarity index of parts i and j, R_{ij}

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	1	0.85	0.85	0.71	1	1	0.85	0.57	0.85	0.57	0.57	0.85	0.85	0.85
2	1	0	0.85	0.85	0.71	0.71	1	1	0.85	0.85	0.57	0.57	0.85	0.85	0.85
3	0.85	0.85	0	1	0.71	0.71	0.85	0.85	1	1	0.57	0.57	1	1	0.85
4	0.85	0.85	1	0	0.71	0.71	0.85	0.85	1	1	0.57	0.57	1	1	0.85
5	0.71	0.71	0.71	0.71	0	1	0.71	0.71	0.71	0.71	0.57	0.57	0.71	0.71	0.85
6	0.71	0.71	0.71	0.71	1	0	0.71	0.71	0.71	0.71	0.57	0.57	0.71	0.71	0.85
7	1	1	0.85	0.85	0.71	0.71	0	1	0.85	0.85	0.57	0.57	0.85	0.85	0.85
8	1	1	0.85	0.85	0.71	0.71	1	0	0.85	0.85	0.57	0.57	0.85	0.85	0.85
9	0.85	0.85	1	1	0.71	0.71	0.85	0.85	0	1	0.57	0.57	1	1	0.85
10	0.85	0.85	1	1	0.71	0.71	0.85	0.85	1	0	0.57	0.57	1	1	0.85
11	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0	1	0.57	0.57	0.57
12	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	1	0	0.57	0.57	0.57
13	0.85	0.85	1	1	0.71	0.71	0.85	0.85	1	1	0.57	0.57	0	1	0.85

14	0.85	0.85	1	1	0.71	0.71	0.85	0.85	1	1	0.57	0.57	1	0	0.85
15	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.57	0.57	0.85	0.85	0
16	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.57	0.57	0.85	0.85	1
17	0.85	0.85	0.85	0.85	0.71	0.71	0.85	0.85	0.85	0.85	0.57	0.57	0.85	0.85	0.85
18	0.85	0.85	0.85	0.85	0.71	0.71	0.85	0.85	0.85	0.85	0.57	0.57	0.85	0.85	0.85
19	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.57	0.57	0.85	0.85	1
20	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.57	0.57	0.85	0.85	1
21	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.43	0.43	0.57	0.57	0.71
22	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.43	0.43	0.57	0.57	0.71
23	0.85	0.85	1	1	0.71	0.71	0.85	0.85	1	1	0.57	0.57	1	1	0.85
24	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.43	0.43	0.57	0.57	0.71
25	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.43	0.43	0.57	0.57	0.71
26	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.57	0.57	0.85	0.85	1
27	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.43	0.43	0.57	0.57	0.71
28	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.43	0.43	0.57	0.57	0.71
29	0.71	0.71	0.71	0.71	1	1	0.71	0.71	0.71	0.71	0.57	0.57	0.71	0.71	0.85
30	0.71	0.71	0.71	0.71	1	1	0.71	0.71	0.71	0.71	0.57	0.57	0.71	0.71	0.85

Appendix A: (Contd.)

	16	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
1	0.85	0.85	0.85	0.85	0.85	0.57	0.57	0.85	0.57	0.57	0.85	0.57	0.57	0.71	0.71
2	0.85	0.85	0.85	0.85	0.85	0.57	0.57	0.85	0.57	0.85	0.85	0.57	0.57	0.71	0.71
3	0.85	0.85	0.85	0.85	0.85	0.57	0.57	1	0.57	0.57	0.85	0.57	0.57	0.71	0.71
4	0.85	0.85	0.85	0.85	0.85	0.57	0.57	1	0.57	0.57	0.85	0.57	0.57	0.71	0.71
5	0.85	0.71	0.71	0.85	0.85	0.57	0.57	0.71	0.57	0.57	0.85	0.57	0.57	1	1
6	0.85	0.71	0.71	0.85	0.85	0.57	0.57	0.71	0.57	0.57	0.85	0.57	0.57	1	1
7	0.85	0.85	0.85	0.85	0.85	0.57	0.57	0.85	0.57	0.57	0.85	0.57	0.57	0.71	0.71
8	0.85	0.85	0.85	0.85	0.85	0.57	0.57	0.85	0.57	0.57	0.85	0.57	0.57	0.71	0.71
9	0.85	0.85	0.85	0.85	0.85	0.57	0.57	1	0.57	0.57	0.85	0.57	0.57	0.71	0.71
10	0.85	0.85	0.85	0.85	0.85	0.57	0.57	1	0.57	0.57	0.85	0.57	0.57	0.71	0.71
11	0.57	0.57	0.57	0.57	0.57	0.43	0.43	0.57	0.43	0.43	0.57	0.43	0.43	0.57	0.57
12	0.57	0.57	0.57	0.57	0.57	0.43	0.43	0.57	0.43	0.43	0.57	0.43	0.43	0.57	0.57
13	0.85	0.85	0.85	0.85	0.85	0.57	0.57	1	0.57	0.57	0.85	0.57	0.57	0.71	0.71
14	0.85	0.85	0.85	0.85	0.85	0.57	0.57	1	0.57	0.57	0.85	0.57	0.57	0.71	0.71
15	1	0.85	0.85	1	1	0.71	0.71	0.85	0.71	0.71	1	0.71	0.71	0.85	0.85
16	0	0.85	0.85	1	1	0.71	0.71	0.85	0.71	0.71	1	0.71	0.71	0.85	0.85
17	0.85	0	1	0.85	0.85	0.57	0.57	0.85	0.85	0.85	0.85	0.57	0.57	0.71	0.71
18	0.85	1	0	0.85	0.85	0.57	0.57	0.85	0.57	0.57	0.85	0.57	0.57	0.71	0.71
19	1	0.85	0.85	0	1	0.71	0.71	0.85	0.71	0.71	1	0.71	0.71	0.85	0.85
20	1	0.85	0.85	1	0	0.71	0.71	0.85	0.71	0.71	1	0.71	0.71	0.85	0.85
21	0.71	0.57	0.57	0.71	0.71	0	1	0.57	1	1	0.71	1	1	0.57	0.57
22	0.71	0.57	0.57	0.71	0.71	1	0	0.57	1	1	0.71	1	1	0.57	0.57
23	0.85	0.85	0.85	0.85	0.85	0.57	0.57	0	0.57	0.57	0.85	0.57	0.57	0.71	0.71
24	0.71	0.57	0.57	0.71	0.71	1	1	0.57	0	1	0.71	1	1	0.57	0.57
25	0.71	0.57	0.57	0.71	0.71	1	1	0.57	1	0	0.71	1	1	0.57	0.57
26	1	0.85	0.85	1	1	0.71	0.71	0.85	0.71	0.71	0	0.71	0.71	0.71	0.85
27	0.71	0.57	0.57	0.71	0.71	1	1	0.57	1	1	0.71	0	1	0.57	0.57
28	0.71	0.57	0.57	0.71	0.71	1	1	0.57	1	1	0.71	1	0	0.57	0.57
29	0.85	0.71	0.71	0.85	0.85	0.57	0.57	0.71	0.57	0.57	0.71	0.57	0.57	0	1
30	0.85	0.71	0.71	0.85	0.85	0.57	0.57	0.71	0.57	0.57	0.71	0.57	0.57	1	0

Appendix B: Machine set-up cost

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
0	3.45	4.12	3.45	3.45	4.12	4.12	4.7	5.39	4.12	5.84	4.12	4.57	3.45	4.7	3.45
1	-	2.19	1.19	1.52	2.19	2.19	2.77	3.46	2.19	3.91	2.19	2.64	1.19	2.77	0
2	1.52	-	1.52	1.52	2.19	2.19	2.77	3.46	2.19	3.91	0	2.64	1.52	2.77	1.52
3	1.19	2.19	-	1.52	2.19	2.19	2.77	3.46	2.19	3.91	2.19	2.64	0	2.77	1.19
4	1.52	2.19	1.52	-	2.19	2.19	2.77	3.46	2.19	3.91	2.19	2.64	1.52	2.77	1.52
5	1.52	2.19	1.52	1.52	-	0	2.77	3.46	2.19	3.91	2.19	2.64	1.52	2.77	1.52
6	1.52	2.19	1.52	1.52	0	-	2.77	3.46	2.19	3.91	2.19	2.64	1.52	2.77	1.52
7	1.52	2.19	1.52	1.52	2.19	2.19	-	3.46	2.19	3.91	2.19	2.64	1.52	0	1.52
8	1.52	2.19	1.52	1.52	2.19	2.19	2.77	-	1.17	2.89	2.19	2.64	1.52	2.77	1.52
9	1.52	2.19	1.52	1.52	2.19	2.19	2.77	2.44	-	2.89	2.19	1.62	1.52	2.77	1.52
10	1.52	2.19	1.52	1.52	2.19	2.19	2.77	2.44	1.17	-	2.19	1.17	1.52	2.77	1.52
11	1.52	0	1.52	1.52	2.19	2.19	2.77	3.46	2.19	3.91	-	2.64	1.52	2.77	1.52
12	1.52	2.19	1.52	1.52	2.19	2.19	2.77	2.44	1.17	2.44	2.19	-	1.52	2.77	1.52
13	1.19	2.19	0	1.52	2.19	2.19	2.77	3.46	2.19	3.91	2.19	2.64	-	2.77	1.19
14	1.52	2.19	1.52	1.52	2.19	2.19	0	3.46	2.19	3.91	2.19	2.64	1.52	-	1.52
15	0	2.19	1.19	1.52	2.19	2.19	2.77	3.46	2.19	3.91	2.19	2.64	1.19	2.77	-

16	1.52	2.19	1.52	1.52	2.19	2.19	2.77	2.44	1.17	2.44	2.19	1.17	1.52	2.77	1.52
17	1.52	2.19	1.52	0	2.19	2.19	2.77	3.46	2.19	3.91	2.19	2.64	1.52	2.77	1.52
18	1.19	2.19	1.19	1.52	2.19	2.19	2.77	3.46	2.19	3.91	2.19	2.64	1.19	2.77	1.19
19	1.52	2.19	1.52	1.52	2.19	2.19	2.77	2.44	1.17	0	2.19	1.17	1.52	2.77	1.52
20	1.52	2.19	1.52	1.52	0	0	2.77	3.46	2.19	3.91	2.19	2.64	1.52	2.77	1.52
21	1.52	2.19	1.19	1.52	2.19	2.19	2.77	3.46	2.19	3.91	2.19	2.64	1.19	2.77	0
22	1.52	2.19	1.52	1.52	2.19	2.19	2.77	3.46	2.19	3.91	2.19	2.64	1.52	2.77	1.52
23	1.52	2.19	1.52	1.52	0	2.19	2.77	3.46	2.19	3.91	2.19	2.64	1.52	2.77	1.52
24	1.19	2.19	1.52	1.52	2.19	2.19	2.77	3.46	2.19	3.91	2.19	2.64	1.52	2.77	1.19
25	0	2.19	1.19	1.52	2.19	2.19	2.77	3.46	2.19	3.91	2.19	2.64	1.19	2.77	1.52
26	1.52	2.19	1.52	1.52	2.19	2.19	2.77	2.44	1.17	2.44	2.19	1.17	1.52	2.77	1.52
27	1.52	2.19	1.52	0	2.19	2.19	2.77	3.46	2.19	3.91	2.19	2.64	1.52	2.77	1.52
28	1.19	2.19	1.19	1.52	2.19	2.19	2.77	3.46	2.19	3.91	2.19	2.64	1.19	2.77	1.19
29	1.52	2.19	1.52	1.52	2.19	2.19	2.77	2.44	1.17	0	2.19	1.17	1.52	2.77	1.52
30	1.52	2.19	1.52	1.52	0	0	2.77	3.46	2.19	3.91	2.19	2.64	1.52	2.77	1.52

Appendix B: (Contd.)

	16	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
0	5.27	3.45	3.45	5.84	4.12	1.52	1.52	2.19	1.19	0	3.34	2.77	3.46	2.19	2.19
1	3.34	1.52	1.19	3.91	2.19	1.52	1.52	2.19	1.52	1.52	3.34	2.77	3.46	2.19	2.19
2	3.34	1.52	1.52	3.91	2.19	1.19	1.52	2.19	1.52	1.19	3.34	2.77	3.46	2.19	2.19
3	3.34	1.52	1.19	3.91	2.19	1.52	1.52	2.19	1.52	1.52	3.34	2.77	3.46	2.19	2.19
4	3.34	0	1.52	3.91	2.19	1.52	1.52	0	1.52	1.52	3.34	2.77	3.46	2.19	0
5	3.34	1.52	1.52	3.91	0	1.52	1.52	2.19	1.52	1.52	3.34	2.77	3.46	2.19	0
6	3.34	1.52	1.52	3.91	0	1.52	1.52	2.19	1.52	1.52	3.34	2.77	3.46	2.19	2.19
7	3.34	1.52	1.52	3.91	2.19	1.52	1.52	2.19	1.52	1.52	2.32	2.77	2.44	1.17	2.19
8	2.32	1.52	1.52	2.89	2.19	1.52	1.52	2.19	1.52	1.52	1.87	2.77	2.44	1.17	2.19
9	2.32	1.52	1.52	2.89	2.19	1.52	1.52	2.19	1.52	1.52	3.34	2.77	2.44	1.17	2.19
10	1.87	1.52	1.52	0	2.19	1.52	1.52	2.19	1.52	1.52	1.87	2.77	3.46	2.19	2.19
11	3.34	1.52	1.52	3.91	2.19	1.52	1.52	2.19	1.52	1.52	3.34	2.77	2.44	1.17	2.19
12	1.87	1.52	1.52	2.44	2.19	1.52	1.52	2.19	0	1.19	3.34	2.77	3.46	2.19	2.19
13	3.34	1.52	1.19	3.91	2.19	1.19	1.52	2.19	1.52	1.52	3.34	2.77	3.46	2.19	2.19
14	3.34	1.52	1.52	3.91	2.19	1.52	1.52	2.19	1.19	1.52	3.34	2.77	3.46	2.19	2.19
15	3.34	1.52	1.19	3.91	2.19	0	0	2.19	1.52	1.52	3.34	0	3.46	1.17	2.19
16	-	1.52	1.52	2.44	2.19	1.52	1.52	2.19	1.52	1.19	3.34	2.77	2.44	2.19	2.19
17	3.34	-	1.52	3.91	2.19	1.19	1.52	2.19	1.19	1.52	1.87	2.77	3.46	2.19	2.19
18	3.34	1.52	-	3.91	2.19	1.52	1.52	2.19	1.52	1.19	3.34	2.77	3.46	1.17	2.19
19	1.87	1.52	1.52	-	2.19	1.52	1.52	0	1.52	1.52	3.34	2.77	2.44	2.19	2.19
20	3.34	1.52	1.52	3.91	-	1.52	1.52	2.19	1.52	1.52	3.34	2.77	3.46	2.19	2.19
21	3.34	1.52	1.19	3.91	2.19	-	1.52	2.19	1.19	0	3.34	2.77	3.46	2.19	2.19
22	3.34	0	1.52	3.91	2.19	1.52	-	2.19	1.52	1.52	3.34	2.77	3.46	2.19	0
23	3.34	1.52	1.52	3.91	0	1.52	1.52	-	1.52	1.52	3.34	2.77	3.46	2.19	2.19
24	3.34	1.52	1.19	3.91	2.19	1.19	1.52	2.19	-	1.19	3.34	2.77	3.46	2.19	2.19
25	3.34	1.52	1.19	3.91	2.19	0	1.52	2.19	1.19	-	3.34	2.77	3.46	2.19	2.19
26	3.34	1.52	1.52	2.44	2.19	1.52	1.52	2.19	1.52	1.52	-	2.77	2.44	1.17	2.19
27	3.34	1.52	1.52	3.91	2.19	1.52	1.52	2.19	1.52	1.52	3.34	-	3.44	2.19	2.19
28	3.34	1.52	1.52	3.91	2.19	1.19	0	2.19	1.19	1.19	3.34	2.77	-	2.19	2.19
29	1.87	1.52	1.52	3.91	2.19	1.52	1.52	2.19	1.52	1.52	1.87	2.77	3.44	-	2.19
30	3.34	1.52	1.52	3.91	2.19	1.52	1.52	0	1.52	1.52	3.34	2.77	3.46	2.19	-

APPENDIX C

No. of Groups	Problem No.	Sequence	Set-up Cost	Total Set-up Cost
2	1 (i)	0-21-25-24-28-22-27	10.87	39.54
	(ii)	0-1-8-5-30-23-20-6-14-7-11-2-26-29-10-19-9-17-4-16-12-18	28.67	
	2 (i)	0-21-24-5-6-2-11-14-3-1-22	16.02	49.31
	(ii)	0-10-19-29-8-26-12-9-18-13-25-16-4-17-7-27-28-20-23-30-15	33.29	
	3 (i)	0-5-6-30-4-7-24-11-1-29-28-27	17.02	43.78
	(ii)	0-17-22-25-1-15-18-26-3-13-20-23-2-14-8-10-19-9-16-21	26.76	
	4 (i)	0-13-24-25-21-15-27-28-22-14-23-16-26	18.72	41.99
	(ii)	0-1-8-9-11-2-7-4-17-18-3-12-29-10-19-30-5-20-6	23.27	
	5 (i)	0-3-18-20-6-5-30-4-17-11-12-29-10-9	15.47	42.05
	(ii)	0-1-15-27-26-19-16-21-25-13-7-14-23-8-24-2-28-22	26.58	
3	1 (i)	0-12-22	6.76	45.33
	(ii)	0-5-6-20-17-4-26-3-13-1-15-18-30-23-14-7-8-9-10-19-16-2	27.7	
	(iii)	0-28-22-27-24-21-25	10.87	
	2 (i)	0-3-1-3-11-23-5-17-7-21-15-1-19-9	18.72	55.16
	(ii)	0-2-14-8-25-27-4-6-29-10-16-12	21.39	
	(iii)	0-22-20-18-24-30-26-28	15.05	

	3 (i)	0-11-2-29-12-17-4-1-30-18-3	15.42	53.45
	(ii)	0-21-7-20-6-5-27-28-22-19-8	17.97	
	(iii)	0-23-25-13-24-15-14-26-9-16-10	20.06	
	4 (i)	0-26-27-28-22-20-23-25-21-24	15.38	49.7
	(ii)	0-19-29-16-30-15-18	13.78	
	(iii)	0-3-6-5-13-2-11-10-12-9-4-17-8-1-14-7	20.54	
	5 (i)	0-25-21-22-11-23-12-24	13.51	61.53
	(ii)	0-10-9-21-15-20-8-4-17-14-18-3-10-9	24.07	
	(iii)	0-13-27-28-1-30-5-6-19-29-26-7-2	23.95	
4	1 (i)	0-29-30	6.31	44.34
	(ii)	0-3-13-18-1-15-23-2-14-7-5-6-20-16-19-10-9-8-26-4-17	20.4	
	(iii)	0-28-22-27-24-21-25	10.87	
	(iv)	0-12-11	6.76	
	2 (i)	0-19-29-16-30-15-18	15.38	64.96
	(ii)	0-25-21-22-11-23-12-24	13.51	
	(iii)	0-3-8-9-6-5-14-17	14.56	
	(iv)	0-1-13-2-7-20-27-4-10-26-28	21.51	
	3 (i)	0-2-5-29-6-30-7-1-26-19-13	16.48	53.53
	(ii)	0-28-22-27-24-21-25	10.87	
	(iii)	0-14-23-16-9-10-15-13	12.56	
	(iv)	0-18-3-11-17-4-12-8-20	13.62	
	4 (i)	0-26-27-28-22-20-23-25-21-24	15.38	56.3
	(ii)	0-19-29-16-30-15-18	13.78	
	(iii)	0-10-12-9-11-6-5	12.56	
	(iv)	0-3-13-1-2-17-4-7-14-8	14.58	
	5 (i)	0-21-24-5-6-2-11-14-3-1-22	16.02	60.99
	(ii)	0-19-29-16-30-15-18	13.78	
	(iii)	0-13-4-12-8-7	11.3	
	(iv)	0-20-23-10-26-9-28-25-27-17	18.99	

APPENDIX C (CONTD)

No. of Groups	Problem No.	Sequence	Set-up Cost	Total Set-up Cost
5	1 (i)	0-17-18	4.97	53.28
	(ii)	0-10-19-26-23-20-14-7-2-3-13-15-1-8-16-4	24.37	
	(iii)	0-28-22-27-24-21-25	10.87	
	(iv)	0-12-11	6.76	
	(v)	0-6-30-5-29	6.31	
	2 (i)	0-1-13-10-4-7-2	15.03	67.36
	(ii)	0-15-18-30-16-19-29	13.78	
	(iii)	0-3-8-9-6-5-14-17	14.56	
	(iv)	0-21-23-20-28-22-27-26	14.19	
	(v)	0-24-11-12-25	9.8	
	3 (i)	0-24-25-21-27-22	8.93	65.21
	(ii)	0-10-16-9-14-15-13-23	16.55	
	(iii)	0-3-18-11-12-8-17-4-20	15.62	
	(iv)	0-1-7-5-6-2	10.6	
	(v)	0-30-19-26-29-28	13.51	
	4 (i)	0-15-18-30-16-19-29	18.67	72.16
	(ii)	0-21-24-28-22-20-23-27-26	11.45	
	(iii)	0-13-14-11-17-10-12-25	16.53	
	(iv)	0-6-5-8-9	8.75	
	(v)	0-3-4-2-4-7	16.76	
	5 (i)	0-26-27-28-22-20-23-25-21-24	15.38	61.95
	(ii)	0-3-8-9-6-5-14-17	14.56	
	(iii)	0-12-11	6.76	
	(iv)	0-13-15-29-30	8.35	
	(v)	0-4-7-1-18-2-10-19-16	16.9	

APPENDIX C (CONTD)

No. of Groups	Problem No.	Sequence	Set-up Cost	Total Set-up Cost
6	1 (i)	0-17-18	4.98	56.34
	(ii)	0-3-15-1-8-9-13-14-7-23-26-10-16-2-4	21.11	
	(iii)	0-28-22-27-24-21-25	10.87	
	(iv)	0-12-11	6.76	
	(v)	0-6-30-5-29	6.31	
	(vi)	0-20-19	6.31	
	2 (i)	0-5-30-7-29-5	11.27	76.77

	(ii)	0-18-13-14-12-11-20-12	15.95	
	(iii)	0-21-1-22-10-2-4-6	16.3	
	(iv)	0-15-27-23-9-8-16	12.59	
	(v)	0-23-19-28-3	12.68	
	(vi)	0-25-24-26	7.98	
	3 (i)	0-6-30-5-29	6.31	69.08
	(ii)	0-26-27-28-22-20-23-25-21-24	17.38	
	(iii)	0-18-19-16	10.23	
	(iv)	0-13-11-14-12-15	15-58	
	(v)	0-3-1-7-8-17-4-2	12.58	
	(vi)	0-9-10	7.01	
	4 (i)	0-19-10-16-9-26-20-23-14-3-13-4-15	20.99	60.4
	(ii)	0-6-30-5-29	6.31	
	(iii)	0-1-8-7-2	11.87	
	(iv)	0-22-17-18-24-25-21	7.35	
	(v)	0-27-28	7.14	
	(vi)	0-12-11	6.76	
	5 (i)	0-19-20	8.03	66.71
	(ii)	0-23-28-15-27-8-16-7-10-26	23.1	
	(iii)	0-1-13-3-4-9-14-2	13.31	
	(iv)	0-12-11	6.76	
	(v)	0-30-5-6-22-29-25-21-24	10.54	
	(vi)	0-17-18	4.97	

APPENDIX C (CONTD)

No. of Groups	Problem No.	Sequence	Set-up Cost	Total Set-up Cost
8	1 (i)	0-12-11	6.76	68.24
	(ii)	0-2-1	5.64	
	(iii)	0-28-22-27-24-21-25	10.87	
	(iv)	0-5-6	4.12	
	(v)	0-29-30	6.31	
	(vi)	0-17-18	4.97	
	(vii)	0-7-8	8.16	
	(viii)	0-19-16-9-26-20-23-14-3-13-4-15	21.41	
	2 (i)	0-4-3-19-9-20	12.24	73.32
	(ii)	0-6-8-7	10.35	
	(iii)	0-2-1	5.64	
	(iv)	0-5-30-29	6.31	
	(v)	0-27-28-22	7.14	
	(vi)	0-16-21-25-24	6.46	
	(vii)	0-12-18-17-11	9.8	
	(viii)	0-23-13-15-10-26-14	15.38	
	3 (i)	0-29-27-30-28	12.54	79.72
	(ii)	0-8-25-24-7	10.87	
	(iii)	0-5-6	4.12	
	(iv)	0-20-17-19-18	11.07	
	(v)	0-16-4-13-3-23-10	14.41	
	(vi)	0-14-15	6.22	
	(vii)	0-2-21-22-9-1	11.54	
	(viii)	0-11-23-12	8.95	
	4 (i)	0-17-18	4.97	71.93
	(ii)	0-24-23-22-26	10.5	
	(iii)	0-6-5-3-10-9	10.72	
	(iv)	0-12-11	6.76	
	(v)	0-15-13-20-14-19	10.74	
	(vi)	0-27-25-21	6.22	
	(vii)	0-29-30	6.31	
	(viii)	0-1-4-8-16-2	15.71	
	5 (i)	0-30-5-29	6.31	70.34
	(ii)	0-1-2	5.64	
	(iii)	0-25-20-23-27-19-26	14.19	
	(iv)	0-15-3-13-9-4-10-16	14.13	
	(v)	0-17-18	4.97	
	(vi)	0-28-22-21-24	7.41	
	(vii)	0-11-14-12	9.53	
	(viii)	0-8-7	8.16	