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Optimization and Simulation of Facility Layout Using Merger Coefficient Formulae-A Case Study

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Abstract

A poor layout would result in high work in process, longer waiting times, low efficient scheduling and increased material handling costs. Facility layout design determines arrangement, location and distribution of machines in a manufacturing facility to achieve minimization of makespan time, maximization of productivity with respect to production schedule. This paper focuses on optimization and simulation of facility layout using Merger Coefficient Formulae for a typical facility layout. As a case study the existing facility layout of Vane Pump Manufacturing industry is considered and then the layout is optimized using merger coefficient formulae. Then the basic layout modules obtained from merger coefficient formulae are embedded in the existing layout thus forming a modular layout. To study the performance of the existing layout and the obtained modular layout in terms of average work-in-process (WIP), average time in system, average machine utilization and value added time in the system both the layouts are simulated in a discrete event simulation software namely FLEXSIM. With the help of this software it is easy to visualize the relocation of equipments in order to reduce the travelling distance between them since that will ultimately result in reduction of material handling and WIP costs incurred by current layout.

Keywords: *Modular Layout, Merger coefficient formulae, work-in- process, machine utilization, average time in system.*

1. Introduction

A typical manufacturing system consists of sequence of operations that convert raw materials to a desired form. A facility layout is defined as the method of arrangement of various facilities i.e. machines in a manufacturing company so that smooth flow of material or product takes place. Generally, three types of layouts are considered suitable for a manufacturing facility they are functional, cellular and product layouts. In functional layout machines with same machining capability are grouped into a single area, whereas in a cellular layout each department could be divided and machines in it are arranged in two or more cells. In Flow line layout machines are arranged in a linear layout according to the operation sequences of the product or the product family. Functional Layout has advantages of flexibility, but it also possesses disadvantages such as high production lead-times, high work-in-process (WIP) inventory levels and complex scheduling tasks. Whereas cellular layouts have major drawbacks such as high cost of cell organization when demand of a product mix change and operator non attending.

Therefore there is a need to use new approaches that combine the attributes of traditional functional, cellular and flow line layouts suitable for manufacturing companies that are having High mix Low volume (HMLV) environment [1]. Huang and Irani [5] proposed a novel layout approach that can be used for designing a layout having methodical product flows and high flexibility i.e. modular layout. A modular layout is a group of layout modules. A layout module is essentially a group of machines connected by a material flow network that exhibits a flow pattern characteristic of a specific type of layout such as flow line, functional and cell. In essence, the layout module expands the ideas of “cells” in a cellular layout and “departments” in a functional layout by allowing a module to have a product, process or part family focus. Flexible layouts are those that can effectively survive with variations in product demand and product mix [2].Their performance is measured by expected material handling cost over the various possible demand scenarios.

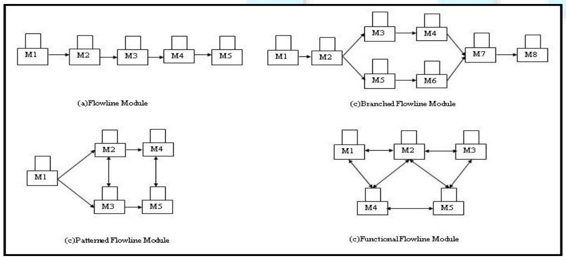
Fractal Layout is an extension of cellular layout. In fractal layout the manufacturing facility is splitted into identical machine cells. Each cell contains a different mix of machines. The mix of machine types forming a cell is called a fractal. The products coming to the fractal are availed with large number of resources with respect to product requirements [4].

For the modular layout a heuristic approach is used to generate layout modules that have five stages based on a similarity measure for comparison of operation sequences. In our case study we use this heuristic method to generate basic layout modules for designing modular layout for a vane pump manufacturing industry. In this paper, the performance of the existing layout and the proposed modular layout in terms of average work-in-process (WIP), average time in system, average machine utilization and value added time in the system are simulated using Flexsim simulation software. Flexsim is discrete event simulation software used as a tool to aid in production and process planning.

The rest of the paper is organized as flows: Section 2 discusses the different types of layout modules and Section3 presents the problem definition.Section4 describes the methodology for designing the modular layout.Section5 represents the performance evaluation of the proposed layout using simulation approach whereas Section6 demonstrates the results and discussions. Finally, section 7 presents the conclusions.

2. Layout Modules

The concept of designing any facility layout as a network of layout modules provides a methodical product flows for the design of multi-product manufacturing facilities. The total material flow network in correlation with the operation sequences of the products being produced by the facility may not be correctly represented by one of the traditional layouts. The proposed concept uses the idea of grouping and arranging the machines in any facility layout which can be decomposed as a network of layout modules, with each module being the subset of the entire facility. Fig. 1 illustrates the different types of Layout modules.



(a)Flowline Module

(c)Branched Flowline Module

(c)Patterned Flowline Module

(c)Functional Flowline Module

Figure 1: Types of layout modules [5]

2.1 Flow line Module: A Flow line module is a linear arrangement of machines such that all inter machine moves for consecutive pairs of operations on any product moving through the line would be forward, either in sequence or bypass.

2.2 Branched (Convergent/Divergent) Flow line module*:* A branched flow line module results when a set of products has operation sequences with one or more substrings of operations common to all of them.

2.3 Patterned Flow Module: The material flow network in a patterned flow line module exhibits a flow dominance and precedence hierarchy property of a Directed Acyclic Diagraph (DAG)

2.4 Functional Layout module: A Functional layout module is analogues to the process-focused department in a traditional Functional layout in which material flows are random.

3. Problem definition

The objective of this paper is to design a multi-product facility layout for a vane pump manufacturing industry operating in a High-mix low volume (HMLV) manufacturing environment. The facility layout is designed based on the sequence of parts generated by a different product varieties and volumes.The main idea here is to use each of the three traditional layouts as a unit of being together that are assembled into a different configuration to design a different layout for a facility.

After the layout was designed performance analysis is done for both the existing layout and developed layout with the aim of minimizing distance travelled,Work in process and average lead time etc. A discrete event simulation software Flexsim has been chosen for simulation

This is a batch shop company manufacturing a different product mix. Machines are grouped by function,which provides the shop a great deal of flexibility.There are 26 computer numerically controlled (CNC)machines with 3,4 and 5 axis capabilities.There are also manually operated drills as well as precision machines and deburring stations.Presently,the shop runs a 6 days/2 shifts operation,fully manned on first shift with manpower decreasing approximately by half in the next shift.

4. Research Methodology

This section consists of developing a layout based on the design criteria and information obtained from the user industry under consideration. The information includes transportation cost per unit distance, machine dimensions, routings of the products that provide good revenue, existing layout of the company and number of products and material handling capacity. A software package called FLOW PLANNER was used to model access the distance travelled by the parts. Additional information provided by the company includes such as safety recommendations for construction features.

The layout was designed with the product mix contains 47 products and 31 machines as shown in Table 1 and Table2 and the remaining departments we have arranged based on From to chart. The typical path followed by all the components are shown in figure 2.

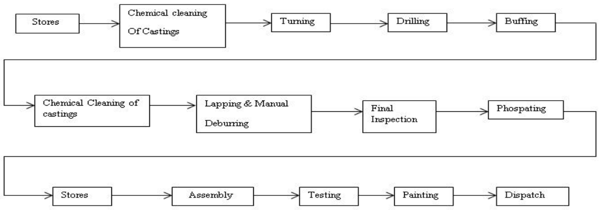


Figure 2:Typical path followed by the product

(Table 1: Description of Machines)

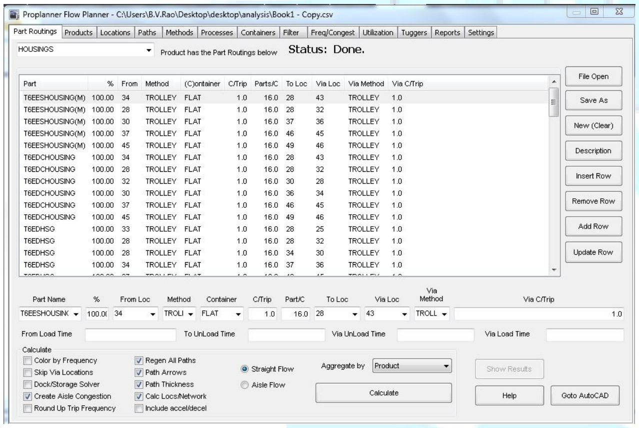
Machine no	Description	Quantity
1	PILATUS20T190	1
2	PILATUS20T191	1
3	PILATUS20T193	1
4	RIGI25194	1
5	RIGI25195	1
6	RIGI25196	1
7	RIGI25197	1
8	LL20TL3199	1
9	TAKISAWA1921	1
10	TAKISAWA1923	1
11	TAKISAWA1922	1
12	TAKISAWA1924	1
13	SMC250VSANDS30	1
14	SMC300VSANDS31	1
15	SMC300VSANDS32	1
16	KODI4533	1
17	SMC300VSANDS34	1
18	KODI4535	1
19	LV55	1
20	OOTY40500	1
21	MAXPROH540501	1
22	OOTY40502	1
23	OOTY40503	1
24	MAKINO5005	1
25	MAKINO5006	1
26	DRILLING 1	1
39	DRILLING 2	1
40	DRILLING 3	1
41	DRILLING 4	1
42	DRILLING 5	1
43	DRILLING 6	1

(Table 2: Description of Parts)

#Part	Operation sequence	Annual Quantity
1	43	55
2	5,6,13,43,43	58
3	5,6,19,44,41	107
4	4,5,16,43,39	695
5	4,16	522
6	20,22	529
7	4,6,18,44,41	626
8	1,3,,17	808
9	2,3,17,40	373
10	25,42	333
11	4,6,16	368
12	20,22	162
13	1,3,17	200
14	2,3,14,41	1158
15	26	3175
16	5,6,18,43,41	2737
17	5,6,18	225
18	2,3,17,41	11132
19	2,3,17,41	2983
20	2,3,17,41	623
21	11,16,43	67
22	4,7,16,43	957
23	4,5,16,44,19	8
24	22,23,42	600
25	5,18	30
26	20,25,42,21	298
27	11,21,43,41	97
28	4,6,18	626
29	8,19,12	2688
30	20,22	238
31	8,19	3110
32	26	1402
33	11,16,43	45
34	5,6,16,40	2647
35	5,18,7,16	81
36	5,19	37
37	8,19	1653
38	5,16	2578
39	4,5,16	134
40	4,5,16,44,19	1523
41	4,18,19,43	118
42	12,16,43,40	468
43	5,18,7,16	25
44	5,18,7,16	25
45	4,5,16,16,43,19	1523
46	25,43	25
47	9,15,40	50
48	10,14,40	521

Analysis is performed to assess the distance trips for work-in process and raw materials among all the departments.We use spaghetti diagram as a visual representation by using a continuous flow line tracing the product through a process.This analysis improves the part flows of the distance trips through the departments and potential areas of improvement using optional handling equipment. From these analyses it is helpful to lay machining centers in such a way that the total forward flows on the line are maximized, or total backward flows are minimized. The spaghetti diagram of the existing facility layout is as shown in the Figure 4.The total travelling distance from this analysis is found to be 502.95Km.

Based on this analysis some improvements are suggested such as 1)Exchange and relocation of machines so that efficient product flows can be attained.2)The operations which are performed outside the factory should be brought inside to improve the access of work-in-process.



HOUSINGS Product has the Part Routings below Status: Done.

Part	%	From	Method	(C)ontainer	C/Trip	Parts/C	To Loc	Via Loc	Via Method	Via C/Trip
T6EESHOUSING(M)	100.00	34	TROLLEY	FLAT	1.0	16.0	28	43	TROLLEY	1.0
T6EESHOUSING(M)	100.00	28	TROLLEY	FLAT	1.0	16.0	28	32	TROLLEY	1.0
T6EESHOUSING(M)	100.00	30	TROLLEY	FLAT	1.0	16.0	37	36	TROLLEY	1.0
T6EESHOUSING(M)	100.00	37	TROLLEY	FLAT	1.0	16.0	46	45	TROLLEY	1.0
T6EESHOUSING(M)	100.00	45	TROLLEY	FLAT	1.0	16.0	49	46	TROLLEY	1.0
T6EDCHOUSING	100.00	34	TROLLEY	FLAT	1.0	16.0	28	43	TROLLEY	1.0
T6EDCHOUSING	100.00	28	TROLLEY	FLAT	1.0	16.0	28	32	TROLLEY	1.0
T6EDCHOUSING	100.00	32	TROLLEY	FLAT	1.0	16.0	30	28	TROLLEY	1.0
T6EDCHOUSING	100.00	30	TROLLEY	FLAT	1.0	16.0	36	34	TROLLEY	1.0
T6EDCHOUSING	100.00	37	TROLLEY	FLAT	1.0	16.0	46	45	TROLLEY	1.0
T6EDCHOUSING	100.00	45	TROLLEY	FLAT	1.0	16.0	49	46	TROLLEY	1.0
T6EDHSG	100.00	33	TROLLEY	FLAT	1.0	16.0	28	25	TROLLEY	1.0
T6EDHSG	100.00	28	TROLLEY	FLAT	1.0	16.0	28	32	TROLLEY	1.0
T6EDHSG	100.00	28	TROLLEY	FLAT	1.0	16.0	34	30	TROLLEY	1.0
T6EDHSG	100.00	34	TROLLEY	FLAT	1.0	16.0	37	36	TROLLEY	1.0

Part Name	%	From Loc	Method	Container	C/Trip	Part/C	To Loc	Via Loc	Via Method	Via C/Trip
T6EESHOUSIN(	100.0(	34	TROLI	FLAT	1.0	16.0	28	43	TROLL	1.0

From Load Time
To UnLoad Time
Via UnLoad Time
Via Load Time

Calculate
☐ Color by Frequency
☐ Skip Via Locations
☐ Dock/Storage Solver
☑ Create Aisle Congestion
☐ Round Up Trip Frequency
☑ Regen All Paths
☑ Path Arrows
☑ Path Thickness
☑ Calc Locs/Network
☐ Include accel/decel
● Straight Flow
○ Aisle Flow
Aggregate by Product

Figure3: Material flow analysis using Flow planner software

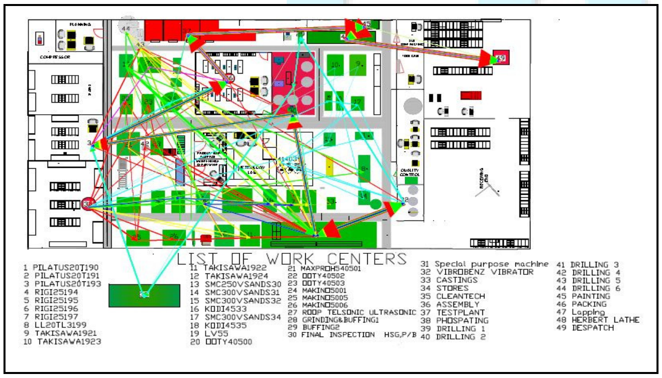


Figure 4: Spaghetti diagram of facility layout drawn using Flowplanner software

4.1. Generation of layout modules using heuristic procedure

In this section we describe the heuristic procedure for solving the problem for design of a modular layout.This is a hybrid method that combines the methods of Functional and cellular layouts. The industrial data is collected and studied as shown in Table1 and Table2 is used to demonstrate the method.

Stage1:Identification of common substrings,if any between all pair of operation sequences

A Layout module is essentially a group of machines connected by a material flow network that exhibits a flow pattern characteristic of a specific type of layout and thus could have a product, process or part family focus. A common substring is defined as a sequence of consecutive operations that is common to two or more operation sequences.

First,we find all the unique common substrings between all pair of routings.We choose only representative common substrings to be the dominant common substrings.The chosen dominant common substrings are shown in Table 3.These dominant common substrings are obtained from a Production flow analysis and simplification toolkit(PFAST) software.

PFAST is a layout optimization tool capable of providing much of the required information to design and make decision to design of a new facility layout or to modify existing layout.The algorithm for finding common substrings is shown in figure 3.

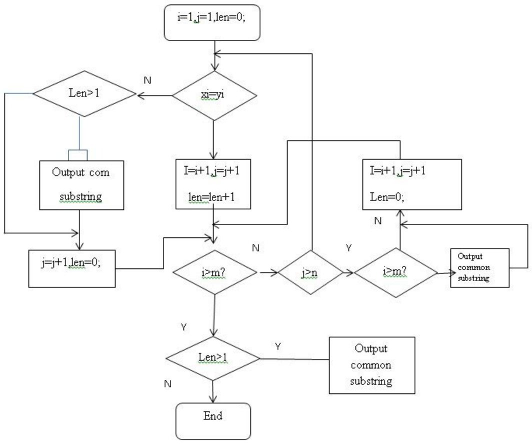


Fig 3: Algorithm for finding common_substrings in Two operation sequences[7]

Where:

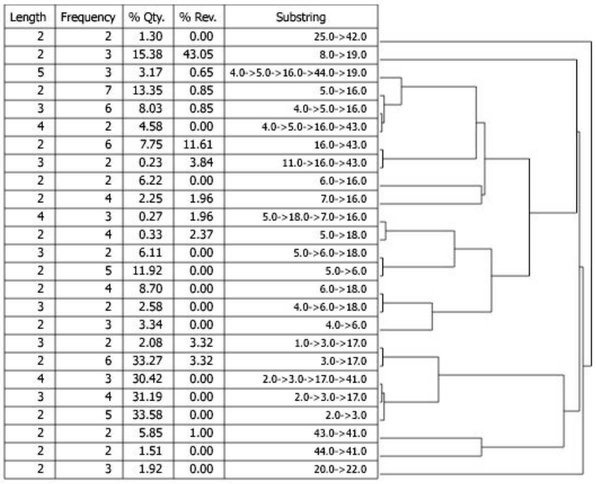
X_i -The i^{th} operation in sequence X

Y_j : The j^{th} operation in sequence Y

Len: Number of matching consecutive operations in Sequences X and Y.

Com_substr: Sequence of matching consecutive operations in sequences X and Y

Table 3. Common substring clustering



Length	Frequency	% Qty.	% Rev.	Substring
2	2	1.30	0.00	25.0->42.0
2	3	15.38	43.05	8.0->19.0
5	3	3.17	0.65	4.0->5.0->16.0->44.0->19.0
2	7	13.35	0.85	5.0->16.0
3	6	8.03	0.85	4.0->5.0->16.0
4	2	4.58	0.00	4.0->5.0->16.0->43.0
2	6	7.75	11.61	16.0->43.0
3	2	0.23	3.84	11.0->16.0->43.0
2	2	6.22	0.00	6.0->16.0
2	4	2.25	1.96	7.0->16.0
4	3	0.27	1.96	5.0->18.0->7.0->16.0
2	4	0.33	2.37	5.0->18.0
3	2	6.11	0.00	5.0->6.0->18.0
2	5	11.92	0.00	5.0->6.0
2	4	8.70	0.00	6.0->18.0
3	2	2.58	0.00	4.0->6.0->18.0
2	3	3.34	0.00	4.0->6.0
3	2	2.08	3.32	1.0->3.0->17.0
2	6	33.27	3.32	3.0->17.0
4	3	30.42	0.00	2.0->3.0->17.0->41.0
3	4	31.19	0.00	2.0->3.0->17.0
2	5	33.58	0.00	2.0->3.0
2	2	5.85	1.00	43.0->41.0
2	2	1.51	0.00	44.0->41.0
2	3	1.92	0.00	20.0->22.0

<u>Stage 2:Cluster analysis of dominant common substrings to generate basic layout modules</u>

The objective of this stage is to form basic layout modules using dominant common substrings.Dominant common substrings are whose frequencies of occurrence in the original routings are higher than the user defined threshold.to calculate of the merger coefficient between two operation sequences,the following two distances need to be defined first.

1.Merger Distance:The Merger distance for the absorption of sequence x into sequence y is defined as the smallest number of substitutions and insertions of operations in sequence y required to derive x from y using trace analysis,based on the set of trace analysis of the differences between x and ,denoted by $\{T_i(x,y)\}$:

$$md(x,y)=\min\{(S_i+I_i)|i\rightarrow T_i(x,y)\} \qquad (1)$$

md(x, y)= Merger Distance for the absorption of sequence x into sequence y.

S_i =Number of substitutions of operations in sequence y required in the ith trace analysis

2. Interruption distance: The interruption distance for the absorption of x into y is defined as the smallest number of non- ending deletions required, with md(x,y)fixed.Non ending deletions are defined as the deletions of one operation or several consecutive operations whose position in sequence y is neither start nor the end.

The formulation of the interruption distance is given as follows

$$id(x,y)=\min\{(D_i-D_i^e)|i\rightarrow[S_i+I_i=md(x,y)\} \qquad (2)$$

id(x,y)= Interruption Distance for the absorption of sequence x into sequence y.

D_i =Number of deletions of operations in sequence y required in ith trace analysis

D_i^e =Number of ending deletions of operations in sequence y required in the ith trace analysis

Once the merger distance and interruption distance between any two operation sequences x and y are identified, the merger coefficient between x and denoted by mc(x,y),can be calculated using formula proposed by Irani, S.A. and Huang H[7] shown below.

$$mc(x,y)=\left\{\begin{array}{l} \max\left(1-\dfrac{md(y,x)+\dfrac{id(y,x)}{N_{\max}}+\dfrac{N_x-N_y}{N_{\max}^2}}{N_y},0\right) \\ if N_x > N_y \\ \max\left(1-\dfrac{md(x,y)+\dfrac{id(x,y)}{N_{\max}}+\dfrac{N_y-N_x}{N_{\max}^2}}{N_x},0\right) \\ if N_x < N_y \\ \max\left(1-\dfrac{md(x,y)+\dfrac{id(x,y)}{N_{\max}}}{N_x},1-\dfrac{md(x,y)+\dfrac{id(x,y)}{N_{\max}}}{N_y},0\right) \\ if N_x = N_y \end{array}\right\} \qquad (3)$$

Where $N_{\max}$ is the number of operations in the longest operation sequence in the sample .N_x and N_y represent the number of operations in sequences x and y respectively.

Table 4.Unique common substring

No.	Common substrings	No	Common substrings
1	2-3-17-41	17	5-16
2	4-5-16-44-19	18	5-18-7-16
3	4-5-16-41-19	19	5-18
4	44-41	20	5-6
5	43-41	21	5-16-19
6	11-16-43	22	5-6-18
7	5-18-7-16	23	6-18
8	6-18	24	4-6-18
9	8-19	25	4-6
10	16-43	26	20-22
11	5-16	27	2-3
12	25-42	28	2-3-17
13	6-16	29	2-3-17-40
14	7-16	30	3-17
15	4-5-16-43		
16	4-5-16		

Next cluster analysis of dominant common substrings needs to be performed to group similar substrings and generate basic layout modules. Following Mulvey and Crowder[10] mathematical modeling for homogenous clustering of dominant common substrings to form basic layout modules is given as follow.

$$\text{Minimize} \sum_{I} \sum_{J} m_{ij} \cdot x_{ij} \qquad (4)$$

$$\text{Subjected to} \sum{}_{j} x_{ij} = 1, \text{for all i} \qquad (5)$$

$$\sum{}_{J} x_{jj} = K \qquad (6)$$

$$X_{ij} \leq x_{jj} \text{ for all i,j} \qquad (7)$$

$$x_{ij} \text{ binary,for all i,j} \qquad (8)$$

where

I= set of substrings

J=set of eligible medians

K=number of clusters

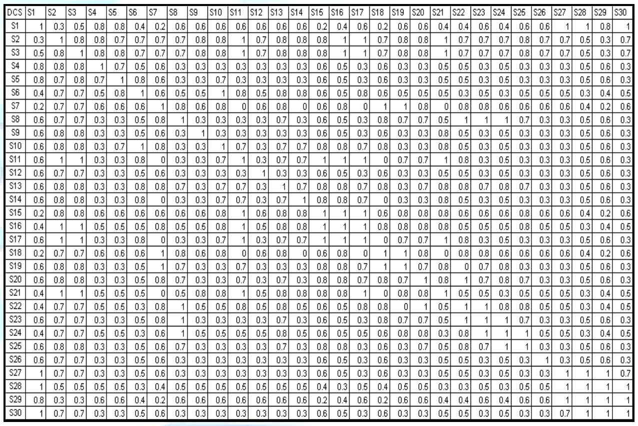
m_{ij} =Merger coefficient between substrings i and j

x_{ij} =1 if substring i is assigned to cluster median j

=0 Otherwise

From the above equation the merger coefficient for all pairs of dominant common substrings are computed as shown in table5.In several investigations of the cluster analysis literature [3] and [9],Average linkage was mostly suggested for its working under various scenarios.Figure 4 shows the dendrogram for agglomerative hierarchical clustering of dominant common substrings with the unweighted pair-group average linkage method,based on merger coefficients in Table 5.

Table5: Merger coefficients for all pairs of Dominant common substrings (DCS)



DCS	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
S1	1	0.3	0.5	0.8	0.8	0.4	0.2	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.2	0.4	0.6	0.2	0.6	0.6	0.4	0.4	0.6	0.4	0.6	0.6	1	1	0.8	1
S2	0.3	1	0.8	0.8	0.7	0.7	0.7	0.7	0.8	0.8	1	0.7	0.8	0.8	0.8	1	1	0.7	0.8	0.8	1	0.7	0.7	0.7	0.8	0.7	0.7	0.5	0.3	0.7
S3	0.5	0.8	1	0.8	0.8	0.7	0.7	0.7	0.8	0.8	1	0.7	0.8	0.8	0.8	1	1	0.7	0.8	0.8	1	0.7	0.7	0.7	0.8	0.7	0.7	0.5	0.3	0.7
S4	0.8	0.8	0.8	1	0.7	0.5	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.6	0.5	0.3	0.6	0.3	0.3	0.5	0.5	0.3	0.5	0.3	0.3	0.3	0.5	0.6	0.3
S5	0.8	0.7	0.8	0.7	1	0.8	0.6	0.3	0.3	0.7	0.3	0.3	0.3	0.3	0.6	0.5	0.3	0.6	0.3	0.3	0.5	0.5	0.3	0.5	0.3	0.3	0.3	0.5	0.6	0.3
S6	0.4	0.7	0.7	0.5	0.8	1	0.6	0.5	0.5	1	0.8	0.5	0.8	0.8	0.6	0.5	0.8	0.6	0.5	0.5	0.5	0.3	0.5	0.3	0.5	0.5	0.5	0.3	0.4	0.5
S7	0.2	0.7	0.7	0.6	0.6	0.6	1	0.8	0.6	0.8	0	0.6	0.8	0	0.6	0.8	0	1	1	0.8	0	0.8	0.8	0.6	0.6	0.6	0.6	0.4	0.2	0.6
S8	0.6	0.7	0.7	0.3	0.3	0.5	0.8	1	0.3	0.3	0.3	0.3	0.7	0.3	0.6	0.5	0.3	0.8	0.7	0.7	0.5	1	1	1	0.7	0.3	0.3	0.5	0.6	0.3
S9	0.6	0.8	0.8	0.3	0.3	0.5	0.6	0.3	1	0.3	0.3	0.3	0.3	0.3	0.6	0.5	0.3	0.6	0.3	0.3	0.8	0.5	0.3	0.5	0.3	0.3	0.3	0.5	0.6	0.3
S10	0.6	0.8	0.8	0.3	0.7	1	0.8	0.3	0.3	1	0.7	0.3	0.7	0.7	0.8	0.8	0.7	0.8	0.3	0.3	0.8	0.5	0.3	0.5	0.3	0.3	0.3	0.5	0.6	0.3
S11	0.6	1	1	0.3	0.3	0.8	0	0.3	0.3	0.7	1	0.3	0.7	0.7	1	1	1	0	0.7	0.7	1	0.8	0.3	0.5	0.3	0.3	0.3	0.5	0.6	0.3
S12	0.6	0.7	0.7	0.3	0.3	0.5	0.6	0.3	0.3	0.3	0.3	1	0.3	0.3	0.6	0.5	0.3	0.6	0.3	0.3	0.5	0.5	0.3	0.5	0.3	0.3	0.3	0.5	0.6	0.3
S13	0.6	0.8	0.8	0.3	0.3	0.8	0.8	0.7	0.3	0.7	0.7	0.3	1	0.7	0.8	0.8	0.7	0.8	0.3	0.7	0.8	0.8	0.7	0.8	0.7	0.3	0.3	0.5	0.6	0.3
S14	0.6	0.8	0.8	0.3	0.3	0.8	0	0.3	0.3	0.7	0.7	0.3	0.7	1	0.8	0.8	0.7	0	0.3	0.3	0.8	0.5	0.3	0.5	0.3	0.3	0.3	0.5	0.6	0.3
S15	0.2	0.8	0.8	0.6	0.6	0.6	0.6	0.6	0.6	0.8	1	0.6	0.8	0.8	1	1	1	0.6	0.8	0.8	0.8	0.6	0.6	0.6	0.8	0.6	0.6	0.4	0.2	0.6
S16	0.4	1	1	0.5	0.5	0.5	0.8	0.5	0.5	0.8	1	0.5	0.8	0.8	1	1	1	0.8	0.8	0.8	0.8	0.5	0.5	0.5	0.8	0.5	0.5	0.3	0.4	0.5
S17	0.6	1	1	0.3	0.3	0.8	0	0.3	0.3	0.7	1	0.3	0.7	0.7	1	1	1	0	0.7	0.7	1	0.8	0.3	0.5	0.3	0.3	0.3	0.5	0.6	0.3
S18	0.2	0.7	0.7	0.6	0.6	0.6	1	0.8	0.6	0.8	0	0.6	0.8	0	0.6	0.8	0	1	1	0.8	0	0.8	0.8	0.6	0.6	0.6	0.6	0.4	0.2	0.6
S19	0.6	0.8	0.8	0.3	0.3	0.5	1	0.7	0.3	0.3	0.7	0.3	0.3	0.3	0.8	0.8	0.7	1	1	0.7	0.8	0	0.7	0.8	0.3	0.3	0.3	0.5	0.6	0.3
S20	0.6	0.8	0.8	0.3	0.3	0.5	0.8	0.7	0.3	0.3	0.7	0.3	0.7	0.3	0.8	0.8	0.7	0.8	0.7	1	0.8	1	0.7	0.8	0.7	0.3	0.3	0.5	0.6	0.3
S21	0.4	1	1	0.5	0.5	0.5	0	0.5	0.8	0.8	1	0.5	0.8	0.8	0.8	0.8	1	0	0.8	0.8	1	0.5	0.5	0.3	0.5	0.5	0.5	0.3	0.4	0.5
S22	0.4	0.7	0.7	0.5	0.5	0.3	0.8	1	0.5	0.5	0.8	0.5	0.8	0.5	0.6	0.5	0.8	0.8	0	1	0.5	1	1	0.8	0.8	0.5	0.5	0.3	0.4	0.5
S23	0.6	0.7	0.7	0.3	0.3	0.5	0.8	1	0.3	0.3	0.3	0.3	0.7	0.3	0.6	0.5	0.3	0.8	0.7	0.7	0.5	1	1	1	0.7	0.3	0.3	0.5	0.6	0.3
S24	0.4	0.7	0.7	0.5	0.5	0.3	0.6	1	0.5	0.5	0.5	0.5	0.8	0.5	0.6	0.5	0.5	0.6	0.8	0.8	0.3	0.8	1	1	1	0.5	0.5	0.3	0.4	0.5
S25	0.6	0.8	0.8	0.3	0.3	0.5	0.6	0.7	0.3	0.3	0.3	0.3	0.7	0.3	0.8	0.8	0.3	0.6	0.3	0.7	0.5	0.8	0.7	1	1	0.3	0.3	0.5	0.6	0.3
S26	0.6	0.7	0.7	0.3	0.3	0.5	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.6	0.5	0.3	0.6	0.3	0.3	0.5	0.5	0.3	0.5	0.3	1	0.3	0.5	0.6	0.3
S27	1	0.7	0.7	0.3	0.3	0.5	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.6	0.5	0.3	0.6	0.3	0.3	0.5	0.5	0.3	0.5	0.3	0.3	1	1	1	0.7
S28	1	0.5	0.5	0.5	0.5	0.3	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.5	0.4	0.5	0.5	0.3	0.3	0.5	0.3	0.5	0.5	1	1	1	1
S29	0.8	0.3	0.3	0.6	0.6	0.4	0.2	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.2	0.4	0.6	0.2	0.6	0.6	0.4	0.4	0.6	0.4	0.6	0.6	1	1	1	1
S30	1	0.7	0.7	0.3	0.3	0.5	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.6	0.5	0.3	0.6	0.3	0.3	0.5	0.5	0.3	0.5	0.3	0.3	0.7	1	1	1

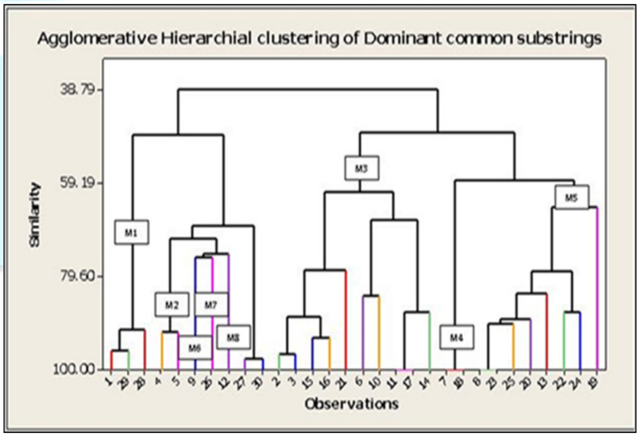
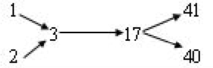
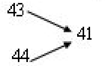
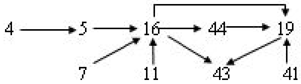
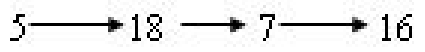
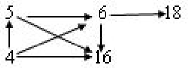
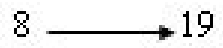


Figure 5.Agglomerative Hierarchical clustering drawn using statistical analysis software Minitab

Table 6:Basic layout modules

Module#	Cluster of Dominant common substrings	Diagraph of the Layout module
M1	S1,S27,S28,S29, S30	
M2	S4,S5	
M3	S4,S5,S6,S7,S8	
M4	S7,S18	
M5	S8,S23,S25,S20,S13 S22,S24,S19	
M6	S9	
M7	S26	
M8	S12	

Stage 3:Generation of Functional Layout modules if necessary

If two layout modules have many common machines,they are merged into a functional layout module to reduce machine duplication.The commonality between layout modules M_i and M_j is defined as

$$\frac{n_{ij}}{\min(n_i,n_j)} \qquad (9)$$

Where n_{ij} is the number of distinct operations common to both modules: n_i and n_j are the number of distinct operations in M_i and M_j

1. Calculate the commonality between each set of layout modules

2. Search for the set of layout modules with highest commonality.If the commonality is higher than user threshold level V,then sum up the two modules into one;if not go to step 1

The choice of V is a kind of problem that involves the user that will effect the classical tradeoff between inter-modular flow and machine duplication costs among the modules to eliminate or decrease the flows [6]

Stage 4:Expression of the original operation sequences in terms of the layout modules

In this stage, we replace the original part routings by the combination of residual machines and the layout modules generated using the above procedure.

Stage 5: Generation of facility layout as a network of layout modules

Based on the adjusted modular sequences, a diagraph representation between layout modules and residual machines in the facility layout are generated.

The numbers of machines required in a module are calculated as follows

$$N_{jk}=\sum_i \frac{T_{ijk}}{A_i} \qquad (10)$$

N_{jk} =Number of machines in type j required in module K

T_{ijk} =Capacity requirement for operation i on machine type j in module k

Based on the flow frequency between all the machines for all product flows, we design the modular layout using Flow Planner software.This Flow planner calculates the flow frequency in number of trips between any two locations on a route-by-route basis. These routes are then aggregated and used to scale the thickness of the flow lines between each pair of locations.

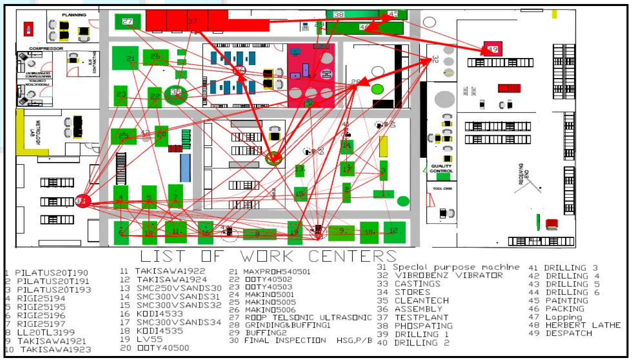


Figure 6:Final implementation of modular layout

In this case study based on the standard distance calculations, the total travel distance reduces from 502.95Km to 362.99Km the modular layout i.e. a significant improvement that can be expected from this layout change.

5. Performance Evaluation

The imitation of the behavior of a real-world process or system overtime is called simulation. Simulation involves the production of an artificial background of the system and the examination of that artificial history to draw conclusions about the operational characteristics of the real system that is represented. It is used to describe and analyze the behavior of a system. It is described as an aid in the design of real systems as explained by Jain and Leong[11].

In this section an experimental study is conducted to investigate the performance of our conceptual layout compared to the current layout.Flexsim simulation software is used in this study.There are main factors in this experimental study including 1)layout type 2)machine capacity 3)Material handling capacity 4)Move times. The batch size ranges from 30 to 150.The simulation parameters are shown in table 7.

Table 7.Simulation Parameters

Parameters	Values
Number of Part types	44
Number of machine Types	12
Annual demand	1752-2628
Setup time	0
Process times	2-18
Batch Sizes	30 to 150
Move times	Fixed
Job selection	First come first served basis
Machine capacity	Limited

Figure 7:Snapshot of the simulation model in Flexsim

Figure 8:Topview of the simulation model in Flexsim

Both current and proposed systems are modeled and simulated with the given values in order to find out the optimum layout strategy.

6. Results and Discussions

The results obtained from the simulation run are shown in the Figures 10 to14.From the material flow analysis the travel distance is reduced from 502.95km to 362.99km annually a significant improvement obtained from a layout change From the experimental design we derived the following results contains (1) average machine utilization (2) average completion times in hours per part (3)average Work in process which are the average number of parts being processed (4)value added time in system

Figure 9 shows the performance of current and proposed layout. From this result it is concluded that there is an increase in average machine utilization from 30% to 33%

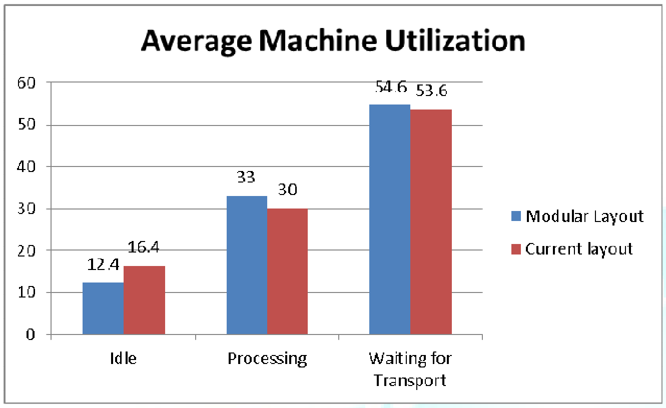


Figure 9 shows the average machine utilization for current layout and Modular layout

Also the average time in system which is the average time a part spent in the system has decreased significantly in modular layout. Figure 10 shows the average stay time of part in the system

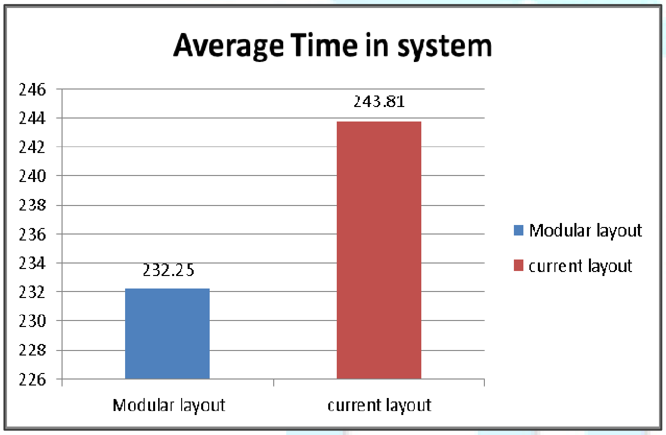


Figure 10 Average Time in system in Current layout and modular layout

The average work in process inventory is the average of the opening work in process inventory and the closing work in process inventory. It has been observed that the average work in process in the system decreased considerably about 1591 units.Figure11 shows the comparison of Average work in process for both current layout and modular layout

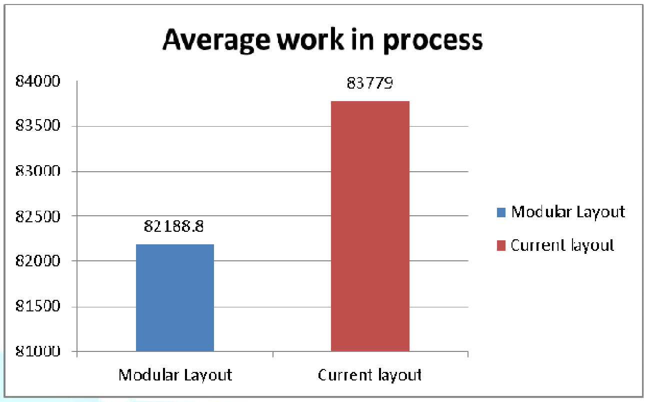


Figure 11 Average work in process for current layout and modular layout

Figure 12 shows the total distance travelled in Current layout and modular layout obtained from Flow Planner software. Flow planner calculates the flow frequency in number of trips between any two locations on a route-by-route basis .These routes are aggregated and then total distance travelled is calculated

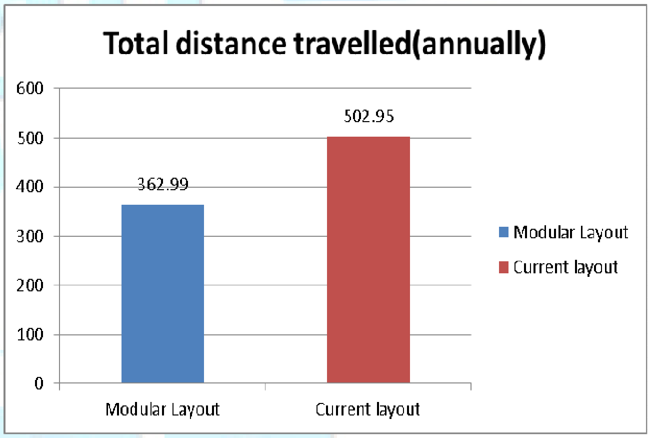


Fig12:Total distance travelled in material flow analysis(annually) in Flow planner

Figure 13 shows the Value added time in system increased from 26.38% to 32% which are obtained from simulation. The results shows there is a significant increase in value added time thereby indicating better work flow in production processes

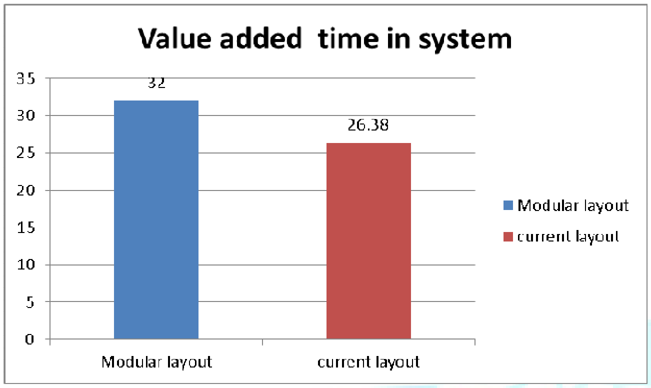


Figure 13:Value added time in system

7.Conclusions

From the experimental study it can be concluded that the performance of the proposed layout can do significantly well. A modular layout can vastly reduce the amount of distances that travelled annually from 502.95 km to 362.99 km in current layout when different machines are grouped together. The modular layout outperform current layout in terms of average time in system whose values are 232.5hrs and 243.81hrs.The modular layout performed good in terms of average machine utilization whose value are 33% for modular layout and 30% for current layout and average work in process decreased considerably from 83779 units in current layout to 82188.8 units in modular layout. The value added time in system increased drastically from 26.38% in current layout to 32% in modular layout.

Finally in this paper we have presented the requisite that a batch manufacturing company changes their layout to facilitate the flow that is the first step to lean manufacturing. We have addressed these need by proposing novel layout approach a modular layout. An earlier mathematical model and concept for design of layout were introduced. We have presented an experimental study using Flexsim a discrete simulation software. We have identified from experimental study that performance of the modular layout is potentially fit when operating in a real time system. Therefore modular layout can be a solution for bringing both flexibility and distance travelled reduction.

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