Equipments Selection for Material Handling in Flexible Manufacturing System

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Abstract

Material handling (MH) is important issue for every production site and has a great dependence upon the layout of the system. The important issue in the design of MH system is the selection of material handling equipment for every MH operation. Based upon the literature survey in this area, our purpose is to focus on the evaluation of the MHS-Layout of the system, due to their strong interdependence. The aim of this paper is to present a method for selection of material handling equipment (MHE) for flexible manufacturing system. In the first phase, the system consider major issues, rate of transfer, average time to transfer, flexibility *etc*, which is essential for the system. In second phase, the system selects the most feasible MHE types for every MH operation in a given application depends upon these major issues using fuzzy logic controller.

Keywords: Material Handling System; Layout; Strategic Indicators; Flexible manufacturing system; Material Handling Equipment, Fuzzy inference system

1. Introduction

The selection of material handling equipment is an important function for the design of material handling system. The production process, effective utilization of manpower, production and flexibility can also be improved by using the proper material handling equipment. The importance of selection of material handling equipment cannot be overlooked. Today a wide range of material handling equipment available, for a given production scenario determination of best equipment is not an easy task. A Material Handling (MH) system is responsible for transporting materials between workstations with minimum obstruction and joins all workstations and workshops in manufacturing systems by acting as a basic integrator. According to our definition, "MH is the art of implementing movement economically and safely" [1]. In industry MH play a vital role because materials movement is not possible without MH equipment and therefore production could not be accomplished.

Nowadays manufacturing systems have become more and more complex. The design of the manufacturing system is very challenging. Because of this decision makers possess decision tools and assistances necessary to manage this activity. For these reasons, we are interested in the evaluation of the performance of physical part of the flexible manufacturing system (FMS). This physical part is widely known as material handling systems (MHSs) [2]. This fact highlights the importance of selection of MHEs when a manufacturing system is designed. This Choice greatly affects the performances and is complex for different reasons [3,4]. Firstly, there are considerable interactions between machines and MHSs; secondly the layout/framework exerts a major influence over it [5], thirdly many various MHSs are available. The design of FMS is also a difficult activity because existing methods only evaluate specific aspects of the solutions proposed by designers [6]. In order to help the designer or the decision makers in their work, it would be very useful to have indicators which could measure the performance of the various solutions. A few useful indicators have been suggested in the literature related to FMS design [7-8]. As a result of literature survey in this area, we present in this paper the indicators for material handling system, we have retained as suited to this purpose and easily implemented.

An efficient MH system greatly improves the competitiveness of a product through the reduction of handling cost, enhances the production process, increases production and system flexibility, provides effective utilization of manpower and decreases lead time [9,10]. The basic principle of material handling include the use of system approach (layout of the system) where the material handling required for the entire factory is considered and simplification of moves through the reduction and /or elimination of unnecessary moves of the material handling equipment. Traditionally, MHS have been determined by “experts” who analyze some alternatives from which selection of material handling equipment (MHE) is made on the experience of the experts in the application environment. In this paper we give indicators for the selection of material handling equipment such as AGV, Conveyor etc. for the layout of the system. These indicators are flexibility, average time, quickness etc. Flexibility word taken from *Latin* word *bendable* which means mobile and adjustable. Flexibility can be defined as the ability or capability of the system to adopt the change. Flexibility is a multidimensional and polymorphous concept with many definitions. Indicators for material handling are about monitoring key trends and conditions within a system area or region leading to an understanding of ‘what we want’ and ‘what we need to take action’ to achieve system-wide goals. These indicators reflect a move away from traditional indicators which tend to focus on economic measures, to ones that better reflect the quality of the system. In these indicators, flexibility and average time indicator play direct role for the selection of material handling equipment in flexible manufacturing system. In this paper we focus our study on flexibility indicator, indicator for quickness and indicator for average time taken between the machine and work. Flexibility indicator is for the measuring the flexibility of the pair MHS-Layout of the system, indicator for quickness is for the system to take quick action between the work and machine and indicator for time is for counting the time taken by the MHE to transfer the load from one station/machine to another station/machine.

2. Literature Review

Many authors have done work to handle the material handling issues related to FMS. Despite this there has been very less work related to selection of material handling equipment based upon the indicators for material handling of the FMS. Few of the studies related to MHEs selection are shown in table 1.

Table 1 Present the summary of literature studied

Sr. no.	Year	Author	Work done/ remark
1	1997	Thelma D. Mavridou et.al.	Author finds out the optimal layout using simulated annealing and Genetic Algorithm.
2	1998	Ying –chinho	Author investigates the effect of layout design and

		et.al	flow path characteristics on the machine layout.
3	1999	Massoud Bazargan-Lari	Author focused his attention to the layout of the machinery and proper aisle structure for the movement of the material handling equipment. Author developed the final inter-cell layout of the system by providing the management showing the impact of design on material handling equipment cost.
4	2000	Devise et.al	Author developed some new indicator for solving the layout problem. Author used ARENA software for the simulation of the result.
5	2001	C.N. Potts et.al.	Author considered the loop layout with a unidirectional conveyor belt as a MHE. They performed a combined operation of scheduling and machine layout of the system. The objective of the problem is to minimize the throughput and minimize the movement between machine and work.
6	2004	M. Ficko et.al	Author designing the single or multiple row layouts for the flexible manufacturing system. Author use Genetic algorithm for coding the solution into organisms.
7	2005	M.Solimanpur et.al	Author select single row machine layout for developing the non-linear 0-1 programming model, and Ant algorithm is developed for the problem.
8	2005	Taho yang et.al.	To achieve high productivity in a flexible manufacturing system (FMS), an efficient layout arrangement and material flow path design are important due to the large percentage of product cost that is related to material handling. Author
9	2006	Iris F.A. Vis	Author focused his study on design and control issues of AGV systems at manufacturing, distribution, transshipment and transportation systems.
10	2011	Ying-Chin Ho et.al	Author studied the location point of input and output station, and intra-cell layout problem. In this problem author consider single row layout.
11	2012	R Kia et.al.	Author presents a novel mixed-integer non-linear programming model for the layout design of a Dynamic cellular manufacturing system (DCMS).
12	2013	Diana Rossi et.al	Author developed an efficient multi-criteria approach for the selection of optimal alternative for material handling.
13	2015	Birgit keller	Author considers a single row layout problem for finding the most efficient arrangement of machine.

3. Problem description

Based upon the literature review on various MH Aspects related to FMS layout, it is assumed that rate of transfer ($R_{transfer}$), average time to transfer ($T_{average}$) , flexibility indicator ($I_{flexibility}$) and indicator of quickness($I_{quickness}$) , these are the major issues , which needs further investigation. To this effect, in this study we have considered $R_{transfer}$), average time to transfer ($T_{average}$), flexibility indicator ($I_{flexibility}$) and indicator of quickness ($I_{quickness}$) and designed equipments to interface the performance of various layout in FMS. Table 2 shows the formula used for the indicator.

Table 2 Indicators with their respective formulas

Sr.no	Indicators for MHS		Abbreviation	Formula
1	Transfer of parts	Rate	$R_{transfer}$	$R_{transfer} = \frac{N_{exist}}{N_{max}}$
		Average time	$T_{average}$	$T= \frac{1}{N_{exist}} \sum_{i \neq j} t_{i,j}$
2	Flexibility	Flexibility	$I_{flexibility}$	$I_{Flexibility} = \frac{N_{real}}{N_{interesting}}$
		Quickness	$I_{quickness}$	$I_{Quickness} = \frac{1}{N_{interesting}} \sum_{i \neq j} t_{i,j}$

Let us define $t_{i,j}$ which represents the transfer time from workstation *i* to workstation *j* (the shortest time if several paths exist). The value ∞ means that no transfer is possible from *i* to *j*. If *i=j*, then $t_{i,j}$=0 If M is the set of machines and R is set of real numbers, $t_{i,j}$ may be described by

$$M \times M \longrightarrow R \quad (1)$$

$$f : (M_i , M_j) \longrightarrow t_{i,j} \quad (2)$$

A transportation matrix T is used to describe the transfer time between machines or workstations. The elements of T are $t_{i,j}$.

N_{exist} = the number of element of T which are different from ∞

N_{max} = the number of elements of T, minus its diagonal:

$$N_{exist} = card \{(M_i, M_j) \varepsilon M \times M \; T|_{i,j} \neq \infty \text{ and } i \neq j\} \quad (3)$$

$$N_{max} = card \{(M_i, M_j) \varepsilon M \times M \; i \neq j \} = N_m (N_m -1) \quad (4)$$

The system (the pair MHS-Layout) will not only offer new possible path between two machines, but also offer an efficient path. Let us compute the average transfer time between machines. This indicator will talk about the quickness of the pair MHS-framework. The quickness of a transfer is important since there is often no added-value on the transported product during its transfer. In mechanical manufacturing industry, some transfer will not occur. Usually no part will require a transfer from finishing machine to roughing machine.

$$N_{Real} = card\{(M_i, M_j) \varepsilon\, G \;\; t_{i,j} \neq \infty \text{ and } i \neq j\} \quad (5)$$

$$N_{interesting} = card\{(M_i, M_j) \varepsilon\, G \;\; i \neq j\} \quad (6)$$

These indicators play a vital role in selection of material handling equipment used in flexible manufacturing system.

Assumption –

(i) In this system only 6 machine/station are considered and assume as machine M1,M2 are roughing machine, M3,M4 and M5 are finishing machine, and M6 is a super finishing machine.

(ii) A machine can perform only one operation at a time.

(iii) Tools, jigs and fixtures are always available.

(iv) For conveyor no accumulation is allowed.

(v) The distribution is normally distributed with a standard deviation of 10%.

(vi) The load /unload of the system are automatic.

(vii) The machines have equally spaced between the two consecutive stations.

4. Experimental design

Case 1 Single circular layout problem of flexible manufacturing system

A hypothetical FMS is considered consisting of six CNC machine with individual input and output station, having single circular layout (see Fig.1). Four material handling equipment are considered for the transporting the parts in the system. Each material handling equipment has different capacity. The load/unload systems of the six machines are automatic. The queues in the front of each station have a capacity of two palettes. The mean transfer times from the input to the machines 1 or 6 are six seconds. The mean transfer times between machines one and six and the output are the same (the standard deviation is 10%). The mean transportation time between the machine and the MHSs are given in table 4. The four parts P1, P2, P3 and P4 are processed. The mean processing time (in sec) are given in table 3(standard deviations are 5%). The speed of material handling equipment is constant in both loaded and unloaded condition.

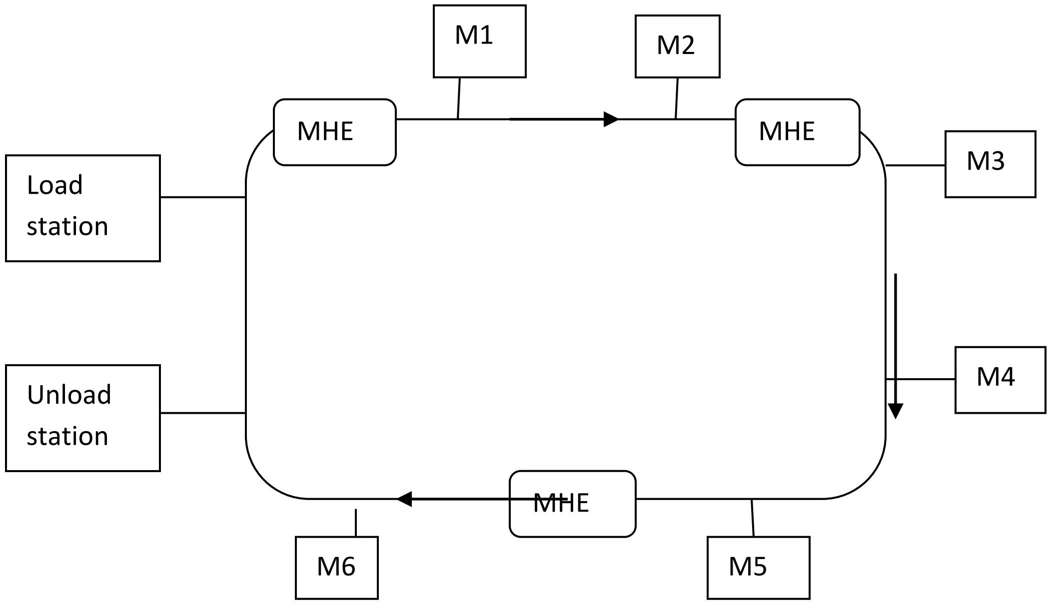

Fig. 1 Semicircular layout

The mean transportation times (sec) of different material handling equipment (AGV, Conveyor, Industrial Truck, and Industrial crane) are shown in table4. For the processing of part the processing time of parts on each machine is given in table 3.

Table 3 Processing time (in sec) of part P1, P2, P3 and P4

Parts	M1	M2	M3	M4	M5	M6
P1	180	360	60	420	360	180
P2	600	480	300	240	600	600
P3	540	60	300	240	420	480
P4	300	300	300	180	480	540

Table 4 Single circular layout problem with mean transportation time matrix

Sr. no.	**Types of MHS**	**MHS capacity**	**Speed of MHS(m/s)**	**Mean transportation time matrix (sec)**
1	AGV	100	1	(matrix below)

	M1	M2	M3	M4	M5	M6
M1	0	10	20	30	40	50
M2	10	0	10	20	30	20
M3	20	10	0	10	20	30
M4	30	20	10	0	10	20
M5	20	30	20	10	0	10
M6	10	20	30	20	10	0

<table>
<tr><td>2</td><td>Conveyor</td><td>25</td><td>2</td><td>
<table>
<tr><th></th><th>M1</th><th>M2</th><th>M3</th><th>M4</th><th>M5</th><th>M6</th></tr>
<tr><td>M1</td><td>0</td><td>17</td><td>22</td><td>27</td><td>22</td><td>17</td></tr>
<tr><td>M2</td><td>∞</td><td>0</td><td>17</td><td>22</td><td>27</td><td>22</td></tr>
<tr><td>M3</td><td>∞</td><td>∞</td><td>0</td><td>17</td><td>22</td><td>27</td></tr>
<tr><td>M4</td><td>∞</td><td>∞</td><td>∞</td><td>0</td><td>17</td><td>22</td></tr>
<tr><td>M5</td><td>∞</td><td>∞</td><td>∞</td><td>∞</td><td>0</td><td>17</td></tr>
<tr><td>M6</td><td>∞</td><td>∞</td><td>∞</td><td>∞</td><td>∞</td><td>0</td></tr>
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<tr><td>3</td><td>Industrial truck</td><td>100</td><td>1</td><td>
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<tr><th></th><th>M1</th><th>M2</th><th>M3</th><th>M4</th><th>M5</th><th>M6</th></tr>
<tr><td>M1</td><td>0</td><td>22</td><td>32</td><td>42</td><td>32</td><td>22</td></tr>
<tr><td>M2</td><td>22</td><td>0</td><td>22</td><td>32</td><td>42</td><td>32</td></tr>
<tr><td>M3</td><td>32</td><td>22</td><td>0</td><td>22</td><td>32</td><td>42</td></tr>
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<tr><td>4</td><td>Industrial crane</td><td>25</td><td>3</td><td>
<table>
<tr><th></th><th>M1</th><th>M2</th><th>M3</th><th>M4</th><th>M5</th><th>M6</th></tr>
<tr><td>M1</td><td>0</td><td>15.33</td><td>18.66</td><td>21.99</td><td>18.66</td><td>15.33</td></tr>
<tr><td>M2</td><td>15.33</td><td>0</td><td>15.33</td><td>18.66</td><td>21.99</td><td>18.66</td></tr>
<tr><td>M3</td><td>18.66</td><td>15.33</td><td>0</td><td>15.33</td><td>18.66</td><td>21.99</td></tr>
<tr><td>M4</td><td>21.99</td><td>18.66</td><td>15.33</td><td>0</td><td>15.33</td><td>18.66</td></tr>
<tr><td>M5</td><td>18.66</td><td>21.99</td><td>18.66</td><td>15.33</td><td>0</td><td>15.33</td></tr>
<tr><td>M6</td><td>15.33</td><td>18.66</td><td>21.99</td><td>18.66</td><td>15.33</td><td>0</td></tr>
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Case 2 Single row layout problem of flexible manufacturing system

A hypothetical FMS is considered consisting of six CNC machine with individual input and output station, having single row layout (see Fig.2). Four material handling equipment are considered for the transporting the parts in the system. Each material handling equipment has different capacity. The load/unload systems of the six machines are automatic. The queues in the front of each station have a capacity of two palettes. The mean transfer times from the input to the machines 1 or 6 are six seconds. The mean transfer times between machines one and six and the output are the same (the standard deviation is 10%). The mean transportation time between the machine and the MHSs are given in table 5. The four parts P1, P2, P3 and P4 are processed. The mean processing time (in sec) are given in table 3(standard deviations are 5%). The speed of material handling equipment is constant in both loaded and unloaded condition. .

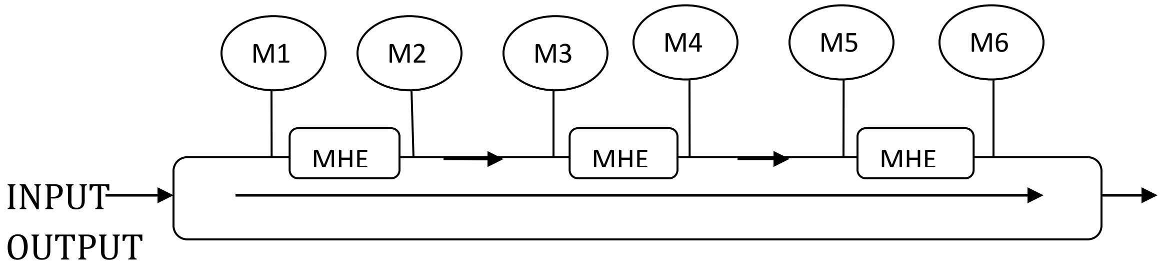

Fig.2 Single Row layout with machine station /work station

Table 5 Single row layout problem with mean transportation time

Sr. no	Types of MHS	MHS capacity	Speed of MHS(m/s)	Mean transportation time matrix (sec)						
					M1	M2	M3	M4	M5	M6
1	AGV	100	1	M1	0	22	32	42	52	62
				M2	∞	0	22	32	42	52
				M3	∞	∞	0	22	32	42
				M4	∞	∞	∞	0	22	32
				M5	∞	∞	∞	∞	0	22
				M6	∞	∞	∞	∞	∞	0
2	Conveyor	25	2	M1	0	2	4	6	8	10
				M2	∞	0	2	4	6	8
				M3	∞	∞	0	2	4	6
				M4	∞	∞	∞	0	2	4
				M5	∞	∞	∞	∞	0	2
				M6	∞	∞	∞	∞	∞	0
3	Industrial truck	100	1	M1	0	10	20	30	40	50
				M2	∞	0	10	20	30	40
				M3	∞	∞	0	10	20	30
				M4	∞	∞	∞	0	10	20
				M5	∞	∞	∞	∞	0	10
				M6	∞	∞	∞	∞	∞	0
4	Industrial crane	25	3	M1	0	15.33	18.66	21.99	25.32	28.65
				M2	∞	0	15.33	18.66	21.99	25.32
				M3	∞	∞	0	15.33	18.66	21.99
				M4	∞	∞	∞	0	15.33	18.66
				M5	∞	∞	∞	∞	0	15.33
				M6	∞	∞	∞	∞	∞	0

Case 3 Fuzzy Inference System

Figure 4.3 shows the architecture of proposed Fuzzy inference system (FIS) for selection of material handling equipment. The input to Mamdani type fuzzy system is composed of weight, Average time of transfer and Indicator for quickness. For the weight inputs (figure 4.3) , four linguistic terms of 'light', 'medium' , 'Heavy' and 'Very Heavy' are defined and for other two inputs (Average time and indicator for quickness), three linguistic terms of 'low' , 'medium', 'High' are defined. The output of the system is MHE that is identified by any of the four linguistic terms, ' light', ' medium' , 'heavy' or 'very heavy'. The maximum membership grade of linguistic term 'very heavy' is 2000.

Table 9 Inference Rules for MHE selection using three inputs and one output

Sr. no.	Inputs			Output
	Weight	**Average time**	**Quickness**	**MHE**
1	Low	High	Moderate	AGV
2	Medium	Low	Fast	Conveyor
3	Heavy	Medium	slow	Industrial Truck
4	Very heavy	High	slow	Industrial Crane

In order to identify different material handling indicators such as Weight, average time to transfer and quickness for material handling equipment selection a fuzzy interference system (FIS) is developed to identify MHEs using fuzzy logic toolbox. Table 9 shows the inference rules, which is used in fuzzy knowledge based system.

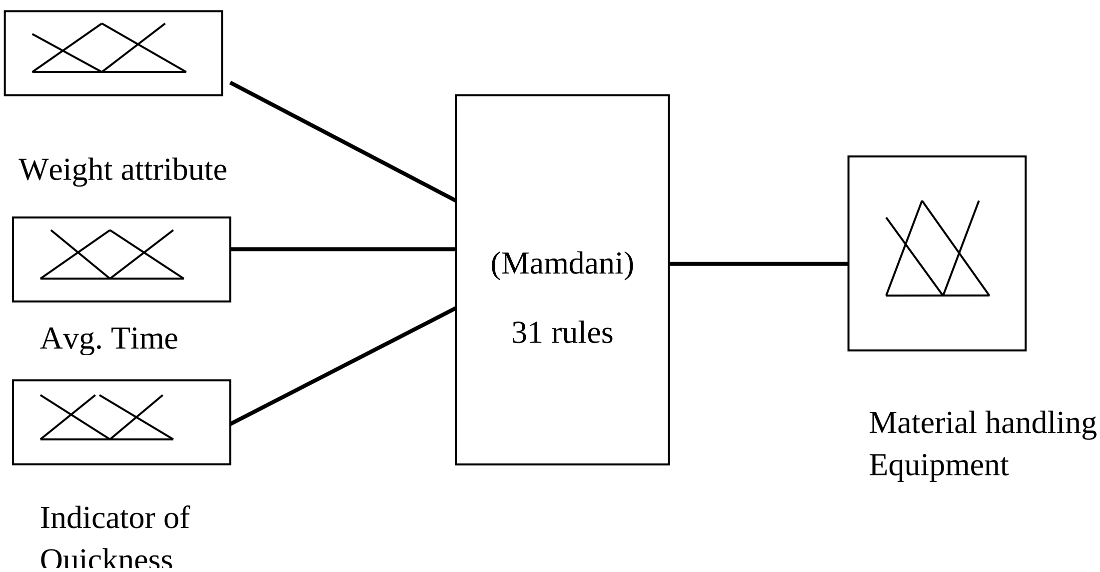

Figure 5: The architecture fuzzy system

The fuzzy system has the merit to take advantage of the following 31 rules:

If (weight attribute is light) and (Avg. Time to transfer is low) and (Indicator of quickness is fast) then (Material Handling Equipment is CONVEYOR)

2. if weight attribute is light) and (Avg. Time to transfer is medium) and (Indicator of quickness is Fast) then (Material Handling Equipment is AGV)

3. If weight attribute is light) and (Avg. Time to transfer is high) and (Indicator of quickness is Fast) then (Material Handling Equipment is Industrial Truck) .

4. If (weight attribute is light) and (Avg. Time to transfer is high) and (Indicator of quickness is Moderate) then (Material Handling Equipment is AGV)

5. If (weight attribute is Medium) and (Avg. Time to transfer is low) and Indicator of quickness is Fast) then (Material Handling Equipment is CONVEYOR)

6. If (weight attribute is Medium) and Avg. Time to transfer is medium) and (Indicator of quickness is Fast) then (Material Handling Equipment is Crane)

7. If (weight attribute is Medium) and (Avg. Time to transfer is high) and (Indicator of quickness is Fast) then (Material Handling Equipment is Crane)

8. If (weight attribute is Medium) and (Avg. Time to transfer is low) and (Indicator of quickness is Moderate) then (Material Handling Equipment is CONVEYOR)

9. If (weight attribute is Medium) and (Avg. Time to transfer is medium) and (Indicator of quickness is Moderate) then (Material Handling Equipment is Industrial Truck)

10. If (weight attribute is Medium) and (Avg. Time to transfer is high) and (Indicator of quickness is Moderate) then (Material Handling Equipment is AGV)

11. If (weight attribute is Heavy) and (Avg. Time to transfer is low) and (Indicator of quickness is Fast) then (Material Handling Equipment is Industrial Truck)

12. If (weight attribute is heavy) and (Avg. Time to transfer is medium) and (Indicator of quickness is fast) then (Material Handling Equipment is Industrial Truck)

13. If (weight attribute is heavy) and (Avg. Time to transfer is high) and (Indicator of quickness is fast) then (Material Handling Equipment is Crane)

14. If (weight attribute is heavy) and (Avg. Time to transfer is low) and (Indicator of quickness is Moderate) then (Material Handling Equipment is CONVEYOR)

15. If (weight attribute is heavy) and (Avg. Time to transfer is medium) and (Indicator of quickness is Moderate) then (Material Handling Equipment is AGV)

16. If (weight attribute is heavy) and (Avg. Time to transfer is high) and (Indicator of quickness is Moderate) then (Material Handling Equipment is AGV)

17. If (weight attribute is very heavy) and (Avg. Time to transfer is low) and (Indicator of quickness is Fast) then (Material Handling Equipment is Crane)

18. If (weight attribute is very heavy) and (Avg. Time to transfer is medium) and (Indicator of quickness is Fast) then (Material Handling Equipment is Crane)

19. If (weight attribute is very heavy) and (Avg. Time to transfer is high) and (Indicator of quickness is Fast) then (Material Handling Equipment is Crane)

20. If (weight attribute is very heavy) and (Avg. Time to transfer is low) and (Indicator of quickness is Moderate) then (Material Handling Equipment is CONVEYOR)

21. If weight attribute is very heavy) and (Avg. Time to transfer is medium) and (Indicator of quickness is Moderate) then (Material Handling Equipment is AGV)

22. If (weight attribute is very heavy) and (Avg. Time to transfer is high) and (Indicator of quickness is Moderate) then (Material Handling Equipment is AGV)

23. If (weight attribute is very heavy) and (Avg. Time to transfer is low) and (Indicator of quickness is Slow) then (Material Handling Equipment is CONVEYOR)

24. If (weight attribute is very heavy) and (Avg. Time to transfer is medium) and (Indicator of quickness is Slow) then (Material Handling Equipment is Industrial Truck)

25. If (weight attribute is very heavy) and (Avg. Time to transfer is high) and (Indicator of quickness is Slow) then (Material Handling Equipment is Crane)

26. If (weight attribute is light) and (Avg. Time to transfer is low) and (Indicator of quickness is Moderate) then (Material Handling Equipment is AGV)

27. If (weight attribute is light) and (Avg. Time to transfer is medium) and (Indicator of quickness is Moderate) then (Material Handling Equipment is AGV)

28. If (weight attribute is light) and (Avg. Time to transfer is high) and (Indicator of quickness is Moderate) then (Material Handling Equipment is AGV)

29. If (weight attribute is light) and (Avg. Time to transfer is low) and (Indicator of quickness is Slow) then (Material Handling Equipment is CONVEYOR)

30. If (weight attribute is light) and (Avg. Time to transfer is medium) and (Indicator of quickness is Slow) then (Material Handling Equipment is AGV)

31. If (weight attribute is light) and (Avg. Time to transfer is high) and (Indicator of quickness is Slow) then (Material Handling Equipment is AGV)

5. Result and discussion

The assessment of the methodology's operation was carried out using the associated data for a production site. In mechanical manufacturing industry some transfer will not occur, for example part from super finishing machine will not go to roughing machine so we will defined a restriction matrix for the system. The restriction G is given by the matrix R where the value 1 shows that pair (M_i,M_j) is in G and the value 0 means otherwise.

$$R=\begin{bmatrix}1&1&1&1&1&1\\1&1&1&1&1&1\\0&0&1&1&1&1\\0&0&1&1&1&1\\0&0&1&1&1&1\\0&0&0&0&0&1\end{bmatrix}$$

(8)

The results for various indicators are present in the table 6 and table 8. In first case we study different MHE for single circular line layout/framework. From table 6 we can see that average time to transfer between the machines in case of AGV is minimum as compared to other MHEs and indicator for quickness should represent the system's speed, for AGV quickness is fast as compared to others. From these result we can say that for singular circular layout problem as MHE, AGV will be the better choice pair MHS-Layout.

Table 6 Result for single circular line

Sr.no	Indicators	AGV	Conveyor	Industrial truck	Industrial crane
1	$R_{transfer}$	1	0.5	1	1
2	$T_{average}$	10.66	11.0	18.26	19.01
3	$I_{flexibility}$	1	0.7894	1	1
4	$I_{quickness}$	16.84	16.578	28.842	30.025

Fig.3 and fig.4 shows the utilization rate of each machine. Processing time for each machine is same, shown in table 3, the make span time is the sum of mean transportation time and mean processing time of the machine. For single circular line layout the mean transportation time for each material handling equipment is different and mean processing time for each machine is same for all MHEs. So make span time will depends upon the mean transportation time of the material handling equipment. Make span time (min) for single circular layout, and single row layout are shown in table 7.

Table 7 Make span time for the layout

Sr.no.	Layout	Material handling Equipment	Make Span Time (min)
1	Single circular layout	AGV	66
2		Conveyor	68
3		Industrial Truck	69
4		Industrial Crane	68.5
5	Single row layout	AGV	69
6		Conveyor	67
7		Industrial Truck	68
8		Industrial Crane	68.5

From table 7 we can see that, for single circular layout the make span time for AGV is less as compared to other MHEs. And for the utilization rate of machine (fig.3) in case of AGV utilization is good as compared to other MHEs. So from above discussion we can say that for single circular layout AGV is good choice as material handling equipment.

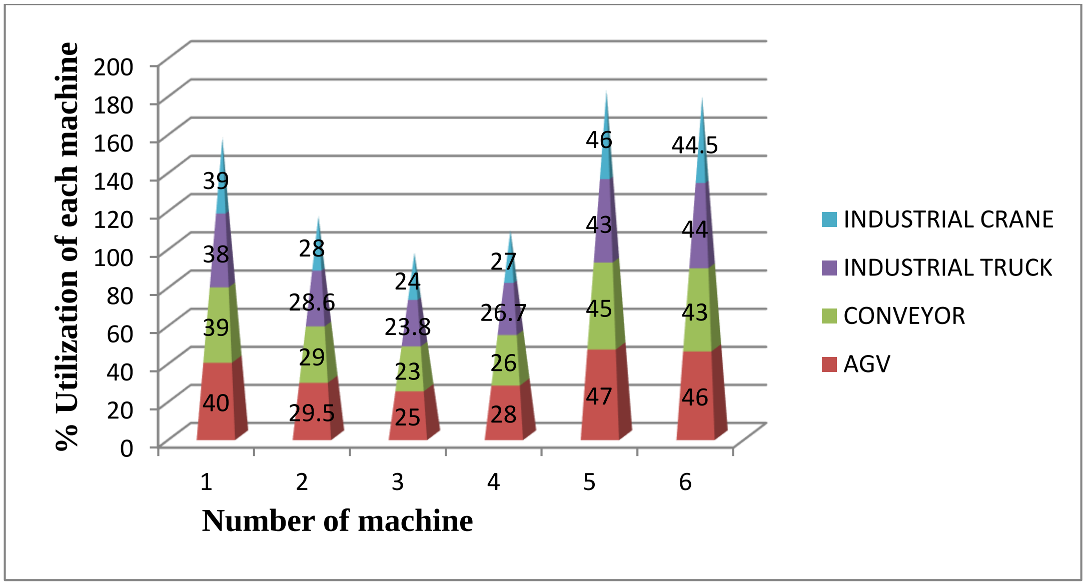

Fig.3 Utilization rate of each machine for single circular layout

In second case of single row layout problem Table8 shows the result of different value of the indicators .we can see that in this case rate of transfer for each material handling equipment is same for all. An indicator for average time taken to transfer the material is less in case of conveyor as compared to other material handling equipments used in this system. Indicator of flexibility shows system flexibility, for conveyor indicator for flexibility shows system is more flexible as compared to other pair MHS-layout of the system and conveyor shows the quickness also. From table 8 it seems clear that conveyor is better choice for single row layout system. The make span time (min) for single row layout is shown is table 7. From table 7 we can see that the make span time for conveyor is minimum i.e. total processing time in case of conveyor is minimum as compared to other MHEs. Fig. 4 shows the utilization rate of each machine. From fig.4 we can see that % utilization rate of each machine is good and maximum as compared to other MHEs. So for single row layout Conveyor is good choice as MHEs.

Table 8 Result for single row layout

Sr.no	**indicators**	**AGV**	**Conveyor**	**Industrial truck**	**Industrial crane**
1	$R_{transfer}$	0.5	0.5	0.5	0.5
2	$T_{average}$	35.33	4.66	23.34	19.77
3	$I_{flexibility}$	0.5	0.789	0.633	0.5
4	$I_{quickness}$	17.66	4.842	11.667	9.885

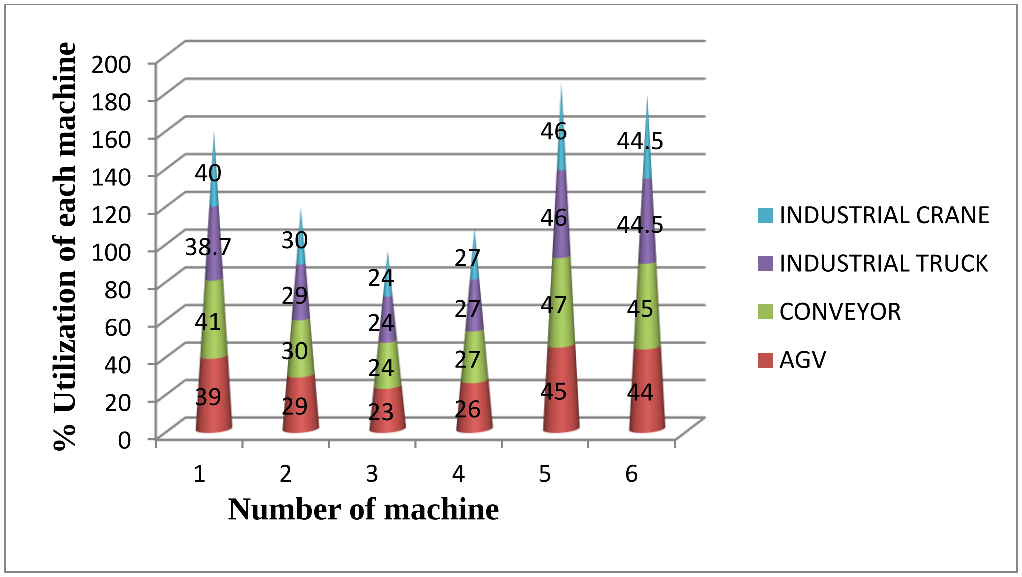

Fig.4 Utilization rate of each machine for single row layout

We scaled all the input values to lie in the interval [20, 2000]. Experts, considering their knowledge and past experience, pointed out that if the material handling equipment is AGV for the layout of the system, the correlation between weights is light and Average quickness is fast. Based upon this, the weight is set to be in [20,500]. We also decide to set the value of average quickness in the interval [0, 8] and average time to transfer for medium in the interval [8, 25]. Feeding these input values to our fuzzy system, the proposed MHE (figure 5) is:

Value of material handling equipment for AGV = 260

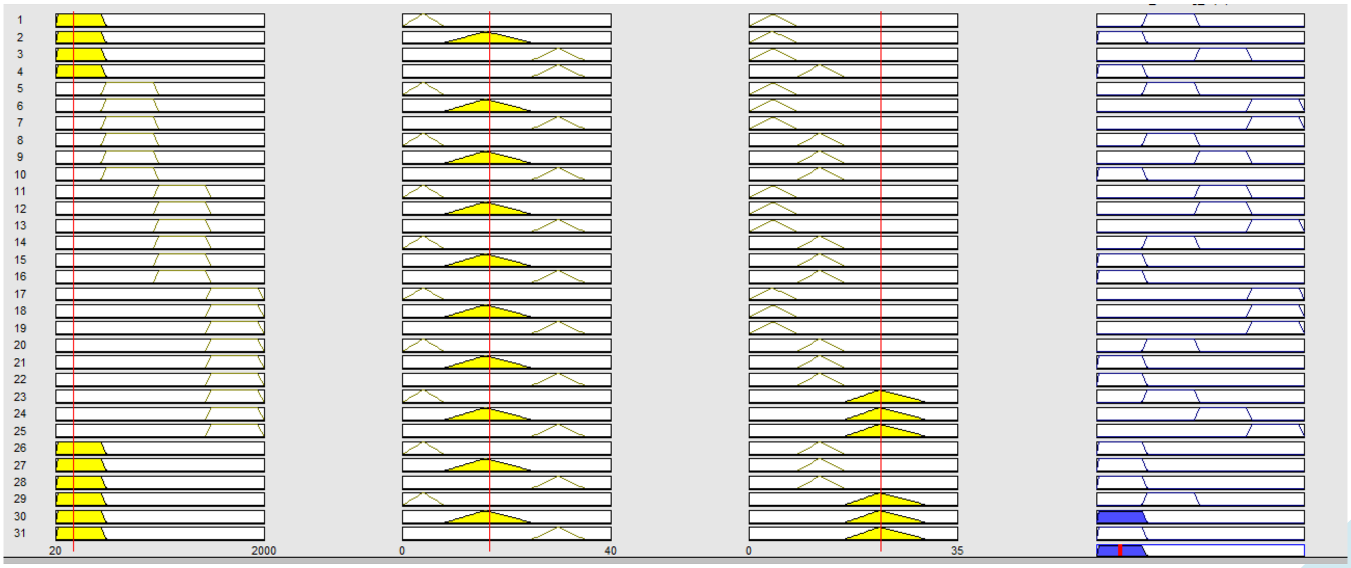

Figure 5 The Fuzzy result of the system

To investigate the selection of material handling equipment in this system, we considered weight, average time and indicators of quickness as input parameters. In this system we calculate the values of these parameters, which are shown in above tables. from that table it is clear that material handling equipment not only play a role to transfer of material from one station to another, but also effect the production of the system.

5. Conclusion

The purpose of this paper was to focus on the selection of material handling equipment used in flexible manufacturing system. In this paper two layout/ framework were considered and based upon flexibility, quickness; make span time etc. material handling equipments were considered. The result shows that for single circular type of layout, rate of transfer for conveyor is less the AGV, and flexibility of the system in case of AGV is good as compared to other MHEs. For single circular type layout the make span time and % utilization of machine for AGV is better than other MHEs. Similar for single row layout result shows that conveyor is good for this system. As the result of a survey of the literature related to FMS design, we give a best possible way to select the material handling equipment. Indicators for material handling represent a major issue in the evaluation of the performance of pair MHS-layout in flexible manufacturing system. In the MHE selection indicators play a vital role for the decision maker. we have used fuzzy logic methodology for the selection of material handling equipment used in flexible manufacturing system. Three variables (1) Transfer of weight (2) Average time to transfer and (3) Indicators for quickness are used for the selection of MHEs. Using these variables we make some rules (IF, THEN) for the output i.e. Material handling equipment. So we can select the material handling equipment used in flexible manufacturing system. We are now interested in to consider indicators for economics and other layouts for further investigation.

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