Analysis & evaluation of plant production layout PT Arkha Jayanti Persada using group of technology concept with genetic algorithm approach

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ANALYSIS & EVALUATION OF PLANT PRODUCTION LAYOUT PT ARKHA JAYANTI PERSADA USING GROUP OF TECHNOLOGY CONCEPT WITH GENETIC ALGORITHM APPROACH

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ABSTRACT

PT. Arkha Jayanti Persada is a company in which they are involve in manufacturing business. Currently, the problems they are facing are the inefficient layout of their machines inside their production floor, where they put their machines too far away from each others. In order to solve the problem, the concepts of group of technology with genetic algorithm (GA's) for optimization have already been proposed as a method for designing the layout of production machines. Utilizing GA's cellular manufactur will generate grouping efficiency of 83.47% in the 25th generation and GA's machine arrangement will generate coefficient flow of 274.356 annually on the 7th generation.
Key words: Genetic Algorithm, Group of Technology, Optimization

1. INTRODUCTION

1.1. Background

Inside the manufacturing industry, one of the most common problems is how to optimize and how to generate production time more efficiently without increasing cost too significantly.

Object of research has been done inside PT. Arkha Jayanti Persada's factory which is located in the industry area Citeureup, Bogor, West Java. They are known as metal manufacturer company which produces various excavator components.

Genetic Algorithm (GA's) will be used during this research. This method will divide every work center and put them insed the cells of Group Technology, where each combination of possibilities of machine placement will be calculated by their performance to produce optimum solution until *n* generation.

1.2. Identification of Problem

PT Arkha Jayanti Persada have 5 department of production. The research object is located in the 3rd department, where that particular department produces component of *Assy Skirt LH* and *RH.* This department has 16 units of machine and production facilities including raw material warehouse and finished material warehouse.

The layout of machines this company applies is called process layout. This type of production layout has rather unique characteristic in which the shift of material relatively slow resulting in bigger queue in component products. The machine set up is always changing because each machine produces various type of component and often the process is back and forth.

Formulation of problems is how layout production should be applied and how much is the difference of efficiency by utilizing proposed layout. In other side research never examine the cost to re-layout the machines and Only examined the 3rd department with 16 machines and 58 components.

2. THEORETICAL BACKGROUND

2.1. Factory Layout Design

Factory Layout Design is an activity that includes analysis, creating concept, devise and fulfill system for manufacturer of service industry. With a purpose to optimize connection between operators, material

flows, information flows, and etc with hope to produce accurate production prototype, low cost, and safe (Apple, 1990).

2.2. Group Technology Layout

In this type of layout, commonly different component will be grouped together based on the similarity of component shape, type of machines or equipments used. Machines were grouped together and placed inside manufacturing cells. (Purnomo, 2008)

2.3. Grouping Efficiency

Grouping Efficiency Method is sum up between utilization ratio of machines and movement between cells. Value of n_1 is the ratio of number 1 inside the block. Meanwhile, the value of n_2 is the ratio of number 0 outside the block. Value w shows weighting towards n_1 and n_2. The suggested value for w is 0.5, because assuming weighting for n1 and n2 is the same. Perfect value for *Grouping Efficiency* is 1, where acquired efficiency will reach 100% (Chandrasekharan & Rajagopalan; 1986).

Equation for *Grouping Efficiency* is:

$$\eta_1 = \frac{o-e}{o-e+v} \quad (1)$$

$$\eta_2 = \frac{MP-o-v}{MP-o-v+e} \quad (2)$$

$$\eta = w\eta_1 + (1-w)\eta_2 \quad (3)$$

o = number of 1 in the matrix
e = *exceptional elements*
v = Number of Voids
M = Number of Machines
P = Number of Parts
n = Grouping Efficiency

2.4. Distance Calculation Method

Distance is one of the parameters measure from material handling component. In order to handle materials, there is a movement from one place to another, the formula to measure distance is: (Heragu, 1997)

$$Dij = |x_i - x_j| + |y_i - y_j| \quad (4)$$

xi = center coordinate x from i facility
yi = center coordinate y from j facility

2.5. Genetic Algorithm (GA's)

Genetic Algorithm was invented in 1970 by John Holland. John Holland was inspired by Charles Darwin's theory of natural selection.

2.6. Parameter of Genetic Algorithm

Goldberg define the parameters to be used in Genetic Algorithm is: (Obitko, 2008)

- Population Size
- Number of Generations
- Probability of crossover
- Probability of mutation

2.7. Genetic Operators

Genetic Operators is useful to introduce new strings in the populations (Gen, M, 2000).

2.8. Selection

Processes that have been done is to find new population prior to the next generations This new populations came from parents and offspring which have the best fitness level.

2.9. *Crossover*

Increase random numbers between 0 to 1 for every chromosome and parents. Compare the values of random number with the probability of crossover (Pc) with the parameters. If the value of random number is lesser of equal to value of Pc, then chromosomes will experience crossover process and will become parent and vice versa.

Match parents in the population randomly, with maximum number of parents pairs is equal to chromosomes parent divided by two. Decide the value of crossing site r position of gen exchange by increasing random number between 1 until (m-1) in 2 units where m is the length of gen.

Crossed gens with one parent to another that placed between crossing site until shape like chromosome offspring crossover. (Tompkins et.al., 1996)

2.10. *Mutation*

Increase random number between 0 and 1 in every gen of chromosome. Compare that random number with probability of mutation (Pm). If the random number generated is lesser of equal to Pm, then gen inside the sub-chromosome will experience mutation. Furthermore, exchange mutated gen with gen in the right side. If there are 2 gens that experiencing mutation then exchange the right side gen first.

2.11. *Encoding & Decoding*

Encoding (chromosome representation) is a process to transfer from real information to the chromosome. This process of chromosome representation has the purpose to decide what kind of information will enter the chromosome.

A chromosome is consisted of gen, where one gen shows one work station. One chromosome is consisted of group of gen, where every gen shows the work element from the rail of production.

Decoding process is the opposite of encoding process. Decoding process transfer information inside every chromosomes to the real information. Every chromosomes inside the population will be processed until they generate several feasible line of production according to the population size. The generated line of production will be evaluated with the fitness value according to the fitness function.

3. RESEARCH METHOD

Research method for data collection has been done with two ways, by primary data and secondary data. The primary data is colecting data with directly observation and calculation like as flow process, machine dimesion, work center dimension and distance between facillity.

In other side, a secondary data is colecting data with undirectly observation. This type data obtained from supervisior and foremen in the factory. Like as type material handling, lot production, machine capacity, production cost and others.

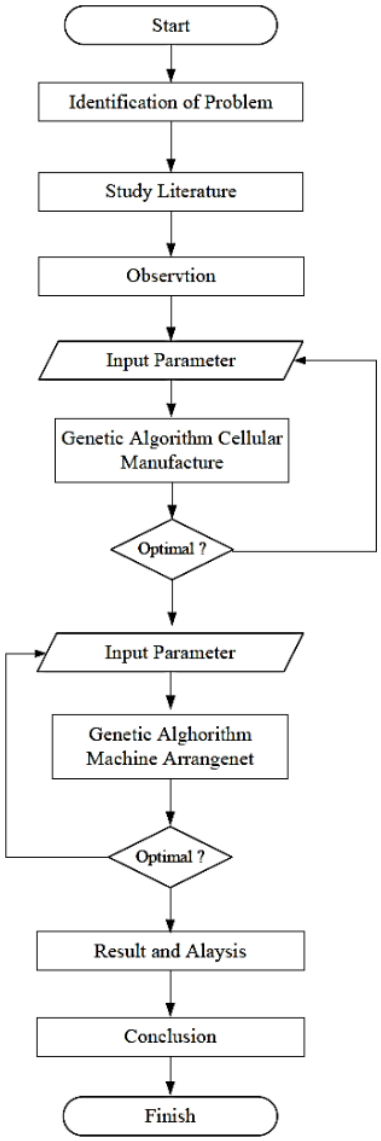

Figure 1. Research Method

After data was collected. Then calculated by genetic alghorithm. There are two type's of calculations. First, using genetic alghorithm cellular manufacture for clustering machine and facility in the group of technology. And secondly by genetic alghorithm for machine and facility arrangement for searching best value or finding optimize solution.

4. RESULT AND DISCUSSION

Data processing has been done in 2 steps, grouping of manufacture cells, machine layout design and production facility using genetic algorithm (GA's) method.

4.1. Genetic Algorithm Cell Manufacture

GA's cell manufacture will grouped machines and component to incidence matrix which only has 2 value 1 and 0. Value 1 shows that component will go through machines. Value 0 shows component do not go through machines.

4.1.1. Fitness Function

Fitness Function that used for incidence matrix is grouping efficiency function.

4.1.2. Parameter

Deciding the parameters is as follows:
- Number of generations : 25
- Number of Cells : 5
- Population Size : 8
- Crossover Probability : 0,95
- Mutation Probability : 0,05

4.1.3. Encoding Process

Gen Initialization for every chromosomes in the first generation, by increasing random number as shown in table.

Table 1 Initialization of Chromosome

Machine															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
3	1	2	3	5	1	1	3	5	1	4	2	3	5	2	3

Part																												
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
4	2	2	4	2	2	2	2	3	5	3	1	1	5	5	5	4	3	5	5	3	5	5	1	2	3	2	2	2
30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
2	3	2	1	2	2	4	5	3	3	5	1	3	1	3	3	4	3	1	4	4	1	2	3	4	1	4	2	5

4.1.4. Decoding Process

Translate gen value in the table 1 to the incidence matrix. Every gen will be group to group cell of technology as shown in below table.

Table 2. Decoding Chromosome 1

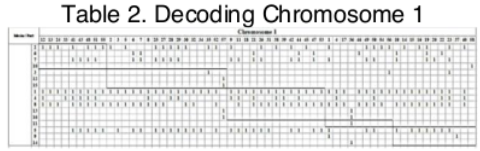

Table 3. Grouping efficiency Chromosome 1

Total Matrix Element	:	234
Exceptional Element	:	181
Void Element in Solution	:	138
Total Machine Productioı	:	16
Total Part Production	:	58
Weight	:	50%
Intercell Ratio	:	27,749%
Void Ratio	:	75,441%
Grouping Efficiency	:	51,595%

4.1.5. Crossover Process

Decide the chromosome that is feasible to be parent using random number between 0 and 1. If the value of crossover probability higher than the random number then that particular chromosome is feasible to be parent and vice versa as shown below:

Table 4. Determination of parent

No	Chromosome Code	Chromosome	Random Value	Crossover's Probability	Decision
1	G2-CHO-01	Chromosome 1	0,62	0,95	Crossover
2	G2-CHO-02	Chromosome 2	0,52	0,95	Crossover
3	G2-CHO-03	Chromosome 3	0,27	0,95	Crossover
4	G2-CHO-04	Chromosome 4	0,01	0,95	Crossover
5	G2-CHO-05	Chromosome 5	0,94	0,95	Crossover
6	G2-CHO-06	Chromosome 6	0,46	0,95	Crossover
7	G2-CHO-07	Chromosome 7	0,70	0,95	Crossover
8	G2-CHO-08	Chromosome 8	0,84	0,95	Crossover

Decide the parent pair and gen that will be cross. Increase the random number between 1 and 16 for machines. Then increase the random number from 1 to 58 for part as shown below:

Table 5. Crossing site

Crossing Limit	Chromosome Relationship			Mesin		Part	
				From	To	From	To
Parent 1	1	&	2	7	11	8	24
Parent 2	3	&	4	7	13	22	46
Parent 3	5	&	6	5	10	30	54
Parent 4	7	&	8	9	11	5	30

Exchange gen from both of parents until they generate chromosomes for the next generation. The result from crossover is called chromosome offspring crossover as shown below:

Table 6 Offspring crossover

Mesin / Fasilitas															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
3	1	2	3	5	1	1	3	5	1	4	2	3	5	2	3
1	2	3	2	2	5	4	4	5	1	3	1	3	1	3	1
3	1	2	3	5	1	4	4	5	1	3	2	3	5	2	3
1	2	3	2	2	5	1	3	5	1	4	1	3	1	3	1

Once again do decoding process for offspring crossover using incidence matrix to find grouping efficiency.

4.1.6. Mutation Process

Generate random value between 0 and 1 in every gen. compare that random number with mutation probability (Pm), if the random number that generated is lesser or equal to Pm, then gen in that sum-chromosome will experience mutation with gen located in the right side as shown in the table 6.

Do decoding process once again for offspring mutation using incidence matrix to find grouping efficiency.

4.1.7. Selection Process

Sort grouping efficiency from big to small as shown in the table below:

Table 7 Chromosome Selection Process

No	Chromosome Code	Chromosome Name	Grouping Efficiency	Decision
1	G2-COM-04	Chromosome Offsprings Crossover 4	53,732%	Next Generation
2	G1-CHR-02	Chromosome 2	53,339%	Next Generation
3	G1-CHR-01	Chromosome 1	51,595%	Next Generation
4	G1-CHR-04	Chromosome 4	51,517%	Next Generation
5	G1-CHR-07	Chromosome 7	50,678%	Next Generation
6	G1-CHR-03	Chromosome 3	50,571%	Next Generation
7	G1-CHR-05	Chromosome 5	50,361%	Next Generation
8	G2-COM-09	Chromosome Offsprings Mutation 1	50,361%	Next Generation
9	G2-COM-05	Chromosome Offsprings Crossover 5	50,037%	Dead
10	G2-COM-11	Chromosome Offsprings Mutation 3	49,941%	Dead
11	G2-COM-07	Chromosome Offsprings Crossover 7	49,701%	Dead
12	G2-COM-14	Chromosome Offsprings Mutation 6	49,695%	Dead
13	G2-COM-06	Chromosome Offsprings Crossover 6	49,375%	Dead
14	G2-COM-02	Chromosome Offsprings Crossover 2	49,217%	Dead
15	G2-COM-12	Chromosome Offsprings Mutation 4	49,128%	Dead
16	G2-COM-01	Chromosome Offsprings Crossover 1	49,106%	Dead
17	G1-CHR-06	Chromosome 6	48,751%	Dead
18	G1-CHR-08	Chromosome 8	48,706%	Dead
19	G2-COM-10	Chromosome Offsprings Mutation 2	48,408%	Dead
20	G2-COM-13	Chromosome Offsprings Mutation 5	47,806%	Dead
21	G2-COM-08	Chromosome Offsprings Crossover 8	47,560%	Dead
22	G2-COM-03	Chromosome Offsprings Crossover 3	47,489%	Dead

Eight chromosomes above is feasible as a parent for the next generations and chromosome that did not selected will be eliminated. Repeat the process above for 25 generations.

Inside the graphic shape then GA's cell grouping manufacturer generate value like graphic below:

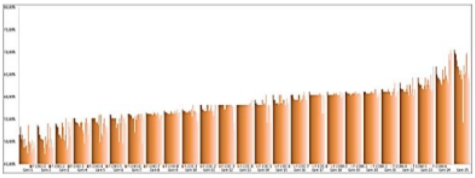

Figure 1. GA's Cellular Manufactur 25th gen

The result from GA's cell grouping after 25 generation optimum solution with the value of 83.45% will be retrieved.

Table 8. Machines grouping 25th generation

Number Of Cell	No	Machine	Number Of Cell	No	Machine
Cell 1	3	Lathe	Cell 3	6	STP
	11	Positioner LH		12	Positioner RH
	13	Dummy		15	Assy Finishing RH
	14	Assy Finishing LH		16	Storage
Cell 2	1	Raw Material	Cell 4	4	Bending
	2	Cutting		8	Sub Assy Finishing
	5	Drilling	Cell 5	9	TW Assy LH
	7	Welding		10	TW Assy RH

4.2. GA's Machine Arrangement

GA's machine layout is used for arranging machines in each cells in production floor. This method needs input such as production volume, machine distance, process flow.

4.2.1. Fitness Function

Fitness Function that used as algorithm method for machine layout is function to minimize coefficient in flow.

4.2.2. Parameter

- Number of Generations : 7 Generasi
- Number of Gen : 21 Gen
- Population size : 6 Kromosom
- Crossover Probability : 0,95
- Mutation Probability : 0,02

4.2.3. Encoding Process

Gen initialization every chromosomes in the first generations. Increase random number for every gen in the table below:

Tabel 9 Initialization chromosome

Grouping Cell					Cell -1				Cell -2					Cell -3				Cell -4		Cell -5	
1	2	3	4	5	3	11	13	14	1	2	5	7	6	12	15	16	4	8	9	10

4.2.4. Decoding Process

Decoding process for layout machines using cell placement to cartesius coordinate. Create alternative machines placement inside the cell with cube shape shown in the table below :

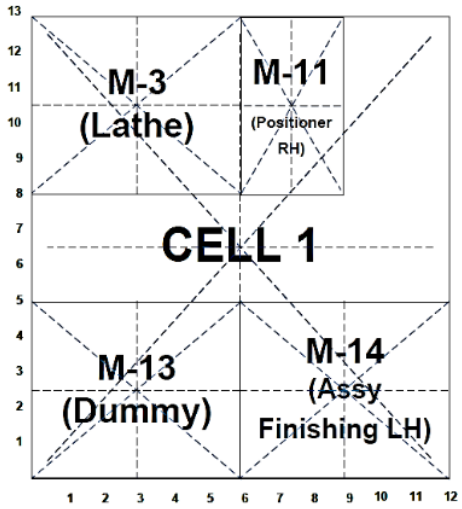

Figure 2. 1st Alternative for Cell 1

Coordinate point receive from the center of dimension inside the cell 1 shown in the table below :

Tabel 10 machine coordinates in cell 1

No Dept	Machine	Cordinate's	
		X i	Y i
3	Lathe	3,0	10,5
11	Positioner LH	7,5	10,5
13	Dummy	3,0	2,5
14	Assy Finishing LH	9,0	2,5

Calculate distance rectilinier using 4th equation formula in the references until it generates the value as shown below:

Table 11 Matrix Distance For Cell 1

M_{ij}	Cell 1			
	3	11	14	15
3	0	4,5	8	14
11	4,5	0	12,5	9,5
14	8	12,5	0	6
15	14	9,5	6	0

Calculate material flow using this formula:

$$M_{ij} = \frac{\text{volume produksi part a}}{\text{ukuran lot part a}} + \frac{\text{volume produksi part b}}{\text{ukuran lot part b}} + \cdots + \frac{\text{volume produksi part n}}{\text{ukuran lot part n}}$$

The result of calculation of material flow:

Table 12 *Material flow* for cell 1

	Cell - 1			
	3	11	13	14
3	0			
11		0	5	
13			0	5
14				0

Coefficient in flow generated from the multiplication between rectilinear matrix distance and material flow. In the table below for the result of calculation of coefficient in flow from cell 1 chromosome 1.

Table 13 Coefficient in flow for cell 1

	Cell - 1				
	3	11	13	14	TOTAL
3	0	0	0	0	0
11		0	63	0	63
13			0	30	30
14				0	0
			TFC		93

Do alternative machine layout inside the cells and alternative cells placement in the production floor for every cell for each chromosomes. Repeat the decoding process above for the whole alternatives until we find the value of coefficient in flow.

4.2.5. Crossover Process

Increase random number from o to 1 until to find parents. If the value of probability is bigger than the random number then the chromosomes is feasible to be parent.

Table 14 The determination of parent

No	Chromosome Code	Chromosome	Random Value	Crossover's Probability	Decision
1	AL-B-Gen-1-CHO-01	Chromosome 1	0,75	95%	Crossover
2	AL-B-Gen-1-CHO-02	Chromosome 2	0,20	95%	Crossover
3	AL-B-Gen-1-CHO-03	Chromosome 3	0,95	95%	No Crossover
4	AL-B-Gen-1-CHO-04	Chromosome 4	0,56	95%	Crossover
5	AL-B-Gen-1-CHO-05	Chromosome 5	0,01	95%	Crossover
6	AL-B-Gen-1-CHO-06	Chromosome 6	0,30	95%	Crossover

Increase again the random number to decide parent pair and gens that are going to be used for crossover.

Table 15 *Crossing site*

Crossing Site	Chromosome Relationship			Group Cell		Cell 1		Cell 2		Cell 3	
				From	To	From	To	From	To	From	To
Parent 1	1	&	4	1	3	2	3	1	1	1	3
Parent 2	2	&	5	2	3	1	2	1	3	1	1
Parent 3	4	&	6	2	4	2	3	3	3	1	3

Table 16 *Chromosome Offsprings Crossover*

Chromosome & Chromosome	: 1	1	2	3	4	5	:	3	11	13	14	:	1	2	5	7	:	6	12	15	16	:	4	8	:	9	10
	: 4	4	5	1	2	3	:	14	3	11	13	:	7	1	2	5	:	16	6	12	15	:	8	4	:	10	9
Chromosome Offsprings Crossover 1	:	4	5	1	3	2	:	13	3	11	14	:	7	2	5	1	:	16	6	12	15	:	4	8	:	9	10
Chromosome Offsprings Crossover 2	:	1	2	3	5	4	:	14	11	13	3	:	1	7	2	5	:	6	12	15	16	:	8	4	:	10	9

4.2.6. Selection Process

The function used is minimize coefficient in flow, then we will only get 6 lowest value to be used as parents in the next generations, shown in the table below:

Table 17 Chromosome selection

No	Chromosome Code	Chromosome Name	Coefficient In Flow	Decision
1	AL-B-Gen-2-COC-05	Chromosome Offsprings Crossover 5	25.093	**Next Generation**
2	AL-B-Gen-1-CHO-01	Chromosome 1	35.368	**Next Generation**
3	AL-B-Gen-1-CHO-02	Chromosome 2	36.215	**Next Generation**
4	AL-B-Gen-1-CHO-04	Chromosome 4	36.553	**Next Generation**
5	AL-B-Gen-2-COM-02	Chromosome Offsprings Mutation 2	37.280	**Next Generation**
6	AL-B-Gen-1-CHO-06	Chromosome 6	37.553	**Next Generation**
7	AL-B-Gen-2-COM-01	Chromosome Offsprings Mutation 1	38.328	Dead
8	AL-B-Gen-1-CHO-03	Chromosome 3	38.758	Dead
9	AL-B-Gen-2-COM-04	Chromosome Offsprings Mutation 4	38.793	Dead
10	AL-B-Gen-2-COC-04	Chromosome Offsprings Crossover 4	38.808	Dead
11	AL-B-Gen-2-COC-01	Chromosome Offsprings Crossover 1	38.818	Dead
12	AL-B-Gen-2-COC-02	Chromosome Offsprings Crossover 2	38.818	Dead
13	AL-B-Gen-2-COC-03	Chromosome Offsprings Crossover 3	39.643	Dead
14	AL-B-Gen-2-COM-03	Chromosome Offsprings Mutation 3	43.925	Dead
15	AL-B-Gen-1-CHO-05	Chromosome 5	45.615	Dead
16	AL-B-Gen-2-COC-06	Chromosome Offsprings Crossover 6	46.073	Dead

After the value of coefficient in flow of 7 generation retrieve, it will be like this graphic below:

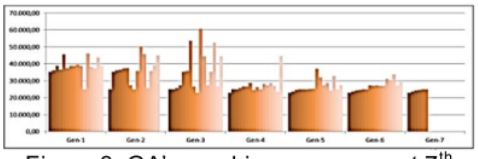

Figure 3. GA's machine arrangement 7th gen

4.3. Analysis and Discussion

Results from genetic algorithm cell manufacture grouping on the 25th generation prove that the most effective of machine grouping is located in the 1st chromosome with the order shown below:

Table 18 Order of machine in the cell

Number Of Cell	No	Machine	Number Of Cell	No	Machine
Cell 1	3	Lathe	Cell 3	6	STP
	11	Positioner LH		12	Positioner RH
	13	Dummy		15	Assy Finishing RH
	14	Assy Finishing LH		16	Storage
Cell 2	1	Raw Material	Cell 4	4	Bending
	2	Cutting		8	Sub Assy Finishing
	5	Drilling	Cell 5	9	TW Assy LH
	7	Welding		10	TW Assy RH

With the value of grouping efficiency of 83.47% there has been significant rise of 31.88% compare to the default layout. The default layout only has grouping efficiency of 51.59%

Output from cell grouping will be input for machine placement. Furthermore, the result from genetic algorithm calculation of machine placement after 7 generations have coefficient in flow of 22,863 per month or 274,356 meter annually and followed by second chromosome of 23,638 monthly Comparison of machines layout with default production facility with the suggestion of the ideal width of production floor of 13 meters and the length of 108 meters as shown in the picture below:

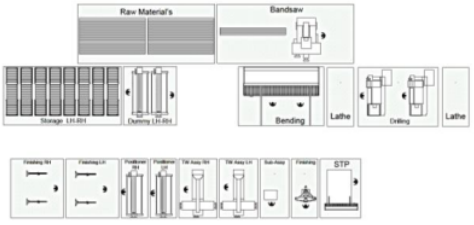

Figure 4. Default layout

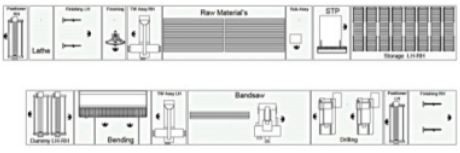

Figure 5. Suggested layout

5. CONCLUSION

The drawback of the current machine layout is slow movement of material flow because of the far distance between machines.

Layout production should be done by grouping several machines inside the group cells of technology, where machines which have the same process grouped to 1 cell that relatively close to each other.

Efficiency generated from the suggested layout generated value of 274,356 meter annually. The different is quite significant if we compare it with the default machine layout that only generated around 827,342.5 annually.

Suggestion that can be given is related to this research is to revamp the current layout. Beside, the company must hire new employee specialized in material handling of production component so it will not disturb the performance of machine operators. Additionally, creating more alternatives of material handling which can process as many components as possible.

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Analysis & evaluation of plant production layout PT Arkha Jayanti Persada using group of technology concept with genetic algorithm approach

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