Pacific Business Review International
Volume 5 Issue 6 (December 2012)

Improving Facility Layout of An Automotive Industry: Using Graph Theory

Komal Verma*, Ramakant Upadhyay **, Sandeep Gangawat***

Facility layout design is a strategic issue and has a significant and lasting impact on the efficiency of a manufacturing system. An ideal facility layout provides the optimum relationship among output, floor area and manufacturing process. Facility layout facilitates the production process, minimizes material handling time and cost, and allows flexibility of operations makes optimum use of the building, promotes effective utilization of manpower. It is also important because it affects supervision and control, use of space and expansion possibilities.

This paper presents a case study for improvement in layout in an automobile component manufacturing company. The company has process layout in which similar machines are put together in a department. The first visit to the company revealed a variety of problems due to its improper layout. For improvement in layout Graph Theory is used with the framework of systematic layout planning methodology. The cost analysis shows a saving of about 62.4% per year in material handling cost by this method. The proposed layout however requires lot of changes in the existing layout. Seeing the constraints of time in implementation one case is developed along with cost analysis which is most affecting area of material handling in the plant and can save huge money of the organization and management can implement this case in less time without effecting the other department.

The current work has only practical data of material handling cost, but for cost analysis needs some other cost such as equipment cost, wages, salaries, inventory carrying cost and operating cost. These costs are not providing by the management, that's why analysis excluded these costs.

Key Words: Graph Theory, effective manpower, cost reduction, facility enhance and smooth functioning.

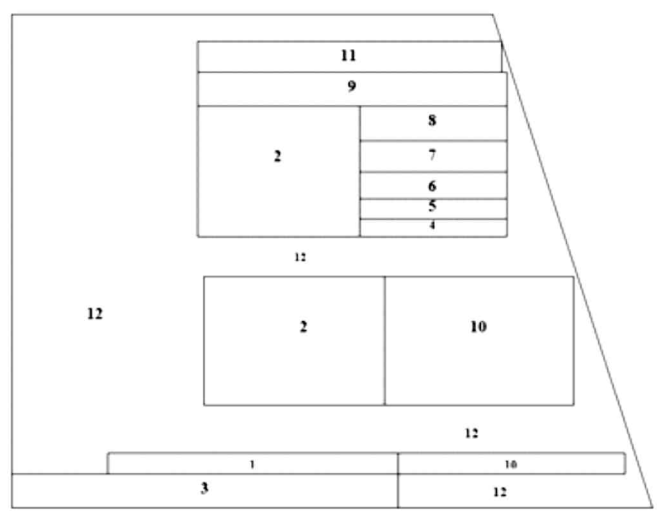
Basic Operation Of Manufacturing

The company produces die casting components for automobile locks. Raw material is purchased from outside. The raw material goes through different processes to produce final product. Figure 1 shows material flow chart for die casting components production.

Figure 1: Flow chart for die casting component

Existing Layout of The Company

The company has process layout in which similar machines are put together in a department.



*International Institute of Management, Engineering & Technology, Jaipur.

S.NO.	LEGEND NAME
1.	Raw material store
2.	Die casting
3.	Finish die casting store
4.	Broaching
5.	Drilling
6.	Reaming
7.	Tapping
8.	Milling
9.	Finish quality store & packaging
10.	Tool & maintenance
11.	Administrative block
12.	Free space

Figure 2: Existing Layout of the Company

Material Flow In The Existing Layout

Most of component produced in the company follow the same path though the departments. The flow of material is shown in figure 3

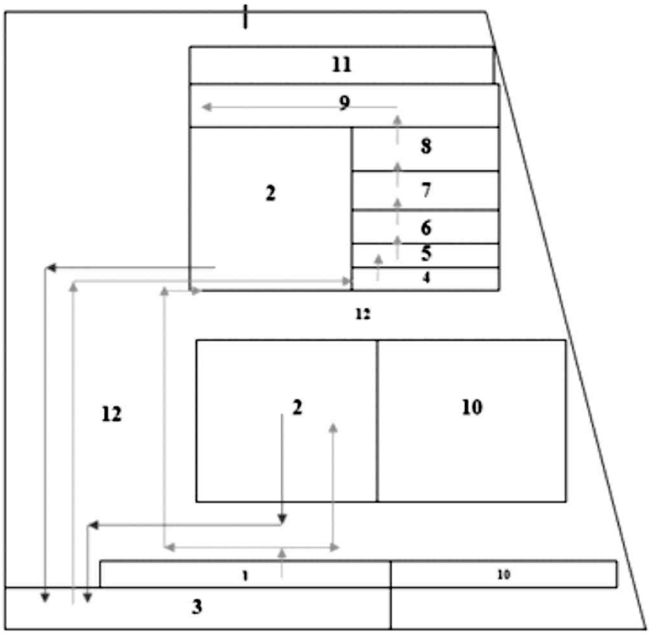


Figure 3: Material flow in the existing layout

Legend	
→	In ward flow of material
→	Out ward flow of material

Problem Description

The first inspection of the company exposed various problems due to its unorganized layout. These problems are as follows:

- Excess flow of material between departments.
- Excess production time.
- Excess work in process.
- Improper department location

The present study aims:

- To investigate existing layout.
- To propose enhanced layout and several feasible alternatives for the management to select optimum from them.

Analysis Of Existing Layout

In this section the existing layout is studied in detail to facilitate improvement. As a first step the areas of the different departments were calculated. Table 1 shows planer areas (in sq. ft) for different departments. These areas are kept same in the future analysis.

Table 1: Planer area of the different departments

Department No.	Department Name	Length * width (in ft)	Total Area Square ft
1.	Raw material store	25*9	225
2.	Die casting	100*55 +(82*65)	10830
3.	Finish die casting store	30*64	1920
4.	Broaching	24*14	336
5.	Drilling	30*24	720
6.	Reaming	12*24	280
7.	Tapping	19*24	456
8.	Milling	9*24	216
9.	Finish quality store & packaging	26*24 + (25*16) +(17*25)	1449
10.	Tool & maintenance	84*15 + (9*65)	1845
11.	Administrative block	54*25	1350

From in order to facilitate future analysis a block plan is prepared for the existing layout. The block plan is show in figure 4. The numbering of the departments is kept same as shown earlier in figure 3. Departments 10 and 11 are the departments in which no material flow takes place (shown shaded in figure 4).

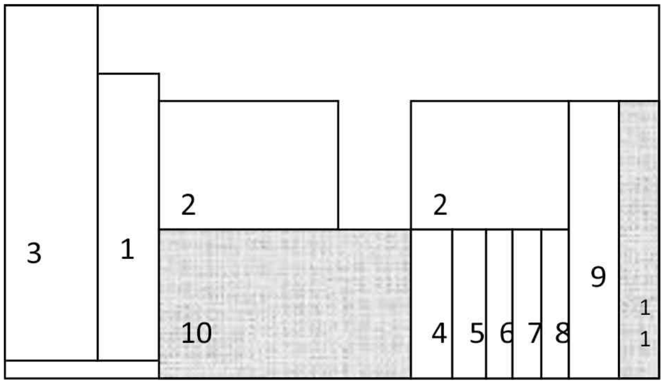


Figure 4: Block plan of existing layout

The material flow is assumed to be rectilinear. The rectilinear and centroid to centroid distance between different departments was measured and shown in table 2. Department 10 and 11 are not shown in table 2 due to no material flow from –to - these departments.

The total distance traveled by the material in the existing layout

= 222+264+314+52+46+41+39+90

= 1068 ft

To determine the flow of material between different departments the

FROM \ To	1	2	3	4	5	6	7	8	9
1		222							
2			264						
3				314					
4					52				
5						46			
6							41		
7								39	
8									90
9									

Table 2: Distance between departments

production data for financial year 2010-2011 was considered. The monthly production in each of the departments is given in Table 3

Month	Raw materia store	Die casting	Finish die casting store	Broachin	Milling	Reamin	Tapping	Drilling
April	438.984	328.288	326.637	250.765	249.345	249.123	248.299	246.465
May	556.005	547.493	546.628	540.262	539.647	538.857	538.231	537.978
Jun	501.079	498.765	498.241	487.548	487.142	486.812	486.123	487.986
July	411.833	406.028	404.893	404.271	403.921	403.382	402.842	402.521
August	480.153	470.260	460.837	459.956	459.521	459.195	458.953	458.645
Septembe	595.238	464.957	462.638	462.254	461.356	461.124	460.963	460.689
October	215.433	198.848	197.621	197.290	196.900	196.421	196.094	195.986
Novembe	267.012	240.168	240.008	239.698	239.401	239.198	238.762	238.590
Decembe	1107.18	783.362	780.462	780.390	779.746	779.433	779.398	779.278
January	475.719	470.621	465.832	465.642	465.023	464.956	464.875	464.683
February	465.891	450.871	450.354	450.134	449.782	449.748	449.701	449.598
March	397.534	396.132	395.897	395.605	395.588	395.528	395.300	395.287
Total Productio (in tonne	5912.07	5255.79	5230.04	5133.815	5127.37	5123.77	5119.54	5117.70

Table 3: Yearly production in the departments

- The material flow between different departments is shown in table 4. As can be seen the flow reduces with the progression of production. This is due to rejections of material at different stages of production. The reverse flows due to rejections however are not considered in the analysis. Department 10 and 11are not show in table 4 due to no material flow to/ from these departments.

	1	2	3	4	5	6	7	8	9
1		5912.07							
2			5255.79						
3				5230.04					
4					5133.81				
5						5127.37			
6							5123.77		
7								5119.54	
8									5117.70
9									

Table 4: From- to chart showing material flow

Determining unit cost of material flow

For analysis, the unit cost of material flow is required. But this is not available with the company. So this cost is calculated indirectly as below

Assume total manufacturing cost Rs. 35000 per tonne as given by company and material handling cost is 20 to 30% of the total manufacturing cost per tonne. For analysis taking 25% material handling cost then material handling cost is 8750 per tonne.

Unit material handling cost

$$= \frac{\textbf{material handling cost}}{\textbf{total distance travel by the material}}$$

$$= \frac{8750}{1068} \text{ Rs/tone/ft}$$

$$= 8.19 \text{ Rs/tone/ft}$$

The unit material handling cost Rs 8.19 is calculated for one tonne material for one ft distance traveled. The unit material handling cost is considered to be fixed in future analysis. The total material handling cost for the existing layout can be calculated by

Total material handling cost between department

$$= \sum_{i=1}^{n}\sum_{j=1}^{n} fij * dij * cij$$

Where

n is the number of departments.

i = 1, 2… n and j = 1, 2… n are the indices for departments.

C_{ij} is the material handling cost for a unit material for a unit distance between departments i and j.

f_{ij} is the material flow from department i to j determined from yearly production targets.

d_{ij} is the rectilinear distance between centroids of departments i and j

Material handling cost analysis

S.No.	Department (From□to)	f_{ij}	d_{ij}	C_{ij}	Material handling cost in years $f_{ij} * d_{ij} * C_{ij}$
1.	1-2	5912.074	222	8.19	10749215
2.	2-3	5255.793	264	8.19	11363865
3.	3-4	5230.048	314	8.19	13449905
4.	4-5	5133.815	52	8.19	2186389
5.	5-6	5127.372	46	8.19	1931686
6.	6-7	5123.777	41	8.19	1720513
7.	7-8	5119.541	39	8.19	1635233
8.	8-9	5117.706	90	8.19	3772261
Total material handling cost					46809067

Table 5: Material handling cost analysis

New Layout Design By Graph Theory

As shown from the previous calculation, the material handling cost for existing layout is too high. This needs to be reduced by making changes in the existing layout. As seen in the literature review there is a variety of tools and techniques used for the purpose. But due to its simplicity the graph theory for improvements in the existing layout is used. The details of the graph theory are given below.

Graph Theory

The basic idea of graphs was introduced in 18th century by the great Swiss mathematician Leonhard Euler. He used graphs to solve the famous Konigsberg bridge problem. In the graph theory approach, relationships (flows) among facilities can be represented by a (relationship) graph in which vertices denote facilities and edges denote existence of flows or relationships between facilities. A requirement for existence of a block layout satisfying the relationships represented by a graph is that the graph be planar. A graph is planar if it can be drawn in the plane and each edge intersects no other edges and passes through no other vertices.

A typical graph theoretic heuristic for the layout problem consists of the following steps:

Step I:

Firstly construct an activity relationship chart (REL chart). This can be done in consultation with the production manager and workers.

Step II:

In this step the REL chart is converted into the relationship diagram. For this, convert the rating in the form of line and take those departments first, which have "A" rating and then take other departments which have "E" rating. Follow same steps, until all the pairs of departments and ratings are not satisfied. In the graph theory, relationship diagram is also called as activity relationship graph.

Step III:

In this step develop a dual graph from the planer graph. There are two types of region in the graph, one is bounded and another is unbounded, the unbounded outside region is called exterior and the region defined by a graph are referred to as faces. The unbounded outside region is also called exterior face. To construct the dual of a planer graph, place a dual node in each phase of the planer graph whenever two faces share an arc in their common boundary join the nodes of the corresponding faces by an edge. The edge for the dual graph is shown with dashed line and faces of dual graph shows the departments.

Step IV:

The dual graph gives only the relation between relative locations of the departments. Finally, convert the dual graph into the block layout with the help of REL chart and try to satisfy maximum closeness rating.

The above steps are implemented to the case as follows:

Step I: Construct an Activity Relationship Chart

Activity relationship chart give the information about the closeness between the departments, in activity chart or REL chart all pairs of relationships are evaluated and closeness rating (A, E, I, O, U, and X) is assigned to each pair. Closeness ratings represent an ordered preference for "closeness". Specifically an "A" rating and "X" rating are considered to be most important ranking and a layout must satisfied the "A" and "X" ratings. An E rating is the second ranked and most, if not all "E" rating should be satisfied by layout. An "I" rating is ranked third and they should be satisfied by the layout without sacrificing "A", "X" and "E" ratings. "O" rating is ranked fourth and they should be satisfied by the layout without sacrificing "A", "X", "E" and "I" rating. "U" rating is neutral rating and hence they can be ignored while designing the layout. With the help of production manager, REL chart was constructed which is shown in table 5.6

	1	2	3	4	5	6	7	8	9	10	11
1		A	U	U	U	U	U	U	U	U	U
2			O	U	U	U	U	U	U	E	U
3				A	U	U	U	U	U	U	U
4					E	I	O	O	U	O	U
5						E	I	O	U	O	U
6							E	I	U	O	U
7								E	I	O	U
8									I	O	U
9										U	O
10											U
11											

Table 6: Activity relationship chart

Step II: Construct Activity Relationship Diagram:

The purpose of the activity relationship diagram is to especially depict the relationship of the activities. In the relationship graph, vertices denote facilities and edges denote existence of flows or relationships between facilities. It is also called the planer graph. The planer graph for REL chart is given in figure 5

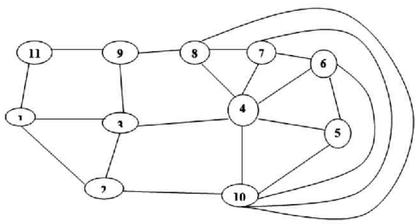


Figure 5: Relationship Diagram

Step III: Dual Graph:

Construction of a dual graph is very important step in a layout design, in this step convert the relationship diagram into dual graph. Dual graph for relationship diagram is shown in figure 6.

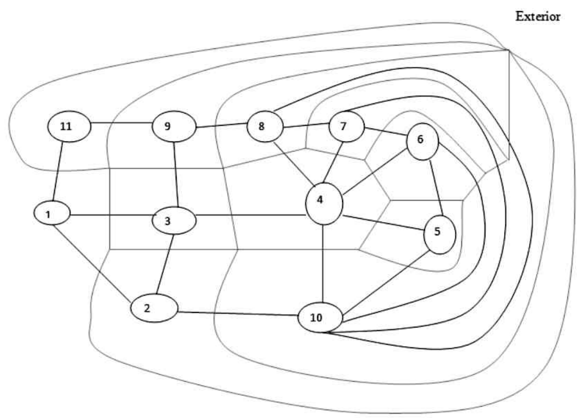


Figure 6: Dual graph for proposed layout

Step IV: Block Layout:

Finally for generating the block layout conversion of dual graph into block layout is being carried out. New block layout for the company by the graph theory is show in figure 7

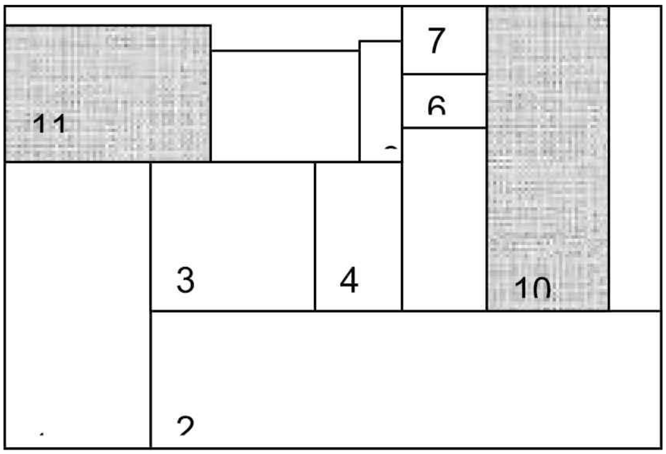


Figure 7: Block diagram of proposed layout of the company

Cost Analysis For The Proposed Layout

For analysis of the proposed layout the number of department and the areas of the different departments are kept same as that of the existing layout, so as to make the analysis easy but shape has been changed to rectangular.

Table 7: Planer Area of the departments

Department No.	Department Name	Length * width	Total Area Square ft
1.	Raw material store	75*3	225
2.	Die casting	212.35*51	10830
3.	Finish die casting store	80*24	1920
4.	Broaching	24*14	336
5.	Milling	30*24	720
6.	Reaming	24*12	280
7.	Tapping	24*19	456
8.	Drilling	24*9	216
9.	Finish quality store & packaging	63*23	1449
10.	Tool & maintenance	61*30.2	1845
11.	Administrative block	54*25	1350

The length and width of different departments along with the areas are given in Table 7

The material flow is assumed to be rectilinear. The distances between different departments were measured. The centroid to centroid distances for different departments is show in table 8. Department 10 and 11 are not shown in table 8 due to no material flow to/ from these departments.

From \ TO	1	2	3	4	5	6	7	8	9
1	0	120	67	114	136	157	172.5	140.5	104
2		0	103.6	56.6	40.6	61.6	77.1	78.1	113.6
3			0	47	69	90	105.5	73.5	37
4				0	22	43	58.5	26.5	57
5					0	21	36.5	37.5	73
6						0	15.5	16.5	53
7							0	32	68.5
8								0	36.5
9									0

Table 8: From – to - chart for Distance travelled by material in proposed layout

Total distance traveled by the material flow in new layout =120+103.6+47+22+21+15.5+32+36.5

= 397.35 ft

S.No.	Department (From□to)	f_{ij}	d_{ij}	C_{ij}	Material handling cost in years $f_{ij} * d_{ij} * C_{ij}$
1.	1-2	5912.074	120	8.19	5791018
2.	2-3	5255.793	103.6	8.19	4459456
3.	3-4	5230.048	47	8.19	2013202
4.	4-5	5133.815	22	8.19	925010
5.	5-6	5127.372	21	8.19	881856
6.	6-7	5123.777	15.5	8.19	650437
7.	7-8	5119.541	32	8.19	1341729
8.	8-9	5117.706	36.5	8.19	1529861
Total material handling cost					17592573

Table 9: The total material handling cost for the new layout

Total material handling cost of the new layout is Rs 17592573 per year

Total saving in material handling cost =

[Material handling cost in existing layout – material handling cost in new layout]

= 46809067 – 17592573

= 29216494

Total saving in material handling cost is Rs 29216494 per year

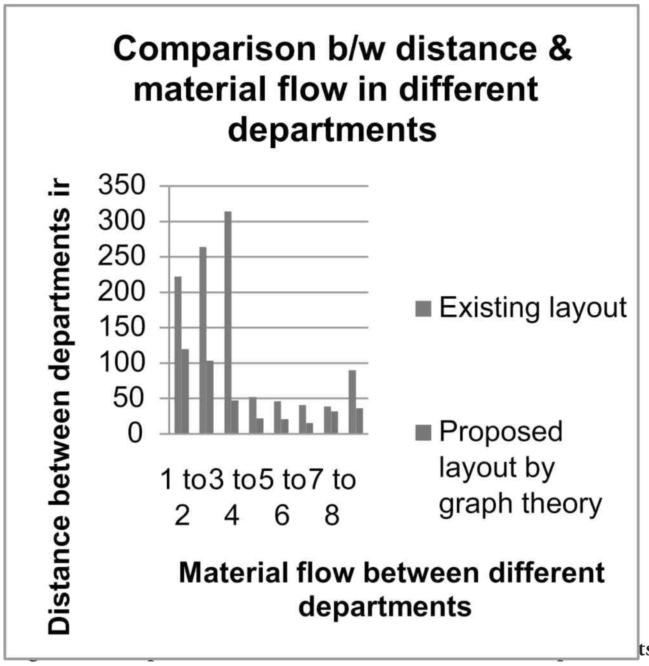
Saving as % of original cost= $\frac{29216494}{46809067} \times 100$

= 62.4%

Comparison Between Existing and Proposed Layout

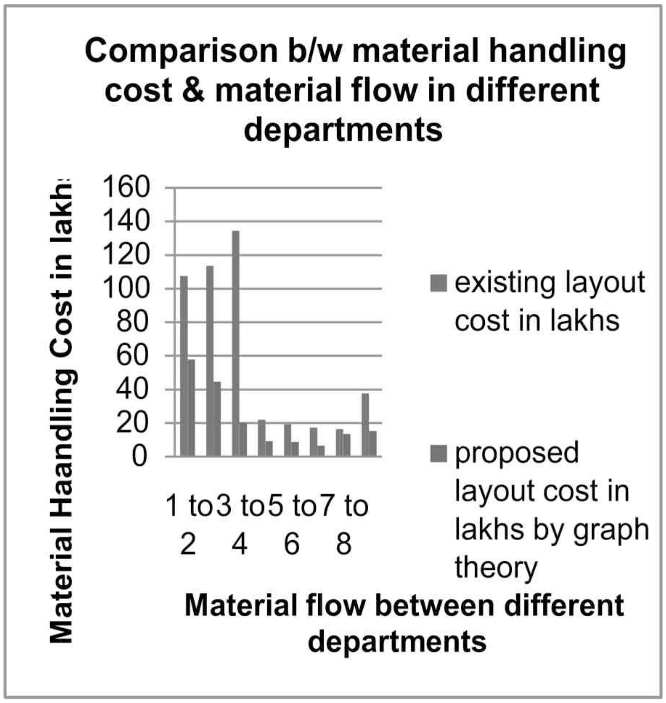
(1) On the basis of distance between different departments

The figure 8 shows the comparison between existing and proposed layout on the basis of distance between different departments.



(2) On the basis of material handling cost

The figure 9 shows the comparison on the basis of material handling cost.



It is seen from the above cost analysis that the proposed layout is better than the existing layout and can save huge sums of money. This however, requires lot of disturbances which may not be acceptable to the management.

10. Conclusion

Facility planning is the arrangement of work space which, in general term smoothes the way to access facilities that have strong interactions. The main concern with the plant facility layout planning is to reduce the cost of materials handling as poor materials handling can generate business problems. To stay competitive in today's market a company must reduce costs by planning for the future. By the use of Graph Theory we can reduce the cost of material handling up to 62.4%

11. Acknowledgment

The beautiful, bliss and euphoria that accompany the successful completion of any task would not be complete without the expression of appreciation of simple virtues to the people who made it possible. So with reverence, veneration honour I acknowledge all those whose guidance and encouragement has made successful in winding up this.

First and foremost, I would like to thank my research guide. His attitude towards excellence and his enthusiasm has been source of constant inspiration. I am grateful to him for all the advice, encouragement and support he has given me during the work with him.

Last but not the least I would appreciate my parents, which made me, reach this level and almighty at the top.

REFERENCE

Andre, A. (2006). "On the exact solution of a facility layout problem." *European Journal of Operational Research*, 173, 508-518.

Balakrishnan, J., Hung, C., Conway, D. G., & Z, M. (2003). "A hybrid genetic algorithm for the dynamic plant layout problem." *International journal of Production Economics,* 86, 107-120.

Baykasoglu, A., Dereli, T., & Sabuncu, I. (2006). "An ant colony algorithm for solving budget constrained and unconstrained dynamic facility layout problems." *Omega the international journal of management,* 34, 385 - 396.

Bazaraa, M.S. (1975). "Computerized layout design: a branch and bound approach." *AIIE Transaction.* 7, 432-437.

Chwif, L., Barretto, M. R. P., & Moscato, L. A. (1998). "A solution to the facility layout problem using simulated annealing." *Computers in Industry,* 125-132.

Datta, D., Amaral, A. R. S., & Rui, J. (2011). *"Single row facility layout.*