Modified SLP for Layouts in the Production of Small Items Using Small Machinery

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Abstract
Some products are made from many very small off the shelf components. In these cases normally the devices and work stations used for production or assembly are also small. In the existing layout design methodologies, particularly the Systematic Layout Planning, SLP, material flow plays a significant role in the layout design process. In fact most of these methods have been designed to deal with large flow and equipment. This paper discusses the issues and techniques required in layout design in a manufacturing environment for small products using small machinery. It attempts to modify the SLP to cater for these cases by additional checks and calculations. In particular it uses commonality ratio, to identify component commonality between products or facilities, as a basis for development of their relationships. The methodology was applied to redesign the layout of a manufacturing situation. The existing evolved layout has gone to its limits of congested flow, low traceability of products, lack of visibility and disorganisation. Implementation of the new approach resulted in a layout with higher efficiency of space usage, good visibility, and effective material flow, as compared with the current layout.

Keywords*:* *Layout design, high variety low volume, component commonality*

1. Introduction

Facilities Layout modelling has much further progressed in the last two decades through introduction of mathematical modelling and new algorithms to solve them. Material variety, size, flow intensity and material handling equipments are considered in these models due to their impact on the layout design. Bozarth C. and P. M. Vilarinho, (2006) discusses the impact of space utilization and production planning on the space requirement. It highlights the fact that layout is affected by all other activities. Chung S-H., W. L. Pearn and A. H. I. Lee, (2006) provides some production performance measures on product mixes in semiconductor fabrication, which also clarifies the complexities involved in this environment.

Although traditionally layout problems were mainly focusing on process layout scenarios, mathematical modelling of product based layouts have also been developed considerably. According to Baudin (2002), the two main factors in assembly performance are part supply and assembly work design. The latter extends to analysis of parts and components through bills of materials, product quantity (P-Q) analysis, part commonality and the aggregate part consumption volume by item. Kusiak (1990), (Propen 1990), (Heragu, S 1997), among many others, describe the idea of group technology (GT) as a basis for layout design of product based cases. Jay Jina et al (1997) describes the main characteristics of HVLV situations and contrasts these characteristics with those of the typical large lean manufacturing company and debates some of the major organizational and technological barriers which need to be overcome in HVLV environments. This paper aims at fulfilling parts of these requirements.

SLP has traditionally been developed for situations where material handling normally has a major impact on the layout design due to the physical characteristic of material and the need for major material handling tools. In HVLV situation however, impact of material flow is minimal due to the small size and weight of the very many small and light weight components involved. Womack et al. (1990) concludes that there are three major problems like, lack of clarity in understanding of what HVLV actually means the problem with the term turbulence and finally problem with the management. Other authors have attempted to further clarify the problems associated with HVLV. Suzue et al (1990) described the variety reduction techniques in order to reduce the complexity while maintaining the product variety.

The classical methods do not provide the necessary tools and procedures to deal with so many components. The aggregate approach they adopt may lead to insufficiently detailed assignment of the small facilities, into their appropriate physical locations. When there are too many activities, the relationship diagram becomes very intricate (Dweiri, 1999). Chitturi, et al (2007) in relation to dealing with these environments due to their complexities and differences, is emphasizing on product grouping and states that " … to improve the validity of the of the map within the job shop environment modifications are made by drawing an improved map considering the product groups, average product family, customer demand and the information flow data which will help to generate a meaningful future state map".

This paper discusses an approach which employs ways of utilising the available information in creation of the layout for HVLV scenarios. These ideas are then imbedded in the systematic layout planning (SLP), (Muther, 1973).

2. The Layout Procedure

Systematic Layout Planning (SLP) procedure (Muther 1973) is the backbone of the process described here. However there are some tools and procedures added in this work which would further facilitate the process to a more effective approach.

We have summarized the SLP procedure below. Note that the normal text is the traditional text and the italic text is the additional steps of the procedure as added by the authors.

Procedure: The Modified SLP for Small machines, Products with many Small Components

1. **Data gathering**
   Current layout
   - **Product Data! Here products have very many small components**
     . *Identification of high demand products (HDPs)*
     . *Develop the Commonality Matrix:*
       To identify common components in products
     . *Measure Commonality Ratio*
2. **Material flow→Material handling: Not significant in volume as a basis for analysis** *Use the Commonality Ratio (CR) as the basis*
3. **Development of the Activity Relationship Chart and Diagram** *based on Commonality Matrix*
4. **Space Relationship Diagram,** *on CR*

5. **Modifying Considerations & Practical Limitations**
6. **Detailed Layout:** *considerations for smallness*
7. **Choice of the most desirable layout Space Utilization:** *Effectiveness of Flow of Small Components*

Section 3 is the additional analyses proposed by this paper to enable SLP to cope with small cases. The procedure is then exemplified by a real case development.

3. Commonality Analysis

Commonality analysis identifies the common parts between the products, or facilities, and their relationships.

3.1 Commonality Analysis

Consider an incidence matrix $A=\{ a_{ij} \}$, $A(m \times n)$ of m components and n products
$a_{ij}=1$ if component i belongs to product j and
$a_{ij} = 0$ otherwise.

$a_k = \{a_{ki} \}=$ Vector of components a_{ki}, $i =1,\dots, m$ of product k $k= 1,2,\dots,m$.

$C_{kp} = a^T_k . a_p =$ the number of components shared between products k, p.

Matrix $C=\{C_{kp}\}$ is the Product Commonality Count Matrix. $K,p= 1,2,\dots,m$,

Note that C_{kk} shows the total number of components in product k.

Let $C^R_{kp}=2C_{kp}/(C_{kk}+ C_{pp})$, then
$C^R = \{C^R_{kp}\}$ is the Commonality Ratio Matrix

Notice that C^R can be easily implemented using a spreadsheet. Entries in row i and column j in Table 1 show the percentage of common components between any two products i, j. The data relates to some of the high demand products, see next section, for the case under consideration. Obviously the products with high C^R_{kp} must be grouped together to minimise handling.

3.2 High Demand Rule:

A product is of high demand if its quantity and its processing time follow certain rules. An example of this is given below, as used in the case development.

$Qd \geq 50$ per annum, or
$35 \leq Qd \leq 50$ per annum and process time above 1 hour, or
$25 \leq Qd \leq 34$ per annum and process time more than 2 hours.

3.3 Rules for conversion of the Commonality Ratio to Relationship codes

1. A (Absolutely necessary): more than 50% parts in common and using same testing instrument
2. E (Especially important): more than 50% parts in common
3. I (Important): Use the same testing instrument.
4. O (Ordinary): Have the same product base or above 20% parts in common
5. U (Unimportant): Nothing in common.

Section 4: Case Study

The case was developed in an electronic manufacturing company. The result was accepted and implemented by the company, with some minor modifications based on realities on the floor that we missed due to short time presence.

4.1 Data gathering:

In a period of observation and discussions with management, supervisors and operators, all the data related to products, processes and supporting functions were collected, measured, recorded and validated.

Current layout of the production area is shown in Figure 1. (L1, L2 and L3) are carousels where small products are stored, WL are storage shelves for some cartons, components and sub-assemblies while L refers to finished goods and some packed accessories for the assembly area.

There is some flow of products between the workstations for assembly and testing. The final calibrations are performed in the testing area after assembly. Only SPS is assembled and tested in the same area. Two products get assembled and tested on the dedicated tables. Two other products, PSD, GTA, are huge assemblies that take significant time in assembling and testing. The CD copying area was found irrelevant to the assembly process while obstructing the flow of the present layout. It was decided to exclude this from future layout.

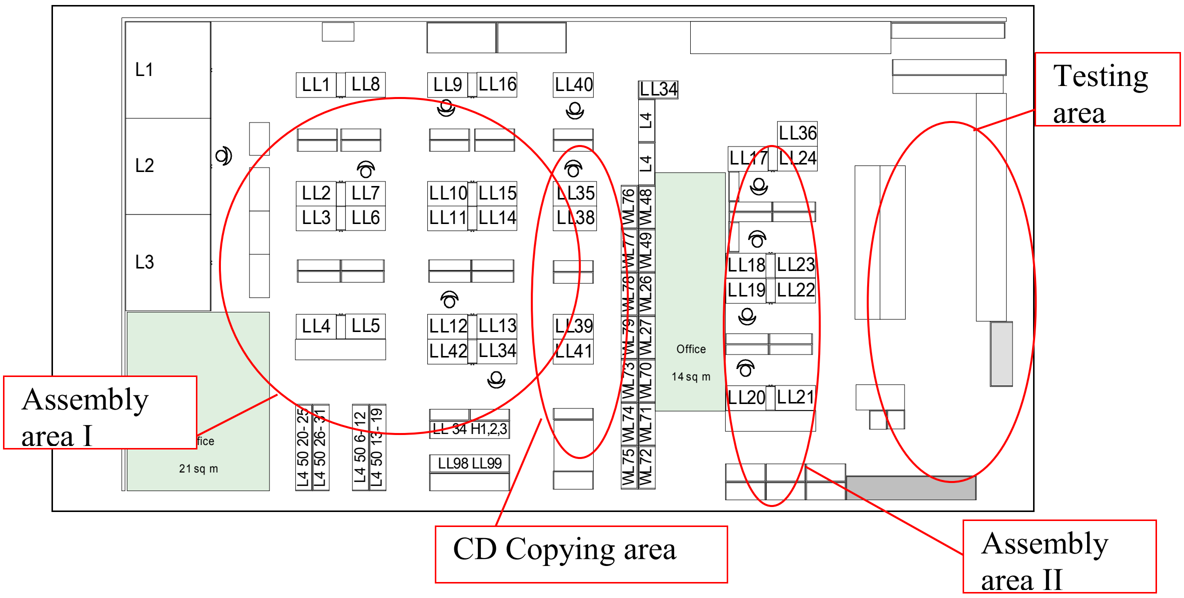


Figure 1. Current Layout of Spares and Accessories Department

There is some flow of products between the workstations for assembly and testing. The final calibrations are performed in the testing area after assembly. Only SPS is assembled and tested in the same area. Two products get assembled and tested on the dedicated tables. Two other products, PSD, GTA, are huge assemblies that take significant time in assembling and testing. The CD copying area was found irrelevant to

the assembly process while obstructing the flow of the present layout. It was decided to exclude this from future layout.

4.2 Product Data:

Demand Analysis led to a PQ-chart of 50 products as in Figure 2. Each product is composed of up to several hundred components. A great deal of standard assembly operation times were developed as the company data was old and unreliable. Meanwhile standard procedures for assembly were also developed for each product to ensure consistency.

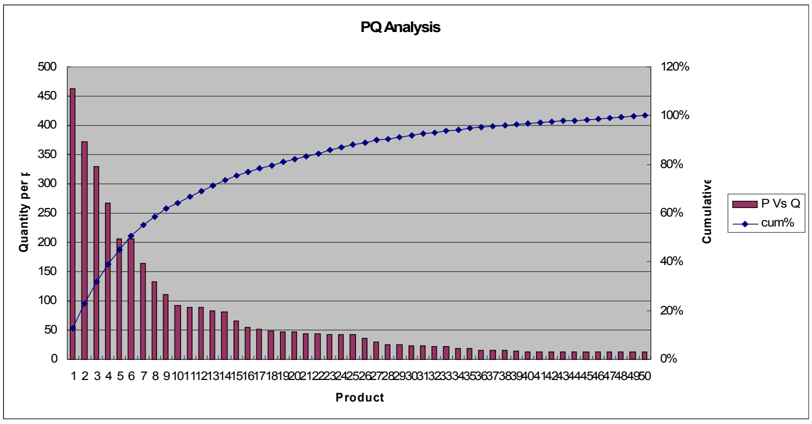


Figure 2. P-Q Analysis on 50 products

Table 1 Product commonality ratio matrix $C^R = \{C^R_{kp}\}$, in %

	VGA77	Ultra	SPS	SPS3	50RCH	50SSH	50 18CH	Trans	Tem p C	CHYLT	CHRECT	1/3 SRA
VGA77	100	7	24	4	1	4	13	6	22	0	1	6
Ultra	7	100	3	3	0	5	14	2	5	2	0	2
SPS	24	3	100	1	1	2	9	3	15	1	1	3
SPS3	4	3	1	100	0	1	0	0	3	0	0	0
50RCH	1	0	1	0	100	4	0	0	0	39	96	0
50SSh	4	5	2	1	4	100	11	15	11	0	4	0
50 18Ch	13	14	9	0	0	11	100	4	13	0	0	6
Trans	6	2	3	0	0	15	4	100	17	4	0	9
Temp C	22	5	15	3	0	11	13	17	100	0	0	1
CHYLT	0	2	1	0	39	0	0	4	0	100	36	0
CHRECT	1	0	1	0	96	4	0	0	0	36	100	0
1/3 SRA	6	2	3	0	0	0	6	9	1	0	0	100

Identification of the high demand products (HDPs):

The high demand products are those that contribute to 70-75% of the production volume. These products are used as the basis for the design of a layout. It is reasonable to assume that a layout designed for the high demand products can accommodate the other products with minor modifications.

4.3 Material flow:

Some products are moving through the working areas to reach the final station, the testing areas in this case. Despite the low volume, the material flow may still cause problems if it is not smooth due to barriers or bad material handling. For example improperly placed racks may obstruct the flow. Flow diagrams were prepared for current and then for proposed layouts to visualise the flow paths and facilitate its smoothing before measure of distances are made.

4.4 Development of the Activity Relationship Chart and Diagram based on commonality Matrix:

It only makes sense to define the relationship between the assembly tables, the main facilities in this case, based on the products and components they share. We found the application of commonality matrix a useful idea to establish the relationship chart. Therefore the Commonality Ratio Matrix was prepared for the working tables as in Table 3.

Table 3. Commonality Matrix of High Demand Worktables

	VGA77	ultraa	sps3	50RCH	50 18CH	TempC	CH REC	1/ 3RSP	1/ 3TPR	1/ 3 6x6	1/ 3 8x6	FLR MPR	FLR pelt
VGA77	100%	7%	4%	1%	13%	22%	1%	9%	0%	18%	16%	15%	0%
ultraa	7%	100%	3%	0%	14%	5%	0%	5%	0%	12%	9%	9%	9%
sps3	4%	3%	100%	0%	0%	3%	0%	1%	0%	0%	0%	0%	3%
50RCH	1%	0%	0%	100%	0%	0%	96%	4%	0%	9%	4%	9%	4%
50 18CH	13%	14%	0%	0%	100%	13%	0%	9%	0%	25%	32%	13%	3%
TempC	22%	5%	3%	0%	13%	100%	0%	5%	0%	10%	9%	8%	7%
CH RECT	1%	0%	0%	96%	0%	0%	100%	9%	0%	9%	4%	4%	4%
1/ 3RSPU	9%	5%	1%	4%	9%	5%	9%	100%	3%	23%	20%	15%	5%
1/ 3TPRO	0%	0%	0%	0%	0%	0%	0%	3%	100%	6%	6%	0%	0%
1/ 3 6x6	18%	12%	0%	9%	25%	10%	9%	23%	6%	100%	56%	12%	4%
1/ 3 8x6	16%	9%	0%	4%	32%	9%	4%	20%	6%	56%	100%	14%	3%
FLR MPR	15%	9%	0%	9%	13%	8%	4%	15%	0%	12%	14%	100%	6%
FLR pe	0%	9%	3%	4%	3%	7%	4%	5%	0%	4%	3%	6%	100

Application of these rules on data from Table 3 leads to the Diagram of Figure 3 which shows the activity relationship chart for the high demand workbenches.

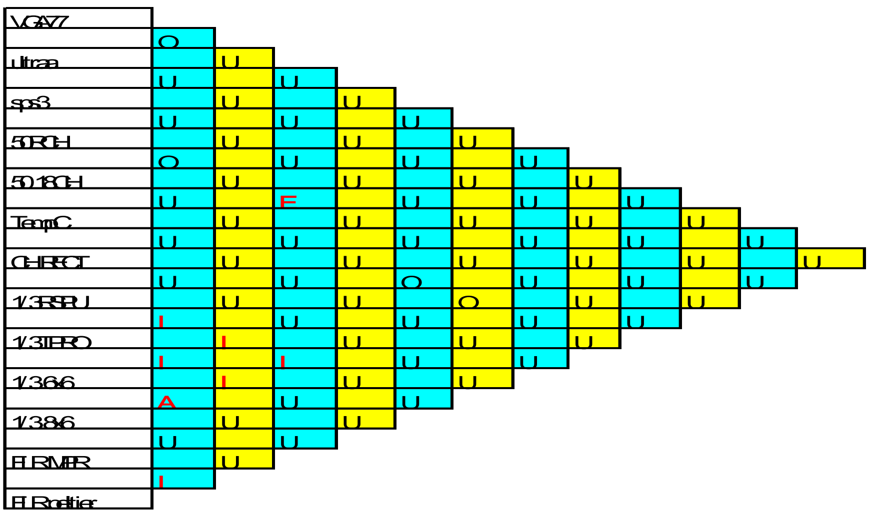


Figure 3. Activity Relationship Chart for High Demand Tables

Figure 4 shows the Relationship Diagram between the working tables, as extracted from Figure 3.

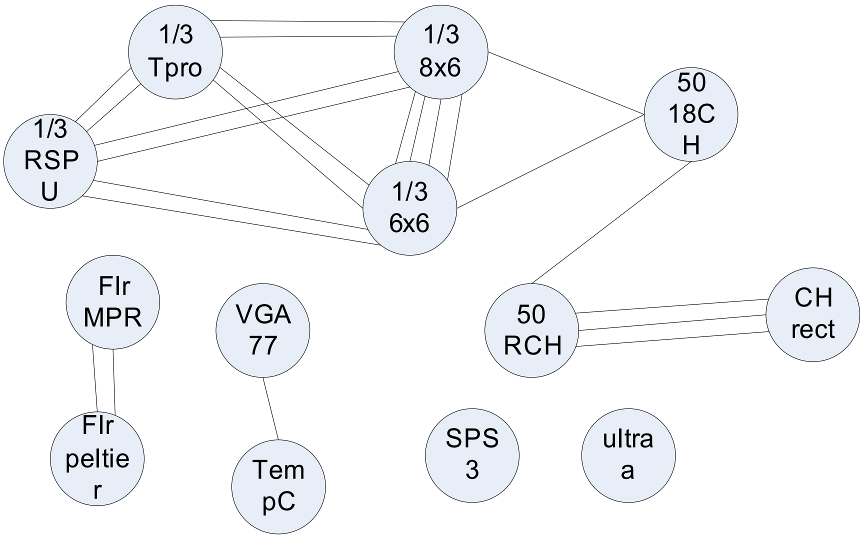


Figure 4. Relationship Diagram for high demand working tables

Four lines are used for the A rating relationship. Similarly, table pairs that have an E, I, and O relationships are connected by means of three, two and one line, respectively. Some products like SIP10, 20, SPS3, ULTRA are individual tables with no relationships and can be placed arbitrarily as even they have their dedicated testing areas. The rest of them fall under the relationship from the Figure 4.

4.5 Space Relationship Diagram:

Superimposing the spaces occupied by every workstation, from Table 2, on Figure 4 results in the space relationship diagram. This is the basic layout that improves by other factors considerations.

4.6 Modifying Considerations & Practical Limitations:

Figure 5 shows the first proposed layout of the complete assembly area of Spares after consideration of the modifications and limitations due to available space and other constraints.

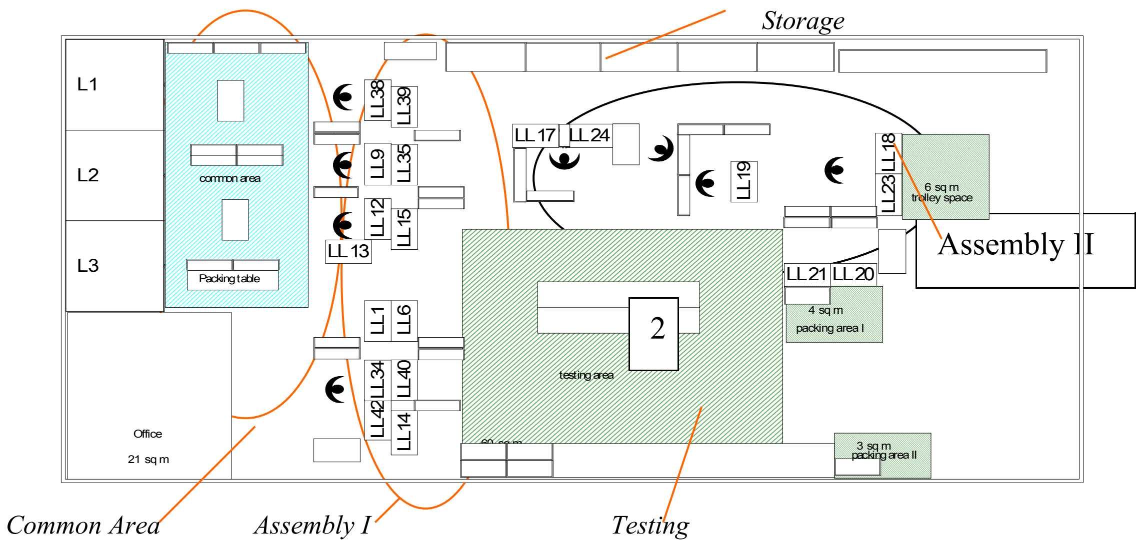
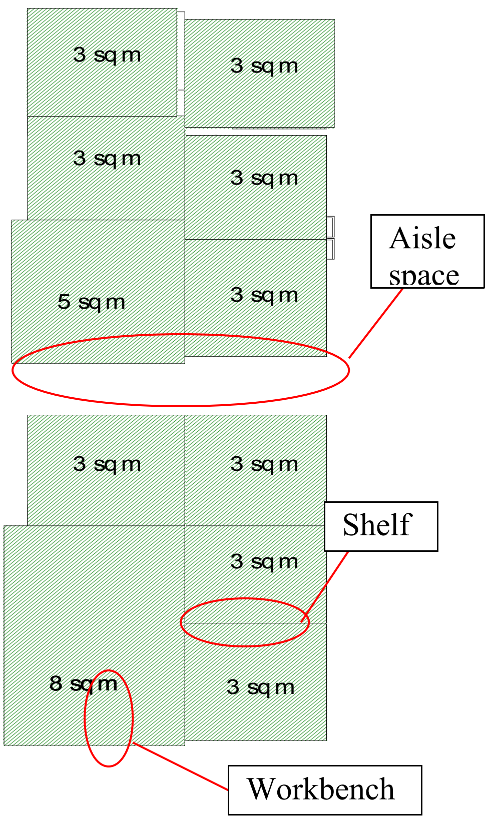


Figure 5. First Proposed Layout for Spares and Accessories Department

4.7 Detailed Layouts

Figure 6 for example, describes how the Assembly Area 1 is proposed in Figure 7. The tables LL 14, 40, 6, 15, 35, 39 are placed on right side as they all need to be tested in the common testing area. These are grouped on two factors, frequently produced ones and common test equipments with same storage group. Working table LL1, 38 also fall under this category but they are low demand products so they are placed on other side. Working tables LL 42, 34, 12, 9 are products for which testing is also done on the same tables, and products flow straight to the stores after assembly and their storage facilities are placed in the Carousels (L1, 2, 3).

Products are grouped to undergo testing in their own allocated production areas. A common area is provided for the products of low demand with two tables, 9 shelves and packing is done online in that area. Storage area is segregated into carousels for small components and storage racks for larger components or products. Packing is done online in the provided dedicated space. This new concept is introduced in order to bring a single piece flow in the layout.



Product's table location	
table	product
LL34&42	SPS 3
LL12&13	VGA 77
LL35	ULTRAA
LL06	1/3 TPRO
LL15	Temp C
LL01	50 18CH
LL40	1/3 6x6 & 1/3 8x6
LL14	1/3 RS PU
LL09	CH REC T & 50 RCH
LL39	FLR PELTIER
LL38	FLR MPR

Figure 6 Layout Structure of Assembly Area 1 with Modifications

Figure 7 demonstrates the complete layout of the first alternative.

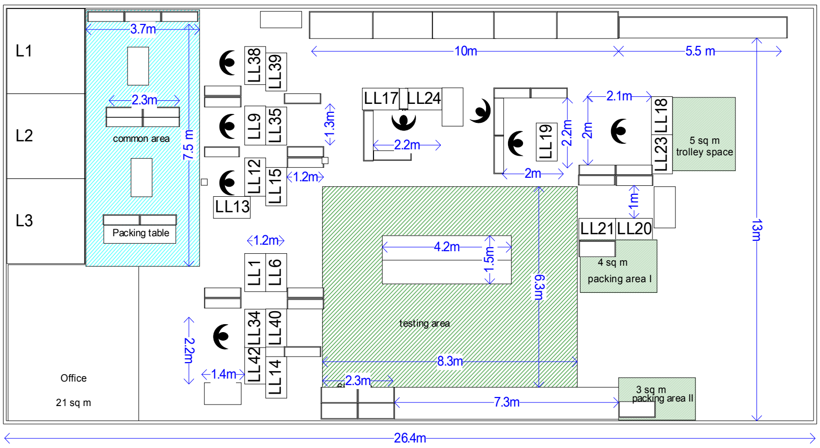


Figure 7 First Complete layout.

4.7.1 Second alternative Layout:

The second alternative layout is proposed in Figure 8. The common area and the packing area remain the same. The tables in each assembly area are grouped so that the testing is done immediately, with the racks placed on back of the workstations. The products like SIPS 10, SIPS 20 are moved to the Table 20 & 21 and are placed on the other side when compared with the first layout as these workstations can be arbitrarily positioned in the layout.

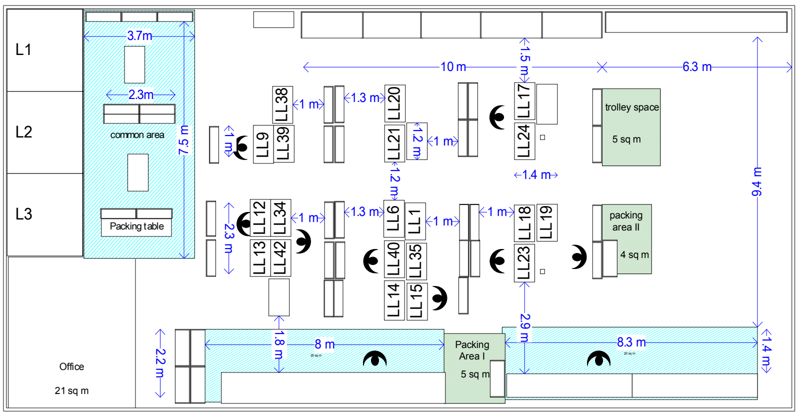


Figure 8. Second Layout

So, this arrangement provides a good visibility of work area with more dedicated test areas though it occupies more space.

4.8 Selection of the Most Desirable Layout

The two proposed layouts were evaluated based on three criteria namely: Space utilization, Flow of materials effectiveness, and Ease of future expansion.

4.9 Space Utilization:

The proposed layouts use only 20 working tables, a reduction of 12 tables compared to the current layout. The different arrangement patterns produce different efficiency of layouts and they are summarized in Table 4.

	Current layout	Proposed layout I	Proposed layout II
Total space usage	127 m^2	82 m^2	102 m^2
Total all workstations space usage	97 m^2	69 m^2	76 m^2
Efficiency	76%	84%	74%

Table 4 Comparison of Space Usage & Efficiency

4.10. Effectiveness of solution

Table 5, shows the comparison of walking distance for all the products, measured from drawings after flow diagrams were developed for each model.

From Table 5, both the proposed layouts have improved the walking distances. The second proposed layout has the least travel distance of 10.45m per product on average.

However the second layout has some obstructions in the flow as products from LL6 or LL40 needs to pass through the workstations on their way to testing. The first proposed layout accommodates a much smoother flow with better aisle space which made it preferred over the second layout. In addition the first layout having high space effectiveness also leaves enough space for future expansions while the second layout uses most of the available spaces.

	Current Layout		Proposed Layout I		Proposed Layout II	
Measures	Testing/packing	Storage	Testing/packing	Storage	Testing/packing	storage
Total	147.97 m	145. 41 m	90.65 m	121.55 m	54.80 m	81.05 m
Average	11.38 m	11.19 m	6.97 m	9.35 m	4.22 m	6.23 m
Total avg	22.57 m		16.32 m		10.45 m	

Table 5 Comparison of Walking Distance (current & proposed layouts)

5. Conclusions

The standard systematic layout design methodology has been designed and traditionally applied to cases where volume of material flow and size or workstations or machinery are significant factors in design of layout or material handling. However when SLP is being applied to high variety low volume situations, the factors named are lose their significance in layout design. Rather in such cases especial attention is required to cater for the small size and volume of components and devices used. The problem was exemplified by a case in electronic products in this paper. Measures of commonality between small parts and also between small devices were developed and applied, to simplify groupings of such components and small machineries used in these environments. The measures were added to enhance the SLP process. The new methodology produced improved layout measures for the case implemented in a host company.

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