New Systematic Layout and Information System Planning Method

SLIM

Shigehiro Nakamura
TP Management Consultant
Japan Management Association

Productivity Europe
Table of Contents

Overview: The Significance of Utilising Layout Design Techniques .......... 1

Simplified Layout Design .............................................................................. 2

Specific Procedures for SLIM-I ..................................................................... 3

Specific Procedures for SLIM-II ................................................................. Appendix 1

SLIM-III ...................................................................................................... Appendix 2

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Section 1

Overview

The Significance of Utilising Layout Design Techniques, and their Position within a Company

Productivity Europe
The Aims of SLIM
(New Systematic Layout and Information System Planning Method)

- To achieve the kind of production that positively impacts bottom-line results.

- Systematically, step-by-step, to build the ‘factory of the future’ – one that consistently and comprehensively achieves its quality, cost and delivery objectives.

- To proceed logically and rationally, with full employee commitment and involvement.
Difference between SLIM and Conventional Layout Design

Conventional approach

- Investigation of status quo
  - Focuses on problem areas only
  - Focuses on topics temporarily in the limelight, mainly to do with equipment and computers

- Procedure
  - Approach depends on interests of particular individuals
  - Analysis lacks objectivity
  - Judgements are based on scant data

- Action (short-sighted)
  - People are satisfied with a succession of separate countermeasures addressing problems individually
  - People feel they have made a significant improvement even if the original situation gets only slightly better
  - Decisions are easily swayed by different opinions (including those of non-experts)

"SLIM"

- Market check
  - Enables the essence of the problem to be addressed
  - Ensures that strategy is coolly reviewed from an objective standpoint and the causes of change are identified and borne in mind from the start

- Advance review of problems and countermeasures
  - Focuses on objectives rather than techniques; people are free to choose the most effective means of attaining the goals
  - Adopts a step-by-step approach towards the idea
  - Makes systematic use of past experience
  - Uses simulation to discover where the effects of change will occur
  - Involves all employees, aligning everyone's thoughts and actions in the same direction

Figure 1-1
<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>SLIM</th>
<th>SLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Product analysis strategy</td>
<td>Uses customer-oriented analytical techniques</td>
<td>Taken as read; not clearly identified</td>
</tr>
<tr>
<td>2</td>
<td>Objective-setting</td>
<td>Establishes policy based on management analysis</td>
<td>Concentrates on layout design techniques</td>
</tr>
<tr>
<td>3</td>
<td>Clarification of production technology</td>
<td>Clarifies key points</td>
<td>Taken as read; not clearly identified</td>
</tr>
<tr>
<td>4</td>
<td>Analysis of status quo</td>
<td>Utilises specific IE analysis techniques</td>
<td>Implements countermeasures by evaluating invisible elements</td>
</tr>
<tr>
<td>5</td>
<td>Product analysis</td>
<td>Involves no strategic analysis of products or line division (is aimed at mixed-model production)</td>
<td>Focuses mainly on line division (focuses on distinguishing volume production and non-volume production mathematically)</td>
</tr>
<tr>
<td>6</td>
<td>Materials flow analysis and load-capacity analysis</td>
<td>Applies step-by-step analytical procedure following movement of materials, equipment and people</td>
<td>Treats relationships between flow of materials and production activities at same level</td>
</tr>
<tr>
<td>7</td>
<td>Basic layout formulation</td>
<td>Compares three proposals based on a combination of basic SLP concepts with idea generation and selection techniques</td>
<td>Formulates alternative proposals (X, Y, Z)</td>
</tr>
<tr>
<td>8</td>
<td>Diagramming of conditions</td>
<td>Aims for comprehensive review, with nothing omitted</td>
<td>Focuses on selected layout</td>
</tr>
<tr>
<td>9</td>
<td>Simulation techniques</td>
<td>Designed to check layout in actual operation</td>
<td>No dynamic confirmation methods developed</td>
</tr>
<tr>
<td>10</td>
<td>Preparation of investment proposal</td>
<td>Prepared business plan summarising 1-9 above</td>
<td>No clear method used</td>
</tr>
<tr>
<td>11</td>
<td>Implementation and operation</td>
<td>Uses PERT in combination with risk analysis</td>
<td>No clear method used</td>
</tr>
</tbody>
</table>

Table 1-1
Basic SLP Procedure

(For reference)

Product (P) — Quantity (Q) analysis

Flow of Materials

Activity Relationships

Relationship Diagram

Space Requirements

Space Available

Space Relationship Diagram

Modifying Considerations

Practical Limitations

Plan X

Plan Y

Plan Z

Evaluation (of costs and tangibles)

Selected Layout Plan

General Overall Layout Plan

or

Detailed Layout Plans for each sub-area

Figure 1-2
The Corporate Environment

1. Diversification of corporate management, shift to high-variety/small-lot production, greater requirement for international transactions.
2. Collaborations and mergers with companies in different industries possessing different technologies.
4. Utilisation of advanced data-processing technologies.
5. Increasing quantity and complexity of administrative work (need for more efficient decision-making and data processing as information volumes and transfer speeds increase).
6. Heightening and diversification of individual demands; need to revitalise workplaces.
7. Pursuit by developing countries, worsening international balance of payments positions of developed countries.
8. Shift in consumer demand, from material affluence to spiritual fulfilment.
9. Emergence of knowledge-based service industries.
10. Increasing involvement of women in traditionally male-dominated areas of society; shortages of skilled labour; 'greying' of society; spiralling labour costs; young people's aversion to hard, dirty or dangerous work; demand for shorter working hours, etc.
11. Development of new materials; products not previously rivals suddenly becoming competitors.
12. Need to address environmental and welfare issues.

Table 1-2: Examples of Pressures for Change on Companies

In layout design, thorough planning is the key to success.

1. Utilise accumulated knowhow fully in the preparatory stage.

2. Predict problems and plan preventive and emergency measures.

3. Unite the company in Q, C and D improvement activities.

Figure 1-3: Factory Activities Before and After Establishment of New Layout (Ideal)
Efficiency-Boosting Measures Based on Fundamental Manufacturing Principles

Stage 1 — Product analysis and materials flow analysis

Stage 2 — Equipment layout and load/capacity analysis

Stage 3 — Instrumentation and tooling considerations

Stage 4 — Establishment of operating procedures

Stage 5 — Line staffing and establishment of job classifications

Stage 6 — Production management; full utilisation of human, material and equipment capabilities

(a) Layout design procedure

(b) The workplace improvement approach (taking quality improvement as an example)

Figure 1-4: Relationship Between Layout Design and Workplace Improvement
1. Marvin E Mundel: In the 1960’s Japanese companies’ productivity was a quarter of that achieved by top American companies. It could be assessed by the following formula:

\[
\text{Japanese companies’ productivity} = \frac{\text{methods}}{65\%} \times \frac{\text{operating rate}}{70\%} \times \frac{\text{work rating}}{75\%} \times \frac{\text{line balance}}{70\%}
\]

2. Overall equipment effectiveness = availability \times \frac{\text{performance rate}}{\text{quality rate}}

3. JIT: creating a system that produces zero defects and zero breakdowns.
<table>
<thead>
<tr>
<th>Item to be evaluated</th>
<th>System level</th>
<th>Low-level control and operation</th>
<th>Moving towards unattended operation</th>
<th>Unattended operation level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Health and strength of system (operation control)</td>
<td>Manual production scheduling, instructions and follow-up</td>
<td>Partial rationalisation of manual procedures</td>
<td>Automation of routine tasks (on-line)</td>
<td>Combination with equipment automation (data highway or hierarchy)</td>
</tr>
<tr>
<td>2. Production regime</td>
<td>Production to order; problems attended after they occur</td>
<td>Group technology applied in production flow, activities to detect and solve process problems</td>
<td>Systematic load-smoothing production; SMED</td>
<td>Small-lot production; shop floors accomplished within cycle time</td>
</tr>
<tr>
<td>3. Equipment automation</td>
<td>One operator per machine, processes performed individually</td>
<td>Multi-machine and multi-process working with anomaly monitoring</td>
<td>Multi-machine working; quality control implemented by microprocessors installed</td>
<td>Unattended operation at right (with Poka-Yoke devices); multi-process computer control</td>
</tr>
<tr>
<td>4. Automation of control</td>
<td>Macro-control in units of tonnes</td>
<td>Load control using number of moves and standard times</td>
<td>Automatic computer generation of process smoothing schedules</td>
<td>Integrated system controlled by central computer</td>
</tr>
<tr>
<td>6. Factory constitution improvement campaigns</td>
<td>Problem-awareness and participation campaigns (planned initiatives)</td>
<td>Standardisation and systematic application of PDC cycle</td>
<td>Activities focusing on improvement; training of operators in productive maintenance skills</td>
<td>Elimination of wasteful working practices by means of improvement team activities</td>
</tr>
<tr>
<td>7. Equipment management</td>
<td>Operating rate stabilisation by means of daily reports, breakdown maintenance</td>
<td>Operating rate control by means of operating-rate meters; preventive maintenance</td>
<td>Preventive maintenance and improvement with total employee involvement</td>
<td>Corrective maintenance</td>
</tr>
<tr>
<td>8. Quality control</td>
<td>Statistical analysis and discussion performed after the discovery of defects (post-mortem style)</td>
<td>Investigation of problems as they occur by means of FMEA, cause and effect diagrams, use of Six Sigma concepts and ATE technical troubleshooting techniques</td>
<td>Prompt solution of problems detected by in-line inspection; hardware devices (Poka-Yoke, etc.)</td>
<td>Zero-defect measures; complete elimination of rework</td>
</tr>
<tr>
<td>9. Workplace</td>
<td>Promotion of small-group activities</td>
<td>QC and PM circle activities</td>
<td>Multi-skilling, multi-process handling, research activities</td>
<td>In-house fabrication of materials-handling robots</td>
</tr>
<tr>
<td>10. Office</td>
<td>Rationalisation of manual procedures and interfaces to reduce documentation (office automation, introduction of PC)</td>
<td>Standardisation of production know-how</td>
<td>Introduction of computerised on-line POB point of service systems</td>
<td>Preemptive control</td>
</tr>
<tr>
<td>11. Production control systems</td>
<td>Production by means of macro-scale production orders; monitoring by means of graphs</td>
<td>Load control for individual equipment lines by means of daily scheduling</td>
<td>Systematic production ordering and monitoring for individual equipment units and time periods</td>
<td>Automatic production ordering and monitoring systems</td>
</tr>
<tr>
<td>12. Abnormality (problem) detection systems</td>
<td>Manual data compilation and review</td>
<td>Problem display by use of QC techniques</td>
<td>Signal displays using electronic devices</td>
<td>Automatic advance abnormality detection; systematic feedback for immediate improvement</td>
</tr>
<tr>
<td>13. Production response</td>
<td>Reactive-type problem detection and follow-up</td>
<td>Immediate solution of problems in the workplace, with importance given to actual facts</td>
<td>Systematic solution of problems through management by objectives</td>
<td>Rapid and continuous measures to deal with idling, minor stoppages and other disturbances</td>
</tr>
<tr>
<td>14. Material-handling technology</td>
<td>Transportation by means of pallets, manual loading and unloading</td>
<td>Loading/unloading and transportation using robots and auxiliary devices; improvement of materials handling</td>
<td>Materials flow control by automated transportation systems</td>
<td>Minimisation of materials handling by improvement of process links</td>
</tr>
<tr>
<td>15. Layout</td>
<td>Cluster type with independent shops</td>
<td>Rasterised material handling with 2-3 linked processes per line</td>
<td>Efficient, integrated materials handling linking all times</td>
<td>Smoothed lines with minimum WP</td>
</tr>
</tbody>
</table>

Table 1-3
Section 2

Simplified Layout Design

Process Analysis and Improvement

Productivity Europe
Process Analysis Symbols and Their Use

Figure 2-1 is a schematic diagram of what takes place when products are made in a factory. The factory has the function or role of converting materials into products. In order to do this, something called a process has to act on the materials. This 'process' can be defined as follows:

Process: An operation that applies a transformation in order to change principally the form or properties of materials (or information) and that attains this objective through the action of men/women, materials and machinery.

![Process Diagram](image)

**Figure 2-1: The Production Process and the Role of the Factory**

2.1
Process Analysis and Improvement continued

Processes can be classified as operation, inspection, transportation or delay, defined as follows:

**Operation**
- an operation occurs when machining, heat-treatment, assembly or other processes essential for making the product take place.

**Inspection**
- the process of examining and monitoring the quality of a product made in an operation. Since inspections do not add value if the factory’s operations produce non-defective products, inspections should always be targeted for elimination.

**Transportation**
- a process whose objective is to transfer objects from one process to another (‘transportation’ is used for objects, ‘movement’ for people).
  Transportation is unnecessary if processes are joined together. If transportation is unavoidable, efforts should be made to make the routes taken as short and ‘wide’ (as measured by the volume-distance product, i.e. the product of the distance moved and the volume of items transported simultaneously) as possible, since transportation does not add value.

**Delay**
- delay occurs whenever something stops as a result of timing mismatches between processes. Delays arise as a result of the occurrence of defectives and rework, the breakdown of machinery and equipment, changeovers, and when operatives stand idle for personal reasons or reasons to do with the way in which the work is organised. Since WIP is money, any delay means that the flow of money has stopped, and countermeasures must be devised. In JIT production, reduction of WIP is employed as a technique for exposing hidden problems in the workplace.
Review the processes in order to identify the current situation, while considering what improvements can be effected by applying the ECRS principle.

Use the 5W1H approach to identify the current situation.

Note improvement proposals, classifying them according to whether they should be implemented now, when the layout is rearranged, or at some time in the future.

Process Analysis Sheet

Product name:

<table>
<thead>
<tr>
<th>No.</th>
<th>Description of process</th>
<th>Symbols</th>
<th>Activity elements</th>
<th>Improvement ideas arising during process analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>□</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>○</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Use process analysis to break the process up into its separate elements and look for ways of improving it by searching for waste. (treat everything except actual operation as waste)

Use activity indices to think about improvements.

Review means of controlling temperature, dimensions and measurements.

Review lot sizes, storage methods and setups.

Review aptitudes, skill levels, causes of failure to operate and so on.

Review layout changes, designs, jigs and tools.

Figure 2-2 Process Analysis and its Application

Improvement sequence

E : Eliminate
C : Combine
R : Rearrange
S : Simplify

2.3
Quantitative Methods of Assessing Waste in Process

1. Transportation distance ratio:

\[
\frac{ym}{xm}
\]
Ideal value: 1

2. Empty transportation ratio:
Objective: to move objects from A to B (distance R)

\[
\frac{a + c + d}{R}
\rightarrow \text{Ideal value: 0}
\]
Movement of personnel: \(a + R + c + d\)
Movement of objects: \(R\)

3. Vertical movement:

Ideal value: \(a + b = 0\)

4. Activity index
# Activity Index

<table>
<thead>
<tr>
<th>Status</th>
<th>Description</th>
<th>Handling operations required</th>
<th>Activity index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loose</td>
<td>Left lying loose on the floor</td>
<td>○ ○ ○ ○</td>
<td>4 0</td>
</tr>
<tr>
<td>In containers or bundles without supporting blocks</td>
<td>The products are collected together in containers or bundles but must be picked up off the floor before they can be moved</td>
<td>X ○ ○ ○</td>
<td>3 1</td>
</tr>
<tr>
<td>On pallets or skids with supporting blocks</td>
<td>Ready for insertion of lifting gear such as the forks of a fork-lift truck, for immediate transportation</td>
<td>X X ○ ○</td>
<td>2 2</td>
</tr>
<tr>
<td>On trolleys or conveyors</td>
<td>Ready to be moved simply by pushing the trolley or starting the conveyor</td>
<td>X X X ○</td>
<td>1 3</td>
</tr>
<tr>
<td>On automatic conveyors or in chutes</td>
<td>Already moving; no action required</td>
<td>X X X X</td>
<td>0 4</td>
</tr>
</tbody>
</table>

Table 2-1: Readiness for Transportation
Mini Layout Design

Procedure

Step 1: Understand present situation
Use process analysis to find out how materials are moving.

Step 2: Ask about workplace problems
To involve the people in the workplace, collect information on their opinions, problems, desires, constraining factors, etc.

Step 3: Perform process and layout analysis, and consider possible improvements
Draw up a process analysis chart and diagram the problems.

Step 4: Clarify problems and set improvement objectives
Identify waste quantitatively and set numerical improvement targets.

Step 5: Formulate layout improvement proposals
Draw up three different proposals and compare their advantages and disadvantages.

Step 6: Select specific plan
Work out one or two concrete action plans based on the three original proposals.

Step 7: Consider plans for future
Consider plans for the future and revise the selected action plan.
Simplified Example: Steps 1 and 2

Current situation

1. Load WIP in the inspection area onto a trolley
2. Wheel the trolley to the packing area
3. Unload the trolley
4. Select the items that need to be packed
5. Load these items on to a trolley and transport them to the packing table
6. Perform the packing operation
7. Load the packed items onto a fork-lift truck
8. Transport the packed items to the storage area and store ready for loading into trucks
## Example of Improvement Ideas for Inspection and Packaging Process

<table>
<thead>
<tr>
<th>No.</th>
<th>Process</th>
<th>E: Eliminate</th>
<th>C: Combine</th>
<th>R: Rearrange</th>
<th>S: Simplify</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Place on trolley</td>
<td>Combine inspection and packing processes</td>
<td>Place materials on trolley as they exit from the previous process</td>
<td>Place in packages</td>
<td>Connect by means of a conveyor</td>
</tr>
<tr>
<td>2.</td>
<td>Move trolley</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Remove from trolley</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Select the required items</td>
<td>Inspect in conjunction with packing</td>
<td>Lengthen the conveyor and pass the materials along it in work sequence</td>
<td>Use stacker cranes to synchronise storage, transportation and sorting</td>
<td>Use computer control</td>
</tr>
<tr>
<td>5.</td>
<td>Move them to the packing station</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Pack</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Load by fork-lift truck</td>
<td>Place directly on truck beds</td>
<td>Redesign trolleys and synchronise storage and transportation</td>
<td>Store on conveyor after packing</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Place in storage area</td>
<td>Place in containers to be used for transportation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2-2: Simplified Example of Step 3
<table>
<thead>
<tr>
<th>Stage</th>
<th>Process</th>
<th>Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example of Stage 1 improvement</td>
<td>Place on trolley and store</td>
<td>• For each package type, contact previous process in advance and store on trolley</td>
</tr>
<tr>
<td></td>
<td>Transport</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Store</td>
<td>• Install a sorting conveyor between the packing process and the delivery dock</td>
</tr>
<tr>
<td>Trolley + conveyor</td>
<td>Select necessary items and transport</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pack</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Store on conveyor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Waiting for loading onto truck)</td>
<td></td>
</tr>
<tr>
<td>Stage 2 improvement</td>
<td>Sort on conveyor by package type in inspection process</td>
<td>• Install a sorting conveyor that sorts the items by package type and transports them directly from the inspection process to the packing station</td>
</tr>
<tr>
<td></td>
<td>Store</td>
<td>• Install a sorting conveyor at the packing process and create an automated line</td>
</tr>
<tr>
<td></td>
<td>Pack and sort</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Store on conveyor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Waiting for loading onto truck)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Load onto truck</td>
<td></td>
</tr>
<tr>
<td>Direct connection by means of conveyors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 3 improvement</td>
<td>Inspection</td>
<td>• Connect the inspection and packing lines directly together</td>
</tr>
<tr>
<td></td>
<td>Transportation</td>
<td>• Install an automated sorting line after the packing process</td>
</tr>
<tr>
<td>Link processes directly together</td>
<td>Packing</td>
<td>• Load directly into containers and leave products in containers while they wait to be loaded onto trucks</td>
</tr>
<tr>
<td></td>
<td>Sorting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Container loading</td>
<td></td>
</tr>
</tbody>
</table>

Table 2-3: Use of Process Analysis to Investigate Possible Improvements
# Basic Layouts (Creating Efficient Combinations of Men/Women, Materials and Machinery)

<table>
<thead>
<tr>
<th>No.</th>
<th>Layout type</th>
<th>Features</th>
</tr>
</thead>
</table>
| 1   | I-type layout | - Equipment is arranged in straight lines in line with flow of materials.  
- Usually expanded by adding further straight lines of equipment parallel to the existing ones.  
- Effective when returns and swarf are disposed of by conveyor. |
| 2   | S-type layout | - Used when materials must be introduced from the lineside, e.g. when flows of different workpieces merge or when dies, etc. must be introduced or removed.  
- Effective for assembly lines, welding lines, etc. where assembly-type operations take place. |
| 3   | T-type layout | - Basically, a modification of the L-type line. For space reasons, the main line is generally installed down the centre, and other materials flow into it from both sides.  
- Effective when large numbers of components need to be assembled. |
| 4   | U-type layout | - Generally used for ‘circuit-type’ multi-process handling. Aligns the flow of materials with the movement of the operators.  
- Improves operational efficiency and clearly assigns responsibility for quality. |
| 5   | O-type layout | - Used when operators must sit or stand in the same place.  
- The central space can be used for storing maintenance materials, jigs, tools, etc.  
- The turntable-type layout is a development of this. |

Table 2-4: Basic Layouts and their Characteristics
Practice Exercise 1: Mini Layout Design

Example of mini layout improvement .......... results of standard work analysis (mini layout Step 1).

To bring together the information in the previous section, we will perform a step-by-step analysis of how to effect a mini layout improvement utilising process analysis (focusing principally on layout improvement). As an example, we will take the process from packing to shipping of a certain component. Step 1 (understand present situation) has already been performed and the process is currently as described below.

Step 1 : Understand present situation ...... collect information by interviewing people

X Company makes 30 different kinds of electrical components, and packs them for delivery to its customers. The following information was collected by interviewing the people on the shop floor:

1. Five machines are used to produce the components, and they are processed in lots of approximately 1,000. After processing, each lot is placed in a bin, and the bins are stored temporarily in a storage area. Three operators work the five machines.

2. After temporary storage, the processed parts are taken out in accordance with instruction slips issued by the office, wheeled by trolley to a lift 6m away and taken up to the first floor on the trolley.

3. Since nobody is allowed to ride in the lift for safety reasons, operator T goes to some stairs 10m away, walks up to the first floor, pulls the trolley out of the lift, and pushes it to a temporary storage area near the washing unit where the components wait 30-60 minutes.

4. Because the components must be placed in the washer loose, they are removed from the bins and placed in a hopper. They then have to wait a further 30-60 minutes for the previous washing cycle to be completed. Once the previous lot of components has been washed, the hopper is switched over and the new lot of components is placed in the machine.
5. The hopper is fitted with a Poka-Yoke device that allows only correctly-dimensioned components to enter the washing machine and excludes any having the wrong dimensions. It also excludes components with burrs or fins on them, and these are reworked and included with the next lot. The operator at this station is operator H. The yield is approximately 97%. The machines take approximately 25 minutes to wash 10 lots.

6. Once the washing operation is finished, operator H collects the components into lots. When he has collected 4 lots, he places these separately into a bin. He then wheels the components over to the rustproofing process on a trolley.

7. The components then wait for a short time before they are placed in the rustproofing unit. They are placed in the unit lot by lot in order to avoid mixing up different lots. The rustproofing unit consists of three separate items of equipment, each performing one of the three processes of degreasing, immersion in rustproofing liquid and drying. Each lot passes through these three processes in the order given. Operator Q is responsible for this. After the rustproofing operation has been completed, operator Q places the components one lot at a time into a bin, and, as before, uses a trolley to wheel groups of four lots over to the packing process. Items that cannot be packed immediately are left in a temporary storage area.

8. The packing process consists of placing the components ten at a time into PVC bags and placing these bags ten at a time into boxes. This process is performed by five female operators. Delivery advice notes are attached to the boxes in accordance with shipping orders issued by the office. Since the components are packed in accordance with the times of delivery requested by customers, a certain amount of WIP is kept on hand after the rustproofing process. Items that are scratched or otherwise defective in appearance are removed during the packing process. The defect rate is approximately 2% relative to the previous rustproofing process. The packing operatives are kept very busy and generally work 1-2 hours overtime per day.
9. In addition to the above, a changeover is required in the initial machining process each time a different type of component is machined. These changeovers consist mainly of exchanging jigs and tools, and the required tools are brought from the toolroom together with the necessary programme tapes. The present factory layout is as shown in Figure 2-3. Since there is a shortage of labour and it is difficult at the moment to increase the number of employees in the plant, the workplace is required to make the operation as efficient as possible. Top management also wants to reduce the number of workers by one and make an annual saving of around £14,000. They have asked the plant manager to work out an improvement plan. All the equipment can easily be moved and can be rearranged at little cost in any way desired.

Figure 2-3 Present Layout
Output cycle time (OCT)

\[
OCT = \frac{\text{Number of hours factory operates in a day}}{\text{Number of products produced in a day}}
\]

**Figure 2-4: Concept of Output Cycle Time Controlling Flow**

**Practice Exercise**

Calculate the OCT for the following operation:

1. Production volume: 15,000 items/month (product A only)
2. Factory operation: 25 days x 2 shifts/month, 1 shift = 7.5 h, overtime = 20 h/month
3. Operating rate: 90%
Calculation of Process Balance Ratio

Process balance ratio = \( \frac{\text{total of time values for each process}}{\text{time for bottleneck process \times number of processes or complement}} \times 100\% \)

Calculate the process balance ratio for the operation shown in Figure 2-5

<table>
<thead>
<tr>
<th>Process</th>
<th>OCT</th>
<th>Balance loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.10</td>
<td>2.90</td>
</tr>
<tr>
<td>2</td>
<td>10.0</td>
<td>0.00</td>
</tr>
<tr>
<td>3</td>
<td>7.70</td>
<td>2.30</td>
</tr>
<tr>
<td>4</td>
<td>6.50</td>
<td>3.50</td>
</tr>
</tbody>
</table>

Figure 2-5: Work Arrangement Before Improvement, with Balance Losses

Process balance ratio = \( \frac{\text{ }}{\text{ }} \times 100\% = \)

Practice exercise 2: Draw the above diagram after improvement

2.15
Method of Improving Process Balance Ratio

Figure 2-6: PERT Diagram for Reducing Balance Losses
## Evaluating and Improving Process Links

<table>
<thead>
<tr>
<th>No.</th>
<th>Evaluation formula</th>
<th>Explanation</th>
</tr>
</thead>
</table>
| 1   | \( \frac{(\text{transportation} + \text{manual handling} + \text{waiting})}{(\text{processing} + \text{inspection})} \) | - Identify tasks that do not add value, and assess them in terms of frequency and time taken.  
- Use this formula after analysing transportation processes.  
- Do not include automated tasks in the numerator; identify the problems to do with manual work and set improvement targets. |
| 2   | \( \frac{(\text{automated transportation, handling and waiting})}{(\text{all transportation, handling and waiting})} \) | - Perform this evaluation in order to set objectives for the automation of process linkage operations. Use frequency or labour-hours for this evaluation.  
- Assess manual linkage work in terms of return on investment and ease of automation to determine whether automation is worthwhile, and set targets for promoting automation. |
| 3   | \( \frac{(\text{number of labour-hours required for linkage work})}{(\text{total labour-hours})} \) | - Use work sampling techniques to find out what proportion of the total amount of work done in the workplace is occupied by linkage work (in terms of labour-hours), or use motion study to analyse the procedure in terms of frequencies. Use the findings for promoting improvement and automation. |

Table 2-5: Example of Formulae for Evaluating Inter-Process Links and Automation

The basis of improving process links (ECRS):

1. Apply E, C, and R to the flow of materials.  
2. When (1) is impossible, save labour by means of S.  
3. Use motion study to improve process linkage work step-by-step.

Table 2-6 gives some hints for improving process linkage work.
<table>
<thead>
<tr>
<th>No.</th>
<th>Type of work</th>
<th>Example of problem</th>
<th>Example of improvement approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Transportation</td>
<td>(1) Items are transported manually between processes.</td>
<td>Use dedicated carts or shuttles.</td>
</tr>
<tr>
<td></td>
<td>Hints:</td>
<td>• Lines of movement should be short and wide.</td>
<td>(Examples: shuttle cart, automated guided vehicle (AGV), direct conveyor connection, etc.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reduce losses due to weight.</td>
<td>Arrange at same level.</td>
</tr>
<tr>
<td></td>
<td>(2) Items are moved up or down.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3) Work point varies.</td>
<td>Use lifting mechanism.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(4) Work distance varies.</td>
<td>Use smaller lots, introduce turntables, etc.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Change to fixed distance.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Grasping and moving</td>
<td>(1) Randomly-placed items must be lined up.</td>
<td>Place in designated container.</td>
</tr>
<tr>
<td></td>
<td>Hints:</td>
<td>• Utilise objects' shapes and stable surfaces.</td>
<td>Line up at end of previous process.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Avoid complex movements.</td>
<td>Or use a parts feeder or similar mechanism to line up automatically.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Set up in previous process (prepare in advance).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2) Parts must be selected.</td>
<td>Arrange in sets.</td>
<td>Introduce spool system to component assembly.</td>
</tr>
<tr>
<td></td>
<td>B C D A Assemble</td>
<td></td>
<td>Use jigs, etc. for arranging Parts in sets.</td>
</tr>
<tr>
<td></td>
<td>(3) Awkward objects must be picked up.</td>
<td>Use suction plates or magnets.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Use jigs, compressed air, etc. to make objects easy to separate.</td>
</tr>
<tr>
<td></td>
<td>(4) Items must be placed in a particular position.</td>
<td>Change orientation to facilitate handling.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>90° rotation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2-6: Key Points for Discovering Problems with Inter-Process Links, and Examples of Improvement Ideas
<table>
<thead>
<tr>
<th>No.</th>
<th>Type of work</th>
<th>Example of problem</th>
<th>Example of improvement approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Prepositioning</td>
<td>(1) Orientation varies.</td>
<td>Use chutes. Use turntable.</td>
</tr>
<tr>
<td></td>
<td>Hints:</td>
<td>(2) Items turn upside down.</td>
<td>Use inverting mechanism (180°, 90° etc.).</td>
</tr>
<tr>
<td></td>
<td>- Utilise natural forces.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Utilise shapes.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Use simple tools as part of transportation process.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Assembly</td>
<td>(1) Positioning is required.</td>
<td>Use positioning jigs, stoppers, etc.</td>
</tr>
<tr>
<td></td>
<td>Hints:</td>
<td>Adjustment is needed</td>
<td>Guide jig</td>
</tr>
<tr>
<td></td>
<td>- Utilise shapes.</td>
<td>Take out one by one.</td>
<td>Positioning pin</td>
</tr>
<tr>
<td></td>
<td>- Utilise guide jigs, positioning.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Use grouped processing to reduce number of assembly operations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2) Item must be repeatedly inverted between processing steps.</td>
<td>Group processing steps together.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Step 1 Step 2 Step 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adjustment is required each time.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3) A large number of parts is handled.</td>
<td>Change design</td>
<td>Integrate; employ monolithic casting, shrink-fitting, etc.</td>
</tr>
<tr>
<td>5</td>
<td>Assembly</td>
<td>(1) Items interfere with work position.</td>
<td>Use empty space on opposite side of workstation.</td>
</tr>
<tr>
<td></td>
<td>Hints:</td>
<td>Repositioning is necessary.</td>
<td>Avoid setups, interference with work position, etc. (dispersion).</td>
</tr>
<tr>
<td></td>
<td>- Group together or disperse.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2) Connection positions, equipment inspection points, etc. are dispersed.</td>
<td>Group together at one point, introduce one-touch connectors, use bundled wiring/piping, or use point (grouping).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3) Items are transported and processed in batches.</td>
<td>Introduce in processing sequence.</td>
<td></td>
</tr>
</tbody>
</table>
Section 3

Specific Procedure for SLIM-I

(Opimum Arrangement of Men/Women, Materials and Machinery)

Productivity Europe
The SLIM Concept

1. Analyse customer needs
2. Analyse environment in which product will be used and perform strategic analysis
3. Compare with competing products and draw out own company's strengths

Set objectives and create layout design concept

1. Perform management analysis
2. Create environment

Clarity production technology

1. Consider production characteristics

Analyse status quo and review concept

1. Review by applying mini layout design procedure
2. Analyse by means of card classification techniques

Check geographical conditions and select site

1. Confirm using checklists

Perform product analysis and decide strategy

1. Perform ABC Analysis of product and classify production lines

Analyse materials flow and perform load-capacity analysis

1. Perform routing analysis using From-To charts (consider production systems and location)
2. Review using materials flow diagram
3. Consider line balance by means of load-capacity analysis

Formulate basic layout and establish selection guidelines

1. Formulate three alternative plans and compare these
2. Establish basic approach for specific plan
3. Formulate basic layout and establish selection guidelines

Diagram conditions

1. Consider production constraints and select production system

Review through application of simulation techniques

1. Establish contingency plans for operating problems

Summarise in form of investment plan

1. Investment plan, schedule, etc.

Install equipment and begin operating

1. Scheduling
2. Operation

Figure 3-1: SLIM Layout Design Procedure

3.1
Product Strategy Analysis and Design

SLIM is a tool for achieving management reform. It is therefore necessary to analyse the market environment carefully, find out what competitors are doing, and consider the characteristics, marketing strategies and production systems of the products to be manufactured.

**Product strategy considerations**

- **Upper-level production techniques**
  - Strengths
  - Weaknesses
  - Objectives & counter-measures

**Upper-level product investigation**

- Investigate customer needs
  - Wishes
  - Technical policies
  - Solutions to pressing problems (QCD)
  - Other

- Analyse customer needs
  - Why, When, Where and How much will the product be used?
  - What will it be used for?
  - Any problems? etc.
  - (Examples)
    - Usage environment
    - Distribution, relations with other companies
    - Sales revenue, number of units, price
    - Distribution

- Analyse the production techniques to be used in the factory and express processes as functions (clarify production engineering processes). Build up an image of what is necessary and desirable regarding product name, men/women, materials, machinery and so on.

**Product strategy**

- Compare with rival products
  - Item
  - Strength
  - Weakness
  - Objective & countermeasure

**Processes**

- Analyse production inputs and levels
  - Level 1
  - Level 2
  - Level 3

- Materials
  - Factory functions
  - Product name

**Visualise the production techniques to be used in the factory and express processes as functions (clarify production engineering processes). Build up an image of what is necessary and desirable regarding product name, men/women, materials, machinery and so on.**

- To identify upper-level functions, ask what the product is to be used for.
- Clarify the positioning of products being planned by examining superior rival products.

**Utilise customer needs identified in previous step.**

**Figure 3-2: Product Strategy Clarification Technique**

3.2
Converting to a Customer-Focused Product Strategy

Figure 3-3: Example of Functional Analysis (Pencil-Sharpening Machine)
MQC evaluation index = (expectation of product) + (degree of satisfaction in use)

\[
\text{ MQC evaluation index } = \frac{\text{ selling price}}{\text{ price level hoped for by market}} + \frac{\text{ actual functions and performances}}{\text{ market function and performance level}} + \frac{\text{ possible delivery conditions}}{\text{ delivery levels and reliability promised to market (including co-ordination with customer's new product development and marketing plans)}} + \frac{\text{ actual product attractiveness index}}{\text{ market attractiveness index (colour, shape, size etc.)}}
\]

\[
\text{ actual usability index } = \frac{\text{ actual usability index}}{\text{ market usability index (by standard-value assessment; user's policy on installability, operability, applicability/developability, exchangeability, maintainability, remodelability, etc.)}} + \frac{\text{ product's image index}}{\text{ image index at time of use (technical reputation, reliability, sales figures, safety, etc.)}} + \frac{\text{ other}}{\text{ (e.g. quantity)}}
\]

\[
\text{ Degree of satisfaction in use } = \frac{\text{ new running costs}}{\text{ old running costs}} + \frac{\text{ new serviceability}}{\text{ old serviceability (MTBF, after-sales service, future outlook when model changes are introduced)}} + \frac{\text{ new life expectancy}}{\text{ old life expectancy and durability}} + \frac{\text{ other}}{\text{ other}}
\]

Table 3-1: Market-Oriented QC (MQC) Evaluation Index
Techniques for Analysing Potential Problems to do with Product Manufacture and Marketing

Key Points

1. Devise and implement measures to prevent problems from occurring in the first place.
2. Work out strategies for action to be taken if problems occur anyway.

<table>
<thead>
<tr>
<th>Topic:</th>
<th>(Who is to do what by when; include target values)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted problems</td>
<td>Seriousness</td>
</tr>
<tr>
<td>Hold a brainstorming session and list at random.</td>
<td>Use ABC ranking to show impact of problem on project.</td>
</tr>
</tbody>
</table>

Examples:
A : Extremely serious
B : Serious, should be considered
C : No need to consider at present

Table 3-2: Example of Contingency Planning Table for Addressing Potential Problems
Examples of Potential Problems

1. Drop in price
2. Competitors' more effective marketing strategy or greater advertising power.
3. Entry of companies from other industries
4. Delay or mistiming in launch of new product
5. Loss of customer confidence owing to problems with product
6. Insufficient capacity
7. Lack of technical confidence on part of customers
8. No clear prospects for solving various technical problems
9. Insufficient consideration of customers' needs as a consequence of focusing on specific customers
10. Labour shortages, reluctance of young workers to engage in dirty, difficult or demanding tasks
11. Insufficient financial strength on part of manufacturer
12. Model changes by purchasers; changes in product environment
13. Changes in users' preferences and usage environments
Production Technology Analysis and Design

Handling production technologies

Implementation of layout for introducing innovative technology

- Take account of future changes.
- Prepare for emergencies.
- Eliminate constraints.

Provide space for unexpected contingencies and make a flexible plan to allow for future changes.
Establish buffer lines and bypasses; allow for human intervention, etc.
Use tests and verification procedures to decide whether constraints can or cannot be eliminated.

Create remodelling plan

Follow the basic rules

1. Check by formulae.
2. Check by flowchart.
3. Use checklists. Identify constraints.

Create a production system that everyone understands and accepts.

Analyze status quo. Clarify production technology in the form of physical conditions.

Figure 3-4: How to Deal with the Production Technology that Needs to be Considered when Designing a Layout

Example: Heat-treatment of steel

Cooling curve (external)
Cooling curve (internal)

Curve A
Curve B

A: Austempering
Yields a tough steel that does not require further tempering.

B: Martempering
High hardness, high toughness.

Equipment conditions and layout must preserve constraints.

Figure 3-5: Quenching Curve (S Curve)
<table>
<thead>
<tr>
<th>Market strategy</th>
<th>Important tactics</th>
<th>Specific actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Increase market share</td>
<td>1. Reduce costs</td>
<td>1. Introduce high-variety, small-lot production and mixed-model lines</td>
</tr>
<tr>
<td>2. Develop distribution and marketing routes</td>
<td>2. Raise sales price by increasing value added</td>
<td>2. Increase per-capita productivity</td>
</tr>
<tr>
<td>3. Initiate joint development projects</td>
<td>3. Reduce distribution and transportation costs</td>
<td>3. Improve ability to introduce new products and models</td>
</tr>
<tr>
<td>4. Diversity and globalise</td>
<td>4. Improve quality and yield</td>
<td>4. Help to reduce customers' labour-hours</td>
</tr>
<tr>
<td>5. Secure established customers</td>
<td>5. Reduce delivery times, WIP, etc.</td>
<td>5. Save energy and resources</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6. Create model workshops</td>
</tr>
<tr>
<td><strong>Strategy / aim</strong></td>
<td><strong>Objectives</strong></td>
<td><strong>Technical Innovation items</strong></td>
</tr>
<tr>
<td>1. Sales (£k/month)</td>
<td>1. Profitability (%)</td>
<td>1. Labour cost reduction and ratio (%)</td>
</tr>
<tr>
<td>2. Price (£/item)</td>
<td>2. Total costs (%) reduction</td>
<td>2. Outsourcing cost reduction and ratio (%)</td>
</tr>
<tr>
<td>3. Market share (x% → y%)</td>
<td>3. Per-capita productivity (%) increase</td>
<td>3. Defect rate (%)</td>
</tr>
<tr>
<td>4. Export ratio (%)</td>
<td>Labour reduction (headcount)</td>
<td>4. Number of complaints (%)</td>
</tr>
<tr>
<td>5. Sales outlets (x → y)</td>
<td>4. Yield (%) increase</td>
<td>5. Energy and materials consumption per product unit</td>
</tr>
<tr>
<td>6. Reliability improvement</td>
<td>5. Inventory turnover rate</td>
<td>6. Distribution and transportation costs and ratio (%)</td>
</tr>
<tr>
<td>7. Delivery compliance rate improvement, etc.</td>
<td>6. Lead time (days)</td>
<td>7. Distribution and transportation costs and ratio (%)</td>
</tr>
<tr>
<td><strong>Strategy / aim</strong></td>
<td><strong>Objectives</strong></td>
<td><strong>Technical Innovation items</strong></td>
</tr>
<tr>
<td>2. Unattended operation, multi-machine handling, multi-process handling</td>
<td>2. Information network rationalisation (CAD, CAM, CIM, etc.)</td>
<td>6. Design + factory + product warehouse + control system</td>
</tr>
<tr>
<td>3. Automation of materials flow, packing and transportation (including materials handling)</td>
<td>3. Production streamlining, JIT</td>
<td>7. Development + sales + factory + product warehouse + control system</td>
</tr>
<tr>
<td>4. Automated measurement and control, Poka-Yoke</td>
<td>4. Centralised processing, group technology</td>
<td></td>
</tr>
<tr>
<td>5. Equipment speed increase</td>
<td>5. Re-use of scrap materials, environmental protection measures</td>
<td></td>
</tr>
<tr>
<td>6. Introduction of new technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Scope of application</strong></td>
<td><strong>Technical Innovation items</strong></td>
<td><strong>Technical Innovation items</strong></td>
</tr>
<tr>
<td>1. Rationalisation of model workshops</td>
<td>5. Factory + product warehouse + control system</td>
<td>1. Raise morale</td>
</tr>
<tr>
<td>2. Individual machining, assembly and inspection processes</td>
<td>6. Design + factory + product warehouse + control system</td>
<td>2. Conduct thorough training</td>
</tr>
<tr>
<td>3. Initial process → final process (inspection, packing)</td>
<td>7. Development + sales + factory + product warehouse + control system</td>
<td>3. Practise management by objectives</td>
</tr>
<tr>
<td>4. All processes + control system</td>
<td></td>
<td>4. Run plantwide campaigns</td>
</tr>
<tr>
<td><strong>Scope of application</strong></td>
<td><strong>Technical Innovation items</strong></td>
<td><strong>Technical Innovation items</strong></td>
</tr>
<tr>
<td>1. Speedier customer response</td>
<td>1. Eliminate waste time in work processes</td>
<td>1. Raise morale</td>
</tr>
<tr>
<td>2. Better administrative accuracy and efficiency</td>
<td>2. Reduce setup times</td>
<td>2. Conduct thorough training</td>
</tr>
<tr>
<td>3. Improved process control</td>
<td>3. Introduce TOC, TPM, S5s</td>
<td>3. Practise management by objectives</td>
</tr>
<tr>
<td>4. Prompt provision of specifications and estimates</td>
<td>4. Improve space utilisation</td>
<td>4. Run plantwide campaigns</td>
</tr>
<tr>
<td>5. More efficient handling of non-routine situations</td>
<td>5. Improve transportation and materials handling efficiency</td>
<td>5. Develop a multi-skilled workforce</td>
</tr>
<tr>
<td></td>
<td>6. Increase equipment speed and reduce downtime</td>
<td>6. Introduce visual controls</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7. Increase number of suggestions</td>
</tr>
</tbody>
</table>

Table 3-3: Example of Strategy and Objective Setting Checksheet for Use in Layout Design (Plan XX)
Establishing Concepts and Building a TEI Culture
(TEI: Total Employee Involvement)

Management objectives and layout-setting (clarification of relationships)

a. Table 3-3: examples of strategy, target-setting and checksheet for XX Plan when designing layouts.
Organise on target-setting checksheet.
b. Table 3-4: equipment investment plan at the concept stage.
Organise project and adjust as each step is taken.

Clarify layout design concept and ideal.
Organise ideas systematically as shown in Tables 3-5 and 3-6.

Aims:

1. To create an ideal or concept that will secure everybody’s participation and unify their actions.
2. Create a dream or vision for employees that focuses on satisfying the customer.
3. Create a robust system that improves progressively in a balanced fashion and has continuity and a form direction.

Use of diagnostic techniques for analysing and assessing the status quo and evaluating the present level.

Assess the current situation using the kind of table shown in Table 1-3. Then list the problems and work out exactly what level of improvement is required.

As Figure 3-6 shows, combine the top-down and bottom-up approaches and try to solve problems as part of the process of designing the layout.
## Equipment Investment Planning

### 1. Reason for proposal (background, purpose, new-product marketing strategy, etc.)

<table>
<thead>
<tr>
<th>Background</th>
<th>Example: Increased orders are forecast and a new product is being developed, mainly for company X</th>
</tr>
</thead>
</table>
| Purpose    | (2) Increase market share from 0% to X%  
|            | Establish sales of £Y,000/month  
| Strategy   | (3) Enter electronics field, focusing on material A  
|            | Establish a quality differentiation in aspect A, featuring B of technology C |

### 2. Objectives (strategies: technology, equipment, personnel, yield, delivery, etc.)

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Outline</th>
<th>Benefit</th>
<th>Technical level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Rationalisation</td>
<td>Labour-saving; reduce headcount by X (present # planned)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Yield improvement</td>
<td>……………………</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Lead-time reduction</td>
<td>……………………</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### (2) Principal equipment

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification (supplier)</th>
<th>No. of units</th>
<th>Price</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conveying device X</td>
<td>24-hr unattended conveying</td>
<td>1 set</td>
<td>£X,000</td>
<td>Replace 4 workers</td>
</tr>
<tr>
<td>……</td>
<td>……</td>
<td>……</td>
<td>……</td>
<td>……</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3. Equipment planning framework

**Sales plan**

![Sales revenue diagram]

**Market-share increase**

![Market-share increase diagram]

**Example: FMS line concept**

- Rationalisation of physical distribution
- S/WED
- CAD/CAM
- LAN systems
- JIT

- Headcount reduction: X workers replaced
- Lead-time reduction: Y days

- Development lead-time reduction: Z days

### 4. Profit plans

**Product A: sales revenue = unit price x quantity**

**Return on investment = x %**

**Sales – cost of sales = gross profit**

**Payback period = x years**

### 5. Schedule

<table>
<thead>
<tr>
<th>Item</th>
<th>Person responsible</th>
<th>Schedule</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Move X</td>
<td>……………………</td>
<td>………………</td>
<td>……</td>
</tr>
<tr>
<td>Bring in automatic device Y</td>
<td>……………………</td>
<td>………………</td>
<td>……</td>
</tr>
<tr>
<td>Make official application</td>
<td>……………………</td>
<td>………………</td>
<td>……</td>
</tr>
</tbody>
</table>

### 6. Notes: titles of appended documents

…………………

Table 3-4: Example of Organisation at Concept Stage
<table>
<thead>
<tr>
<th>Step</th>
<th>Explanation</th>
<th>Application Example</th>
</tr>
</thead>
</table>
| 1. Strategy          | Think in terms of the product's characteristics, technology, marketability,  | • Improve quality of life  
                        | sales volume and international acceptability, and the company's philosophy.          | • Contribute to a better environment  
                        | Incorporate the customer-focused approach.                                        | • Support basic technology  
                        |                                                                                   | • Reduce customers' labour-hours, etc.                                            |
| 2. Product characteristics | Write down specific product names and features. Identify key points of      | • Large-volume storage freshness  
                        | production technology. Specifying the target values gives the product a clear         | • Compactness, lightness (passport-size)  
                        | quality image.                                                                     | • XX grams, energy-saving type, quadraple-strength materials                       |
| 3. Factory mission   | Review from quality, delivery, cost and after-sales service aspects, and    | • Factory lead-time: 2 days  
                        | factory's manufacturing approach.                                                  | Flexible JIT production  
                        |                                                                                   | • Build in quality via the equipment, making full use of innovative technology     |
| 4. Scope             | Identify the range to be covered, from identifying customer needs (market    | • Integrated production line from intake of raw materials to despatch of finished     |
                        | surveys) through research, prototype development, marketing, production,        | product  
                        | sales and distribution.                                                            | • From order breakdown to installation                                               |
| 5. Methods           | Explain the features of the new layout in terms of the factory's strategies  | • FA lines, CIM  
                        | and a comparison with other companies. Describing the present technical state of the | • Non-polluting, labour-saving factory  
                        | art is effective.                                                                 | • World-class factory in terms of component precision, assemblability, etc.       |
| 6. Philosophy        | Excite the enthusiasm of all the factory's employees and challenge them to   | • Focused on unattended operation  
                        | provide excellent quality, delivery and service to customers. Describe the basic      | • A manufacturing facility that makes full use of hand-made devices                |
                        | activities that everyone in the factory will be undertaking as a united team.    | • Improving the environment through XX technology                                     |

Table 3-5: Checksheet for Layout Design and Concept Creation
<table>
<thead>
<tr>
<th>Step</th>
<th>Company A</th>
<th>Company B</th>
<th>Company C</th>
<th>Company D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Strategy</td>
<td>Improve accuracy, offer lightweight materials</td>
<td>Introduce JIT, build product families, offer</td>
<td>Manufacture small lots of products meeting</td>
<td>Offer high-quality, full-sized household</td>
</tr>
<tr>
<td></td>
<td></td>
<td>radical cost reductions</td>
<td>customers' needs</td>
<td>electrical products that double as items of</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>furniture</td>
</tr>
<tr>
<td>2. Product characteristics</td>
<td>10 years' trouble-free operation at X,000 rpm</td>
<td>Manufacture of lighter, thinner products with new</td>
<td>Thin-walled products with dimensional variety in small</td>
<td>High variety, small-lot production, custom</td>
</tr>
<tr>
<td></td>
<td></td>
<td>materials</td>
<td>lots</td>
<td>built</td>
</tr>
<tr>
<td>3. Factory mission</td>
<td>Non-mass-production, automation, CAD/CAM</td>
<td>SMED, systematic daily management</td>
<td>Width dimension control in response to orders</td>
<td>Volume production using one-piece-flow, mixed-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(timely production)</td>
<td>model lines</td>
</tr>
<tr>
<td>4. Scope</td>
<td>Materials processing lines</td>
<td>Integrated production line from casting to</td>
<td>Slitting – inspection – packing – shipping</td>
<td>Parts setting + assembly + inspection + packing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>inspection and packing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Methods</td>
<td>Standardisation of direct numerical control</td>
<td>Transportation automation, computer-controlled</td>
<td>Automatic warehousing system for automated</td>
<td>Advanced design system for individual products,</td>
</tr>
<tr>
<td></td>
<td>machining knowledge</td>
<td>production management</td>
<td>picking and packing</td>
<td>improved assemblability</td>
</tr>
<tr>
<td>6. Philosophy</td>
<td>Pursue automation of worlds' best veteran</td>
<td>A waste-free factory with no dirty, dangerous</td>
<td>Creation of a system for accumulating</td>
<td>A highly-efficient JIT assembly plant that</td>
</tr>
<tr>
<td></td>
<td>skills</td>
<td>or physically demanding work</td>
<td>intangible productivity know-how</td>
<td>respects humanity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Products</td>
<td>Aircraft parts</td>
<td>Automobile parts</td>
<td>Electronics materials</td>
<td>Household electrical goods</td>
</tr>
</tbody>
</table>

Table 3-6: Example of Concept Creation
Plant Vision
1. Build a production system capable of delivering world-class quality and productivity.
2. Create a plant that continually strives for flexible production and unattended operation in both materials handling and processing.
3. Pursue an insatiable quest to upgrade men/women, materials and machinery in response to the demand for ever-shorter lead times and JIT operation.

1. MQC (market-in QC, i.e. customer-focused QC)
   * lighter, thinner
   * reduce customers’ labour-hours
2. Full use of technologies
   * double product strength and serviceable life
   * apply new materials and production techniques
     (examples) ... ... ... ...

   * Double productivity
   * Raise straight-through rate to 98%
   * Reduce lead-time from 5 days to 3 days

1. Investigate new manufacturing techniques
   Build in quality via the equipment
2. Create a production system that produces according to ideal plans
3. Create a factory setup that makes materials flow and waste visible and ceaselessly strives to improve

Layout improvement
(Before improvement)

* Integrate the currently higgledy-piggledy lines
* Increase area ratio, reduce WIP

After improvement

Space freed up by consolidating lines

Targets

<table>
<thead>
<tr>
<th>Targets</th>
<th>Section</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Materials</td>
<td></td>
</tr>
<tr>
<td>Melting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Casting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cores</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

“Double our production capability within 3 years”

Create an excellent working environment, eliminate dust, establish preventive maintenance, improve checking procedures, introduce low-cost automation and error-proofing

Problem-solving activities with full employee participation

Analysis of existing problems (KJ Method)

Automation and equipment problems
Improved flexibility of automatic equipment
Error-proofing
Maintainability

Quality • Operability • Countermasures against 3D tasks

Work preparation
Work standardisation

Smoothing the production flow
Setup improvement
Layout improvement
Automation
Computerisation

Visual controls

Computerisation

Project activities by support staff

Figure 3-6: Relation between Layout Design Concept and Workplace Improvement in an Integrated Casting Plant
Confirming Installation Conditions for New Layout

Approach When Designing New Layouts

![Diagram showing layout design process]

Figure 3-7: Basic Approach to Layout Design

Items to be considered when designing factory layouts:

1. Does it conform to the factory design concept or policy?
2. Comprehensively review all the conditions, and establish the theoretical basis for why this particular plan has been chosen (show clearly how the various possible plans were evaluated).
3. Ensure that the plan includes guidelines indicating how future concerns are to be dealt with (ensure that the plan incorporates a story explaining how problematic technology will be improved in the future).

To satisfy the above conditions, we formulate a plan for the future, working out a current plan as the first step in moving towards this. Although the current plan is based on existing technology and conditions and is therefore highly practical, it is also important to break out of the current paradigm and move in the direction of the future plan.

To achieve this, we perform a review using items of the kind listed in Table 3-7 and utilising information such as the existing layout (Table 3-7 shows a list of in-plant evaluation items; it does not include checkpoints to be used when selecting factory sites).
<table>
<thead>
<tr>
<th>No.</th>
<th>Evaluation Item</th>
<th>Example and formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Forward-flow ratio</td>
<td><img src="image" alt="Diagram" /></td>
</tr>
</tbody>
</table>
|     | - In the process illustrated here, steps 1 - 2, 2 - 3, 2 - 4, etc. are forward steps, while steps 3 - 2 and 4 - 2 are backward steps. Estimate the forward flow as a proportion of the total flow, and try to increase this proportion.  
- Examples of possible strategies: 1. Develop technology that obviates the need for backtracking. 2. Group sub-processes 2, 3 and 4 together at a single piece of equipment. 3. Instead of returning the work to the previous process, perform the operation in the current process. |
|     | Forward-flow ratio = number of forward steps / total number of steps (distance x number of movements) |
| 2   | Flowline proximity ratio                 | ![Diagram](image)                                                                    |
|     | - This diagram uses single, double and triple lines to represent the flow of materials in terms of number of items. Classify the sub-processes according to whether they are directly linked (separated by 1 metre or less) or not, and review the layout from the closeness aspect.  
- Examples of strategies: 1. Combine sub-processes 1 and 2.  
2. Bring processes closer together than 1 metre. 3. Introduce improvements to eliminate work involving small quantities such as shown by the arrows leading to and from sub-process 5.  
4. Raise the capacity of certain sub-processes in order to eliminate flowlines arising from under-capacity. |
|     | Flowline proximity ratio = number of flowlines connecting directly-linked processes / total number of flowlines (distance x number) |
| 3   | Building utilisation ratio               | ![Diagram](image)                                                                    |
|     | - Evaluate the height of the building in terms of area. When space above or below the production floor can be used (e.g. mezzanines) include it in the calculation as available space.  
- Include area occupied by equipment, offices, toolrooms, etc. in production-related area. Also include area of WIP storage, despatch-dock inventory, etc. as necessary. (Include all items regarded as eligible for improvement). |
|     | Space utilisation ratio = area used for production / total area |
| 4   | Process synchronisation ratio            | ![Diagram](image)                                                                    |
|     | - When materials flow through a production process as shown in the diagram, WIP will always build up between sub-processes as a result of lack of synchronisation between sub-processes, the need to wait for products to build up into lots of a certain quantity before a changeover can take place and the next sub-process can start, equipment problems, quality problems and so on.  
- Devise separate countermeasures to suit each type of cause. |
|     | WIP time = (number of WIP items) x (time taken for subsequent process) / monthly production  
WIP area ratio = WIP area / (total area - area used for production) |

Table 3-7: Layout Evaluation Items and Formulae
<table>
<thead>
<tr>
<th>No.</th>
<th>Evaluation item</th>
<th>Example and formula</th>
</tr>
</thead>
</table>
| 5   | Future available space ratios          | - The future available space ratio can be worked out in terms of either the space available within the existing building or the space available if the existing building were extended, as a proportion of the existing total floor space, by the following formulae:
  
  \[
  \text{Future available space ratio} = \frac{A}{A + S}, \quad \frac{A + B}{A + S}, \quad \text{etc.}
  \]
  
  - This ratio can be increased by reducing the floor space presently occupied by equipment. This can be done by introducing new technology to make the equipment more compact, raising machine capacity to reduce the number of machines needed, etc. |
| 6   | Production area reduction ratio        | - Calculate this with reference to a past point in time or using a competitor as a model (compare with a production operation of the same scale over a particular time period).
  
  - The 'production multiple' term in the formula is the factor by which production has been increased as a result of productivity improvements.
  
  - Strategy examples: increase the performance, efficiency or speed of individual processes, make equipment more compact or integrate vertically, eliminate processes, etc. |
| 7   | Control simplicity ratio              | - Use the number of contacts as the base for the calculation (do not count as a contact if a worker only has to walk one or two steps to obtain or convey the necessary information).
  
  - Examples of contacts: reporting equipment failures, communicating about jigs, tools and setups, informing and reporting or work volumes, liaising about essential quality items, etc. Think how these can be simplified.
  
  - Methods: increase contact with office by improving aisles and visibility and positioning communications devices such as notice boards, telephones and loudspeakers more effectively. |
| 8   | Rearrangeability                      | - Count the number of items of equipment that can be rearranged cheaply (at less than a certain specified cost) in about a day including rewiring, repiping and auxiliary equipment.
  
  - Leave enough space for easy rearrangement of those items for which the need is predicted, while identifying and taking special care over immovable facilities such as pits, cranes, heavy equipment, etc. |
  
  \[
  \text{Rearrangeability ratio} = \frac{\text{number of equipment items that can be moved within the laid-down criteria}}{\text{total number of equipment items}}
  \]
  
  \[
  \text{Immobility ratio} = \frac{\text{number of items of equipment that cannot be moved}}{\text{total number of equipment items}}
  \]
  
  - In assessing the rearrangeability of a layout, it is necessary to clarify the constraints that make it impossible to rearrange certain items. |

Table 3-7: Layout Evaluation Items and Formulae (continued)
<table>
<thead>
<tr>
<th>No.</th>
<th>Evaluation Item</th>
<th>Example and formula</th>
</tr>
</thead>
</table>
| 9   | Workplace safety                                       | 1. Visibility along aisles, height of WIP storage areas.  
                                                | 2. Danger anticipation, evenness of aisle floors.  
                                                | 3. Safety racks, safety instructions, designation of managers responsible for safety, labelling of dangerous articles, signposting of dangerous areas: assess in terms of number of safety directions given. |
| 10  | 5 Ss                                                   | 1. Placement and classification of materials  
                                                | 2. Handling of jigs, tools, dies, etc.  
                                                | 3. Ease of cleaning, inspection and maintenance  
                                                | 4. Countermeasures against sources of dust, etc.  
                                                | Evaluate on a 5-step scale                                                                           |
| 11  | Work environment                                       | 1. Ventilation, refreshment rate  
                                                | 2. Ease of installation of coolers, fans, etc. and ability to increase the number of these  
                                                | 3. Isolation from noise, heat, odours, etc.                                                        |
| 12  | Maintainability                                        | 1. Ease of finding and handling parts, reliability of storage management  
                                                | 2. Ease of operation when servicing and repairing equipment (including interference with various conditions)  
                                                | 3. Ease of installation and operation of abnormality alarms                                         |
| 13  | Employee welfare                                       | 1. Ease of discussion for small groups, etc.  
                                                | 2. Closeness of cafeteria and toilets, availability of drinks, snacks, etc.  
                                                | 3. Factory environment (sports ground, relaxation areas, etc.)                                     |
| 14  | Environmental friendliness                             | 1. Measures to comply with various regulations relating to environmental standards  
                                                | 2. Maintainability of pollution-prevention equipment                                               |
| 15  | Energy reduction                                       | 1. Energy reduction measures  
                                                | 2. Ease of reuse of waste heat                                                                     |
| 16  | Handling of recycled materials and waste products      | 1. Ease of transportation, storage and control of recycled materials  
                                                | 2. Ease of storage, extraction and control of waste materials, etc.                                 |

Table 3-7: Layout Evaluation Items and Formulae (continued)
Product Analysis and Production System  
(Application of SLP)

SLP: Systematic Layout Planning – Richard Muther

Figure 3-8: Method of Classifying Production Lines by P-Q Analysis (from SLP Technique)

Application using SLIM ... Strategic application method

1. Assess product life cycle (perform P-Q analysis + life cycle analysis).
2. Group together and stratify similar products  
   (Examples: switch to in-house fabrication, rearrange lines,  
   consolidate, etc.).
3. Instigate cost countermeasures using cost x production volume  
   (identify priority strategies).
4. Indicate problematical products  
   (Examples: establish separate lines, bypass, etc.)
5. To save time and effort during the calculation, take the top 95% for this  
   procedure and continue.
Materials flow analysis

Procedure

1. Use a routing analysis such as that shown in Figure 3-9

2. Circles show processes through which the product flows – lines represent routes taken

3. Note in the circles the time taken to manufacture each item (ST or CT)
Figure 3-9: Example of Multi-Product Process (Routing) Analysis (Processing of Worked Material)
GT Codes and Standardisation

Examples of standardisation

1. GT codes showing the flow of materials (placing into similar groups)

2. Clarification of production standards

3. Labour-hours standards (ST, CT)

4. Standardisation of parts and machining techniques

Use as is for computer control
Example of use of materials flow GT

Example of GT coding system (store on computer as a reference)

<table>
<thead>
<tr>
<th>Initial process</th>
<th>Heat-treatment process</th>
<th>Painting process</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>Cutting</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Cutting – rework</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Cutting – machining – rework</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Cutting – machining – welding</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Cutting – machining – welding</td>
<td></td>
</tr>
<tr>
<td>Hand finishing</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example of GT code registration for individual make-to-order items (store as file)

Assignment of parameters for make-to-order items

Customer name: MMC  Material: stainless steel
Specification: welded, quenched, tempered, machined
GT code 4 2 C 1 Average lead time: 5.5 days

Automatic setting of process pattern and lead time

Process pattern → Cutting → Machining → Welding → Quenching → Tempering → Degreasing → Painting A → Packing → Shipping

Lead time (days) → 0.5 0.5 0.5 1.0 1.0 0.5 0.5 0.5 0.5

GT code → 4 2 C 1

Note: for lead times, the number of days registered against the GT code is used. In some cases, a standard yield is also appended to the GT code.

Figure 3-10: Example of a GT Coding System and its Application

3.22
### From-To Analysis:
Preparation of Materials Flow Relationship Diagrams

#### From-To analysis

<table>
<thead>
<tr>
<th>From</th>
<th>Cutting</th>
<th>Machining</th>
<th>Painting A, B</th>
<th>External Inspection</th>
<th>Rework</th>
<th>Final inspection &amp; packing</th>
<th>Shipping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting</td>
<td>7,200</td>
<td>5,800</td>
<td>5,800</td>
<td>2,200</td>
<td>7,500</td>
<td>460</td>
<td></td>
</tr>
<tr>
<td>Machining</td>
<td></td>
<td>210</td>
<td>166</td>
<td></td>
<td>370</td>
<td>630</td>
<td></td>
</tr>
<tr>
<td>Painting A, B</td>
<td>2,200</td>
<td>146</td>
<td></td>
<td></td>
<td>2,000</td>
<td>630</td>
<td></td>
</tr>
<tr>
<td>External inspection</td>
<td>2,500</td>
<td>166</td>
<td></td>
<td></td>
<td>5,800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rework</td>
<td>7,500</td>
<td>460</td>
<td>2,000</td>
<td>146</td>
<td></td>
<td>7,500</td>
<td></td>
</tr>
<tr>
<td>Final inspection &amp; packing</td>
<td>5,000</td>
<td></td>
<td>2,200</td>
<td>166</td>
<td>2,500</td>
<td>5,800</td>
<td></td>
</tr>
<tr>
<td>Shipping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,200</td>
<td>5,800</td>
<td></td>
</tr>
</tbody>
</table>

#### Preparation of materials flow relationship diagram

- **Flow Sections**:
  - **Forward-flow section**
  - **Reverse-flow section**

**Example:** When the external inspection process is performed after the rework process but before the painting processes

---

**Figure 3-11: Example of Materials Flow Analysis**

3.23
Load/Capacity Analysis and Equipment Capacity Considerations

Calculation of Load

Loading time for each process = \( \sum \) (number of items in each process) x (ST for each item)

\[
5 \text{ min/item} \times 1,500 \text{ items/month} = 7,500 \text{ min/month}
\]

<table>
<thead>
<tr>
<th>Product</th>
<th>Production volume (items/month)</th>
<th>Cutting</th>
<th>Machining</th>
<th>Painting (including external inspection)</th>
<th>Rework (including external inspection)</th>
<th>Final inspection and packing</th>
<th>Shipping</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1,500</td>
<td>15,000</td>
<td>12,000</td>
<td>12,000</td>
<td>7,500</td>
<td>15,000</td>
<td>6,000</td>
<td>Processes after improvement shown in Figure 3-9</td>
</tr>
<tr>
<td>S</td>
<td>750</td>
<td>7,500</td>
<td>6,000</td>
<td>6,000</td>
<td>4,000</td>
<td>8,200</td>
<td>7,500</td>
<td>For items that pass through painting processes A and B, use (ST(A) + ST(B)) x number of items</td>
</tr>
<tr>
<td>K</td>
<td>600</td>
<td>3,000</td>
<td>6,000</td>
<td>8,000</td>
<td>6,540</td>
<td>4,500</td>
<td>3,200</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>850</td>
<td>9,350</td>
<td>5,100</td>
<td>8,500</td>
<td>4,250</td>
<td>6,800</td>
<td>6,800</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>1,200</td>
<td>8,400</td>
<td>7,200</td>
<td>6,000</td>
<td>4,800</td>
<td>9,600</td>
<td>9,600</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>580</td>
<td>3,480</td>
<td>3,480</td>
<td>5,220</td>
<td>2,900</td>
<td>3,480</td>
<td>4,060</td>
<td></td>
</tr>
</tbody>
</table>

1. Total 100,000 items/month 1,848 h/month 1,470 h/month 1,000 h/month 1,477 h/month 1,800 h/month 1,300 h/month
2. Equipment or human capacities in h/month 7 machines (2,050) 5 machines (1,466) 4 machines (1,173) 5 people (1,466) 7 people (2,053) 4 people (1,173)
3. Loading ratio = 1 + 2 90% 100% 85% 101% 87% 111%

Table 3-8: Example of Review of Process Balance through Comparison of Load and Capacity Values

Countermeasures and items for consideration

1. Reduce the number of bottleneck processes.
2. The flow of materials down the line becomes smoother when the loading rates for downstream processes are lower than those for upstream processes.
3. Try to improve processes with high loading rates.

Practice Exercise

Calculate the loading rates for the processes shown in Table 3-9.

4. Manual simulation is also effective.
Practice Exercise 3

How many people should be assigned to each process when the processes shown below are used in production?

Process

A → B → C → D → E

Assume mutual assistance between processes is not possible.

<table>
<thead>
<tr>
<th>Process</th>
<th>Production volume per month</th>
<th>Production volume per day</th>
<th>Cycle time: min. per piece</th>
<th>Load</th>
<th>Percentage Loading</th>
<th>Staffing Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>23,000</td>
<td>920</td>
<td>0.501</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>23,000</td>
<td>920</td>
<td>0.825</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>22,000</td>
<td>880</td>
<td>0.624</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>22,000</td>
<td>880</td>
<td>0.400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>20,000</td>
<td>800</td>
<td>0.384</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X115</td>
<td>20,000</td>
<td>800</td>
<td>0.476</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X116</td>
<td>20,000</td>
<td>800</td>
<td>0.923</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X117</td>
<td>20,000</td>
<td>800</td>
<td>0.816</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conditions:
1. There are 25 work days per month
2. Cycle times
3. Capacity: 378 minutes per day = 7 hr x 60 min x 0.9 (availability rate)

Questions:
1. Calculate load and percent loading
2. Assign needed staffing. How did you arrive at this number?
3. Which processes are bottlenecks? How can these be straightened out? Be specific, and record all countermeasures you see as being possible.

Table 3-9: Load Capacity Analysis and Bottleneck Process Countermeasures

3.25
Planning the Basic Layout and Comparing Alternative Proposals

Items to be considered when comparing three alternative proposals:

See Table 3-10 for a practical example

1. Cost considerations (initial cost, additional costs, cost of changes, running costs)
2. Equipment considerations (ease of changeover, maintainability, safety, environmental considerations, constraints on construction of pillars, pits, etc., constraints on removal of swarf, etc.)
3. Materials flow considerations (flow path intersections, disposal of returns, return of empty pallets, ease of unattended operation)
4. Human considerations (operability, mutual supportability, HRD)
5. Control considerations (communications, discussion, computerisation, visual controls)
6. Space utilisation (effective utilisation, accessibility)

Use a ranking scheme such as the following to perform the evaluation:

A : essential
B : important
C : desirable

Select or combine the proposals to create the one or two best options.

List the advantages of the selected proposal(s) and work out ways of dealing with these.

Examples:
1. Insufficient flexibility to accommodate changes in items being produced.
2. Insufficient flexibility to accommodate changes in production methods.
3. Few bypass routes available in case of breakdown.
4. No room for extra workers to intervene when rework is required.
5. Workplace incapable of mastering level of technology required.

Table 3-11 shows a practical example.

Objective: Formulate alternative plans, select the best, minimise its disadvantages, and diagram it.
Table 3-10: Example of Evaluation Table for Selecting Optimum Layout Plan

<table>
<thead>
<tr>
<th>Evaluation Items</th>
<th>Plan P Features</th>
<th>Plan Q Features</th>
<th>Plan D Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Investment £1M or less</td>
<td>£0.9M</td>
<td>£1.10M</td>
<td>£1.05M</td>
</tr>
<tr>
<td>2. Return on investment 25% or more</td>
<td>26%</td>
<td>30%</td>
<td>27%</td>
</tr>
<tr>
<td>3. Time limit for layout change: 10 days</td>
<td>10 days</td>
<td>12 days</td>
<td>9 days</td>
</tr>
<tr>
<td>1. Compatible with policy</td>
<td>Emphasises productivity</td>
<td>Emphasises quality feedback</td>
<td>Highly suitable for JIT</td>
</tr>
<tr>
<td>2. Space available for future expansion</td>
<td>Little free space available</td>
<td>Room to add new line</td>
<td>Expandable for this product only</td>
</tr>
<tr>
<td>3. Personnel required</td>
<td>4 people</td>
<td>4 people</td>
<td>3.5 people</td>
</tr>
<tr>
<td>4. Accessibility</td>
<td>Accessible from outside</td>
<td>Accessible from outside</td>
<td>Some problems: crane required</td>
</tr>
<tr>
<td>5. Equipment mobility</td>
<td>Relatively good</td>
<td>Machine X must be changed</td>
<td>Machine X must be changed</td>
</tr>
<tr>
<td>6. Maintainability</td>
<td>Work required on machine A</td>
<td>Accessible from outside or work side</td>
<td>Same as Plan Q</td>
</tr>
<tr>
<td>1. Workplace controllability</td>
<td>2 sections</td>
<td>3 sections</td>
<td>2 sections</td>
</tr>
<tr>
<td>2. Visual control and ease of mutual support by operators</td>
<td>Multiskilling required</td>
<td>Similar items grouped together</td>
<td>Easy for 3 of the operators</td>
</tr>
<tr>
<td>Final selection</td>
<td>A: 5 points B: 7 points C: 1 point</td>
<td>A: 3 points B: 9 points C: 1 point</td>
<td>A: 3 points B: 8 points C: 3 point</td>
</tr>
<tr>
<td></td>
<td>Cheap and easily changed, but poor future potential</td>
<td>Takes more time and money, but future potential good: adopt</td>
<td>Best for JIT applicability</td>
</tr>
<tr>
<td>Defect items → objective selection</td>
<td>Defect element analysis</td>
<td>Defect countemasure and benefit</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>-------------------------</td>
<td>-------------------------------</td>
<td></td>
</tr>
<tr>
<td>Objective: reduce from £1.10M to</td>
<td>Machine B: £350K</td>
<td>2. Cover part of installation by holiday work £25K</td>
<td></td>
</tr>
<tr>
<td>£1.00M or less</td>
<td>Total: £750K</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A → B</td>
<td>2. Installation cost: £250K</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breakdown: ∎∎∎∎</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Installation time: 12 days</td>
<td>1. Schedule</td>
<td>1. To shorten the critical path, move machine N into place temporarily and construct pits, etc. before the installation</td>
<td></td>
</tr>
<tr>
<td>Reduce from 12 days to 10 days and</td>
<td></td>
<td>2. Work on Path M 24 hours per day</td>
<td></td>
</tr>
<tr>
<td>complete during shutdown period</td>
<td></td>
<td>3. Revise the production plans and stockpile part L</td>
<td></td>
</tr>
<tr>
<td>△ → A</td>
<td>2. The items manufactured include some important ones and there is concern that delivery dates might be missed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Workplaces are separated</td>
<td>1. Support during setups</td>
<td>1. Install intercoms to enable operators to converse</td>
<td></td>
</tr>
<tr>
<td>△ → A</td>
<td>2. Multiskilling has not been accomplished</td>
<td>2. Start multiskill training today</td>
<td></td>
</tr>
<tr>
<td>Devise a communication system</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3-11: Example of Use of Defect Elimination Techniques for Realising Basic Layout
### Designing Working Conditions for Individual Processes (Work Standardisation)

Building the Best Processes for Men/Women, Materials and Machinery for each Process Unit

<table>
<thead>
<tr>
<th>Proposed unit layout</th>
<th>Evaluation points</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure</strong></td>
<td><strong>Features</strong></td>
<td><strong>Financial aspects</strong></td>
</tr>
</tbody>
</table>
| ![Diagram](image)    | ● Dies are brought in from the back  
                       ● Pallets are pulled in to the operators' positions and rotated through 360°  
                       ● Install a conveyor and automatically place materials on pallets after inspection  
                       ● Move materials out to rear of press and transport to inspection table  
                       ● Move materials to small pallets and press (hanging type)  
                       ● Use setup cart as inspection table | ● Cost of change: £50K  
                       ● 360° turntable required  
                       ● 2 conveyors, 360° turntable needed: £75K  
                       ● Little change from existing situation  
                       ● Accomplished through small improvements: £25K | ● Good communication with inspection personnel  
                       ● Work space restricted  
                       ● Good operability  
                       ● Effective use of space  
                       ● Some problems, but possible if operators help one another | ● No problems  
                       ● Possible  
                       ● No problems | ![Adopted](image) |

Examples of evaluation points
1. Investment amount
2. Technical level and ease of achieving technology
3. Ease of change from present situation
4. Constraints
5. Ease of die changeover
6. Maintainability (daily checking and dealing with breakdowns)
7. Equipment reliability, absence of breakdowns

Table 3-12: Unit Processes and Example of Application of Evaluation Techniques (Press)
## Computer Simulation

### Objectives

1. To identify in advance the problems likely to occur during operation, and take steps to prevent them.
2. To pinpoint the bottleneck processes and check any particular concerns.
   - Use for automation and process control.
3. To identify WIP, operating rates and improvement targets for each process.

### Input conditions

1. Production item, number, process sequence, standard times (ST, CT), yield
2. Equipment operating conditions for each process
   - Number of equipment items for each process, operating times, setup times, failure rates
3. Production schedule
4. Recovery time after failures or defect production, limits on size of WIP storage areas, etc.

### Output data analysis

1. WIP trends
2. Equipment operating rates
3. Effect on production of switch to small-lot manufacturing
4. Product lead times
5. Production volumes and effect of various factors

### Computer simulation

1. Establishment of model
   - Example

2. Calculation conditions
   1. Set initial values with existing situation as model
   2. Use following for production schedule:
      - Random schedule
      - 3 examples of schedules set by experienced workers
   3. For painting, use first-in, first-out
   4. For changes over, use those that occur when the product type is changed
   5. Assume that rework occurs randomly at a rate of 5-10%
   6. When a WIP storage area becomes full, stop the previous process

### Figure 3-12: Example of Structure of Simulation Calculation Input, Processing and Output

### Effective Techniques

1. Simulation Language for Alternative Modelling (SLAM II)
2. General Purpose Simulation System (GPSS)
Preparing an Equipment Investment Plan

After collating the results obtained in the previous steps, prepare an equipment investment plan and submit it for approval and implementation.

<table>
<thead>
<tr>
<th>No.</th>
<th>Process</th>
<th>Present level</th>
<th>Improvement</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cutting</td>
<td>3 shifts x 2 operators = 6 operators</td>
<td>• Setup improvement: 1 person operates 2 machines 3 shifts x 1 operator = 3 operators</td>
<td>Headcount reduction of 3</td>
</tr>
<tr>
<td>2</td>
<td>Machining</td>
<td>1. 3 shifts x 2 operators = 6 operators 2. Yield: 78% Breakdown of losses: Surface damage 5% 3% 22% Wrong dimensions 3% Setup losses 3%</td>
<td>• Improve equipment operating rate from 57.1% to 80% • Cope with 50% increase in loading ratio 1. Move some of the products to NC machine 1.5 → 1.15 2. Improve product yield from 78% to 85.5% 1.15 x 78% = 1.055 85% 3. Improve equipment operating rate from 68% to 85% 1.005 x 68% = 84%</td>
<td>Increases yield by 7% with same staffing level</td>
</tr>
</tbody>
</table>

| Total benefits | 1. Number of operators: 65 2. Overall yield: 45% 3. WIP: 2,500 pcs 4. Outsourcing cost: £25K/month | 47 47% 800 pcs £15K/month | Headcount reduction of 18 2% increase Reduced by 1,700 pcs £10K/month saving |

Prepare a broad-brush, see-at-a-glance table Example: "Objectives" section of Table 3-4

Examples of items to include in equipment investment plan

- Heading information: title of plan, cost, completion date, names of proposer and people responsible
- Plan objectives: reasons, background, main aims
- Outline of plan: items to be implemented, with their benefits: profit plan
- Detailed supporting data: drawings, equipment lists, names of vendors, depreciation schedules, etc.
- Contingency plans for serious potential problems
- Simulation results, detailed installation schedule, etc.

Table 3-13: Table of Improvement Benefits (Example of Detailed Analysis)
Installation Planning (PERT)

Features of PERT

1. Clarifies the relationships among tasks.
2. Facilitates control of priority tasks.
3. Permits comprehensive schedule control (including calculations).

PERT symbols and rules

1. → (activity) : indicates a task. The length of the arrow can be regarded as indicating the period available to complete the task.

2. → (dummy) : indicates a hypothetical task. Although there is no actual work or time involved, dummy arrows are used to indicate logical connections between tasks.

3. ○ (node) : indicates a point in time where a task begins or ends. The date or time is usually inscribed in the circle.

4. Prohibition 1 : two tasks must not end at the same node.

5. Prohibition 2 : never introduce a loop

Use a dummy (E) to show that task C must be completed before task D can be started.

Group tasks B, C and D together.
Schedule calculation using PERT

1. The earliest time at which a particular activity can be started is called the earliest start time, or EST.
   \[
   \text{EST} = \text{maximum value of (time of previous node + time taken for tasks on all paths entering the node in question).}
   \]

   Example
   \[
   \begin{array}{c}
   1 \quad (0) \\
   2 \quad 4 \text{ days} \\
   3 \quad 6 \text{ days} \\
   4 \quad 8 \text{ days} \\
   5 \quad (10) \\
   \end{array}
   \]

   Calculation for node 3: figures in brackets represent ESTs.
   Path \( 1 \rightarrow 3 \): \((0) + 8 = \text{Day 8}\)
   Path \( 2 \rightarrow 3 \): \((4) + 6 = \text{Day 10}\)
   Since we take the larger of the two values, the EST for node 3 is Day 10.

2. The latest time by which an activity can be finished is called the latest finish time, or LFT.
   The LFT for a particular node = the minimum of (the date of the subsequent node + the time taken for all activities proceeding from the node in question).

   Example
   \[
   \begin{array}{c}
   3 \quad (10) \\
   4 \quad 7 \text{ days} \\
   5 \quad (22) \\
   \end{array}
   \]

   Calculation of LFT for node 3: figures in brackets represent LFTs.
   Path \( 3 \rightarrow 4 \): \((15) - 5 = \text{Day 10}\)
   Path \( 3 \rightarrow 5 \): \((19) - 4 = \text{Day 15}\)
   Since we select the smallest of the two values, the LFT for node 3 is Day 10.

3. By performing the above calculations, we can work out the critical path through the network of activities (the critical path is the route along which there is no slack, or room for delay, in any of the tasks).

   \[
   \begin{array}{c}
   1 \quad [0] \\
   2 \quad [4] \\
   3 \quad [10] \\
   4 \quad [15] \\
   5 \quad [19] \\
   6 \quad [22] \\
   \end{array}
   \]

   \( [ ] \) : LFT
   \( [ ] \) : Critical path
   \( \rightarrow \) : Critical path

   It is calculated that this project will take 22 days to complete. By entering the number of people and days required for each task, we can work out the daily loads.
Table 3-14: Example of PERT Work Plan for Installation of FA Line
Appendix 1

Specific Procedure for SLIM-II

(Information Layout Design)

Productivity Europe
Analyzing Information Processes
(The Correct Way to View Information Handling)

![Diagram showing the process of analyzing information in production management at manufacturing plants.](image)

**Figure 4-1: The Positioning and Role of Production Management at Manufacturing Plants**

Appendix 1.1
SLIM-II Design Procedure

The basic steps on the SLIM-II information layout design procedure, given below, are very similar to those used in SLIM-0 and SLIM-I:

Step 1: Understand present situation.

Step 2: Ask about workplace problems.

Step 3: Perform information process and layout analysis, and consider possible improvements.

Step 4: Clarify problems and set improvement objectives.

Step 5: Formulate information layout improvement proposals.

Step 6: Select specific plan (taking ECRS and line balancing into account).

Step 7: Consider plans for future (perform function analysis and devise automation plans). (Treat computerisation as a means of implementing these plans).
<table>
<thead>
<tr>
<th>ECRS Process analysis</th>
<th>E (Eliminate)</th>
<th>C (Combine)</th>
<th>R (Rearrange)</th>
<th>S (Simplify)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information processing</td>
<td>● Eliminate non-functional work</td>
<td>● Combine similar tasks performed at different locations</td>
<td>● Convert general guidelines to specific instructions</td>
<td>● Use computers, word processors, etc., for repetitive tasks</td>
</tr>
<tr>
<td></td>
<td>● Use pre-processing to eliminate post-processing</td>
<td>● Centralise information handling</td>
<td>● Decide times and split up tasks (use night hours, etc.)</td>
<td>● Standardise and document</td>
</tr>
<tr>
<td>Inspection (comparison)</td>
<td>● Establish systems that enable inspection to be carried out in the course of processing</td>
<td>● Concentrate inspection at one location (review system of responsibilities)</td>
<td>● Distribute to individual processes and clarify responsibilities</td>
<td>● Create alarm systems and communicate by means of lists, etc.</td>
</tr>
<tr>
<td></td>
<td>● Use alarm functions</td>
<td>● Only inspect priority control items</td>
<td>● Divide up in daily management style</td>
<td></td>
</tr>
<tr>
<td>Transmission (transportation)</td>
<td>● Eliminate wasteful routes</td>
<td>● Review and combine transmission routes</td>
<td>● Convert dispersed distribution and transmission into simultaneous parallel transmission</td>
<td>● Use on-line transmission systems such as LANs (local area networks) and POP (point of production) systems</td>
</tr>
<tr>
<td></td>
<td>● Use visual management to eliminate documents</td>
<td>● Perform mass transmission at specified times</td>
<td>● Formulate rules for processing abnormal situations and exercise priority control</td>
<td></td>
</tr>
<tr>
<td>Storage (filing)</td>
<td>● Eliminate paper</td>
<td>● Combine and integrate files</td>
<td>● Only file information in the areas where it is needed</td>
<td>● Use floppy disks, microfilms, etc.</td>
</tr>
<tr>
<td></td>
<td>● Install counters and eliminate infrequently-used items</td>
<td>● Also integrate information on subcontractors, sales and related companies</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4-1: Process Analysis/ECRS Matrix-Type Improvement Checklist

Appendix 1.3
Figure 4-4: Example of Structure Diagram for Mechanisation of Information Layout
Appendix 2

SLIM-III

(Operating the Layout and Improving its Efficiency)

Productivity Europe
Techniques for Ensuring Smooth Startup
(Make Full Use of Well-Known Improvement Techniques)

1. QC techniques: fact analysis, 5-Why? technique, Pareto analysis, X-R control charts

2. IE techniques: time study, charts showing breakdown of idle time, production volume trend graphs

3. VE techniques: function analysis, VE improvement techniques

Figure 5-1: Example of Visual Activity Control Board for Fast Equipment Startup

Appendix 2.1
Efficiency Improvement Through the Application of PAC (Performance Analysis and Control)

(a technique proposed by Mr Kadota of JMA Consulting)

1. For each division of responsibility
2. Collect and evaluate problems and numbers daily
3. Improve on a daily basis

Figure 5-3: Division of Responsibility and Evaluation Formulae According to Performance Analysis and Control (PAC)

The TPM Approach

Measures for Reducing the Six Big Losses

1. Breakdown losses
2. Setup and adjustment losses
3. Idling and minor stoppage losses
4. Speed losses
5. Defect and rework losses
6. Startup losses

Countermeasure Procedure

Step 1: Implement the 5Ss
Step 2: Apply breakdown-prevention measures
Step 3: Apply defect-prevention measures
Step 4: Establish daily countermeasures
Step 5: Take measures to improve equipment reliability

Develop equipment that does not break down and does not produce defects

Appendix 2.2