Plant Layouts for Enhanced Production Capacity of A Drinking Water Manufacturer

By

Mr. Nisa Sriborthong

A Final Report of the Three - Credit Course CE 6998 Project

Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Computer and Engineering Management Assumption University

November 1999
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The Graduate School of Assumption University has approved this final report of the three-credit course, CE 6998 PROJECT, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer and Engineering Management.

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ABSTRACT

This project examines the improved plant layouts by using the Systematic Layout Planning (SLP) approach. The procedure for starting the layout project with SLP is identification and description of the project, its objective(s), the phases of layout planning that is about P, Q, R, S, T, and activities analysis. The SLP is an excellent technique for correctly assigning activities in which this study concentrates on the relationships between various functions, activities, or workstations then adjusts the relationships and spaces into the layout plan(s) which is drawn by AutoCAD program version 14.

This study uses SLP to make the suitable plant layout by making an activity relationship diagram to visually show the desired closeness of all activities to each other. After that diagram the activity relationships and draw space relationship layouts are done. The evaluation procedure is now used to access the objectives to be the master plan.
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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>iii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>ix</td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1 General Background</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Statement of Problem</td>
<td>2</td>
</tr>
<tr>
<td>1.3 Limitation of the Study</td>
<td>3</td>
</tr>
<tr>
<td>1.4 Objectives of the Study</td>
<td>3</td>
</tr>
<tr>
<td>1.5 Scope of the Study</td>
<td>4</td>
</tr>
<tr>
<td>II. LITERATURE REVIEW</td>
<td>5</td>
</tr>
<tr>
<td>2.1 Plant Layout Method</td>
<td>5</td>
</tr>
<tr>
<td>2.2 Computerized Layout Planning</td>
<td>12</td>
</tr>
<tr>
<td>III. THE EXISTING PLANT LAYOUT UNDER STUDY</td>
<td>15</td>
</tr>
<tr>
<td>3.1 Background of the Enterprise</td>
<td>15</td>
</tr>
<tr>
<td>3.2 The Production Flow Process</td>
<td>16</td>
</tr>
<tr>
<td>3.3 The Existing Plant Layout and Material Flow Process</td>
<td>21</td>
</tr>
<tr>
<td>IV. DATA COLLECTION AND PRELIMINARY ANALYSIS</td>
<td>22</td>
</tr>
<tr>
<td>4.1 Data Collection</td>
<td>22</td>
</tr>
<tr>
<td>4.2 Adding Machines Required</td>
<td>23</td>
</tr>
<tr>
<td>4.3 Input Data for SLP Approach</td>
<td>28</td>
</tr>
<tr>
<td>4.4 Space Requirements</td>
<td>38</td>
</tr>
<tr>
<td>4.5 Diagram Activities Relationship</td>
<td>44</td>
</tr>
<tr>
<td>Chapter</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>------</td>
</tr>
<tr>
<td>V. EVALUATE IMPROVED PLANT LAYOUT</td>
<td>58</td>
</tr>
<tr>
<td>5.1 Identification of Problems in the Existing Plant Layout</td>
<td>58</td>
</tr>
<tr>
<td>5.2 Material Movement Problem</td>
<td>58</td>
</tr>
<tr>
<td>5.3 Space Utilization Problem</td>
<td>59</td>
</tr>
<tr>
<td>5.4 The Improved Plant Layout</td>
<td>59</td>
</tr>
<tr>
<td>5.5 Evaluate Alternative Arrangements</td>
<td>59</td>
</tr>
<tr>
<td>VI. CONCLUSIONS AND RECOMMENDATIONS</td>
<td>66</td>
</tr>
<tr>
<td>APPENDIX A LINE BALANCING</td>
<td>69</td>
</tr>
<tr>
<td>APPENDIX B COMBINING FLOW AND OTHER-THAN-FLOW RELATIONSHIPS</td>
<td>71</td>
</tr>
<tr>
<td>APPENDIX C PEOPLE’S BEHAVIOR WITH THE BOTTLED WATER</td>
<td>78</td>
</tr>
<tr>
<td>APPENDIX D FACTORS IN SELECTING THE BEST LAYOUT</td>
<td>81</td>
</tr>
<tr>
<td>APPENDIX E THE AUTOCAD INTERFACE</td>
<td>87</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>90</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 The Existing Production Area</td>
<td>17</td>
</tr>
<tr>
<td>3.2 The Production Process</td>
<td>18</td>
</tr>
<tr>
<td>3.3 The Existing Process Layout</td>
<td>19</td>
</tr>
<tr>
<td>3.4 The Existing Plant Layout</td>
<td>20</td>
</tr>
<tr>
<td>4.1 The Automatic Rinsing Machine</td>
<td>24</td>
</tr>
<tr>
<td>4.2 The Automatic Filling Machine</td>
<td>25</td>
</tr>
<tr>
<td>4.3 The Automatic Capping Machine</td>
<td>26</td>
</tr>
<tr>
<td>4.4 The Automatic Shrink Film Wrapping Machine</td>
<td>27</td>
</tr>
<tr>
<td>4.5 The Area Reserved for Future Expansions</td>
<td>29</td>
</tr>
<tr>
<td>4.6 The Fully Automatic-line Drinking Water Filling and Packaging Line</td>
<td>30</td>
</tr>
<tr>
<td>4.7 The Production Process Chart of Improving Automatic-line</td>
<td>31</td>
</tr>
<tr>
<td>4.8 The Intensity of Material Flow</td>
<td>33</td>
</tr>
<tr>
<td>4.9 The Flow of Material Relationship Chart</td>
<td>35</td>
</tr>
<tr>
<td>4.10 The Other-than-flow Relationship Chart</td>
<td>36</td>
</tr>
<tr>
<td>4.11 The Combined Flow and Other-than-flow Relationship Chart</td>
<td>37</td>
</tr>
<tr>
<td>4.12 The Activities Area &amp; Feature Sheet</td>
<td>43</td>
</tr>
<tr>
<td>4.13 The Diagram Activities Relationship</td>
<td>44</td>
</tr>
<tr>
<td>4.14 The Alternative I of Modify Plant Layout Diagram</td>
<td>45</td>
</tr>
<tr>
<td>4.15 The Alternative II of Modify Plant Layout Diagram</td>
<td>46</td>
</tr>
<tr>
<td>4.16 The Alternative III of Modify Plant Layout Diagram</td>
<td>47</td>
</tr>
<tr>
<td>4.17 The Alternative IV of Modify Plant Layout Diagram</td>
<td>48</td>
</tr>
<tr>
<td>4.18 The Alternative I Drawing of Modify Plant Layout Diagram</td>
<td>49</td>
</tr>
<tr>
<td>4.19 Adjustment of Drawing Alternative I for Modifying the Plant Layout</td>
<td>50</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>4.20</td>
<td>The Alternative II Drawing of Modify Plant Layout</td>
</tr>
<tr>
<td>4.21</td>
<td>Adjustment of Drawing alternative II for Modifying the Plant Layout</td>
</tr>
<tr>
<td>4.22</td>
<td>The Alternative III Drawing of Modify Plant Layout</td>
</tr>
<tr>
<td>4.23</td>
<td>Adjustment of Drawing Alternative III for Modifying the Plant Layout</td>
</tr>
<tr>
<td>4.24</td>
<td>The Alternative IV Drawing of Modify Plant Layout</td>
</tr>
<tr>
<td>4.25</td>
<td>Adjustment of Drawing Alternative IV for Modifying the Plant Layout</td>
</tr>
<tr>
<td>4.26</td>
<td>Determining the Evaluating Alternative of Four Alternatives Diagrams</td>
</tr>
<tr>
<td>4.27</td>
<td>The Master Plan AA from the Evaluation Alternative</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>The Existing Plant Layout Area</td>
</tr>
<tr>
<td>4.1</td>
<td>Data Collection from Sales Department</td>
</tr>
<tr>
<td>4.2</td>
<td>The Machines Requirement for Capacity Expansion</td>
</tr>
<tr>
<td>4.3</td>
<td>The Materials Flow Load per Day</td>
</tr>
<tr>
<td>4.4</td>
<td>The Space Requirement</td>
</tr>
<tr>
<td>4.5</td>
<td>The Capacity Requirement in the Future</td>
</tr>
</tbody>
</table>
I. INTRODUCTION

1.1 General Background

Facilities planning and plant layout involves the consideration of complex interaction between the physical facilities like operating machinery, material handling equipment, storage space, and service stations; the machine operators and maintenance personnel; and the product being manufacturing. The fact that efficiency of the production operations is dictated, to a large extent, by the material flow pattern, utilization of floor space storage facilities, and efficient operation of machines, highlights the importance of plant layout in achieving competitive performance.

Generally, the plant layout is organized based on initially planned production requirements. This also provides the guidelines for the architecture of the building. However, as the product characteristics and capacity requirements change, rearranging the facilities layout becomes a crucial problem, since it can result in lost time, idling of equipment, disruption of production schedule, inefficient use of company's land and many times being destroyed on tearing down the walls of the factory building.

Plant designers have used various methods to design the initial plant layout as well as to alter the layout to meet the product characteristics and production process requirements.

The layout is an inescapable problem in all industrial plants. Plant layout embraces the physical arrangement of industrial facilities. This arrangement, either installed or in plan, includes the spaces needed for material movement, storage, indirect labors, and all other supporting activities or services, as well as for operating equipment and personnel.

Under such circumstances the Systematic Layout Planning model (SLP) and the associated computer technique (AutoCAD drawing program) look attractive for the estimation of the machine requirements for capacity expansion program. At the same
time, a similar approach can be utilized efficiently to layout the additional machines along with the existing facilities. In this study, the SLP and the related computer programs as AutoCAD program have been used to arrive at an efficient plant layout.

1.2 Statement of Problem

Manufacturing plant layout if designed without taking into consideration the material flow, handling and storage would result into complex flows, excessive WIP, large handling costs, etc. Drinking water manufacturing of a variety of engineering components and assemblies in batch production mode suffers from the problems of poor material flow, low machine and space utilization, low production capacity and a number of other problems.

The kinds of plant-layout problems fall into four classes:

(1) **Planning a complete new plant.** Here the job is one of arranging all the facilities to work as an integrated whole.

(2) **Expanding or moving to an existing plan.** Here the building and services are already there with the limitations on the free hand of the layout engineer. The problem is one of adapting the product, facilities, and personnel of an existing organization to different but existing plant.

(3) **Rearranging a present layout.** The problem is one of using as much of the existing facilities as is consistent with new plans and methods. This problem occurs most often with changes in model or style of products or with the modernization of productive equipment.

(4) **Minor adjustments to existing layouts.** This type of problem generally occurs when there are changes in operating conditions.
In this project, the author has analyzed the layout of the existing plant and suggested improvements in the plant for better system performance. The design of the production plant has also been studied by modeling the system as Systematic Layout Planning (SLP) and suitable recommendations have been made for a better design and minimum of the manufacturing facility.

1.3 Limitation of the Study

The finding of this study applies to the case of mechanical workshop of drinking water manufacturing hence the findings can be generalized. And from the proposed techniques, this may also lead to the inaccuracy of the expected results.

1.4 Objectives of the Study

The specific objectives of the study are:

(a) Improving the existing plant layout. (This does not take into account the reconstruction or the reinvestment cost or the movement cost of the machines). The criteria used for the evaluation of the layout are:

1. Minimize material handling cost.
2. Maximized the utilization of space.
3. Providing a smooth flow of materials and products.
4. Reduced risk to health and safety of the employees.
5. Improved morale and worker satisfaction.
6. Increased output.
7. Fewer production delays.
8. Reduced inventory-in-process.

(b) Designing a new plant layout by considering the expected capacity requirements of the future by using SLP after that drawing the new plant layout by AutoCAD program.
1.5 Scope of the Study

This study looks into the following problem areas in relation to mechanical workshop of drinking water manufacturing as:

(1) The improved plant layout has been designed to meet the expected production capacity and the additional number of machines that should be added has been worked out.

(2) The layout can be altered to recognized the existing facilities.
This research concentrates on problems concerning to improved plant layout and facilities planning (SLP) and combines them with computerized layout planning (AutoCAD). This chapter is divided into two parts which are the issues that related to plant layout approach and computerized layout planning.

The facility layout planning problems involve the selection of the most effective arrangement of physical facilities to allow greatest efficiency with the combination of resources to produce a product or service, and is nonnally required to satisfy multiple objectives such as overall interaction of all functions, minimum material movement, smooth work flow, effective space utilization, employee satisfaction, safety, flexibility, etc.

Since the early 1950s many techniques and approaches, such as schematic and systematic techniques, optimizing and heuristic algorithms, interactive graphics/integrated approach, fuzzy set theory based approach, knowledge-based approach, and multiple criteria approach, have been developed to deal with the facility layout planning problem.

2.1 Plant Layout Method

The research concerning the evaluation and optimization of a given plant layout is directed towards simplifying the routing of the product in layout during processing. This results into relocation of departments to reduce material handling cost and make efficient operation of the processes more efficient. The literature studies herein is mainly concerned with the layout improvement, and some of the solution techniques are cited here.

2.1.1 A "Linguistic Pattern" Approach for Multiple Criteria Facility Layout Problem
Raoot and Rakshit (1993) developed a valuable technique. This technique is based on research work in which a multiple criteria model has been formulated based on the general framework of the "linguistic pattern" approach presented by Grobelny (1987,1988). A heuristic procedure is proposed to generate a set of "efficient" alternative layouts. Evaluation of the various alternative layouts is a difficult task because of the lack of a suitable measure of effectiveness with respect to multiple objectives. Proper measure of effectiveness are more difficult to establish when qualitative objectives are involved than when only quantitative objectives are involved (Moore 1970).

The "fitting" of the facility arrangement to the requirements of the "linguistic pattern", which either represents a goal or restriction, is proposed as a proper measure of effectiveness. The problem-solving methodology includes a heuristic procedure involving shifting of facilities, the placement of which does not satisfy the "linguistic pattern", to generate a set of efficient layout alternatives. The problems of evaluation of alternative layout is formulated as a multiple criteria evaluation problem. Multiple criteria decision making approaches for aggregation of evaluative criteria are discussed and the research work involves an application of the electre method (Szidarovszky et al.1986), based on an "outranking relation" approach, for evaluation and ranking the "efficient" alternatives generated by using the heuristic procedure for a sample facility layout problem.

2.1.2 Virtual Manufacturing Cells: exploiting layout design and intercell flows for the machine sharing problem

Irani, Cavalier, and Cohen (1993) noted that: Traditional approach to cell formation by using machine-part matrix clustering methods has been to create an independent cell for each part family. Machine sharing and intercell flows are discouraged. However, this creates the problems of determining the numbers of
machines of a shared type that must be assigned to each cell, without affecting machine utilization. With product mixes and demands being subject to change, this rigid traditional definition of cells does not support the design principles for flexible manufacturing system (FMSs) and factory integration or exploit the flexible handling capabilities of automated guided vehicle systems (AGVs).

They have developed a flow-based approach for the formation of manufacturing cells which integrates machine grouping, shop layout design and intercell flow handling. Part families with overlapping machine requirements are assumed to be merged to eliminate the need to duplicate shared machines among competing cells. Machines shared by several cells are assumed retained in functional selections if these cells can be located adjacent to each other. This adjacent of the cells allows the machine groups for the part families to be virtual, i.e. the handling system links machines in adjacent cells in order to define the cell for a part family without necessitating rigid physical relocation to group the machines. Further, since the input data for the method is a travel chart, the method automatically suggests a flow line layout for each cell, and a tree network layout of these flow lines for the shop. The intra-cell and inter-cell handling links can be approximately determined from the final flow network.

2.1.3 A "Fuzzy" Heuristic for the Quadratic Assignment Formulation to the Facility Layout Problem

Raoot and Rakshit (1994) developed a good technique. This technique describes a fuzzy set theory based heuristic for the quadratic assignment formulation of the facility layout problem with single/multiple objectives. A heuristic procedure is presented, that involves the assignment of facilities to locations to generate an initial solution and then possibly improving the solution through shifting of facilities as per the scope for improvement identified during the evaluation of the generated solution. The
effectiveness of the heuristic, in terms of quality of solution, is illustrated with a numerical example. Finally, a set of examples, previously used by various researchers, are solved and the results are compared with the optimal solution or with the "best" indicates that the proposed procedure performs well in terms of quality of solution.

2.1.4 Systematic Layout Planning (SLP)

In 1961, Richard Muther presented a method for systematically developing a layout with a single goal objective (Muther 1973). This method called the systematic layout planning (SLP), has been widely used since its introduction. SLP is a method of schematically analyzing the relationship between work centers that may be used to obtain either quantitative or qualitative solutions.

This technique uses two valuable tools for the organization of data problems, the form-to chart and the activity relationship chart. A form-to chart is a matrix with department numbers at the beginning of each row and column. The body of the chart contains the quantitative flow of materials from a row department to a column department. A relationship chart is used to indicate the qualitative relationship between two departments using a matrix structure. This relationship is represented by a letter signifying how important it is that two particular departments be closed together or adjacent. This relationship is subjectively decided by somebody who is knowledgeable about the facility.

Systematic layout planning (SLP) is used as basis to improve the existing layout and design the new layout. This technique used two valuable tools for the organization of data problems. The steps involved in this method are:

1. Relating every activity to each other by a method of "closeness desired rating" which results in a relationship chart.
2. Establishment of required area and configuration for each of the activities.
(3) Graphically relating activities and arranging space to form a basic pattern.

(4) Evaluation of alternative layouts against objectives and constraints as specified by management.

This method is the most appropriate for this research, because the data are available and the problems under study should be concentrated on the relationship between workstations to minimize the material handling cost.

SLP (Systematic Layout Planning) is a set of six procedures to follow when laying out an area. An organized approach to layout planning has been developed by Muther and has received considerable publicity due to the success derived from its application in solving a large variety of layout problems. The approach is referred to as systematic layout planning or simply SLP. SLP has been applied to a variety of problems involving production, transportation, storage, supporting service, and office activities.

The SLP procedure is run once the appropriate information is gathered, and a flow analysis can be combined with an activity analysis to develop the relationship diagram. Space considerations, when combined with the relationship diagram, lead to the construction of the space-relationship diagram. Based on the space-relationship diagram, modifying considerations, and practical limitations, a number of alternative layouts are designed and evaluated. In comparison with the steps in the design process, we see that SLP begins after the problem is formulated.

SLP includes a basic approach that:

(1) Follows a framework of planning phases.

(2) Integrates five physical components (P, Q, R, S, T).

(3) Investigates certain short and long range inputs.

(4) Considers the appropriate non-physical influences.

(5) Tracks through a sequential planning pattern.
(6) Uses a set of rating-recording visualizing conventions.

2.1.5 Framework of Planning Phases

This step identified the four typical phases of a planning project as:

(1) Phase I — Orientation involves scoping the extent of the project and setting schedule converting the needs and desires into tangible requirements.

(2) Phase II — Overall planning involves converting the tangible requirements, the external consideration, and internal influences into an overall or total plan for the facility.

(3) Phase III — Detail planning involves converting the tangible requirements for each subdivided portion of the total facility.

(4) Phase IV — Implementation involves converting the prepared plans for the facility into a program of action — construction, rehabilitation, renovation, and installation.

2.1.6 Five Components in Each Phase

Integration of the planning for each of these five components is ensured by tying the five together at each phase.

(1) The layout which the planner should consider his typical four phases as location, overall layout, detail layouts, and installation.

(2) Handling in which the material handling analyst considers his four phases as external integration, overall handling plan, and installation.

(3) Communication in which the planner considers the four phases as external integration, basic plan, detail plans, and implementation.

(4) Utilities in which it considers four phases as external access, primary distribution plan, secondary distribution plans, and installation.
Building in which it considers the typical four phases as program and site characteristics, preliminary building plans, detail construction documents, and building construction.

2.1.7 Short and Long Range Inputs

Inputs to the planning process are two kinds:

1. The inputs of planning criteria requirements that determines the short range and long range forecasts.

2. The clear definition of the project that is its description, objectives, scope, anticipated time and cost.

The five basic inputs that should be provided and determined by the planner at the beginning of the project are P, (Product) that is what is to be produced, Q, (Quantity) that is how much to be produced, R, (Routing) that is how to be produced, S, (Supporting service) that is what support they produced, and T, (Timing) that is when and how long the facility will produce.

The planner must consider a host of non-physical influences that affect the project which may be both external and internal to the confines of the project. So, the non-physical influences may be grouped into:

1. Legal or regulatory.

2. Economic or financial.

3. Technical or scientific.

4. Social or political.

5. Ecological or environmental.

6. Personal or emotional.

There are six steps that simplifies SLP in which each of the six steps carries its own easy symbol as follows:
(1) Triangle is the shaped relationship chart.
(2) Square is square feet and physical features.
(3) Star is diagram connecting activities at different points.
(4) Circle that is round and round to adjust the layout diagrammed.
(5) Hexagon is used to examine from all side, evaluate all factors.
(6) Rectangle that the layout plan is on sheet of paper or building print.

The SLP method is the most appropriate for this research because the data are available and the problems under study should be concentrated on the relationship between workstations to minimize the material handling cost and increasing the capacity requirements.

2.2 Computerized Layout Planning

Layout planning is a complex problem, requiring simultaneous consideration of a large number of complex, intricately related issues. Layout decisions can both depend on, and affect, other decisions. The design of other types of facilities, such as warehouses or office buildings is equally complex.

Because of the complexity and scope of the layout planning problem, the layout planner will work together with other planners and designers. In fact, it is not unusual to find a layout planning team rather than a single layout planner.

Communication and documentation become critical in such an environment. Documentation requirements for layout planning are substantial. The output of the layout planning process also can be substantial, including engineering drawings, and specifications for equipment, procedures, and staffing.

Layout planning is heavily dependent on data, documentation, and communication, and is therefore a perfect candidate for computerization. Since the mid 1970s, there have been astounding advancements in both the hardware and the software.
available for these kinds of tasks, and the trend should continue for the foreseeable future. Thus the modern facilities planner faces an enormous array of computerization opportunities in layout planning.

The facility layout process can be conceptualized as a process of design database development, where the final content of the database is the layout specification. The layout is created and modified by the layout planner. The design database may contain data in a variety of formats, such as drawings, numerical specifications, and text. The layout data will change over time as different aspects of the layout are elaborated and coordinated with other facility design decisions. At some point in time, the layout is "frozen" and becomes the reference data for implementation.

In the layout process, the layout planner must be able to comprehend the current state of the layout in order to make additional decisions or to revise previous decisions. In making these layout decisions, the layout planner must integrate the current state of the layout database, when he/she understands it, the layout requirement and constraint, as he or she understands them, and any necessary domain-specific knowledge, such as standards and local regulations. Often the layout planner will need to employ models in the search of good layout decisions, or to evaluate tentative layouts.

A primary opportunity is the computerization of the central layout database. In reality, this may be a collection of databases: a CAD database. The layout planner will interact with these databases using AutoCAD systems. Modern computing technology provides the layout planner with a wide assortment of methods for displaying layouts, from graphics workstations to high-speed plotters.

Dealing with multiple databases is not the problem today that it was even a few years ago. Advances in computing capability and the corresponding advances in software provide the layout planner with access to sophisticated windowing software
that will permit access to multiple programs or files simultaneously. However, today's layout planner must still perform the data integration. That is, when data from different databases in different formats represent the same design feature, it is up to the layout planner to translate and ensure consistency. For example, when aisles are defined in a layout drawing, and lift truck specifications are in word processing document, the layout planner must make sure that they are consistent (the lift trucks will fit in the aisles).

A layout procedure such as SLP (Systematic Layout Planning) is simply an orderly way to execute the layout process. SLP calls for the design database to be developed in six steps:

1. Developing the basic data.
2. Identifying material flows and activity relationships.
3. Developing the activity relationship diagram.
4. Determining space requirements and availability.
5. Developing the space relationship diagram.
6. Using the space relationship diagram, practical limitations, and other considerations to develop and evaluate alternative layouts.

Each step involves understanding the current state of design database and adding to or modifying its content. Each step requires decision making by the layout planner and the computerized layout planning as AutoCAD is adapted.
III. THE EXISTING PLANT LAYOUT UNDER STUDY

The study is carried out at a mechanical workshop and the overall areas of C.S. Union Group co., Ltd, Thailand. This chapter gives the background of this enterprise, production process, the overall plant layout and the existing plant layout are highlight here.

3.1 Background of the Enterprise

C.S. Union Group has been established since 1959. It has been started with interior design & housing and real estate business, then running on hardware shop and restaurant businesses and in 1988, the Drinking water business started running.

3.1.1 Introduction of Drinking Water Business

The top executive of the enterprise is the director and the head office of drinking water manufacturer is located at Sukhumvit road, Bangkok, Thailand. The production facilities of drinking water manufacturer is located behind the head office at the other side which consists of the following:

1. Mechanical workshop consisting of different kinds of machines tools and necessary equipment to carry out all types of mechanical works.
2. Packaging workshop.
3. Warehouses.
4. Office area.

3.1.2 Types of the Product

The company runs the business of drinking water that contains in PET plastic bottles (clear bottle). And now, there are 4 sizes of drinking water in PET plastic bottles as 500cc, 750cc, 950cc, and 1500cc. The company uses the PET bottle which is clear bottle for containing the drinking water of Reverse Osmosis (R.O), ozone, and ultra violet system. Note that automatic machines can use with the variety of bottle size.
3.2 The Production Flow Process

The production process of the existing flow process consists of 4 sections. First, it starts at the raw water tank in which contains the raw water and the raw water passed through the Softener system (Manganese Dioxide, Granular Activated Carbon, Water Softener), Filter (1 micron and 5 micron Ceramic) and Reverse Osmosis system before being stored into the Reverse Osmosis water tank (R.O tank). Second, the water from R.O water tank passed through the system of Ultra Violet (U.V) and ozone system before moving into the filling section. Third, the filling and capping is performed into the cleaned bottles (manual). Fourth, packaging by wrapping (manual) and storing in the warehouse is performed.

Selecting and installing a reverse osmosis (R.O) unit to produce high-purity water is now faster, simpler and more convenient than ever.

For the ozone water treatment system, the system consists of three major components: ozone generator, in-line mixer and filter module. The ozone generator either plugs into a standard receptacle or is hardwired (230V). It has an air pump which provides compressed air to an ultraviolet ozone producing lamp, thus producing compressed ozone.

The mixer is installed into the well pump water feed pipe to the holding tank. The ozone gas is routed from the ozone generator, through the mixer, to the filter module within the holding tank. When the well pump is turned on to provide water to the tank, the mixer automatically diverts and mixes the ozone gas into the incoming well water before the water enters the tank. The ozone gas from the mixer is fed to the filter module diffuser, which makes millions of tiny ozone saturated bubbles that rise up the filter module lift pipe, mixing the ozone with the water and drawing water through the filter at the rate of about 10 gallons per minute.
Figure 3.1. The Existing Production Area.
Figure 3.2. The Production Process.
Figure 3.3. The Existing Process Layout.
The Existing Plant Layout.
3.3 The Existing Plant Layout and Material Flow Process

The existing plant layout is shown in enclosed drawing (Figure 3.4). The material flow process is shown in Figure 3.2. the size of this mechanical workshop is about 100 square meter. The position of the machines can be obtained from the layout drawing of the factory and the list of machines related to the processes are shown in Table 3.1.

3.3.1 The Existing Plant Layout Area

The existing plant layout of this enterprise is shown in Figure 3.4. The office area is approximately 12 sq.m., laboratory room is about 8 sq.m., packaging area is about 30 sq.m., the production area is about 100 sq.m. and warehouse area is about 364 sq.m.

Table 3.1. The Existing Plant Layout Area.

<table>
<thead>
<tr>
<th>Department</th>
<th>Existing area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>100 sq.m.</td>
</tr>
<tr>
<td>Warehouse I</td>
<td>250 sq.m.</td>
</tr>
<tr>
<td>Warehouse II</td>
<td>114 sq.m.</td>
</tr>
<tr>
<td>Packaging</td>
<td>30 sq.m.</td>
</tr>
<tr>
<td>Office</td>
<td>12 sq.m.</td>
</tr>
<tr>
<td>Laboratory room</td>
<td>8 sq.m.</td>
</tr>
<tr>
<td>Others</td>
<td>1000 sq.m.</td>
</tr>
</tbody>
</table>
IV. DATA COLLECTION AND PRELIMINARY ANALYSIS

This chapter discusses about how the rate of production is utilized in layout planning and a brief description of the procedures used to determine market demand which is directed towards one objective that is the determination of proper production volume. The rate of production output is very important because it will determine the size of the plant to be designed. As the previous chapter discusses, there are 4 sizes of products to be produced as 500cc, 750cc, 950cc, and 1500cc. So, the most critical information for effective plant layout is the planned rate of production because it will determine the size of the plant to be designed.

4.1 Data Collection

The data concerning in this study is collected from sales department and some data comes from Thai Farmer Research Center Co.,Ltd. (Appendix C).

The sales department estimates that it should be able to market 20000-25000 dozens per month and tends to produce up to 30000 — 50000 dozens per month in the next 5-7 years. (the information is in Table 4.1)

Table 4.1. Data Collection from Sales Department.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>September,1998 — November,1998</td>
<td>60,000 dozens</td>
</tr>
<tr>
<td>2.</td>
<td>January,1999 - April,1999</td>
<td>70,000 dozens</td>
</tr>
<tr>
<td>3.</td>
<td>May,1999 - August,1999</td>
<td>120,000 dozens</td>
</tr>
<tr>
<td>4.</td>
<td>September,1999 and trend into the future market is 15% (there are sign contact with the head company of the customers for increasing the demand that can not allow to disclose).</td>
<td></td>
</tr>
</tbody>
</table>
Note: The trend in the future growth of this study is received from the president of the C.S. Union Group co., Ltd who takes pleasure to give objectives to market 10% up since year 2000 and 15% up for the next 7 years. The further details of the behavior of the people in Bangkok is shown in Appendix C.

4.2 Adding Machines Required

As mentioned before, the company expects 10% growth in the next three years. So, the capacity is not enough and some automatic machines should be determined.

The following figures are about the data of the machines required for increasing output by using the fully automatic in-line drinking water filling and packaging line.

Table 4.2. The Machines Requirement for Capacity Expansion.

<table>
<thead>
<tr>
<th>The machines required for improving the capacity output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic rinsing machine 10 nozzles 1</td>
</tr>
<tr>
<td>Automatic filling machine 6 nozzles 1</td>
</tr>
<tr>
<td>Automatic capping machine 1 nozzles 1</td>
</tr>
<tr>
<td>Automatic shrink film wrapping machine 1</td>
</tr>
</tbody>
</table>
4.2.1 The Automatic Rinsing Machine

Automatic rinsing machine 10 nozzles, the bottles will be placed on the conveyor where they will be delivered into the feeding perform. The bottle will be moved to the nozzles and will be then automatically aligned. It will send the bottle to pass the streaming water jets. The bottles will slowly turn upside down. The water that has been used will be kept in a reserving tank for recycle. After a bottle has completed the process, it will be released from the grip and will be delivered into the process of containing.

Figure 4.1. The Automatic Rinsing Machine.
4.2.2 Automatic Filling Machine

This is in-line, fully automatic of 6 nozzles filling machine for drinking water. It is capable of utilizing both glass and rigid plastic bottle of various sizes, with especially designed pumping action to keep the amount of foam forming at the minimum level. During the process, bottles travel along a delivery conveyor and are positioned under the filling nozzles. The machine can detect the presence of the bottle, therefore performing its task on the basis of no bottles — no fill. The level of the filling nozzle can be adjusted easily by a hand operating knob, allowing the operator to easily cope with
multiple types of job in a short period of time. The frame of the machine is made of stainless steel, carefully assembled to deliver a 100% waterproof standard, protecting its electrical compartment from water getting in. The complete filling machine may be dismantled for cleaning and maintenance.

4.2.3 Automatic Capping Machine

![Figure 4.3. The Automatic Capping Machine.](image-url)
4.2.4 Automatic Shrink Film Wrapping Machine

The film wrapping machine is used for packaging the products so as to be convenient for transportation. The machine is separated into two parts. The machine is separated into two parts. The first part locates the film wrapping machine for wrapping the bottle and cutting down the film. The second part is the heating tunnel to shrink the film. Both parts of the machine will work relatively throughout the process. The
machine has used the electronic controlling system to control the temperature and heating level inside the tunnel. The temperature and heating can be set at any level up to desire in order to get along well with the speed and thickness of the film.

As mentioned earlier, SLP (Systematic Layout Planning) is used for analyzing the layout 'design problems. How the data is organized and analyzed is described in the following page.

4.3 Input Data for SLP Method

The existing plant layout is drawn by using AutoCAD program. The data gathered on products, quantities, sequence of operation, supported service comes from sales and management departments. This data is related with the layout planning for improvement by using SLP method.

It is seen that operation process of drinking water manufacturing is not complex. There are few items that are essential in mass production conditions. The company decides to change the process layout by function to the layout by product or line production in which the machines or assembly work stations are arranged in the sequence of operation, successive operations being performed immediately adjacent to each other. This is, to move the material from one operation directly to the next.

The company condition is suitable for high-volume, low variety, and fast movers that a high degree of mechanization, special-purpose equipment is justified.

The company here produces drinking water. Its processes involve the filling system, rinsing filling and capping, packaging and storing in warehouse. The quantity is very high and the process is relatively simple. So, the line production or layout by product is the best suitable. The management decides to add the set of automatic machine in order to produce enough output and the capacity of the existing machine (semiautomatic) is not enough to produce much more.
From the data of the quantity in the past, the information is shorter period that would generally be used for smaller re-layout projects. From this kind of forecasting, the study is mentioned in the short-range forecasting (1-3 years) because of the limitation of the data and the company just running for only 1-2 years. So, the master plan for the future is beside here in order to work backwards into various increments of expansion, even though the time schedule may not be specific.

The master plan for short-range expansion is as below in which the management committee's objective requires to maintain the production process of the original because it can reserve the production in case the automatic-in-line machines has some problems.

Figure 4.5. The Area Reserved for Future Expansions are Shown as Dotted Lines.
Figure 4.6. The Fully Automatic-line Drinking Water Filling and Packaging Line.
The existing output is about 500 dozens per shift that must take the overtime everyday in order to get about 800 to 1000 dozen per day. So, the management decides on choosing the automatic in-line (automatic machines are detailed above). As automatic in-line, drinking water filling and packaging line is added in the production process, the capacity is about 14,400 to 18,000 bottles / shift / day or 1200 — 1500 dozens per day which is enough for demanding output.

The production process chart of improving automatic-line

Figure 4.7. The Production Process Chart.
Figure 4.7, the operation process chart of drinking water systems showing the chronological sequence of operations and how and where the components go together.

Table 4.3. The Materials Flow Load per Day.

<table>
<thead>
<tr>
<th>Route</th>
<th>Materials</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P-load per day</td>
<td>dozen per day</td>
</tr>
<tr>
<td>1. Receiving — In storage</td>
<td>28000</td>
<td>-</td>
</tr>
<tr>
<td>2. In storage — Rinsing</td>
<td>18000</td>
<td>-</td>
</tr>
<tr>
<td>3. Rinsing — Filling</td>
<td>18000</td>
<td>-</td>
</tr>
<tr>
<td>4. Filling — Capping</td>
<td>18000</td>
<td>-</td>
</tr>
<tr>
<td>5. Capping — Packaging</td>
<td>15600</td>
<td>-</td>
</tr>
<tr>
<td>6. Packaging — Finished</td>
<td>15600</td>
<td>600</td>
</tr>
<tr>
<td>7. Finished - Shipping</td>
<td>12000</td>
<td>-</td>
</tr>
</tbody>
</table>
The management has estimated the above intensities of the product in the previous page. In addition to the flow consideration, there are some other reasons for the closeness of certain activity areas. These are as follows:

1. It is ordinary closeness that Incoming Storage and Finished Goods Storage be close because it is convenient for separated checking.

2. It is especially important that Office and Laboratory be close because they share personnel.

3. It is important that Rinsing, Filling, Capping and Packaging be close together because it uses machine-in-line.

4. It is ordinary closeness that the Office communicates with the Storage and Important for the finished storage for paperwork contact.

5. It is important that the Finished Storage must be convenient for shipping.

These are very acts — adjusting the relationship from flow intensities to vowel-letter rating and relating each service to each operating department that establishes the
common-denominator scale of measure for closeness is used for all relationships. In preparing the chart, identify the activities and list them on the chart. Group together activities which are similar or come under the same supervision. This will make it easier to mark, get approval, and use the chart. Also, it may be difficult to use the chart when there are too many activities listed. The working form supplied with this project has room for only 45. It may be necessary to consolidate, segregate, or temporarily overlook certain activities, rather than including too many.

The term reasons used for this study supporting relationship rating includes:

1. Flow of materials.
2. Degree of communication.
3. Share personnel.

For the existing plant layout it can be seen that the left production section has enough space for producing the products. Moreover, moving the large machines that are used for filtering to the other section is difficult and not safe because of their weight. While removing the areas of storage for materials and finished products is easy and safe.
Figure 4.9. The Flow of Material Relationship Chart.
Figure 4.10. The Other-than-flow Relationship Chart.
Figure 4.11. The Combined Flow and Other-than-flow Relationship Chart.
4.4 Space Requirements

From establishing the activities involved with the flow and other-than flow materials movement that required rearranging area. So, the following Table 4.2 shows the requirements that affect or restrict the shape or configuration of these activity's space.

Table 4.2. The Space Requirements.

<table>
<thead>
<tr>
<th>Department</th>
<th>Existing space</th>
<th>Space requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>100 sq.m.</td>
<td>290-330 sq.m.</td>
</tr>
<tr>
<td>Warehouse I</td>
<td>250 sq.m.</td>
<td>400 sq.m.</td>
</tr>
<tr>
<td>(In-Storage)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warehouse II</td>
<td>114 sq.m.</td>
<td>200 sq.m.</td>
</tr>
<tr>
<td>(Finished Storage)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packaging</td>
<td>30 sq.m.</td>
<td>placed in production area</td>
</tr>
<tr>
<td>Office</td>
<td>12 sq.m.</td>
<td>20 sq.m.</td>
</tr>
<tr>
<td>Laboratory room</td>
<td>8 sq.m.</td>
<td>8 sq.m.</td>
</tr>
<tr>
<td>Other (parking lot)</td>
<td>1000 sq.m.</td>
<td></td>
</tr>
</tbody>
</table>

Note: This information of space requirements for improving layout comes from the department of management of the company and the space requirements is matching with the improving layout that required adding automatic machine-in-line of rinsing, filling, capping, and packaging.

So, the master plan is suitable for this study, and the master plan will be used for the future planning. The areas that must be changed for the future planning is the rinsing,
filling, capping, and packaging areas because of adding more than one automatic machines-in-line for the year 2003 up to 2007, the storage area is enough because the In-Storage area now can store up to 6000 dozens per day and the Finished Storage can store up to 3000 dozens per day. So, the Finished storage must be adapted to 200 sq.m. in order to store enough, this information comes from analysis of the management department.

The above information is used for the short range planning (1-3 years), the sales department plans to 15% up market per year since 2000.

Table 4.5. The Capacity Requirement in the Future.

<table>
<thead>
<tr>
<th>Year</th>
<th>The capacity requirement (dozens per day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>500</td>
</tr>
<tr>
<td>1999</td>
<td>1000</td>
</tr>
<tr>
<td>2000</td>
<td>1100</td>
</tr>
<tr>
<td>2001</td>
<td>1265</td>
</tr>
<tr>
<td>2002</td>
<td>1454</td>
</tr>
<tr>
<td>2003</td>
<td>1672</td>
</tr>
<tr>
<td>2004</td>
<td>1922</td>
</tr>
<tr>
<td>2005</td>
<td>2210</td>
</tr>
<tr>
<td>2006</td>
<td>2541</td>
</tr>
<tr>
<td>2007</td>
<td>2922</td>
</tr>
</tbody>
</table>
For the future long range forecasts, the especially important changing is the areas of automatic adding machine of rinsing, filling, capping, packaging and the finished storage areas.

Table 4.2 shows the space requirements for the short-range that be translated into the Figure 4.8, the activities area & feature sheet that will be used for diagram activity relationships. In this step is to relate the various activities to each other visually and geographically to form the basic pattern for improving layout. Note that the area is expected for the long range also in order to reserve the products storing (Appendix IV).

The diagram developed from the relationship chart 1-3 is shown in the following diagram in the next page, there are three 'As', four 'Es', two 'Is', and two 'Os'.

Since plant layout is essentially the allocation of space to various activities, space requirements are closely interwoven with many of the stages of layout planning. Space requirements can be determined in five ways: calculating, converting, space standards, roughed-out layout, and ratio trend and projection.

For this project study, the roughed-out layout is determined because the calculating or converting is impractical, and no standards are available. The scale plan of this project area is available and the templates or models of the machine involved are already in hand, and particularly certain activities are critical or represent very high investment. So, this study is advisable to rough-out layouts of certain areas and use them for space requirements.

This method of space determination is expected to be used for critical areas of high investment (the production area). Everyone should understand that this rough-out layout is not the layout which will eventually be selected. In fact, the eventual shape of the area may be quite unlike the rough-out version. However, this technique is adequate for establishing the space requirements for use in planning phase II, general overall layout.
The following sale forecast received from sales department of the manufacturer as follows:

<table>
<thead>
<tr>
<th>Month, Year</th>
<th>Market Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>October, 1998</td>
<td>40,000 liters</td>
</tr>
<tr>
<td>November, 1998</td>
<td>40,000 liters</td>
</tr>
<tr>
<td>December, 1998</td>
<td>80,000 liters</td>
</tr>
<tr>
<td>January, 1999</td>
<td>70,000 liters</td>
</tr>
<tr>
<td>February, 1999</td>
<td>60,000 liters</td>
</tr>
<tr>
<td>March, 1999</td>
<td>80,000 liters</td>
</tr>
<tr>
<td>April, 1999</td>
<td>100,000 liters</td>
</tr>
<tr>
<td>May, 1999</td>
<td>120,000 liters</td>
</tr>
<tr>
<td>June, 1999</td>
<td>140,000 liters</td>
</tr>
<tr>
<td>July, 1999</td>
<td>150,000 liters</td>
</tr>
<tr>
<td>August, 1999</td>
<td>150,000 liters</td>
</tr>
<tr>
<td>September, 1999</td>
<td>180,000 liters</td>
</tr>
<tr>
<td>October, 1999</td>
<td>180,000 liters</td>
</tr>
<tr>
<td>November, 1999</td>
<td>180,000 liters</td>
</tr>
<tr>
<td>December, 1999</td>
<td>200,000 liters</td>
</tr>
</tbody>
</table>

The year 2000 is expected to be 200,000 liters monthly because there are contact with the customer's head company.

The year 2001 is expected to be 220,000 liters monthly because the manufacturer plans to market at suburban.

The year 2002 is expected to be 250,000 liters monthly because 10% up for the expected customers.

The next 7 years is expected to be 15% up in the market.
The data shows that the demand is increasing while the capacity of the existing is not enough, so adding the automatic machine-in-line for the future and rearrange the areas is required.

<table>
<thead>
<tr>
<th>Year</th>
<th>Capacity required</th>
<th>Machine required</th>
<th>P-area required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>500</td>
<td>semi-auto</td>
<td>100</td>
</tr>
<tr>
<td>1999-2001</td>
<td>1000-1265</td>
<td>semi-auto</td>
<td>152-300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>fully automatic machine(52)</td>
<td></td>
</tr>
<tr>
<td>2002-2007</td>
<td>1454-2922</td>
<td>semi-auto</td>
<td>250-300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 fully auto-machines</td>
<td></td>
</tr>
</tbody>
</table>

The above is the information about the machines-in-line's requirement in which match with the capacity requirement of the drinking manufacturer.

While moving the set of filtering machine is difficult and not safe, and the existing production area have enough area for adding the new set of automatic machine-in line. So, bottom-left side of the production area of workshop can be used to accommodate the machines that are necessary for filtering the water, and the upper production area of workshop is determined to be used for the automatic-machine in line (rinsing, filling, capping, packaging) machines.
Figure 4.12. The Activities Areas and Feature Sheet.
4.5 Diagram Activities Relationship

This step relates to form the basic pattern of drinking water manufacturer by using a symbol to represent an activity and a line code to show closeness rating.

No.1, '3 A'

No.2, add '4 E'

No.3, add 2 'T' and No.4, add 2 '0'

Figure 4.13. The Diagram Activities Relationship.
Figure 4.14. The Alternative I of Modify Plant Layout Diagram.
Figure 4.15. The Alternative II of Modify Plant Layout Diagram.
Figure 4.16. The Alternative III of Modify Plant Layout Diagram.
Figure 4.17. The Alternative IV of Modify Plant Layout Diagram.
Figure 4.18. The Alternative I Drawing of Modify Plant Layout Diagram.
Figure 4.19. Adjustment of Drawing Alternative I for Modifying the Plant Layout.
Figure 4.20. The Alternative II Drawing of Modifying Plant Layout Diagram.
Figure 4.21. Adjustment of Drawing Alternative II for Modifying the Plant Layout.
Figure 4.22. The Alternative III Drawing of Modifying Plant Diagram.
Figure 4.23. Adjustment of Drawing Alternative III for Modifying the Plant Layout.
Figure 4.24. The Alternative IV Drawing of Modify Plant Layout Diagram.
Figure 4.25. Adjustment of Drawing Alternative W for Modifying the Plant Layout.
In this study, from asking the top management for the more space requirement in order to take place for adding automatic machines and rearranging the plant layout, the data of automatic machine is as previous information. The top management decides to retain the semi-automatic filling and manual rinsing machines because it will still be used in case some problems occur with the automatic machines.

So, the study will determine the improvement layout of adding automatic machines for increasing the output and rearranging the existing layout while the existing semi-automatic machines will still be placed and be used as reserving machine in case emergency problems occur with the automatic machine-in-line.
V. IMPROVED PLANT LAYOUTS EVALUATION

In this part of the study, an evaluation of the different versions of the improved plant layout and new plant layout is carried out. These are evaluated by Weighted Factor Analysis. By using the Weight Factor Analysis, evaluation is done by generating a score and comparing it with the desired relationship chart.

5.1 Identification of Problems in the Existing Plant

In majority of this study applications, the problem of layout is more frequently associated with the relocation of an existing layout in order to add the new machines for increasing capacity and an alternation in the arrangement of layout.

At present, issues of production process and capacity as affected by layout have been identified. Data collection shows that the increasing demand is increasing 10% in three years and 15% in the next seven years. So the floor space in the workshop is not enough for adding the automatic machines in-line and the existing layout is inconvenient for material flows, which is very complex and not smooth. This is responsible for high material handling cost.

5.2 Material Movement Problem

The existing layout reveals that the raw bottles are moved into the production area that produce the drinking water in the PET bottles then moved into the packaging areas which is too far and heavy to carry out because the processing machines are placed in the left and the packaging area is at the other side. It makes the material movement rather complex and not smooth. So, it results into increasing material handling cost. Therefore, improving a plant layout should consider the material flow and the adding automatic machines in the future in order to reserves the increasing demand in the future so as to arrange the machines of same process reasonably close to each other that leads
to considering closeness between the machines in a process with constraint material flow.

5.3 Space Utilization Problem

Space utilization is one of the important problems to be addressed during the plant layout. This may create many problems especially related to material handling movement and lead to complex routing. Moreover, using the space effectively will increase the plant capacity by adding machines to expand production of workshop, and reduce average cost per part that leads the profits to increase.

5.4 The Improved Plant Layout

The improvement in the existing plant layout may involve either cost of reconstruction or re-investment. The improvement plant layout shows that the machines should be sequencing in line (product layout) because of high quantity with the few product items.

5.5 Evaluate Alternative Arrangements

As stated the previous chapter there are four alternatives plan to select the most suitable for C.S. (Drinking water plant). From interviewing with the president of the C.S. company, there are 6 factors or objectives affecting the choice of the best alternative to ease of future expansion, flow of materials effectiveness, ease of control and supervision, space utilization, working condition & employee satisfaction, and least investment (Appendix D).

The factor of flow of materials effectiveness is weighted to 10 because the visions of the president and the objectives of the company is important in materials movement that is convenient for control and supervision in which the space can be easily arranged for expansion in the future. These alternatives are chosen in order to be the master plan
for the long-run planning because it means over-building originally in order to avoid the high capital investment.

The following evaluate alternatives are created in the following form that indicates the objectives and weight values are determined.

Evaluating alternatives are at the following page: The evaluating alternative form that determines the four alternatives in order to take the final alternative that is suitable to be the master plan.
Figure 4.26. Determining the Evaluating of Four Alternatives.
The evaluation of alternative plant layouts of this study is an explicit measure of the extent to which the layout is achieving its goal that is essential to proper layout evaluation. In this case the material movements is the primary problem in establishing the improving of the plant layout. The distance moved by a product could perhaps be considered a proper measure of effectiveness.

The factor analysis technique is merely a ranking procedure with the various considerations weighted according to their importance. So the alternatives I is the best because of its highest total scores of 180. Moreover, the packaging area is combined into the production area so there are increasing areas in the finished storage.

For the future expansion factor, the alternative I can expand the In-storage, Production area, and Finished storage in the front side; while alternative II can expand the In-storage, Finished storage in the front side also but the alternative I is convenient for the products movement from the production areas into the Finished storage because of its shortest distance. For alternative III and IV, it can expand in the right side for alternative IV that is not suitable and the alternative III can expand in front of the In-storage and Finished storage areas.

The flow of materials is almost perfect for alternative I and good for alternative IV because of its smooth flow of materials. The alternative II is important results while alternative III is unimportant results because these are longer distance for movement of the heavy products from the production area into the Finished storage.

The alternative I and IV are almost perfect for control and supervision because the finished products is easy for control by the office personnel while the alternative II is only important because the point of shipping the finished products is far and the alternative III is not suitable because the personnel is hard to control and supervision of
both the In-storage and Finished storage in shipping because they are placed in the opposite side.

For the space utilization, they are equally perfect for alternative I, II, and IV and is especially good for alternative III because of using equal areas.

As seen the workers are satisfied with alternative I because all department areas is suitable and convenient for moving the products in the shorter distance.

For the cost investment is also important, but all the alternative layouts is using close investment for improving layout but the alternative I is least investment because of the production areas still placed in the left at the back side.

The alternative I is the best alternative for the C.S (drinking water plant) for improving the layout in the future then it is suitable to be the master plan of C.S in the future.

So, the alternative plan that used to be the master plan of this study should be the alternative I. The master plan (diagram AA) will be used to guide for planning the next 7 years.
Figure 4.27. The Master Plan AA from the Evaluation Alternatives.
The closeness between departments depends on frequency of from-to each other and depends on succession of materials in the same material flow.

Employing the results of AutoCAD program (Appendix E), the plant manager can recommend an increase in the number of machines, to enhance the capacity of production.
VI. CONCLUSIONS AND RECOMMENDATIONS

This research deals with the improved plant layout to enhance capacity requirement of drinking water manufacturer. The study provides a qualitative viewpoint of the entire subject of plant layout. Even though, the demand is expected to increase, the overall plant layout needs to be rearranged. The layout determines the location for adding automatic machines-in-line and developing the layout for improved plant layout. This study presents an approach that is often used in solving plant layout problems (Systematic Layout Planning developed by Richard Muther) and drawing by AutoCAD.

Furthermore, the significant increase in the demand for the product and the layout problems occur with the bottlenecks in the existing production, unexplainable delays and idle time, obstacle to materials flow effect on the overall effectiveness of the production system. Therefore, it is highly desirable that the optimum plant layout be designed. The SLP approach takes into solving the plant layout problems of this study in order to find a satisfactory solution. In searching for a plant layout design that satisfies in this project agrees on the basis for evaluating alternative designs. The objectives used for emphasizing the layout alternatives are to utilize existing space most effectively; provide employee convenience, safety, and comfort; maintain flexibility of arrangement and operation; ease of future expansion; ease of control and supervision.

The operation process chart of drinking water manufacturer is the model of the operations and inspections involved in producing the product. The flow lines connect the various operations, inspection and the operation process chart in this study is the primary basis for the layout.

The drinking water manufacturer produces the drinking water in PET bottle for the large quantity (there are only 5 sizes in which the automatic machine-in-line can apply every size) and the production process is not complex. So, this study is examined to be
the product layout that refers to the production-line layout and results when machines and auxiliary services are related according to the processing sequence for the product.

From the alternatives result from SLP approach, the problems are deleted. These require one of the four alternatives to be the master plan (diagram AA) for the future expansion. This does not mean that the remaining alternatives are not good but the diagram I is the best suitable for this study (diagram I is used to be the diagram AA for the long range expansion).

In this research, the objective is to improve plant layout of the drinking manufacturer in order to reach the capacity requirements. The simplest way to evaluate alternatives involving several considerations is by a listing of advantages and disadvantages of each alternative. By evaluating the advantage of each alternative using a 4 (or A = Almost perfect), 3 (or E = Especially good), 2 (or I = Important results), 1 (or O = Ordinary results), and 0 (or Unimportant results) will receive the scores when a value opposite each advantage is set down. Besides, this explains the reason for the value explained in the previous chapter and choose the highest scores (Alternative I) to be a conclusive decision because it is better.

The results from the improvement keeps the new imperative. A new layout (Diagram AA) is proposed for the future expansion. The machines that can be added into the new layout are in the dotted line drawn by using the AutoCAD program.

Analyzing the existing layout, the improved layout, and the new layout reveals that the managers of enterprise should consider the possibility of utilizing all vacant floor space of the workshop to increase its capacity. This will be done by using the AutoCAD program, the users can add, remove, or modify the drawing. For increasing the capacity, the automatic machine-in line should be added. Therefore, the plant layout (including the
production area, in-storage area, finished storage area, office, lab) should be rearranged or redesigned.

The managers of enterprise also should plan to increase the production capacity for the sub-products except the major products under this study, by utilizing the vacant floor space effectively and modifying the drawing by using AutoCAD program.
LINE BALANCING

An assembly line consists of numerous workstations. The number of work elements (tasks) assigned to a workstation is adjusted so that it takes the same amount of time to complete the work at each station. As the work is completed on a product at one station, it is passed on to the next station for further processing. The cycle time is the time the product is at each workstation. Balance refers to the equality of output of each successive workstation on the assembly line.

To comprehend line balancing, the following terms must be understood:

Workstation: A unit of work that cannot be divided between two or more operators without conflict between them.

Operation: A set of work elements assigned to a single workstation.

Workstation: An area alongside the assembly line where given tasks (an operation) are performed.

Cycle time: The time the product is at each workstation.

Balance delay: The total idle time in the line as a result of unequal division of work between workstations.

Line balancing is combining work elements into workstations so that the amount of idle time is minimal for the entire line. The line balancing problem is complicated by technological precedence requirements on work sequences.

The trial and error technique simply adds work elements to stations so as not to violate the cycle time.
APPENDIX B

COMBINING FLOW AND OTHER-THAN-FLOW RELATIONSHIP
COMBINING FLOW AND OTHER-THAN-FLOW RELATIONSHIP

Flow of materials is usually not the only reason for closeness ratings. In most industrial plants, relationships among activity-areas involve both flow of materials and service (or other-than-flow) requirements. These two types of relationships must be combined in a meaningful way to determine the resultant combined relationships.

Combining flow and other-than-flow relationships involves joining Box 1 and Box 2 of the SLP Pattern of Procedures. In probably 60 to 70 percent of all layout planning projects, such combining is necessary. That is, in perhaps 15 to 20 percent of the projects, flow of materials so dominates the conditions that the planner can go directly from Box 1 to his diagram in Box 3; and in another 15 to 20 percent of all projects, there is no significant flow of materials involved so the planner can proceed from his other-than-flow relationships (Box 2) directly to his diagram.

When combining the two, use the following general procedure:

1. Develop the planned intensity of flow over each route — between each pair of activity areas. List pairs in the order of increasing identification number and keep the lower activity-number at left.

2. Calibrate or convert the flow intensities between each activity pair into the appropriate vowel-letter rating.

3. Determine the other-than-flow relationships between the same activity pairs; most frequently they are documented on a relationship chart.

4. Determine the relative importance of flow and other-than-flow relationships. Usually the layout planner discusses this with others immediately involved in the operations. Combine the flow and other-than-flow relationship ratings into a resultant relationship.
(5) Use the resultant combined relationship as a basis for making the relationship diagram (combining flow and other-than-flow relationship diagram) — Box 3.

Figure 1. shows the procedure of combining using numerical values for the vowel-letter ratings and re-calibrating the resultant, combined relationships by ranking, plotting, and dividing the total combined values.

Figure 2 uses the same data to show the procedure of combining by following the matrix method of making the same combined relationship ratings.

Figure 3 provides a series of preprinted matrix tables for ready use when different ratios of relative importance of flow and other-than-flow are involved. Note that it is usually not practical to spread the relative-importance ratio between flow and other-than-flow more than 3:1 or 1:3.

Figure 4 shows a working form that is practical to use on major projects. On this work sheet, the planner can summarize the flow (in columns b through f); record the other-than-flow ratings, who says so, and why (in columns g through 1 and in the coded reason block at right); enter the resultant combined relationships (in subdivisions of column m); and account for the number of occurrences of each vowel-letter rating. The combined resultant relationships are then posted to a 'combined' relationship chart, which, when colored, is a ready basis for preparing the relationship diagram.

It is possible to prepare the relationship diagram directly from the combining flow-and-service-relationships worksheet (Figure 4). However, it is awkward and less reliable to do so (even though coloring the vowel-letter entries in column m) because all potential relationships are not automatically accounted for since the pairs of activities on each line are usually not listed in numerical sequence (in as much as flow is usually entered first and other-than-flow relationships entered later). Also the planner must
repeatedly shuffle through several worksheets since the postings are spread out. It is usually best, therefore, to re-post the resultant combined ratings on a combined relationship chart, before making the relationship diagram.

There is at least one other method of arriving at a resultant relationship between activities for flow and other-than-flow reasons. It involves rating for other-than-flow reasons using the flow relationships as a basis for comparison and then taking the more demanding of the flow and other-than-flow closeness ratings for each pair of activities. This procedure assumes that honoring the dominating relationship more than satisfies the requirements of the lesser one.

The specific steps in this method are:

2. Establish several typical benchmark pairs of activities for each of the vowel-letter flow ratings: A, E, I, 0 and U.
3. Rate all pairs of activities for other-than-flow reasons using the flow benchmarks as a direct comparative guide.
4. Select the dominant rating between the flow and other-than-flow relationships for each pair of activities.
Figure B.1. Combining by Re-Calibrating Numeric Values.

Figure B.2. Combining by Using Matrix of Values.
Figure B.3. Preprinted Matrix Tables for Different Ratios.
Figure B.4. Worksheet for Combining Relationship.
APPENDIX C

PEOPLE’S BEHAVIOR WITH THE BOTTLED WATER
ขออภัยด้วย ข้อมูลในภาพไม่ชัดเจน ไม่สามารถอ่านเนื้อหาได้
ใช้จ่าย 76-100 บาทตั้งเป็นร้อยละ 12.0 และคำใช้จ่าย 51-75 บาท ตั้งเป็นร้อยละ 11.0 สำหรับปัญญาที่สมุทรปราการ จากการซื้อสิ่งมิตรรัฐจากส่วนใหญ่คือมีเกินตั้งเป็นร้อยละ 35.0 รองลงมาคือจากไม่สะอาดคิดเป็นร้อยละ 32.4 และน้ำไม่สะอาดคิดเป็นร้อยละ 21.9

ส่วนมูลค่าสิ่งของซื้อเพิ่มเติมคือตั้งบางบนสมุทรปราการตั้งเป็นร้อยละ 5.9 ส่วนใหญ่จะอยู่ในที่นั่นๆคาดคิดเป็นสิ่งมีค่าร้อยละ 42.0 รองลงมาคือสิ่งมีค่าที่ยอมรับร้อยละ 39.1 ราคาไม่สูงสุดไปถึงร้อยละ 8.8 และมีคุณค่าซื้อเสียร้อยละ 6.7

เมื่อวันที่ 14 ตุลาคม ได้รับความนิยมของโลกในจังหวัดพระบาง ไทยชื่นว่าเป็นที่สะอาด และเมื่อจากผู้ประกอบการที่มีเป็นจ้างที่มีสิ่งมีค่ามีค่าสูงสุดได้รับ และไม่ค้ำด้วย ตั้งที่แต่คาดมีมุมโดยการใช้จ่ายจากประชาชนและกิจการปัญญาที่ดีที่บริจาคของผู้มี ซึ่งที่ผ่านมาได้ทำการตรวจพบว่ามี การบริจาคของผู้มีที่ดีที่บริจาคของผู้มีที่ดีที่บริจาคของผู้มีที่ดีที่บริจาคของผู้มี ซึ่งที่ผ่านมาได้ทำการตรวจพบว่ามี การบริจาคของผู้มีที่ดีที่บริจาคของผู้มีที่ดีที่บริจาคของผู้มีที่ดีที่บริจาคของผู้มี

ในขณะเดียวกันปัญญาที่จังหวัดพระบาง ที่มีการจ้างค้านั้น จะมีการที่จะส่งผลให้ประชาชนต้องได้รับผล กระทบ ต้องไม่ใช้งานผ่าน campaña วิธีการเพื่อให้ประชาชนต้องได้รับผล ผลกระทบ ต้องไม่ใช้งานผ่านキャンペーンวิธีการเพื่อให้ประชาชนต้องได้รับผล ผลกระทบ ต้องไม่ใช้งานผ่านキャンペーンวิธีการเพื่อให้ประชาชนต้องได้รับผล ผลกระทบ ต้องไม่ใช้งานผ่านキャンペーンวิธีการเพื่อให้ประชาชนต้องได้รับผล ผลกระทบ ต้องไม่ใช้งานผ่านキャンペ

นี้ที่มีการจ้างค้านั้นเป็นธุรกิจที่มีแนวโน้มมาติดต่อเพิ่มขึ้นตามมาตรการธุรกิจที่ดีที่ได้ แต่สิ่งหนึ่งที่ผู้ประกอบการไม่ค่อยยอมรับคือ กรณีเช่นที่จะมาจากที่มีการจ้างนายจ้าง นั้น  โดยเฉพาะผู้ประกอบการที่ต้องในทาง จังหวัด ซึ่งสำหรับผู้เป็นผู้ประกอบการเองที่อาจจะมีการจ้างนายจ้างจากผู้ประกอบการรายใหญ่จากสวัสดิการ ซึ่งมีข้อได้เปรียบทางด้านการจ้างนายจ้างที่จะทำให้รวมถึงทางพานของสิ่งที่มีข้อเสียเป็นปัญจีในการจ้างนายจ้าง มาพากล แม่นยำที่ผู้ประกอบการที่ต้องรับมือการจ้างนายจ้างโดยสารพานคุณภาพของงานช่างค่าที่เป็นที่ยอมรับ รวมทั้งผลดีทางการผลิตงานมาก ประสิทธิภาพคือ การใช้จ่ายได้ประโยชน์ส่วนด้านที่เกี่ยวข้องอย่างวัสดุหลักจากกลุ่ม ที่มีการจ้างนายจ้างที่มีการจ้างนายจ้างได้เป็นไปตามที่คัดภายในระยะเวลาที่จะรุกข้ามในระยะต่อไป

80
APPENDIX D

FACTORS IN SELECTING THE BEST LAYOUT
FACTORS IN SELECTING THE LAYOUT

When evaluating alternative layouts there are many factors which can affect the selection of the most suitable plan. The factors most frequently identified are listed below. A definition of each is also given. These factors, definitions, and key points—in a consolidated form or together with others that may be added as appropriate for a particular company or project—can be extremely helpful in keeping a clear understanding and meaning for each factor during the process of evaluation.

1. Ease of future expansion. (The simplicity of increasing the space employed)
   (1) Tie-in with long-range potential use of the space with the future plans for building or property development and with the basic overall allocation of space and with the overall flow pattern(s).
   (2) Ability to spread out to adjacent areas—beside, above, below, to encroach on readily moved storage or service areas, or to add vertical storage equipment, balconies, mezzanines.
   (3) Freedom from fixed or permanent building features, from divided or honeycombed areas, and from space blocked-in by physically long equipment, property lines, natural obstructions or limitations, and the like.
   (4) Regularity of allocated space amounts in terms of readily exchangeable amounts and types of areas, modular units of layout space, multiple unit areas.
   (5) The amount of disruption or rearrangement of areas other than the one(s) specifically being expanded.
   (6) Shrinkability—ease of contracting the layout economically, to cut down the size
2. Flexibility of layout. (The ease of physically rearranging the layout to accommodate changes.)

(1) Mobility of machinery and equipment.

(2) Relative size and fixity of equipment.

(3) Standardization of equipment, containers, work places.

(4) Freedom from fixed building features or walls, unmatching floor levels, other barriers.

(5) Overly dense saturation of space.

(6) Independence or self-sufficiency of facilities (not dependent on central coordination or centralized service tie-in).

(7) Ready accessibility of service lines, piping, power distribution, heating and ventilating, service holes, etc.

(8) Access to the area laid out at more than one point or side.

3. Flow of movement effectiveness. (The effectiveness of sequenced working operations or steps — without unnecessary back-tracking, cross flow, transfers, long hauls — of materials, paper work, or people.)

(1) Greatest flow intensities with minimum distances.

(2) Basic regularity or consistency of flow pattern(s).

(3) Proximity of related areas to each other where movement of material, people, or major paper work is involved, or where frequent, urgent or significant personal contact takes place.

(4) Access to, away from, and between major areas (like receiving, shipping, key operating areas).

(5) Flow of auxiliary or service materials: supplies, tools, scrap or waste, and other service materials.
(6) Accessibility for delivery and pick-up, visitors, or employed non-company service personnel.

4. Materials handling effectiveness. (The ease or simplicity of the handling system, equipment, and containers to move materials into, through, and out of the areas laid out).

   (1) Ease of tie-in with external handling methods and equipment: rail line, docks, high-way, and other access ways.

   (2) Necessity for re-handling, extra handling, delays, awkward positioning, undue physical effort, undue dependence on frequency or urgency of moves, undue amount of jury-rig or non-integrated equipment.

   (3) Traffic congestion and interferences other than due to flow pattern.

   (4) Balanced variety of handling systems, equipment and containers.

   (5) High utilization of handling equipment and containers.

   (6) Simplicity of handling devices.

   (7) Equipment integrated for multiple use.

   (8) Avoidance of synchronizing two or more people at same time or place.

   (9) Ability to move completely around buildings on company property.

   (10) Take advantage of gravity.

   (11) Combined purposes of handling equipment for storing, pacing, sequencing, inspecting, work-holding, weighting and the like, as well as moving.

5. Space utilization. (The degree to which floor area and cubic space is put to use).

   (1) Conservation of floor space, property, or land-or most desirable portions thereof

   (2) Utilization of overhead space in terms of cubic density.
(3) Ability to share or exchange space among similar activities, and balancing of areas with seasonally complimentary space requirements. Effectiveness of aisle space to serve areas adjacent to them, to lead to areas needing access, to handle traffic without wasting space or without excessive aisle-ways. (too few, too many, too wide, too narrow, too cornered or crooked, too angular).

(4) Waste or idle space, caused by split, divided, cornered, scattered or otherwise honey combed structures, too-close columns, too-frequent partitions or walls.

(5) Less desirable or out-of-way space utilized for slow, dead areas; convenient space for fast, active areas.

6. Working conditions and employee satisfaction. (The extent to which the layout contributes to making the area(s) a pleasant place to work and free from inconveniences, awkwardness, or disruptions for employees).

(1) Effect of layout on attitude, performance, or general morale of employees.

(2) Working conditions suitable to the type of operation.

(3) Suitability of the layout's arrangement and allocated space to the personnel.

(4) Convenience for employee-access, distances, interruptions, delays, and adequacy and convenience of parking, lockers, rest rooms, food facilities, etc.

(5) Freedom from features causing workers to feel afraid, hemmed-in, embarrassed, discouraged, discriminated against.

(6) Noise, distractions, or undue heat, cold, drafts, dirt, glare, or vibrations.

(7) Utilization of employee know-how and skills

(8) Balanced man-power allocations.
7. Ease of supervision and control. (The ease or difficulty for supervisors and managers to direct and control the operations for which they are responsible).
   (1) Ability to see the area fully and easily.
   (2) Ability to get around the area conveniently.
   (3) Ease of controlling quality, quantity counts, schedules, inventories in process.
   (4) Ease of controlling waste time, lost materials, or supplies.
   (5) Ease of moving or reassigning personnel to other work.

8. Ability to meet capacity or requirements. (How well the layout actually meets the planned needs or output wanted from the installation).
   (1) The right products or materials, properly meeting specifications.
   (2) The right quantities of each variety or item in the operating time planned, without overtime or premium pay.
   (3) The right yield in terms of projected quantities and qualities of product.

9. Compatibility with long-range company plan. (The ability of the planned layout to fit with long-range growth projections and with long-range master site plan or total facilities development plan(s)).
   (1) Degree of tie-in with long-range projections of products and/or materials, sales or operating quantities, process sequence and equipment, services, working hours and operating times,
   (2) The ease of complete renovation, rehabilitation, modernization, or change in function.
   (3) Ease of integration with other buildings, plants, or sites of the organization.
   (4) Effect of the layout on the re-sale value of the property.
THE AUTOCAD INTERFACE

The graphics window is where AutoCAD displays your drawing and where you work on your drawing. The text window display a history of the commands and options you have entered.

The crosshairs are controlled by your pointing device (usually a mouse) and are used to locate points and select objects in your drawing. The status bar displays the coordinate location of your crosshairs and the current settings of grid, snap, and other drawing aids.

When you start the AutoCAD, it creates a new unnamed drawing for you. You can either start drawing objects in this blank drawing or open an existing drawing.

If you open an existing drawing, all of the command and system variable settings last used on that drawing are restored because this information is saved in the drawing file.

When you start a new drawing, there are a few settings you will want to establish to assist you during the drawing process. The Setup Wizard will assist you automatically, however, you can change these basic settings at any time.

1. Units determines the measuring units you will use to draw objects: feet and inches, millimeters, miles, furlongs, and so on.

2. Scale determine the size of a unit when plotted on paper. In AutoCAD, you draw everything full scale in the units you set up, so you don't have to worry about scale unit you are ready to plot your thawing.

3. To help you visualize units, you can display an array of dots, called a grid, on your screen. The grid helps you visualize the size of units on your screen if you increase or decrease the magnification (zoom in or out) of your drawing.
(4) Limits indicate to AutoCAD where in the drawing area’s infinite space you intend to draw. AutoCAD displays the grid only within these limits also control some viewing options.

(5) Snap enables you to locate and position points exactly on the grid or some subdivision of it. For example, you could display a grid with intervals of 4 millimeters but have points snap to exactly 1 millimeter, thus making it easier and faster to draw objects accurately.

Once you have established these basic settings, you may want to use them for subsequent new drawings. You can do this by saving the drawing as a template drawing. A template drawing is typically a black drawing with preset settings that you use to start a new drawing.
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