DESIGN OF LAYOUT REARRANGEMENT OF

ENTERPRISE LOGISTICS

BASED ON THE COMBINATION OF SLP AND SHA

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Bachelor's Thesis

May 2010

Degree Programme in Logistics Engineering

Technology, communication and transport

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DESCRIPTION

Author(s) Mingmei Li	Type of publication Bachelor´s Thesis	Date 01.06.2010
	Pages 46+4	Language English
	Confidential ( ) Until	Permission for web publication (X)

Title DESIGN OF LAYOUT REARRANGEMENT OF ENTERPRISE LOGISTICS BASED ON THE COMBINATION OF SLP AND SHA
Degree Programme Degree Programme in Logistics Engineering
Tutor(s) Mr. Seppo Pietiläinen
Assigned by

Abstract

Material handling and the facility layout problems are interrelated and limited to each other. A good facility layout should provide a reasonable and sufficient space for material handling activities. In other words, a good facility layout design results in the lowest costs in material handling, the shortest distances in staff transportation and the highest efficiency in the whole process.

The objective of the bachelor's thesis was to define the layout problems in the manufacturing industrial enterprises, analyze and evaluate the solution options and select the optimal one. The thesis presented a systematic layout planning method to analyze the layout problems and a system handling analysis method to evaluate the material handling process. As a result of adopting the combination of these two methods, the facility layout rearrangement design was expected to be optimized so that the whole logistics process would be more efficient.

The aim of the thesis was to achieve the lowest handling amount by analyzing the production procedures and logistics status to rearrange and reassess the department layout and logistics system. The idea was rather theoretical but it was feasible in the practical environment when every related factor could be comprehensively taken into account. The thesis demonstrated that the workshop attains smooth logistics, the transportation routes and the production periods shorten and the factor costs decline.

With the help of the bachelor's thesis, the enterprises can obtain an integrated analysis solution for the facility layout rearrangement to fulfill the development plan.

Keywords

Systematic Layout Planning (SLP), System Handling Analysis (SHA), workshop layout rearrangement, logistics systems analysis

Miscellaneous

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ABBREVIATIONS AND DEFINITIONS

SLP	Systematic Layout Planning
SHA	System Handling Analysis
I/O	Input/Output
REL chart	Relationship chart
CNC	Computer Number Control
ASME	The American Society of Mechanical Engineers
CRAFT	Computerized Relative Allocation of Facilities Technique
NP – PROBLEM	A problem is assigned to the NP (nondeterministic polynomial time) class if it is solvable in polynomial time by a nondeterministic Turing machine.

1. INTRODUCTION

1.1. Background

The main research of facility layout involves solving all the possible problems which may appear in different situation in the enterprises during the production process. It also provides some helpful technical methods and guidelines for the layout. Facility layout problems could appear not only regarding tangible products or services but also intangible products or service systems. For example, restaurants, hotels and shopping malls are facing this kind of problems as well.

A good facility layout design can provide the lowest cost for material handling, the shortest distance for staff transportation, and the highest efficiency for the whole work. Normally, the cost of material handling and transportation makes up 20% to 50% of the total manufacturing costs. Simultaneously, most of the work related injures happen during the material handling process. According to some reports, in a medium scale workshop, the time the component on the machines only takes 5% of the total producing time. The other 95% of the time is consumed by the handling and waiting of raw materials, tools and components. Consequently, the goals of a suitable facility layout design are:

1. Satisfy the requirements of the polytechnic process
2. Utilize the space most efficiently
3. Minimize the material handling cost
4. Maintain the flexibility of production and arrangement
5. Adapt the organizational optimization and convenience of management
6. Provide a convenient, safe and comfortable working environment for the staff.

However, these goals are in contradiction sometimes. For example, it is easy to achieve the fifth goal which is shown above if we make similar work units in one area. But this design way may increase the amount of logistics. Similarly, if we meet the requirement of minimizing the transportation and material handling, we may go against the goal of maintaining the flexible arrangement. Therefore, none of these goals can be achieved unilaterally without each other. There is no perfect method to solve all the problems even though the facility layout planning is becoming more and more scientific. Just like there is no super medicine which affects all kinds of diseases. Facility layout is a scientific art.

> *Layout can be considered as a design problem. Seen from this angle, solving the problem involves not only collecting the quantitative information, but also qualitative information, for instance, how different departments are related from the point of view of adjacency.* (Gómez, 2003)

In 1961, Richard Muther presented a method called systematic layout planning (SLP). The method has been widely applied since then. He proposed a representation for the intensive work unit operations. This conception developed the layout design from qualitative phase to quantitative phase. Furthermore, Russell D. Meller and Kai-Yin Gau proposed a flow chart method of planar facility layout. Gómez gave a creative idea which introduced the genetic algorithms into the calculation of quantitative facility layout. In China, there were some researchers such as Wangsheng Liu and Kechang Ju did the experiments and expansions in some Chinese processing enterprises based on the above ideas. Contrary to the limitation of the SLP method, some other researchers made corresponding improvements for the dynamic aspects. But it was not comprehensive.

1.2. Aim of the Thesis

To adapt the production conversion from large-scale but less varieties mode to the small-scale but more varieties mode or mass customization mode, the manufacturing enterprises should make a transition for the focal point of competition from price to customer oriented quick response and supplying. Thus the enterprises need to evaluate the work content quantitatively based on the empirical work, and gradually deepen the quantitative elements. So the optimal plant layout design can be ensured.

This thesis is based on this purpose. For a manufacturing target, firstly the purpose was to make the qualitative layout design according to the SLP method based on the logistics system analysis principles. The second purpose was to make the quantitative assessment according to the SHA method. Finally choose the optimal solution. The aim of this thesis was to make a useful exploration for the research of technology improvement.

1.3. Initial Situation

Nowadays, more and more manufacturing enterprises are facing the problem that the factory volume and development cannot keep pace with the demand. No competitor is willing to miss the expansion opportunity. Therefore, definitely, the production in the factory will be increased dramatically. This means the material handling will become harder. The original design of the workshop layout will not be satisfactory. Certainly, inappropriate rearrangement or redesign will cause even worse problems, such as mass overproduction, waste of related materials and human resources, capital loss and efficiency reduction.

Consequently, to maximally avoid the problems which were mentioned above, a scientific, specific and suitable rearrangement plan is needed urgently.

1.4. Structure of the Bachelor’s Thesis

The bachelor’s thesis is divided into eight different main chapters:

- The first part is an introduction of the historical background of the development of facility layout in manufacturing industries and a synopsis about the thesis
- The second part is the introduction and analysis of all the theories, especially the SLP method and the SHA method
- The third part is a case analysis including the current situation and problems identification
- The fourth part is finding the possible alternative solutions
- The fifth part is the assessment process for choosing the optimal solution
- The sixth part goes through the possible directions or contents for the future development and improvement
- The seventh part is a short paragraph of the conclusion and assessment for the research result
- The last part is the final conclusion of the whole thesis.

At the end of the thesis, a list of references can be found. These eight main chapters are not isolated. They are inseparably connected to one another and gradually go deeper from the theoretical support to practical analysis. There will be a lot of diagrams, tables and figures to assist to clarity represent the ideas of this thesis.

2. THEORETICAL ANALYSIS

2.1. The Analysis of the SLP Method

SLP is an acronym of Systematic Layout Planning which is a technique established by Richard Muther. (Muther, 1961) It is a step-by-step planning procedure allowing users to identify, visualize, and rate the various activities, relationships, and alternatives involved in a layout project. The three fundamental areas of the technique are relationships, space and adjustment. The sub-contents of the relationship area are collection of input data, flow of materials, activity of relationships and relationship diagrams. The sub-contents of the space area are space requirements, space available and space relationship diagrams. The sub-contents of adjustment area are modifying considerations, practical limitations and evaluation and final selection. This technique combines quantitative measurement of materials movement with non-flow considerations such as noise, fumes, temperature, supervision, communications, personnel comfort and movement. Its major advantage is that it clearly documents the logic of the layout and easily allows input from all levels of staff.

2.1.1. Five Important Elements

The basis and entry points for the research of plant layout problems can be generalized into five important elements according to the SLP method. These five elements are the “key” to the solution. They are:

1. P-product

   The product element includes the end product, raw materials, machining components and projects of the service. All the information is provided by the production guideline and design menu. This element is the key factor affects the composition and relationship of all the facilities, equipment categories and material handling way.

2. Q-quantity

   The quantity element indicates the amount of production, supply, utilization or service workload. All the information is provided by production statistics and design menu, and represented by piece, weight, volume and price. This element affects the layout scale, equipment amount, handling workload and construction area.

3. R-route

   In fact, the route element is the achievement of technological process design. It can be represented by plant layout diagram, process route diagram, process flow chart and so on. It affects the relationship among every work unit, material handling route and warehouse and store location.

4. S-supporting service

   The service element indicates public and ancillary service which includes tools, maintenance, propulsion, deliveries, and certain railway lines, health stations, changing rooms, canteens and toilets. This kind of element is provided by professional designers from each specific field. The service department supports the production system and somehow reinforces the production efficiency. The area of service department can be larger than the area of production department sometimes.

5. T-time

   The time element refers to when and how long the production is, in which includes the operating time of every procedure. According to the time requirement, we can estimate the amount of the equipment, required area and the number of staff.

Certainly, besides the above five elements, the other related ones are needed to be gathered to finish the final layout design as well. But P and Q are the basis for any other characteristics, conditions and elements. To get the most optimal system layout design, it is necessary to firstly make a structured and detailed analysis and calculation according to the comprehensive and accurate original data of these five elements. Then draw a variety of forms, mathematical and graphical models based on the calculation to present the core idea in an easy, obvious and clear way.

2.1.2. Stage Structure

The structure of the SLP method is divided into four stages which are shown in the following.

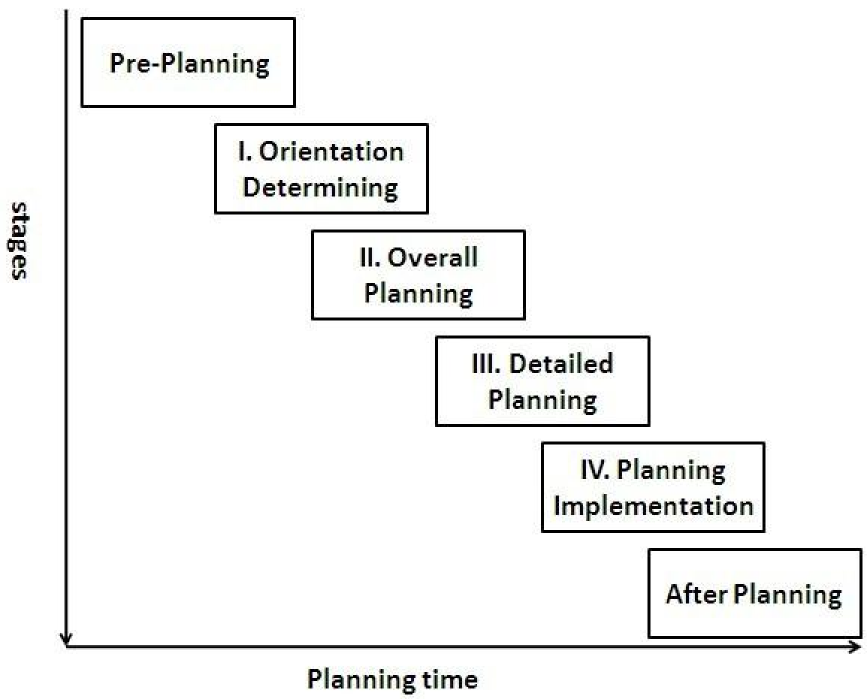


FIGURE 1: SLP stage structure (Adopted from Muther, 1961, SLP)

Stage I. Orientation determining

The aim of this stage is determining the initial orientation. No matter the overall layout of the whole factory and the layout of every workshop, the appropriate location is needed to be determined first. It is very important to find a correct and suitable location and contribution direction.

Stage II. Overall planning

After ensuring the circumscription, an overall layout should be planned in this area. The layout should be combined with the basic logistics models and zoning arrangement. To draw a preliminary zoning map, the shape of every operating unit is needed as very important data. It is necessary to know the relationship between every operating unit as well.

Stage III. Detailed Planning

This planning task should be very detailed for every workshop, work unit and equipment. To obtain the detailed layout, exact facility locations, aisle structures, input/output (I/O) point locations, and the layout with each department should be specified.

Stage IV. Planning implementation

As the name implies, the main job for this stage is making a construction plan, preparing for the construction, implementing the construction and installation.

In addition, the planning and design department should be responsible for stages II and III. There is crossover among the sequences of these four stages. For example, for the small scale factories which need only one or two workshops, it is feasible to implement the construction accompanies with the planning or modification. Sometimes this crossover can be even more economic and efficient. Anyway, the results of each stage should be approved by higher authorities. The sources and information needed for every stage will become deeper and more complicated along with the stage progress.

Furthermore, before stage I, there is a pre-planning period which is used to determine the objectives, forecast the requirements of facilities and estimate the production capacity and demand. After stage IV, there is the actual final stage which will present the test running of the whole layout after all the implementation. The main task during this period is making the conclusion and management summary for the construction, installation and commissioning of the whole project.

2.1.3. Procedures

The methodology is summarized in graph format in Figure 2 which is created originally from Richard Muther and simplified by the following researchers such as Gómez. The overall procedures are consisted by three parts which are analysis, search and selection.

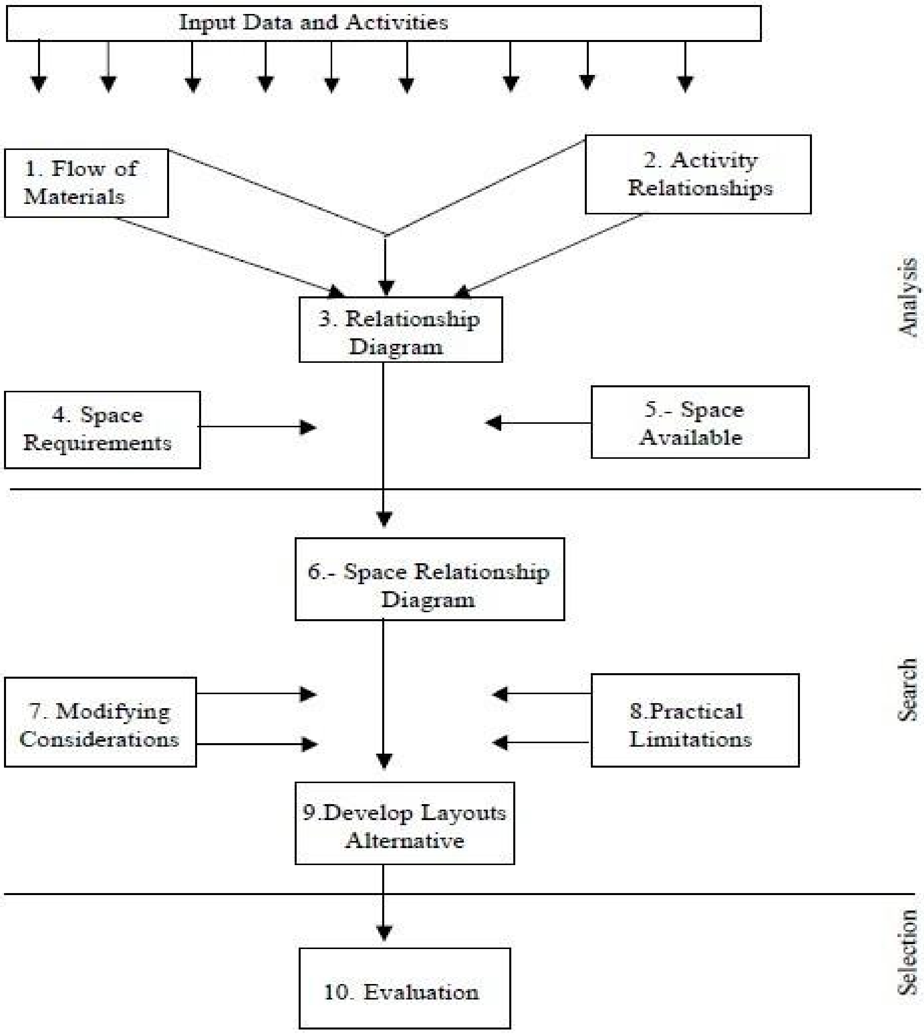


FIGURE 2. SLP method procedures (Gómez, 2003, 271-282)

The first phase of the SLP method involves using a from – to matrix to describe an interdepartmental material flow. In order to do this, a unit of measurement about material handling must have been decided firstly. So the products with different characteristics can be homogenized and comparisons are feasible. Then the REL chart which means the relationship diagram should be made. This chart collects the qualitative information of 'proximity ratios' which consist of a set of letters (A, E, I, O, U, X). They reflect how necessary is for every two work units to be adjacent in the final layout (ranging from A which means 'absolutely necessary' through to X which shows 'not desirable'). The detailed explanation and utilization for these letters will be presented in chapter 4.

According to the from – to matrix and REL chart, an initial relationship diagram will be built up as the first approximation to the relative positions of different work units. However, the spatial analysis has not been achieved yet so the area assigned to each of the work units is equal for all of them.

The following step is space analysis which includes availability and requirements. Space availability consists about the actual facility layout where the different work units should be placed. Space requirements are focus on the necessary production parameters such as staff, equipments and others from a theoretical analysis. Comparison and combination of space availability and requirements will provide the actual area to be assigned to each work unit. As a result of analysis process, the space relationship diagram is emerged based on the above space analysis.

After the space relationship diagram is built up, the designers have to remodel or modify the previous design to a greater or lesser extent. Therefore, certain factors which might affect the following implementation of the layout should be taken into account. These factors include various aspects like natural light in the facility, roof heights, the position of electricity points and doors, and the inclusion of aisles for staff, material and equipment movements and so on.

Additionally, the practical limitations and modifications which are researched in step 7 and 8 are highly dependent on the empirical skill knowledge and the subjectivity of the person who is responsible for the layout.

In the final analysis, again it is dependent on the design person’s experience and opinions to determine how the new information or sources affect the modified layout of the different sections.

2.2. The Analysis of the SHA Method

SHA is an acronym of System Handling Analysis which is applicable for any material handling projects. It is a systematic analysis method which is also proposed by Richard Muther. The contents of the method include stage structures, procedures mode, and symbols for records, diagrams and evaluation.

2.2.1. Four Stages

Every handling project has a certain process. The SHA method is divided into four stages, from setting the goal to archiving the implementation.

Stage I. External connection

In this stage, any materials handling activities including input and output in the analyzing areas should be very clear reported and recorded. To analyze the materials handling situation in the certain area in a comprehensive view, we have to combine the external materials handling situation or conditions outside the area. Therefore, pay attention on the external connection is very significant. However, some of these external circumstances can be under controlled such as coordination with the other companies; the others cannot be controlled like weather conditions.

Stage II. Overall handling planning

The main task for this stage is determining the material handling way among every main zone. It means that make an initial overall strategic decision for the handling route, the handling equipments and the units or container types.

Stage III. Detailed handling planning

During this period, the handling plan needs to gradually expand and deepen in the material handling situation of internal work units in every certain zone. Determining the detailed handling plan for every considered part is the paramount task for this stage.

Stage IV. Planning implementation

It is the last and most practical stage of the SHA method. There are various necessary preparing works which include of ordering the equipments, training the staff, making and implementing the definite handling plan and installing all the accessories. Afterwards, it is the debugging work for the plan, following with testing and verifying for the operation procedures or installed facilities to ensure that all the units can be running regularly.

The four stages mentioned above are operated in sequence by time. However, they can be overlapped by time to get the best and most appropriate effect. Like the SLP method, the planning and design department especially industrial engineers are responsible for stages II and III.

2.2.2. Important Elements

Similar as the SLP method, there are five important elements as input data for the SHA method. They are P (product), Q (quantity), R (route), S (supporting service) and T (time) as well. If there are too many products categories, it is reasonable to ignore some elements which have little impact.

2.2.3. Procedures

The SHA procedure mode is a stratified one which is based on materials (phase 1), activities (phase 2 and 3) and modus (phase 4, 5, 6 and 7). So actually the essence of systematic handling analysis is analyzing the materials which are needed to handle, analyzing the necessary activities and ensuring economic and practical handling modus. The more complicated the problems are, the more useful the mode is. The SHA procedures flow is representing in Figure 3.

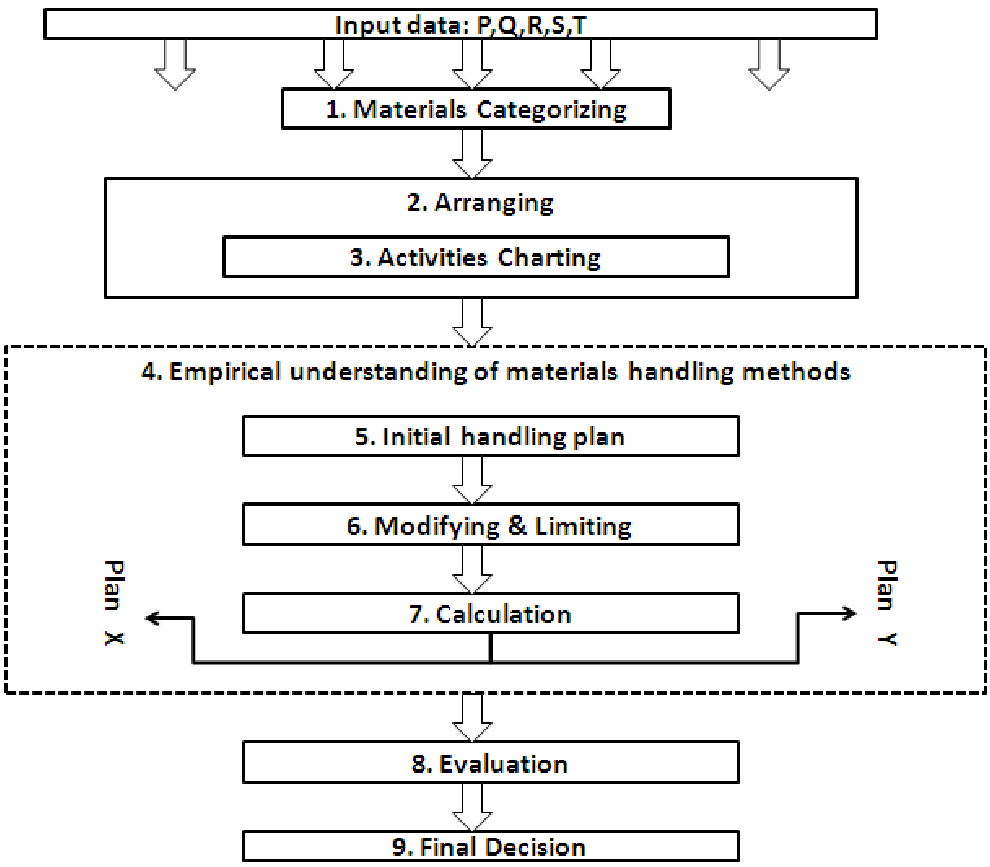


FIGURE 3. SHA method procedures (Adopted from Muther, 1961, SHA)

1. Materials analysis

The main basis of materials categorizing are (1) running possibilities and (2) logistical conditions. The leading factors which affect the material's running possibilities are material's physical and chemical characteristics and external factors such as the species of material handling equipments. The logistical conditions reflect to the requirements of producing process, quality assurance, producing management, environmental protection, laws governing products and other particular requirements.

To draw a table of material characteristics, it is needed to classify the target materials by empirical judgment according their main features. The steps of the judgment are:

- make a table to mark all the goods or groups
- record their physical characteristics and other characteristics
- analyze the characteristics and underline the leading and decisive ones
- ensure the types of materials and categorize the materials which have the similar leading characteristics or specific impact features (e.g. class a, b, c, d)
- draw a detailed table of material characteristics.

2. Activities analysis

Before analyzing the activities during the material handling process, various information or records should be gathered. They are material classes, starting point, ending point and the route of the handling and the logistical workload and conditions.

Currently, there are two common methods to analyze the activities. One is flowing analysis which is used particularly for single or less varieties. It needs to trace the material and gather the information along the whole production process. The other one is start-stop point analysis. If there are not too many material categories, every handling route is targeted as the object of observation. Conversely, it is required to observe the specific area and gather the information of materials' input and output when there are too many material categories.

The last step of analyzing the activities is to make the handling activities list and illustrate the activities in flow chart or coordinate vector graphic.

3. Modus analysis

The material handling activities of enterprise logistics can either use the same one modus or many different ones. Generally, the specific handling plan is the combination of various handling modus. The phases of modus analysis include of initial handling planning, plan limiting and modifying, calculating and evaluating.

(1) Initial handling planning and analyzing

To ensure the initial material handling plan, the original information of material classes, logistical workload, route and distance, facility layout, equipment selection, and time and environmental requirements should be gathered. According to that original information, there must be a few initial handling options. Certain further considerations should be brought into the study so that the initial handling options can be improved, modified, calculated and evaluated based on the system requirements. Finally the optimal initial handling option should be selected.

To analyze the selected initial handling option systematically, various tables, forms or diagrams should be made with a series of material handling symbols.

(2) Limiting and modifying

To judge whether the initial handling plan is realistic and feasible to be implemented, it needs to be modified according to the practical limited conditions. Besides the objective factors of routes, equipments and transportation units, the human factors like the correctness and efficiency of operating the equipments, the coordination and assistance of implementing the material handling should also be taken into account to solve the material handling problems. The issues lists below involves in limiting and modifying the contents of initial material handling plan.

- the certain material handling plan which is connected to external environment

- the satisfaction of the current production requirements and future development or diversification
- the consistency of the production process or equipments
- the utilization of current public facilities and auxiliary facilities
- the limited conditions of area and space
- the architectures and their structure characteristics
- the inventory system and the storing ways and equipments for materials
- the investment limitation
- the factors which affect the staff's safety.

(3) Calculating and evaluating

The contents of the calculation for assessing the initial handling plan are:

- the demands of handling equipments and workers
- the investment and prospective running cost.

As for the evaluation method, approximately it can be divided into two types. One is the comparison of cost, fees or financial factors. The other is the comparison of intangible factors.

For the first type, the comparison emphasis includes of the investment which refers to the capital construction and the project and management cost which means all the management fees of staff, materials and facilities.

For the second type, the advantage-disadvantage comparison method and weighting factors comparison method are common used. The intangible factors contain a lot of subjects. They are mainly:

- the relationship and service ability of production process

- suitability and universality of the material handling way
- flexibility (whether the ensured option is easy to change, rearrange or develop)
- the limitation for the expansion of layout or constructions
- the utilization of area and space
- the management of safety and security
- availability and convenience of management and control
- probable frequency of breakdown and its extent to the producing breakage
- suitability for producing cycle time and effect for producing process time
- coordination with the other warehouse facilities
- cooperation with the external transportation.

In addition, actually after the evaluation, the ensured initial handling plan should be consummated in details like the handling way from one working unit to another. The detailed planning model is the same and coordinative with the overall handling plan. In practical environment, more information, more detailed index and more practical conditions will be involved during this planning period.

2.3. The Relationship between SLP and SHA

According to the introduction and analysis above, it is easy to find that the relationship between SLP and SHA is very close and somehow inseparable. The relationship can be represented in two aspects in the following.

2.3.1. Same Goal

SLP and SHA have the same final goal which is rationalizing the logistics. The SLP method places extra emphasis on logical planning for space utilization. The target is making the shortest logistic route and designing the most reasonable layout to reduce the probability of route intersection, roundabout and reciprocation. The emphasis for the SHA method is rationalizing the material handling ways. It reflects to optimize the whole material handling system with correct and suitable methods and equipments. The factors which should be taken into account are physical characteristics and quantities of materials, distance, speed and frequency of movements.

2.3.2. Interaction and Coordination

As mentioned above, a good facility layout and a logical material handling system are inseparable with each other to ensure the achievement of logistics rationalization. It is predicted to consider about the requirements of material handling system while designing the facility layout. For instance, if the enterprise selects the conveyor as the main handling tool, then the equipments should be distributed in line along with the running direction of the conveyor. If the enterprise selects the forklift as the main handling tool, then it should premeditate to leave sufficient aisles and work space. Moreover, if the enterprise does not pay sufficient attention on the buffering logistics sections like temporary storage and packaging place of the material handling system, it will be probable to make the whole manufacturing system into confusion and congestion.

In all, facility layout design is the premise of material handling system design. The former can only demonstrate through gradually optimizing the handling system. Consequently, the SLP and the SHA method are interacted and coordinated to each other.

2.4. The Combination of SLP and SHA

To make a comprehensive layout by combining the SLP method and the SHA method, it is necessary to create a good precondition for the SHA method according to the following factors while implementing the SLP method.

- the adoption of the successive transportation or handling
- the adoption of the conveyor, forklift or the other lifting and handling machines
- the quantities and scales of buffering logistics sections like temporary storages and transit warehouses
- the place for the product packaging and storing
- the methods to remove the waste or litter

Additionally, to comprehensively apply the combination of SLP and SHA, it is better to modify and supplement the contents of the SLP method after the SHA programming.

3. CASE STUDY

The case in this thesis was based on the practical running situation of the target enterprise and similar theoretical case analysis. All the information and figures about the company were from the public official website and other publications which were listed in the references at the end of the thesis.

3.1. Company Profile

Shanghai Taitong Valve Co., Ltd. was established jointly by China Tin Shing Valve

Group. It is a new comprehensive high-tech enterprise which contains valves and pumps manufacturing, electrical R & D, sales and services. Its factory is located in Wenzhou Industrial Zone, north east of Wenzhou, which is well known as the hometown of pump and valve manufacturing industry in China. The factory covers the area of 23300 m^2. There is a total of 670 staff, including 21 engineers and 7 senior engineers.

The main products are: butterfly valves, American Standard valves, check valves, ball valves, and stop valves, relief valves, regulating valves, solenoid valves, safety valves, hydraulic control valves, water supply and drainage equipments.

Taitong has introduced foreign advanced technology to modernize the scale productions. Besides, it has over 300 professional equipments, which include a processing center from Germany, a CNC lathe from Taiwan, a super precision vertical lathe, an automatic coating line etc. There are also a modern R & D center and a quality testing center near the factory.

The sales center is located in Shanghai. Their market area covers the whole Southeast Asia. Now they are expanding to more international markets such as North America and Japan. Taitong is continuously making an effort on R & D and improving its products' quality. The goals of the company are producing high level products and becoming a world-famous brand. They are on the way.

3.2. Product Presentation

Since most of the valves have the similar manufacturing process, a common used and typical one which is HQ41X sliding ball type check valve was selected as analyzing target. Under the action of medium, the valve ball which is coated with rubber can slide up and down along the integrated slideway to open or close the valve. It has good sealing performance and muffler-type joint so that there will be no water hammer. The valve body adopts all water channels which have less resistance and more flow. The loss in faucet of sliding ball type check valve is 50% less than swing check valve. It can be installed vertically or horizontally and widely used for industry and sewage pipelines in both cold water and hot water. Especially, it is more suitable for submersible sewage pumps. Moreover, the materials of valve body are cast iron, ductile cast iron and cast steel.

The main technical parameters of HQ41X sliding ball type check valve are:

- nominal pressure: 1.0 – 1.6 Mpa
- nominal diameters: 50 – 350 mm
- service mediums: work and weak corrosive fluid
- working temperature: 0 – 80□
- flanged standards: GB/T 17241.6 GB/T 9113
- inspection standards: GB/T 13927 AP1598.

More details about the product such as picture, typical installation diagram, main dimensions and drawing are representing in the appendixes 1, 2, 3 and 4.

3.3. The Analysis of Current Situation

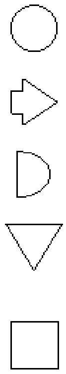
According to the Chinese introduction on the company's website, the general processing procedures for the valves are:

raw materials→ heat treatment (adjusting)→machining (lathing)→heat treatment (quenching)→machining (grinding)→bench working→pressure measuring→assembling→pressure testing→painting→final and overall inspection→end products

As a result of analyzing the material composition of selected product, its manufacturing process was estimated and assumed. The workshops which would be probably involved according to the above producing process were listed in numbers in the following:

1. machining workshop
2. hardware warehouse
3. components and end products workshop
4. raw materials warehouse
5. zone of heat treatment
6. welding zone
7. pressure testing zone
8. assembling and painting zone
9. zone of final and overall inspection
10. zone of bench work
11. tools library
12. office.

When analyzing a process, usually people choose to present it in diagrams, figures or chart. The flow chart is one of the simplest, clearest and most direct ways to describe the whole process. In manufacturing industry, all the practical process flow charts must be drew under the standard of The American Society of Mechanical Engineers – ASME. Figure 4 shows the typical symbols which are involved.



Symbol	Name	Meaning
	Operation	A complex action or process (possibly described elsewhere), often changing something.
	Transport	Movement of people or things. May be accompanied by a distance measurement.
	Delay	Idle time of people or machines, or temporary storage of materials.
	Storage	Longer-term storage of materials or other items.
	Inspection	Checking of items to ensure correct quality or quantity.

FIGURE 4. ASME flow process symbols (Quoted from web:syque/flowprocess)

Therefore, it is brief and clear to describe the manufacturing process which was mentioned at the beginning of this section in a flow chart in Figure 5.

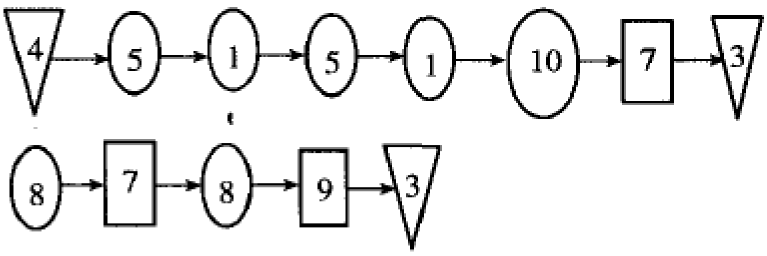


FIGURE 5. Flow chart of valve manufacturing process

Due to the business information security, it is impossible to get the actual drawing papers from the company. There was a typical production plant layout model mentioned in a research proposal by Mr. Kechang Ju and Mr. Zhuan Wang published in the Journal of Logistics Technology, 2006. It was a facility layout of a gearwheel factory. Based on this model, a little modification according to the manufacturing process of the valve was made so that it could be assumed as the infinite similar original layout of the case for thesis analysis. All the symbols and numbers in this layout image in Figure 6 are representing the same meaning as in Figures 4 and 5.

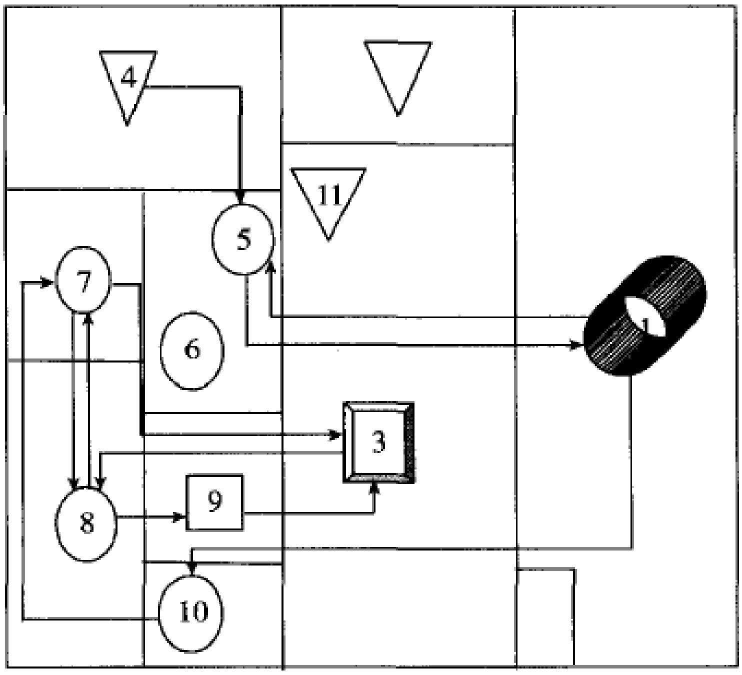


FIGURE 6. Plant layout and logistic routes

Limited by the work procedure modus, the facility layout can be classified in four types which are process layout, product layout, fixed layout and group layout. The process layout is suitable for the production of more varieties but less batches such as hospital. The product layout is suitable for the production of fewer varieties but more batches. The fixed layout is used for the manufacturing of the product with huge volume or weight such as air plane. The group layout is used for the production of limited varieties and middle size or less batches.

According to the diagram above and the features of every layout type, this plant layout can be identified as the product layout type, of which the core idea is distributing all the related equipment or work in a successive array to constitute the production line based on product manufacturing procedures. The basic idea of this layout is easily moving from one work unit to its closest neighboring unit. This kind of layout works significantly only when the batches of given products or components are much more than the ones of produced products or components.

The advantages of the product layout are:

- smoothen the logistic procedures because of the consistency between layout and manufacturing process
- the whole process is cohesive
- short production cycle and less storage
- less material handling workload
- less technical requirements for workers, easy to train
- simple production plan, easy to control
- possible to utilize specific equipments and mechanizing and automatic handling methods.

The disadvantages of the product layout are:

- the whole production line will break off if there is any equipment breakdown
- even little product design change can lead to great layout adjustment
- the production line speed depends on the slowest machine
- larger investment and higher maintenance expenses
- repetitive work on production line can easily make staff tired and dull.

3.4. Identification of the Problem

> *As defined in the literature, the objective of the facility layout problem is to minimize the material handling costs inside a facility subject to two sets of constraints: (1) department and floor area requirements and (2) department locational restrictions (department cannot be overlap, must be placed within the facility, and some must be fixed to a location or cannot be placed in specific regions).* (Russell & Gau, 1996)

The output of the facility layout problem is a block layout, which specifies the relative location of each department. In addition, the detailed layout problem includes flow line layout problems, machine layout problems and cellular manufacturing design problems (machines are assumed to be of equal area or of fixed dimensions). In the literature, the layout's efficiency is typically measured in terms of material handling costs.

For the target factory, it has the stable and mass production of valves every year. Currently, as the result of products output increases constantly, the handling frequency and workload and reserves of raw materials in production line increased as well. Consequently, its logistic problems emerged. Obviously, the productivity and the efficiency of the current department layout will decline because of the increase of handling and producing costs. So the main problem is that the current facility layout cannot keep pace with the development of the product scales. So the principal task is redesigning or rearranging the facility layout to reduce the material handling workload in the whole workshop.

Therefore, it is necessary to redesign and re-plan the original facility layout according to the SLP method to obtain other alternative feasible plans. After the redesign period is to select the optimal option by calculating the material handling costs and evaluating other relative factors according to the SHA method.

4. THE WORKSHOP LAYOUT REARRANGEMENT ACCORDING TO SLP

As a result of logistic system analysis under the technological conditions based on the SLP method, an initial diagram of relationships which is used as a first approximation to the relative positions of the different departments was built up in the following.

TABLE 1. Relationship diagram of every workshop and activity (REL chart)

	1	2	3	4	5	6	7	8	9	10	11	12
1. machining workshop	/	U	U	U	A1	U	U	U	U	A1	O2	O3
2. hardware warehouse	/	/	U	U	U	U	U	E2	U	U	U	U
3. components and end products workshop	/	/	/	U	U	I2	A2	A2	A2	U	U	O3
4. raw materials warehouse	/	/	/	/	A1	U	U	U	U	U	U	O3
5. zone of heat treatment	/	/	/	/	/	U	U	U	U	U	O2	O3
6. welding zone	/	/	/	/	/	/	U	I1	U	U	O2	O3
7. pressure testing zone	/	/	/	/	/	/	/	A1	U	A1	O2	U
8. assembling and painting zone	/	/	/	/	/	/	/	/	A1	U	O2	O3
9. zone of final and overall inspection	/	/	/	/	/	/	/	/	/	U	O2	U
10. zone of bench work	/	/	/	/	/	/	/	/	/	/	O2	U
11. tools library	/	/	/	/	/	/	/	/	/	/	/	O3
12. office	/	/	/	/	/	/	/	/	/	/	/	/

The letters in Table 1 are defined to rate the relationships.

A – absolutely necessary that the activities are next to each other

E – especially necessary that the activities are close to each other

I – important that the activities are close to each other

O – ordinary closeness should be maintained (meaning that it is only necessary that these activities are in the same facility)

U – unimportant that the activities are close to each other

In addition, the figure subscripts beside the letters mean: 1-technological requirements, 2-material handling and 3-management and supporting services.

After the correlation analysis, it is to simplify the REL chart to a correlative diagram based on the approximate level so that the whole following layout processes can be simplified as well. Thus it will be more clarified and direct to show the proximity of every work unit. The correlative diagram is shown in Table 2.

TABLE 2. Correlative diagram

	1	2	3	4	5	6	7	8	9	10	11	12
A	5,10		7,8,9	5	1,4		3,8,10	3,7,9	3,8	1,7		
E		8						2				
I			6			3,8		6				
O	11,12		12	12	11,12	11,12	11	11,12	11	11	1,5,6 7,8,9, 10,12	1,3,4 5,6,8, 11
U												

According to the correlative diagram above, a block layout sample diagram which is reflected in Figure 6 to show the relative location can be easily made. The blocks are used to substitute every work unit. In practical environment, the final facility layout design will be finished immediately once get the detailed location and dimensions of every work unit.

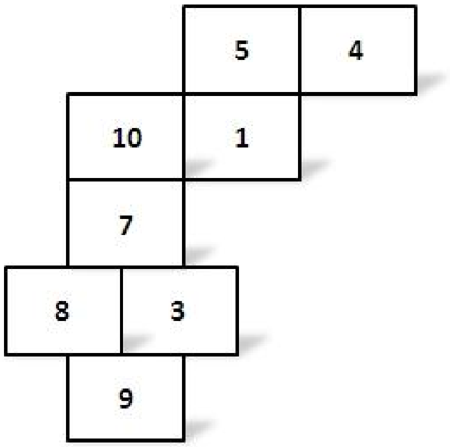


FIGURE 7. Relative location of block layout

However, in some cases, the correlation factor is not the only leading one for layout design. It is also needed to consider about technology and management level, staff capacity, working conditions, environmental protection and other factors. In fact, the location setting is very subjective and the practical conditions are very complicated so there could be so many layout options. Therefore, due to the author's academic and design ability, many factors which less affected the analysis of the thesis idea were ignored. There left only two typical revised layout options. The entire block numbers represent the same work unit as mentioned above.

4.1. Option I

Compared to the original layout, there was little wide range adjustment in this option. A few changes were revised on the location of work units in the three big work areas which were X (left), Y (middle) and Z (right). All the adjustments were related to the block relation diagram in Figure 7.

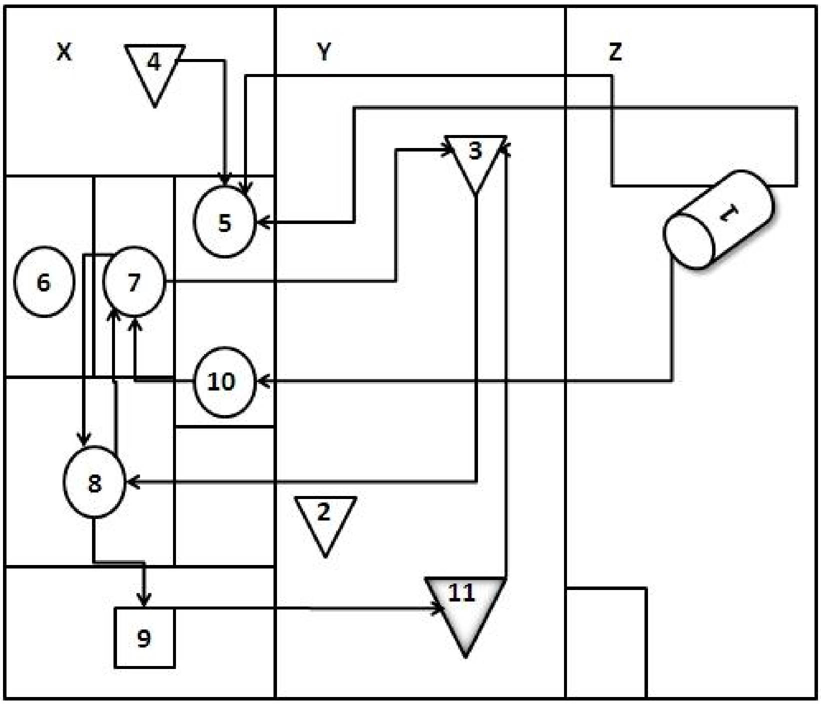


FIGURE 8. Option I of layout rearrangement

4.2. Option II

If look back the option I, it is easily to find out there are too many logistics activities which are concentrated in the area X. All these activities are close connected with the work units in the areas Y and Z. Therefore, the location of the area X and the area Y were adjusted to be exchanged in the option II. Certainly, the locations of small block units in the areas X and Y were also adjusted so that all the logistics routes could be balanced and simplified. The idea of the option II was represented roughly in Figure 9.

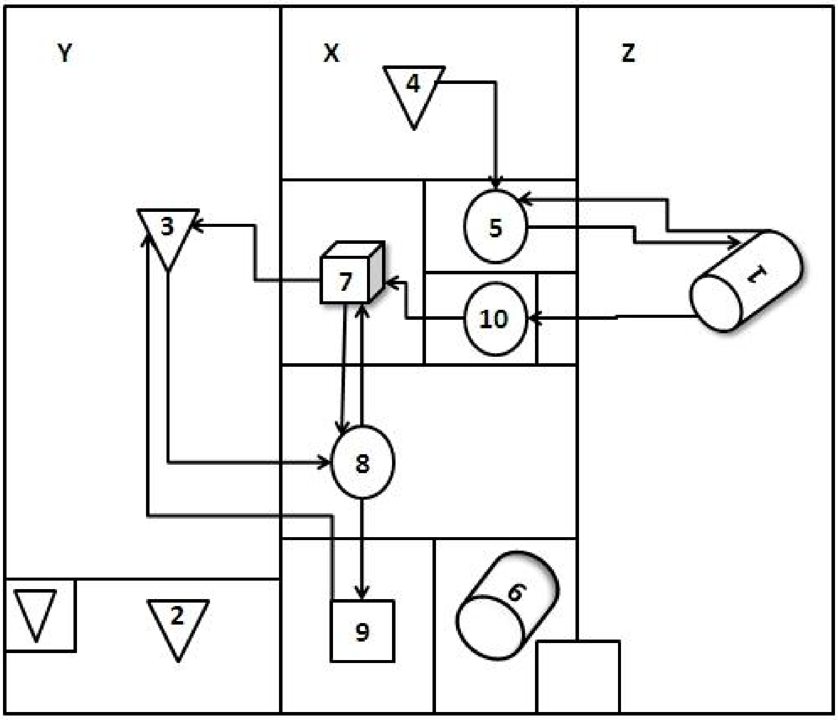


FIGURE 9. Option II of layout rearrangement

5. OPTIMIZATION AND EVALUATION BASED ON SHA

To select the optimal option from the above two options, the SHA method should be applied to make the evaluation. As mentioned above, the original idea of the SHA method was to determine the most economical and practical handling plan by analyzing the materials, logistical activities and handling modus.

The factory in the case only produces valves so the technological process is pretty simple. Therefore, to simplify the evaluation and calculation, the following logistical and ideal conditions were assumed.

- the material handling equipment is the forklift
- the whole material flow process is uniform, continuous and determinate
- the material handling cost difference of different routes (in the factory) is

negligible (It means the relationship between the material handling cost of different routes and the system handling workload is proportional.)

Therefore, to obtain the lowest material handling cost route, the system handling workloads of every option should first be calculated. The target of the analysis is to achieve the minimum system handling workloads. The analysis process is implemented according to the following steps. The data here in Tables 3 and 4 are estimated based on the actual factory or production scales.

1. Calculate the material flow (load units) among every work unit

TABLE 3. Material flow among work units

	1	2	3	4	5	6	7	8	9	10	11	12
1. machining workshop					302					388	41	75
2. hardware warehouse								234				
3. components and end products workshop						114	438	353	319			58
4. raw materials warehouse					397							103
5. zone of heat treatment											38	73
6. welding zone											40	36
7. pressure testing zone								386		375	31	
8. assembling and painting zone									334		29	59
9. zone of final and overall inspection											45	
10. zone of bench work											18	
11. tools library												25
12. office												

2. Measure or estimate the material handling distance between every two correlative work units in rearranged layout options according to the original one (some three figures from top to bottom in the form respectively represent the data in original layout, option I and option II)

TABLE 4. Distance between every two correlative work units (unit/m)

	1	2	3	4	5	6	7	8	9	10	11	12
1.machining workshop					19198					301812	151250	8 8 8
2. hardware warehouse								271410				
3.components and end products workshop						152326	24198	192312	132614			10 16 42
4. raw materials warehouse					11 11 10							424226
5. zone of heat treatment											4 1734	232312
6. welding zone											11 2332	32424
7. pressure testing zone								8 8 8		16106	172514	

8.assembling and painting zone									6 6 6		241813	302820
9. zone of final and overall inspection											151410	
10. zone of bench work											21 1532	
11. tools library												211532
12. office												

3. Calculate the system handling workloads (S)

(1) Assume that *i* and *j* are the two correlative work units, f_{ij} represents the material flow from *i* to *j* and d_{ij} indicates the length of the distance between *i* and *j*. The equation which is used in this approach is shown in the following:

$$S = \sum_{i=1}^{z} \cdot \sum_{j=1}^{z} fij \; dij$$

(2) According to the equation above, the value of S can be calculated, which is shown in the following table.

TABLE 5. Calculated results of S value

	Original layout	Option I	Option II
S	76346	72001	50707

Obviously, according to the results above, the options I and II are better than the original one, the advantage of the option II is especially evident. The system handling workloads of the option I are 4345 less than the original one, while of the option II are 25639 less than the original one. The result number of the option II is 66.4% of the original one and 70.4% of the option I. So the system handling workloads are obviously reduced in the rearranged layout of the option II which proves to save more space, shorten the material handling route and decline the material handling cost. Definitely, the option II will play an important role in reducing the whole production cost when it is applied to the system.

Moreover, the option II more comprehensively consider about the factors of logistics, the integrated proximity of operating units and internal links with other facilities. It also takes into account the architectural form of good-looking, cleanness and fire control. Therefore, the option II is the definite choice of the optimal rearranged layout.

6. FUTURE DEVELOPMENT AND IMPROVEMENT

6.1. Contents of the Improvement

As mentioned at the beginning of this thesis, facility layout is a very complicated technological art, which involves a series of complicated procedures such as design, selection, measurement, calculation, implementation, construction, evaluation and so on. There are a lot of practical factors that should be taken into account. The case analysis in this thesis was implemented in a very ideal situation, so that the calculation and model could be more easily presented here. For example, the material handling tool in the whole factory was assumed to be only the forklift so that the aisles' width could be considered as fixed with a size sufficient for the movement of the forklift. In fact, it is possible to have other material handling tools in the factory besides the forklift.

In addition, in a practical environment, to obtain the most exact and suitable result, all the related factors cannot be ignored. According to the different technology processes, conditions and limitations, the application of the SLP method and the SHA method in the facility layout rearrangement will be various. Moreover, the design is usually very subjective. It is highly dependent on the designers' opinion, idea and empirical skills. One design group may have thousands of plans. In all, the improvement contents of the design of layout rearrangement of enterprise logistics based on the combination of SLP and SHA are:

- build the conception which combines the facility layout design and material handling analysis into consideration
- totally consider the actual situation or realities to have the excellent and exact target designs
- make a detailed and comprehensive selection option so that all the related factors will be taken into account

The conception which was applying the combination of the SLP method and the SHA method in facility layout rearrangement emerged only a few years ago, despite in the fact that the SLP method and the SHA method were widely used since they were introduced in 1961. The development of logistics in the theoretical field was far less than in the practical application field. Nowadays, more and more researchers are devoted to develop some joint application research. In industrial design and logistics, this trend is inevitable. The development and application of the combination of the SLP method and the SHA method is typical. I believe the conception will be vigorously promoted in the future.

6.2. Information Technology Support

As information technology has developed during the last few decades, the development of industry has become more mechanized and intelligent. The wide utilization of high technology has made the orientation, design, contribution, adjustment of the enterprises more exact and meticulous. The same has happened to the facility layout. Since the 70s of the 20th century, computer-aided design for the factories has gradually been brought into the practical phase. Meanwhile, the space design has developed from two-dimensional to three-dimensional.

In this field, a lot of excellent software has emerged such as CRAFT (Computerized Relative Allocation of Facilities Technique) and the combination of Prim arithmetic and Tompkins based on SLP method. Prim and Tompkins are two famous arithmetic which can especially help the relative location of block layout become more exact. Figure 10 shows the example of how it works like in the computer.

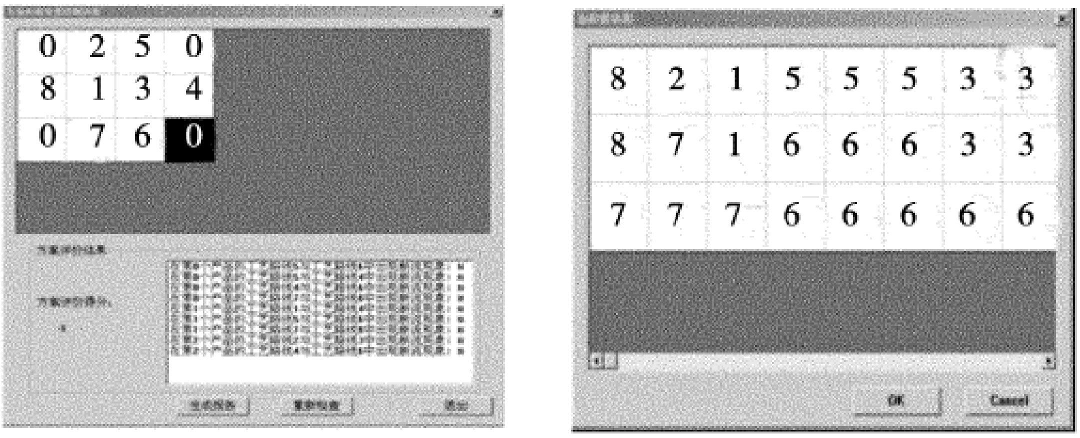


FIGURE 10. Block layout arrangement in computer

As mentioned above, if the SLP method could be more systematically, exactly and detailed used in the layout design or rearrangement, the selected options which need to be evaluated would be less, so the evaluation work could be more specified. Obviously, the result will be more exact and comprehensive. Therefore, the intervention and application of information technology will support the combination of SLP and SHA to become more integrated and completed.

7. RESEARCH RESULT

This thesis aimed to find an integrated solution for industrial design and make a useful exploration of the research of technology improvement. As production scales expand or develop, there will emerge a lot of problems in certain facility layouts. The initial idea was to improve or integrate the current theoretical analysis and verify whether the combination could be applied and implemented or not. As a result, it was proved that the analysis method of the combination of the SLP method and the SHA method was feasible and more optimal than the traditional ones. With the help of the combination analysis, the layout rearrangement can be more comprehensive and suitable for the development of the enterprises, and the whole logistics costs can be reduced significantly.

8. FINAL CONCLUSION

Material handling and the facility layout problem are interrelated and limited to each other. A good facility layout should provide a reasonable and sufficient space for material handling activities. Meanwhile, a good material handling system cannot run successfully without an intelligent facility layout. For example, which material handling method is used is often dependent on the distance the load must travel, which is dependent on the final layout design. Moreover, the size of the work units is often limited by the distance of two closed operations, which is usually dependent on the material handling tools.

Unfortunately, there is a lack of current engineering of facility layout with respect to material handling system design and production system design. Therefore, the research of layout rearrangement contents should totally and concurrently consider and combine the factors of material handling and layout design. Certainly, the facility layout rearrangement is required to effectively serve the production system which emphasizes the shorter lead times, smaller lot sizes and increased flexibility.

As mentioned at the beginning of the thesis, the facility layout design is a scientific art more than a technology. It is proved that the layout problem is a Non-deterministic Polynomial Complete problem which needs a lot of theoretical analysis, calculation, and figures to support the solution research. SLP is a systematic layout planning method, which is widely used in the manufacturing industry design. The advantage of using the SLP method is to ensure that the final product is derived from a group effort by all the participants in the project.

Nowadays, solving the facility layout problem is not finding the best layout for the wrong production system, which means that a suitable production system with a high logistic efficiency should be built up as well. This involves the material handling system. The material handling methods are various, so that the selection is complicated. SHA is a common method which is used for this complicated system handling selection. The advantage of using the SHA method is to ensure that every analysis procedure can be completed along with the modification process.

In conclusion, for the layout rearrangement, the combination of SLP and SHA can exert both the analysis advantages and supplement to the practical application with respect to each other.

With the help of the bachelor’s thesis, the enterprises can obtain an integrated analysis solution for the facility layout rearrangement to fulfill their development plan. The idea is rather theoretical but it is feasible in the practical environment when every related factor can be comprehensively taken into account.

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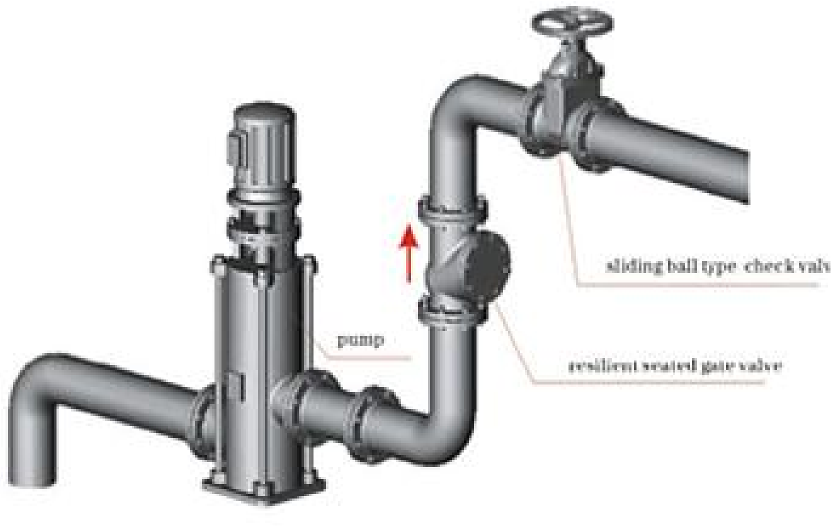
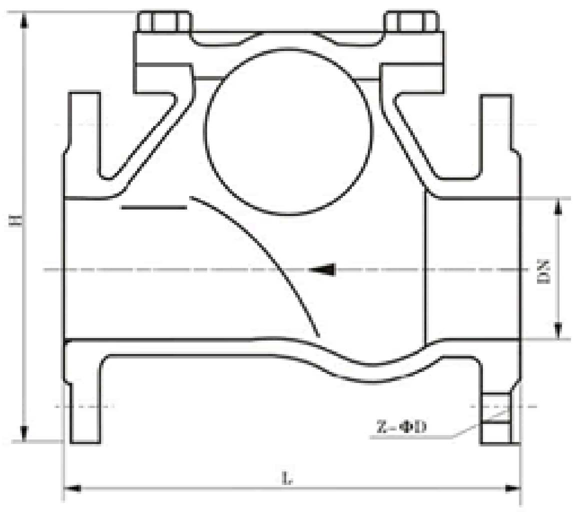
APPENDICES

Appendix 1. HQ41X sliding ball type check valve

Appendix 2. Typical installation diagram



Appendix 3. Drawing



Appendix 4. Main dimensions (unit/mm)

DN	50	65	80	100	125	150	200	250	300	350
L	180	200	260	300	350	400	500	600	700	800
D	185	210	245	280	335	400	495	600	715	820