LAYOUT PLANNING: A CASE STUDY ON ENGINEERING-TO-ORDER COMPANY

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Abstract
The type of layout utilized will largely depend on the nature of the manufacturing activities, including the volume and variety of the products being produced. The plant layout generation is challenging, especially for the process-oriented layout. This paper presents the practical application of Muther's systematic layout planning (SLP) in engineering-to-order company.

Keywords: engineering-to-order environment, layout, systematic layout planning

1. INTRODUCTION

Engineering industry companies belong to the production environment called in the literature "engineering to order - ETO". This environment has a production character of a unit production (small-scale series production) that means production for the custom's individual order. That type of production refers to the products for which the client requires specific engineering, significant modification of a buy of new materials. The design and technology are usually developed individually for specific customer's order. These are generally unique designs characterized by specific requirements for the technical planning and management of production and the way of planning and settlement of expenses. A common problem is the creation of offers for products designed to order in short series. Such projects are carried out on the basis of incomplete initial data, starting with the preparation of an offer and its evaluation, the development of the budget and schedule of implementation, and ending with the supervision of the execution and settlement of the contract. Recurrence of orders is low or even none.

The major problems for an engineering-to-order manufacturing company lie at the front-end of the process flow rather than on the production shopfloor. The following lists the typical difficulties faced by such a company: non-standardized parts and specifications largely because of the obligation to fulfill customers’ needs and requirements in order to secure the deals; customers’ ongoing changes partly owing to the long product manufacturing time which allow customers the opportunity to vary their product specifications; improper shopfloor layout resulting in non value-added and redundant work. [1]

The main objectives of the plant layout function are to enable the manufacture of the product economically in the required volume and variety. Other objectives can be stated as effective utilization of manpower, space and infrastructure, as well as providing for the overall wellbeing and morale of the worker. [2]

Case study was presented in the article on the basis of the production enterprise of industrial automation equipment which faced the problem of placement the machines and devices in a new-built production hall. Systematic layout planning procedure (SLP) was applied to solve the problem, where in next stages, especially in the last one (evaluation) one of the heuristic techniques was used i.e. conception of the "creative abrasion" by G.Hirshberg.

2. SYSTEMATIC LAYOUT PLANNING (SLP) PROCEDURE

Facilities design consists of the facility systems design, the layout design and the handling systems design. The layout design considers all equipment, machinery and support structure within the operational perimeter. [2] Manufacturing factory layouts can be classified as: fixed position layout, process-oriented layout, group or cellular layout, product-oriented layout. [3,4]
The type of layout utilized will largely depend on the nature of the manufacturing activities, including the volume and variety of the products being produced. The plant layout generation is challenging, especially for the process-oriented layout. This paper will focus on plant layout generation for the job shop.

A layout design problem often fall into two major categories as algorithmic and procedural approaches. Algorithmic approaches usually only involve quantitative input data. The outputs from algorithmic approaches often need further modifications in order to satisfy detailed design requirements.

Many algorithmic approaches have been developed in the plant layout research include the systematic layout planning procedure, steepest descent search method by pair-wise exchange, graph-based construction method, Tabu search, genetic algorithms. Based on these approaches, many computer-aided layout routines have been developed (CRAFT, MCRAFT, COFAD, CORELAP etc.). Advanced training in mathematical modeling techniques are often prerequisites for a designer to use algorithmic approaches to solve a layout design problem.

Procedural approaches can incorporate both qualitative and quantitative objectives in the design process [5]. For these approaches, the design process is divided into several steps that are then solved sequentially. The success of a procedural approach implementation is dependent on the generation of quality design alternatives that are often from the outputs of an experienced designer. [6] The success of a procedural approach implementation is dependent on the generation of quality design alternatives that are often from the outputs of an experienced designer.

This paper proposes to use Muther's systematic layout planning (SLP) as the infrastructure to solve a layout design problem in engineering-to-order company. The process involved in performing SLP is relatively straightforward; however, it is a proven tool in providing layout design guidelines in practice in the past few decades.[6] SLP procedures can be segmented into four parts containing 11 steps. Part 1 is the inputting of data as follows: Step 1. P (product), Q (quantity), R (route), S (support), and T (time). Step 2. Flows of material. Step 3. Activity relationships. Step 5. Space requirements. Step 6. Space available. Step 8. Modifying constraints. Step 9. Practical limitations. The second part is the procedure process, which is represented by: Step 4. Relationship diagram. Step 7. Space relationship diagram. The Third part is output result, which is: Step10. Developing layout. The last part is the evaluation process: Step 11. Evaluation.[7]

3. A STUDY ON PROVIDER OF AUTOMATION SOLUTIONS FACILITIES

The chosen enterprise is a global solutions supplier in the range of the industrial automation, control of the processes and information technology. It has its branches, among others, in USA, China, and Poland. The enterprise delivers integrated control and automation systems, and software industries. Company offers a broader range of integrated solutions: industrial computers and monitors, industrial keyboards and pointing devices, limit switches: proximity and photoelectric sensors, limit switches and safety switches, and RFID and operator safety devices, medium voltage products, from across-the-line starters to soft starters and variable frequency AC drives, deliver enhanced protection in applications ranging up to several thousand horsepower. Bringing motors up to speed in a controlled manner limits wear on the motor and other mechanical components.

The layout planning of a new factory in Poland, will be used to illustrate the concepts mentioned in this study. The Board of the firm decided to broaden its productive ability by building the next production plant. Poland as the location was selected. It was assumed that in a new production hall will be manufactured products such as medium voltage products, switches, starters.

Start-up production of new products ran respectively over three years. This article presents the problem of distribution of machinery and facilities at the start of production of medium voltage products. The product is manufactured in engineer-to-order environment (ETO). A short characteristic of next stages taking part in the process of realization of the order is as follows: 1. Application Engineering Part 1 (preliminary engineering works to design components with long-term implementation/delivery. 2. Order of Long Lead Items (the order of components designed in a first stage). 3. Application of Engineering Part 2 (second stage of engineering

Product can be manufactured in many versions, their number can reach over 600 different versions. The structure of the product consists of 6 levels, where: 1st level contains about 100-150 components, all levels contain about 2000 components. The elements building up a product are divided because of the weight and size of the factors: 1. Large components: sheet metal, bus bars, magnetics (CMC, Line reactor, DC link), capacitors, fans, isolation switch. 2. Large subassemblies: doors, low voltage tube, all subassemblies. 3. Medium components: power cage. 4. Small components. 5. Hardware. As a result the maximum dimensions and a weight can reach 7 m, maximum weight – 7000 kg.

Available area space is 110 x 75 square meter. This new factory will consist of a plant, a material warehouse, an inspection room, area for power cables preparation, places for components, door assembly area, fan assembly station, labeling/engraving center, final assembly area, test area, packing area, shipping area, witness test area. With such initial conditions the project team consisting of: layout engineer, logistics specialist, quality assurance, Safety at Work, production manager, process engineer, independent expert, was created.

Step 1: PORST analysis. In an enterprises for medium voltage drivers production there was planned the use of space of 1700 m² but the aim was to use 1500m². At present the manufacturing of the same product in the different plant takes 2360 m².

### Tab. 2 From-to chart

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Source: own preparation

Supervisors are expected to have a throughput rate of 20 drivers out per month under full production. The routing steps of a medium voltage drive is ranging from 50 to 100 steps. Each step is associated with a specific tool set. Similar tools and process flow enabled allocating the following areas: Warehouse (WS),
Labels (LAB), SubAssembly (SUB), LVTube (LVT), FanPanel (FP), Doors (DOR), “Uppender” – a special device for assembling a complicated casing of a product (UPE), PreFa (PrF), Power Cables (PC), Final Assembly (FA), ReWork (RW), Test (Test), DropZone (DrZ), Catwalk (CAT), Shipping (SHP).

Step 2: Flow of materials analysis. This step aggregates all the process flows among different functional areas in order to determine the flow intensity. (Table 2) The numbers in from-to chart indicate the required flow intensity (trips per one shift) for making one of driver.

Step 3: Relationship diagram. Relationship diagram reveals a potential good relative positioning decision among the functional areas. It provides a quick overview of the potential closeness relationship and it is a priori for later space relationship diagramming decision. It is achieved through mapping the flow intensity information among functional areas to create the relationship diagram as shown in Figure 1.

![Fig. 1. Relationship diagram](image)

Source: own preparation

Step 4/5: Space requirements/available analysis. Required surface depends on a kind and quantity of used machines and devices needed for planning output, which equals 20 drivers/month (one and half drives per day). The required floor space includes the required support activities space such as maintenance, human-machine interaction, material handling, future expansion.

On this stage the required size of the surface was measured for each department separately. In this way the average size of the surface was achieved which was at the next step multiplied by the factor 1.2 (the factor is an experience value). Finally, the space requirement planning is fine tuned by area experts. The resulting space requirement for each department is shown in Tab. 3.

### Tab. 3. Summing up of the planned surface for medium voltage drivers production

<table>
<thead>
<tr>
<th>Subassembly area</th>
<th>246 m²</th>
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<tr>
<td>Assembly area</td>
<td>910 m²</td>
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<tr>
<td>Test facilities</td>
<td>404 m²</td>
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<tr>
<td>Shipping area</td>
<td>150 m²</td>
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<tr>
<td>Total</td>
<td>1710 m²</td>
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Source: own preparation
Step 6: Space relationship diagram. This step converts the relationship diagram into space relationship diagram by mapping each department’s area into the relationship diagram (Figure 2). For couples of departments, with a high intensity of flow it is preferred to locate them close to each other or arrange them in groups.

Steps 7-9 Practical limitations. Works started from placing monuments (2 cranes, maintenance area, “uppender”, place where facility will be conducted, packing area, where the crane and truck loading area will be used). Location, especially maintenance area took into account the need to take into account the distribution of the production of the following types of products (the production of which will be launched at a later date). In addition, assumptions have been made: one flow direction – from left to right, final assembly close to test facility – maximum weight of finished driver is 7000 kg, door assembly close to final assembly, one main road through the factory, labeling/engraving center close to wiring and planned MCC cell, area for power cables preparation close to Pre FA, places for components, catwalk close to docks, packing area and test facility, “uppender” close to conveyor belt, skid store, fan assembly station and side sheets kits. Furthermore, layout supports elimination of walking, heavy components mounted after “uppender”.

Step 10 Evaluation. For this evaluation purpose, heuristic techniques were used in this case the concept of “creative abrasion ” G. Hirshberg'a, according to which the project should be worked out with different designers pairs of professionals who differ in approach, style of work, experience, knowledge, etc., it is assumed that such collisions are a source of creative tension, and any new ideas will be considered by the other side and balanced a different idea. [8].

Interactions among people with different expertise, bringing different looks and skills increases the chance of finding innovative solutions. For this purpose a special design team of six people was create from such departments as: layout engineer, logistician of the quality assurance, Health and Safety, production manager, process engineer, independent expert. As a result of the regular meetings following interactions the final layout was elaborated (Figure 3). The proposed system has met most of the selected conditions and limitations.

Fig. 2 Space relationship diagram

Source: own preparation
4. CONCLUSIONS

Plant layouts can be varied and can significantly impact the overall effectiveness of production systems. The type of layout utilized will largely depend on the nature of the manufacturing activities, including the volume and variety of the products being produced. Existing literatures for a layout design problem often fall into two major categories as algorithmic and procedural approaches. Algorithmic approaches usually only involve quantitative input data. Advanced training in mathematical modeling techniques are often basics for a designer to use algorithmic approaches to solve a layout design problem. The success of a procedural approach implementation is dependent on the generation of quality design alternatives that are often from the outputs of an experienced designer. This paper presents the practical application of systematic layout planning (SLP). In further studies we can consider building a knowledge base on the basis of gathered experience of experts. Created system could support works prompting good practices, evaluate options for the deployment of machines and devices.

LITERATURE