MULTI-FLOOR FACILITY LAYOUT IMPROVEMENT USING SYSTEMATIC LAYOUT PLANNING AND SIMULATION

SEYEDEH SABEREH HOSSEINI

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Thanks God to enable me performing this research, I would like to dedicate this dissertation to my beloved father and mother who taught me how to be strong and ambitious and to my beloved brother and best friends whose positive energies always support me the best way.

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ABSTRACT

Every factory encounters with different layout problems from time to time and the operating efficiency of a manufacturing company is significantly influenced by its plant layout. Lack of consideration to facility planning and work flow design, as the company grows, is common. METALKUB is such a company that produces different types of cards and it is located in Iran. This company is facing with two problems in its production layout of which one of them is high distance between packaging department at first floor and pickup storage in ground floor that have high frequency of flow each day. Workers should walk through a long distance between these two departments which lead to high travelling time. Another problem is cross-traffic between some departments at first floor. The objective of this project is minimizing total traveling time, distance and number of cross-traffic. Systematic Layout Planning is employed to identify work/information flow through operation of products. Using this information, design alternative is created which decreases the travelling time and distance of the production flow. The effectiveness of proposed layout is determined using ARENA simulation academic version. Total travel distance from packaging process until keeping in warehouse is reduced significantly by 8417.5 m to 5023 m, which subsequently reduces time of travel as well. The number of cross-traffic is decreased from 38 to 24.

ABSTRAK

Setiap kilang menghadapi dengan masalah susun atur yang berbeza dari masa ke masa dan kecekapan operasi syarikat pembuatan ketara dipengaruhi oleh susun atur kilang. Kekurangan pertimbangan kepada perancangan kemudahan dan aliran kerja reka bentuk, apabila syarikat tumbuh, adalah perkara biasa. Metalkub adalah sebuah syarikat yang menghasilkan jenis kad yang berbeza dan ia terletak di Iran. Syarikat ini sedang menghadapi dengan dua masalah pada susun atur pengeluaran yang mano salah satu ialah jarak yang jauh antara jabatan pembungkusan di tingkat pertama dan penyimpanan kutipan di tingkat bawah yang mempunyai kekerapan aliran yang tinggi setiap hari . Pekerja harus berjalan dengan jarak yang jauh di antara kedua-dua jabatan yang membawa kepada masa perjalanan.Yang tinggi satu lagi masalah ialah trafik rentas antara beberapa jabatan di tingkat pertama. Objektif projek ini adalah meminimumkan jumlah perjalanan masa, jarak dan bilangan trafik rentas untuk memaksimakan kualiti, fleksibiliti dan penggunaan ruang. Perancangan Susunatur sistematik digunakan untuk mengenal pasti kerja / aliran maklumat melalui operasi produk. Menggunakan maklumat ini, reka bentuk alternatif dicipta untuk mengurangkan masa perjalanan dan jarak aliran pengeluaran. Keberkesanan susun atur yang dicadangkan adalah ditentukan menggunakan ARENA versi simulasi akademik. Jumlah jarak perjalanan dari proses pembungkusan jabatan sehingga penyimpanan dalam gudang dikurangkan dengan ketara sebanyak 8417,5 m ke 5023 m, dan seterusnya mengurangkan masa perjalanan. Bilangan trafik rentas menurun dari 38 ke 24.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

With rapid increase of demand in production, industrial factories need to increase their potentials in production and effectiveness to compete against their market rivals. Therefore, the way to solve this production problem is very important. There are many ways to solve the problems concerning productivity such as quality control, total quality management, Standard time and plant layout. Facility Layout Problem (FLP) is described as the efficient formation of physical departments that are identified to be difficult and are normally NP-Hard (Enea et al. 2005). Layout designing objectives lead to minimize the total cost of material transportation and maximize the total closeness rating between some departments. On the other hand, as the criterion for evaluation of layout plans, satisfaction or goodness of closeness between pairs of facilities is also considered (Krishna and Jaafari, 2009).

Typically, the total distance travelled by the "materials" in the facility is used as a proxy for the cost of the facility layout and as a quality indicator in the facility design. Single floor problems and multi floor problems are the major classification. Researches for multi-floor facility layout problems (MFFLP) have been conducted

over a period of years as the multi-floor (multi story) plants which are favorable in terms of utilizing their site efficiently. MFFLPs are more complicated than single floor problems; consequently a lot of researches, using computers, have been conducted (Kohara and Yamamoto, 2008). The focus of this project is on the company with two-floor production operation in which the vertical transportations are done by elevator (Goetschalckx and Irohara, 2007).

The waiting time of vertical transportation, like using an elevator, is more than horizontal one; therefore, the minimization of total waiting time depends on the time consumed in vertical transportation in multi-floor layout (Matsuzaki et al. 1999). The background of the study and the problem definition are discussed in this chapter to describe what the objectives of the thesis are and how improvement challenges are supposed to be solved. Then, Systematic Layout Planning (SLP) is implied to find the better layout in order to decrease the distance and travelling time between departments that have high frequency of material flows between each other. In order to evaluate the proposed alternative layouts, ARENA simulation is used. All these concepts are briefly described in the scope of the study. After considering the scope of study, the goals and advantages are discussed as the significance of the study. Finally, the structure of the rest of the thesis is described to present how this project is going to accomplish the study.

1.2 Background of research

Multi-floor facilities are constructed in countries or areas with high land cost because usable land is either very limited and/or very expensive, especially as one gets closer to industrialized zones. A comparison between MFFLP and single-floor layout problem is, because of vertical traveling between floors, MFFLP is more challenging than single-floor layout problem. The layout analysts should be aware of some factors that may affect the quality and efficiency of any multi-floor facility

layout such as the number and location of vertical handling devices to put, the congestion and delays that may be occurred between departments (Tompkins et al. 2010).

The case study is the company of cards production where the plant layout of the manufacturing company is not properly designed. The materials at ground floor should be transferred by elevator to level one in order to send to different departments. The products after packaging at first floor should be shipped to the final product storage that is located at ground floor. There is a long distance between these two departments that consume a lot of time as well. Another problem which has been found at this company is the cross-traffic flow of materials between departments that occur at first floor. As a result, proper evaluation and improvement to the existing layout is done to overcome this problem. To experiment the manufacturing activities without actual implementation we can use some tools such as computer simulation which can be applied as a stochastic model to estimate the uncertainty of events. Simulation is capable to determine the movement and interactions of system components and can help to design the complex layout and also for examining the flexibility of a design which enables users to evaluate alternative solutions.

1.3 Objective of the study

i. Identify the layout problems in the manufacturing company
ii. Develop improved layouts using SLP
iii. Determine the effectiveness of the proposed alternative layouts using simulation

1.4 Scope of the study

The scopes of this project are as follow:

a) Three different types of cards processes in two floors of the company are considered to be improved
b) SLP procedure will be used to generate the alternative layouts.
c) ARENA software will be used to evaluate future layout alternatives for simulation.
d) The distance between each department is calculated using the rectilinear method.
e) Process total time, transfer time, distance, number of cross-traffics, output and cost are selected as performance measures. Travelling time and distances are quantified

1.5 Significance of study

SLP procedures are applied in this project to improve MFFLP using computer simulation. The greatest benefits to be expected of this study for the improvement processes are maximizing closeness rating and minimizing total travel time and distance.SLP uses a graphical representation and makes up a proximity matrix which depicts the closeness of each facility. Flowcharts can also be used to show quantitative relationships. By simulation, the movement and interaction of system component in departments could be estimated. It is able of aiding in the design of the most difficult automated materials handling system and also helps the user to estimate alternative solutions and to check the flexibility of a design (Eneyo and Pannirselvam,1998).

1.6 Organization of thesis

Chapter 1 begins with an indication of Facilities Layout Planning explanations and its principles. The Objectives and Scopes of the study are defined. Background of problem and significance of finding are described at this chapter.

In chapter 2, some definitions, principles, and approaches of single FLP and MFFLP, heuristic procedures and simulation are demonstrated. Some previous studies which apply different types of solution methods and simulation on single FLP and MFFLP are reviewed in this chapter.

Chapter 3 provides the methodology which has been used to show the procedures of this research including types of data to be collected, tools and techniques to improve the layout and performance measures.

In chapter 4, the identification of problems that exist in current layout is described. The process flow for each product will be observed and documented. The distances travelled by the workers are calculated. Tools such as cross-over chart, From-To-Charts are used to illustrate the closeness importance between each department.

In Chapter 5, SLP will apply for the generation of layout alternatives. SLP is used in this case study as it is a procedural approach which incorporates both qualitative and quantitative data. Three alternatives layouts will be depicted to improve the facilities layout of the company.

Chapter 6 will apply the ARENA software to make the model from current layout and proposed improvement layouts. The types of data distribution will be

justified. The model will be validated and verified. The results will be analyzed and compared with the current layout. Finally the results of each alternative layout are compared to choose the one with the most significant improvement to the company.

1.7 Conclusion

In the beginning of this chapter, an overview of the MFFLP and the importance of facility layout as the main principle for this project are written. The objectives and scopes of study are described. It is indicated that the use of ARENA may improve the performance of company by minimizing its travelling time and distance. At the end of this chapter, the overall structure of the thesis is mentioned. Subsequently, the literature review of improving MFFLP by SLP and simulation will be discussed in the following chapter to further enhance the reader's understanding.

REFERENCE

Abdinnour-Helm, S. and S. W. Hadley (2000). "Tabu search based heuristics for multi-floor facility layout." International Journal of Production Research 38(2): 365-383.

Abdinnour-Helm, S. and S.W. Hadley (1995). "An iterative layout heuristic for multi-Floor facilities." Decision Science Institute Proceedings, Boston, MA.

Abdinnour-Helm, S. and S. W. Hadley (2010). "Tabu search based heuristics for multi-floor facility layout." International Journal of Production Research 38(2): 365-383.

Aiello G, Enea M, et al. (2006). "A multi-objective approach to facility layout problem by genetic search algorithm and Electre method. Robot." Comput. Integr. Manuf. 22: 447-455.

Aiello, S., A. O'Hara, et al. (2007). "Systematic Layout Plan for Baystate Benefit Services." Capstone Design Program: Industrial Engineering.

Al-Sudairi A. A., (2007) Evaluating the effect of construction process characteristics to the applicability of lean principles, Construction Innovation, 7, 99-121.

APPLE , J. M. (1963). Plant Layout and Materials Handling. New York, Ronald Press.

Barbee, G. (,1996). "The Best Laid Plans - Part 1." Bobbin 37(11): 99-101.

BAZARAA, M. S. (1975). "Computerized Layout Design: A Branch and Bound Approach." AIIE Trans 7: 432-428.

BLOCK, T. E. (1977). "A Note on 'Comparison of Computer Algorithms and Visual Based Methods for Plant Layout' by M. Scriabin and R. C. Vergin." Management Science 24: 235-237.

Bozer., Y. A., E. D.Meller., et al. (1994). "An improvement-type layout algorithm for single and multiple-floor facilities." Management Science 40(7): 918-932.

Chien, T.-K. (2004). "An empirical study of facility layout using a modified SLP procedure." Journal of Manufacturing Technology Management 15(6): 455-465.

Daiki Kohara and H. Yamamoto (2008). "Efficient Algorithms Based on Branch and Bound Methods for Multi Floor Facility Layout Problems."

Dimitrios I. Patsiatzis and L. G. Papageorgiou (2002). "Optimal multi-floor process plant layout." Computers and Chemical Engineering 26: 575–583

Enea M, Galante G, et al. ((2005)). "The facility layout problem approached using a fuzzy model and a genetic search." Intell. Manuf 16: 303-316.

Eneyo, E. S. and G. P. Pannirselvam (1998). "The Use of Simulation in Facility Layout Design A Practical Consulting Experience." Proceedings of the 1998 Winter Simulation Conference U.S.: 1527-1532.

Eneyo, E. S. and G. P. Pannirselvam (,1998). "The Use of Simulation in Facility Layout Design A Practical Consulting Experience." Proceedings of the 1998 Winter Simulation Conference U.S.: 1527-1532.

F. Ramtin, M. Abolhasanpour, et al. (2010). "OptimalMulti Floor Facility Layout." Proceedings of the International MultiConference of Engineers and Computer Scientists 3.

Foulds, L. R. (1983). "Techniques for Facilities Layout." Management Science 29(12): 1414-1426.

G. Q. Zhang, J. Xue, et al. (2002). "class of genetic algorithms for multiple-level warehouse layout problem." International Journal of Production Research 40(3): 731-744.

Heizer, J. and B. Render (2006). "Operations Management." New Jersey: Pearson International Edition.

James A.Tompkins, John A.White, et al. (2010). Facilities Planing. New York; John Wiley & Sons Inc.

James A.Tompkins, J. A. W., Yavuz A.Bozer, J.M.A.Tanchoco (2010). "Facilities Planing."

Johnson, R. V. (1982). "SPACECRAFT FOR MULTI-FLOOR LAYOUT PLANNING." Management Science 28: 407-417.

Kenichiro Matsuzaki, Takashi Irohara, et al. (1999). "Heuristic algorithm to solve the multi-floor layout problem with the consideration of elevator utilization." Computers & Industrial Engineering 36: 487-502.

Krishna k. Krishnan1 and A. A. Jaafari (2009). "A mixed integer programming formulation for multi floor layout." African Journal of Business Management 3: 616-620.

Marc Goetschalckx and T. Irohara (2007). "Efficient Algorithms Based on Branch and Bound Methods for Multi Floor Facility Layout Problems."

Dorigo, Marco, Mauro Birattari, and Thomas Stutzle "Ant colony optimization." *Computational Intelligence Magazine, IEEE* 1.4 (2004): 28-39.

MELLER,R.D. and BOZER,Y.A., 1997, Alternative approaches to solve the multi-Floor facility layout problem, Journal of Manufacturing Systems, 16, 192± 203.

Mirzapourrezaei, S.A.; Lalmazloumian, M.; Dargi, A.; Kuan Yew Wong; , "Simulation of a Manufacturing Assembly Line Based on WITNESS," Computational Intelligence, Communication Systems and Networks (CICSyN), 2011 Third International Conference on , vol., no., pp.132-137, 26-28 July 2011.

MUTHER, R. (1955). Practical Plant Layout. New York, McGraw-Hill.

Muther, R. (1973). Systematic Layout planning. Boston, Chaners Books.

Nikakhtar A., Wong K. Y., Zarei M. H., and Memari A., (2011) Comparison of two simulation software systems for modeling a construction process, Proceedings of 2011 Third International Conference on Computational Intelligence, Modelling & Simulation, Langkawi, Malaysia.

Taho Yang, Chao-Ton Su, et al. (2000). "Systematic layout planning: a study on semiconductor wafer fabrication facilities." International Journal of Operations & Production Management 20(11): 1359-1371.

Wang S. and Halpin D.W., (2004) Simulation experiment for improving construction processes Proceedings of the 2004 Winter Simulation Conference, Washington, DC, USA.

W. Wiyaratn and A. Watanapa (2010). "Improvement Plant Layout Using Systematic Layout Planning (SLP) for Increased Productivity." World Academy of Science, Engineering and Technology.

Yanru Chen , Qinxin Xiao, et al. (2011). "Product Layout Optimization and Simulation Model in a Multi-level Distribution Center." Systems Engineering Procedia 2: 300 – 307.

Zhang, K. K. L. C. (2006). "path relinking and genetic algorithms for the multiple-level warehouse layout problems." European Journal of Operational Research 169(2): 413-425.