

CELLULAR FACILITY LAYOUT: MODELS & METHODOLOGIES

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CELLULAR FACILITY LAYOUT: MODELS & METHODOLOGIES

by

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CERTIFICATE

This is to certify that the thesis entitled “**Cellular Facility Layout: Models & Methodologies**” being submitted by **Mr. Ravi Kumar** to the Department of Management Studies, Indian Institute of Technology Delhi for the award of the degree of **Doctor of Philosophy**, is a record of bonafide research work carried out by him. He has worked under my guidance and supervision and fulfilled the requirements for the submission of the thesis, which has attained the standard required for a Ph.D. degree of the institute. The results presented in this thesis have not been submitted elsewhere for the award of any degree or diploma.

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Ravi Kumar

ABSTRACT

Facility layout planning (FLP) includes the arrangement of facilities, departments, machines, tools and instruments on the shop floor in their most efficient position to minimize one or more qualitative such as flow of information, noise disturbances, etc. or quantitative objective such as material handling cost, cost of scheduling, and manufacturing cost, etc. functions. An efficient layout planning is important because it uses most expensive resources of the organization. The layout must be effective to meet the firm's competitive requirement. FLP has a great impact on material handling cost (MHC), productivity and efficiency of an organization. In addition to the upfront investments involved in facility planning, there are operational investments are also critical issues. An efficient layout can reduce the manufacturing costs by 10 to 30% and material MHC by 15 to 40%. It is estimated that about 20 to 50% of the manufacturing cost is due to material handling. An efficient layout planning can decrease material handling, set up time, lead time, throughput time, work in process and inventory, and increase productivity and quality.

Cellular layout is a new production strategy, which overcomes the flexibility issues of product oriented layouts and larger throughput time issues of process layouts. Cellular layouts are based on Group Technology (GT). Cellular layouts can be implemented in three stages as cell formulation (grouping dissimilar machines into machine cells and parts into part families by using part production process), intra-cell layout (layout of dissimilar machines within each cell), and inter-cell layout (layout of each cell within shop floor).

The efficient and effective layout design depends on the product demand. However, due to rapidly changing market and competition, product demand changes very frequently. The continuous and rapidly changing product demand cannot hold the layout design efficient and effective and hence, the FLP cannot be modelled as SFLP. To deal variations in the product

demand the layout model need to be dynamic and must take into account of varying product demand across entire time period. Thus, the SFLP need to be formulated as DFLP. In DFLP, facilities are arranged on shop-floor for each time period, and the overall MHC and re-arrangement cost are minimized over the planning horizon. The re-arrangement cost is occurred if any facility shifts from one location to other in the planning horizon in the form of mantling and dismantling cost.

Due to competitive market, changes in the product demand and production mix are very rapid now-a-days. A dynamic facility layout is not efficient to handle this rapid change of product demand and mix. Moreover, any change in the existing layout incurs re-arrangement cost. Thus, to deal effectively with the highly competitive market, an efficient layout must be one which can handle all these uncertainties effectively. To avoid the re-configuration of facilities in case of change in product mix and product demand, a robust layout is given in this chapter. A robust layout is used when the demand of products is stochastic i.e. demand of products changes over planning horizon frequently, and re-configuration of facilities is not permitted (such as heavy machines, or costly machines should not be moved). In this approach, expected demand of all the time periods for all the products is used to minimize the material handling distance (MHD) among facilities.

The increase use of energy is harmful to environment since it emits greenhouse gases like CO. Also, due to increased use of energy the cost of electrical energy is getting higher. The energy consumption in industrial sector is majorly in the form of electrical energy, which put ups 15% of the production cost. So it is worthy to consider the electrical energy consumption (EEC) in designing phase of facility layout problem (FLP). Therefore, in this chapter a sustainable layout design is proposed considering two objectives. First objective is to minimize the material handling distance (MHD) among machines, and second objective is to

minimize EEC which is in the form of electrical energy consumed by automated guided vehicles (AGVs) in transporting parts from one machine to another.

Also, Big Data approach is used to handle large scale data so that an effective and efficient layout design can be proposed considering multi-attributes scenario. The different attributes considered are MHD, maintenance, adjacency, hazard, and EEC. A framework to select most preferred to least preferred layout among layout alternatives in multi-attribute scenario is also proposed.

The proposed mathematical models and solution methodologies are validated considering real time data from a tower manufacturing industry. Lastly, thesis is concluded by summarizing all chapters, providing major contributions, and future recommendations.

Keywords: Facility layout, Cellular facility layout, Dynamic layout, Robust layout, Sustainable layout, Big Data

सार

फैसिलिटी लेआउट प्लानिंग (एफएलपी) में शॉप फ्लोर पर फैसिलिटीओं, विभागों, मशीनों, औजारों और उपकरणों की व्यवस्था शामिल है, जो एक या अधिक गुणात्मक को कम करने के लिए, जैसे सूचना का प्रवाह, शोर गड़बड़ी आदि या मात्रात्मक उद्देश्य जैसे कम से कम गुणात्मक को कम करने के लिए, सामग्री हैंडलिंग लागत, शेड्यूलिंग की लागत, और विनिर्माण लागत, आदि कार्यों। एक कुशल लेआउट योजना महत्वपूर्ण है क्योंकि यह संगठन के सबसे महंगे संसाधनों का उपयोग करती है। फर्म की प्रतिस्पर्धी आवश्यकता को पूरा करने के लिए लेआउट प्रभावी होना चाहिए। एफएलपी का भौतिक हैंडलिंग लागत (एमएचसी), उत्पादकता और एक संगठन की दक्षता पर बहुत बड़ा असर पड़ता है। फैसिलिटी योजना में शामिल किए गए पहले निवेश के अलावा, परिचालन निवेश भी महत्वपूर्ण मुद्दे हैं। एक कुशल लेआउट विनिर्माण लागत को 10 से 30% और सामग्री एमएचसी 15 से 40% तक कम कर सकता है। यह अनुमान लगाया गया है कि विनिर्माण लागत का लगभग 20 से 50% भौतिक हैंडलिंग के कारण है। एक कुशल लेआउट योजना सामग्री प्रबंधन को कम कर सकती है, समय सेट कर सकती है, लीड टाइम, थ्रूपुट टाइम, प्रक्रिया में काम और सूची, और उत्पादकता और गुणवत्ता में वृद्धि कर सकती है।

सेलुलर लेआउट एक नई उत्पादन रणनीति है, जो उत्पाद उन्मुख लेआउट के लचीलेपन मुद्दों और प्रक्रिया लेआउट के बड़े थ्रूपुट समय के मुद्दों पर विजय प्राप्त करती है। सेलुलर लेआउट ग्रुप टेक्नोलॉजी (जीटी) पर आधारित हैं। सेलुलर लेआउट को सेल उत्पादन के रूप में तीन चरणों में कार्यान्वित किया जा सकता है (भाग उत्पादन प्रक्रिया का उपयोग करके मशीन कोशिकाओं और हिस्सों में भागों को अलग-

अलग हिस्सों में विभाजित करना), इंट्रा-सेल लेआउट (प्रत्येक सेल के भीतर असमान मशीनों का लेआउट), और इंटर-सेल लेआउट (शॉप फ्लोर के तल के भीतर प्रत्येक सेल का लेआउट)।

कुशल और प्रभावी लेआउट डिजाइन उत्पाद की मांग पर निर्भर करता है। हालांकि, तेजी से बदलते बाजार और प्रतिस्पर्धा के कारण, उत्पाद की मांग में अक्सर परिवर्तन होता है। निरंतर और तेजी से बदलती उत्पाद मांग लेआउट डिजाइन को कुशल और प्रभावी नहीं रख सकती है और इसलिए, एफएलपी को एसएफएलपी के रूप में मॉडल नहीं किया जा सकता है। उत्पाद में बदलावों को सौदा करने के लिए मांग लेआउट मॉडल को डायनामिक होने की आवश्यकता है और पूरे समयावधि में अलग-अलग उत्पाद की मांग को ध्यान में रखना चाहिए। इस प्रकार, एसएफएलपी को डीएफएलपी के रूप में तैयार करने की आवश्यकता है। डीएफएलपी में, प्रत्येक समय अवधि के लिए शॉप फ्लोर-मंजिल पर फैसिलिटीओं की व्यवस्था की जाती है, और समग्र एमएचसी और पुनः व्यवस्था लागत नियोजन क्षितिज पर कम हो जाती है। पुनर्स्थापन लागत तब होती है जब कोई फैसिलिटी योजना के क्षितिज में एक स्थान से दूसरे स्थान पर स्थानांतरित हो जाती है और लागत को कम करने के रूप में बदलती है।

प्रतिस्पर्धी बाजार के कारण, उत्पाद की मांग और उत्पादन मिश्रण में बदलाव आजकल बहुत तेजी से हैं। एक डायनामिक फैसिलिटी लेआउट उत्पाद की मांग और मिश्रण के इस तेजी से परिवर्तन को संभालने में सक्षम नहीं है। इसके अलावा, मौजूदा लेआउट में किसी भी बदलाव में पुनः व्यवस्था लागत शामिल है। इस प्रकार, अत्यधिक प्रतिस्पर्धी बाजार के साथ प्रभावी ढंग से निपटने के लिए, एक कुशल लेआउट एक ऐसा होना चाहिए जो इन सभी अनिश्चितताओं को प्रभावी ढंग से संभाल सके। उत्पाद मिश्रण और उत्पाद

की मांग में बदलाव के मामले में फैसिलिटीओं की पुनः कॉन्फिगरेशन से बचने के लिए, इस अध्याय में एक रोबस्ट लेआउट दिया गया है। एक रोबस्ट लेआउट का उपयोग तब किया जाता है जब उत्पादों की मांग stochastic है यानी योजना क्षितिज पर अक्सर उत्पादों की मांग में मांग, और फैसिलिटीओं की पुनः कॉन्फिगरेशन की अनुमति नहीं है (जैसे भारी मशीनें, या महंगी मशीनों को स्थानांतरित नहीं किया जाना चाहिए)। इस दृष्टिकोण में, सभी उत्पादों के लिए सभी समय अवधि की अपेक्षित मांग का उपयोग फैसिलिटीओं के बीच मटेरियल हैंडलिंग डिस्टेंस (एमएचडी) को कम करने के लिए किया जाता है।

ऊर्जा का उपयोग पर्यावरण के लिए हानिकारक है क्योंकि यह सीओ जैसे ग्रीनहाउस गैसों को उत्सर्जित करता है। इसके अलावा, ऊर्जा के उपयोग में वृद्धि के कारण विद्युत ऊर्जा की लागत अधिक हो रही है। औद्योगिक क्षेत्र में ऊर्जा खपत मुख्य रूप से विद्युत ऊर्जा के रूप में है, जो उत्पादन लागत का 15% ऊपर रखती है। तो यह फैसिलिटी लेआउट प्लानिंग (एफएलपी) के डिजाइन चरण में इलेक्ट्रिकल एनर्जी कोन्सुम्प्शन (ईईसी) पर विचार करने योग्य है। इसलिए, इस अध्याय में दो उद्देश्यों पर विचार करने के लिए एक टिकाऊ लेआउट डिजाइन प्रस्तावित किया गया है। पहला उद्देश्य मशीनों के बीच मटेरियल हैंडलिंग डिस्टेंस (एमएचडी) को कम करना है, और दूसरा उद्देश्य है ईईसी को कम करें जो एक मशीन से दूसरे भाग में भागों को परिवहन में ऑटोमेटेड गाइडेड व्हीकल्स (एजीवी) द्वारा खपत विद्युत ऊर्जा के रूप में है।

इसके अलावा, बड़े पैमाने पर डेटा को बड़े पैमाने पर डेटा को संभालने के लिए उपयोग किया जाता है ताकि बहु-गुण परिदृश्य पर विचार करने के लिए एक प्रभावी और कुशल लेआउट डिज़ाइन का प्रस्ताव दिया जा

सके। माना जाता है कि विभिन्न गुण एमएचडी, रखरखाव, आसन्नता, खतरे, और ईईसी हैं। मल्टी-एट्रिब्यूट परिदृश्य में लेआउट विकल्पों के बीच सबसे पसंदीदा लेआउट का चयन करने के लिए एक ढांचा भी प्रस्तावित किया गया है।

प्रस्तावित गणितीय मॉडल और समाधान पद्धतियां टावर विनिर्माण उद्योग से वास्तविक समय डेटा पर विचार करने के लिए मान्य हैं। अंत में, थीसिस सभी अध्यायों को सारांशित करके, प्रमुख योगदान और भविष्य की सिफारिशें प्रदान करके निष्कर्ष निकाला जाता है।

कीवर्ड: फैसिलिटी लेआउट, सेलुलर फैसिलिटी लेआउट, डायनामिक लेआउट, रोबस्ट लेआउट, सस्टेनेबल लेआउट, बिग डेटा

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List of Abbreviations

ACO	Ant Colony Optimization
ALDEP	Automated Layout Design Program
BK	Borda-kendall
CFLP	Cellular Facility Layout Problem
CFP	Cell Formulation Problem
CMS	Cellular Manufacturing Systems
CORELAP	Computerized Relationship Layout Planning
CRAFT	Computerized Relative Allocation of Facilities Technique
DFLP	Dynamic Facility Layout Problem
DCFLP	Dynamic Cellular Facility Layout Problem
DP	Dynamic Programming
EEC	Electrical Energy Consumption
FBS	Flexible Bay Structure
FLP	Facility Layout Planning
GA	Genetic Algorithm
GT	Group Technology
INLP	Integer Non Linear Program
MADM	Multi Attribute Decision Making
MCDM	Multi Criteria Decision Making
MAT	Modular Allocation Technique
MHC	Material Handling Cost
MIP	Mixed Integer Program
MILP	Mixed Integer Linear Program
MINLP	Mixed Integer Non Linear Program
MLT	Manufacturing Lead Time
MOSA	Multi-objective Simulated Annealing

MOVDO	Multi-objective Vibration Damping Optimization
NLGP	Non-linear Goal Program
NP-hard	Non-polynomial Hard
OFV	Objective Function Value
OV	Objective Value
PSO	Particle Swarm Optimization
QAP	Quadratic Assignment Problem
QSCP	Quadratic Set Covering Problem
SA	Simulated Annealing
SCFLP	Static Cellular Facility Layout Problem
SDFLP	Stochastic Dynamic Facility Layout Problem
SFLP	Static Facility Layout Problem
SLP	Systematic Layout Planning
SRFLP	Single Row Facility Layout Problem
RSCFLP	Robust Stochastic Cellular Facility Layout Problem
TS	Tabu Search