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FOR EFFECTIVE FACILITIES PLANNING: LAYOUT OPTIMIZATION THEN SIMULATION, OR VICE VERSA?

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ABSTRACT

It is widely accepted that simulation is an integral part of any effective facilities planning or layout study. Traditional approaches claim that layout optimization produces strategic results and therefore should precede simulation analysis, which focuses on operational issues. On the other hand, more recent studies suggest that running simulation models prior to conducting layout optimization produces more realistic layouts. In this paper, we contrast these two paradigms, with respect to the general assumptions and the types of applications that advocates from each paradigm have used to support their claim. In addition, we propose guidelines on which approach to pursue according to the layout study objectives and the characteristics of the system under consideration.

1 OVERVIEW OF THE FACILITY LAYOUT PROBLEM

Facility layout is the arrangement of activities, features and spaces in consideration of the relationship that exists between them (Hales 1984). It belongs to the class of spatial allocation problems that have been studied in various contexts, including architecture space planning, manufacturing layout, offices layout and VLSI Layout (Tam ,and Li 1991; Tompkins et al. 2003). Facility or plant layout is a part of facilities design, which includes more global issues such as plant location, building design, material handling, etc. In general, plant layout analysis includes a study of the production line process flow charts, material flow diagrams, product routings, processing times, development of from-to charts, relationship diagrams between different departments in the facility and the cost of material movement (Francis, McGinnis ,and White 1992)

In its most basic form, a facility layout problem (FLP) is analytically formulated according to the Quadratic Assignment Problem (QAP), a classical model in discrete optimization which works by enumerating different layout configurations until the best arrangement is obtained. Although mathematically elegant, QAP is an NP-hard problem (Sahni ,and Gonzalez 1976), which implies it is computationally impractical for problems involving over fifteen departments (Partovi ,and Burton 1992). Due to the combinatorial aspects of optimally solving the FLP, analysts have developed various heuristics to substitute for blind search methods. These are categorized as either construction or improvement-type routines:

1. Construction-type layout routines: This type of routine generates a block layout based on the relationship between different departments. Among the most popular routines within this category are CORELAP (computerized relationship layout planning) (Lee ,and Moore 1967), ALDEP (Automated layout design) (Seehof ,and Evans 1967) and PLANET (Plant layout analysis and evaluation techniques) (Deisenroth ,and Apple 1972).
2. Improvement-type layout routines: This type of routine requires an input of a feasible block layout and aim to reduce movement cost by attempting simultaneous pair-wise (or more) position exchanging among the departments. Among the most popular improvement-type routines are CRAFT (computerized relative allocation of facilities technique) (Armour ,and Buffa 1963) and COFAD (Computerized facilities design) (Tompkins ,and Reed 1973).

Although computationally efficient, FLP heuristics are still far from meeting the constraints commonly found in daily layout tasks (Tam ,and Li 1991). Simulation has been requisitely used to incorporate many of these requirements into the facility layout study. The next section explains the benefits of simulation for facility layout studies.

2 WHY SIMULATION IN LAYOUT STUDIES?

According to Grajo (1996), layout optimization and simulation are two tasks that are crucial to any facility planning and layout study. According to Burgess et al. (1993), simulation is the only methodology robust enough to systematically examine the role and impact of product complexity and other key variables on factory performance. This is especially true because simulation models can capture many of the requirements and attributes of real life problems that are difficult to consider using analytical models for the layout optimization problems (Tam ,and Li 1991; Tang ,and Abdel-Malek 1996; Pandey, Janewithayapun ,and Hasin 2000; Castillo ,and Peters 2002). Typically, a simulation study is used in layout studies to estimate system parameters associated with the following tasks:

1. Develop a series of improved layouts that has been generated using traditional facility layout routines or algorithms (Das 1993; Altinkilinc 2004).
2. Contrast different layout configurations in terms of operational parameters, such as utilization, flow-time and buffer sizes (Mosier 1989; Morris ,and Tersine 1990; Sassani 1990; Burgess, Morgan ,and Vollmann 1993; Morris ,and Tersine 1994; Cho, Moon ,and Yun 1996; Hamamoto, Yih ,and Salvendy 1999; Huq, Hensler ,and Mohamed 2001; Adusumilli ,and Wright 2004)
3. Evaluate various strategies for the operation of the facility or justify the embracement of manufacturing concepts such as Group technology and flexible manufacturing systems (Pegden, Shannon ,and Sadowski 1995; Taj et al. 1998; Farahmand 2000; Al-Mubarak, Canel ,and Khumawala 2003; Ranky, Morales ,and Caudill 2003).
4. Identify potential problems and bottlenecks in proposed layout structures prior to implementation (Ramirez-Valdivia et al.).
5. Compress or expand time to study the layout in steady state or under specific short-term scenarios such as product mix changes, breakdowns or emergencies.
6. Incorporate stochastic behavior and uncertainty of demand (Shafer ,and Charnes 1997; Hamamoto, Yih ,and Salvendy 1999; Kulturel-Konak, Smith ,and Norman 2004).
7. Use simulation model to generate random flow volumes to be subsequently supplied to traditional facility layout routines (Gupta 1986).

3 TWO SCHOOLS OF THOUGHT

Despite the wide application of simulation modeling in facility layout studies, the organization of these two tasks has been informally addressed and applied. Specifically, the question of whether a layout study should precede simulation modeling or vice versa to obtain effective layouts has been a point of debate. It seems that two schools of thought exist in this regard. The first school suggests that layout optimization should be conducted prior to a simulation study, while the second one advises that the contrary will result in better layout efficiency. Table 1 compares these two schools of thought. The details of the comparison are provided within the following sections.

3.1 Layout then Simulate

Advocates of the "layout then simulate" paradigm characterize simulation analysis as local and operational, while posting layout optimization as global and strategic. Grajo (1995; 1996) indicate that starting with a layout process with a simulation study will result in around 10%-15% improvement, while missing a much larger opportunity for improvement, had it been the case that layout optimization had been conducted first. Layout studies that embrace this paradigm start by generating a block layout using facility layout routines and deterministic flow volumes; then, improve the operational characteristics based on the results of a simulation study. Applications of this approach typically assume that overall production strategies and manufacturing technologies are predetermined, where the objectives involve comparing, testing, adjusting and validating different layout configurations. In addition, stochastic demand or complex production rules are not significant enough to be incorporated early in the process while the layout optimization is taking place.

While this approach may save time, it runs the risk of inheriting the shortcomings of the preliminary block layout. That is, the window of improvement available to the simulation study is restrained within the primitive block layout generated.

3.2 Simulate then Layout

Contrary to the previous paradigm, advocates from this school of thought claim that a simulation study needs to be conducted prior to layout optimization. That is, an optimized process that delivered the desired levels of throughput, WIP, and utilization, will result in a more efficient layout. In fact, Sly (1997) states that skipping simulation prior to layout optimization will result in layouts that fail to reduce inventory levels and throughput times and will result in only a little more than rearranging furniture within the plant. Applications within this paradigm include justifying operational parameters and adjusting production levels before attempting to optimize the layout (Eneyo ,and Pannirselvam 1998).

Table 1: Two Schools of Thought on Whether to Start By Layout Optimization or Simulation in Facility Planning and Layout Tasks

Paradigm	Layout then simulate	Simulate then layout
Belief	Simulation analysis is local, where layout optimization analysis is global	Simulation prior layout study produces layouts that are efficient and realistic
Benefits	Time efficient	Provides accurate estimate of flow for layout optimization form simulation
Application (Best for)	• Improving existing layout • Resolving congestion and bottlenecks in layout • Only minor system's process' parameters need to be adjusted • Technology embraced requires special layout type and simulation for verification • Insignificant stochastic behavior • Focus is on minimizing traveled distance	• Creating a new layout for a system that exhibit significant: – stochastic behavior/demand • and/or – complex interactions • Major operational policies/technologies are not predetermined or need to be justified prior layout optimization • Simulation is used to generate random flow to be fed for a layout routine • Solving flow congestions and bottlenecks have higher priority than reducing distances

This has the advantage of supplying more accurate volume and flow data to the layout optimization study, especially when significant stochastic intricacies impede the accurate estimation of production levels using analytical models.

In addition, this paradigm has been embraced when simulation is needed to generate random flow volumes to be subsequently used as input for a layout optimization routine (Gupta 1986; Kulturel-Konak, Smith ,and Norman 2004). For instance, Altinkilinc (2004) has first simulated the system to improve its parameters and then supplied the results to the CRAFT method to optimize the layout. Moreover, Pandey et al. (2000) have optimized the dynamic system parameters using simulation then adapted the layout accordingly.

However, as far as development pace, layout studies based on this paradigm are relatively more time consuming, due to the experimental and statistical analysis involved in simulation studies.

4 WHICH PARADIGM TO EMBRACE?

We analyzed the type of applications that advocates from each of the above paradigms pursued to justify their approach. We found that the choice of the approach to pursue depends on the objectives of the facility layout study and the characteristics of the system under study.

4.1 The Objectives of the Layout Study

Facility layout studies can contain several contradicting objectives (Francis, McGinnis ,and White 1992). Minimizing distances while minimizing travel congestion is a case in point. The prioritization of the facility layout objectives largely determine the best approach to pursue. For instance, in a facility layout study, where higher priority is given to reducing the typical traveled distance or improving adjacency score, then the "layout then simulation" paradigm fits better. On the other hand, if the objectives of the study are to produce layouts that improve shop-floor performance measures, such as minimizing congestion, then the "simulate then layout" is expected to outperform the former paradigm. In addition, the second paradigm is better used when the objective is to justify the benefits of implementing general production principles such as Group Technology (GT), switching to flexible manufacturing systems (FMS), introduction of robotics or AGVs (Mitsuhashi ,and Yamato 1987; Farahmand 2000; Al-Mubarak, Canel ,and Khumawala 2003).

4.2 The Characteristics of the System Being Analyzed

The characteristic of the system under the layout study plays a major role in the selecting appropriate paradigm for the study. For example, the gained efficiency of conducting a layout study of a system that is characterized as stochastic and complex is expected to be better when embracing simulate then layout paradigm. On the other hand, case studies that support the layout then simulate paradigm, investigate facilities that exhibit predictable behavior and predetermined managerial and production philosophies.

5 CONCLUSIONS

Two controversial schools of thought debate on when to use simulation in facility layout studies. The first school of thought suggests that the layout optimization tasks are strategic and therefore should precede simulation modeling, which focuses on operational issues. The second school of thought suggests that starting with simulation as opposed to layout optimization produces realistic layout that improves throughput levels and reduces work-in-process. In this paper, we have contrasted these two paradigms and recommended that the gained efficiency of the choice of either paradigm depends on the objectives of the facility layout study, the stochastic nature of the problem and the complexity of the systems' interactions. The former is better when applied to deterministic problems with predefined operational policies and production strategies and that focus primarily on minimizing travel distance and material handling cost. However, the latter is best applied for problems exhibiting uncertainties and those where the objective is to justify production strategies and improve layout operational parameters.

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