A HYBRID SIMULATION MODEL FOR JET ENGINE MAINTENANCE:
AN APPLICATION OF FACILITY LAYOUT PROBLEM[1]

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ABSTRACT

The problem of designing a facility layout that achieves efficient functionality is well studied in the literature [3-9]. In this paper we rely on existing techniques in facility layout problem to model and solve an unequal-area facility layout problem with simulation tools specifically designed for engine maintenance. A comprehensive simulation study [1-2] was undertaken to determine the inherent constraints and the bottleneck operations at a jet engine maintenance shop. The relevant performance measures from the simulation outputs along with such factors as space requirements for each equipment and the expected operational goal of the new facility were analyzed.

INTRODUCTION

Facility layout is one of the key factors in determining the long run efficiency of operations in manufacturing and production plants. The facility layout design problem (FLP) is economically and logistically critical, since well planned layout can contribute to improved flow of information, materiel and people, as well as, an increased in the utilization of space and equipment. Not every kind of layout can be modeled mathematically, and in general, a good layout plan is a combination of both quantitative and qualitative factors. Nevertheless, it is known that a good layout requires material handling equipment and capacity and space requirements.

The most common practice, in designing a process layout, is to arrange the work station in order to minimize the total material handing cost and/or the processing time. Other objectives such as maximizing the number of work centers (i.e., increasing the plant capacity) are also of interest. There are several soft and hard factors that should be considered in layout design. These factors include space and labor utilization, source of bottlenecks, communication and interaction between workers and their supervisors, cycle time or customer service time, wasteful or redundant movements, entry and exit, placement of material, products, or people, safety and security measures, product and service quality, maintenance activities, and finally, visual control of operations or activities.

In general, we assume there are n given facilities, rectangular in shape, of dimensions H and W, where H is the height and W is the width. The number of departments, the area of each department, and the flow values traversed between each pair of department nodes are assumed to be known either as a deterministic parameter or as a distribution function.

The basic formulation can be represented by

$n =$ # of departments being considered. f_{ij} = The total flow between i & j , where i,j=1,...,n

u_{ij} = The utility value of processing an item in dept i and sending to dept j where i,j=1,...,n

P_i = Number of parallel stations i for j=1,…,n

The objective function, in its simplest form, for minimizing the total product flow through out a facility is given by,

[1] This report is condensed in order to comply with the proceedings formatting and limits. A full version of this paper may be obtained directly from the authors.

$$\text{Maximize} \sum_{i=1}^{n} \sum_{j=1,\, j \neq i}^{n} u_{ij} f_{ij} p_i \qquad (1)$$

Subject to: constraints listed above, such as capacity of each station, number of parallel station, assigning the right number of personnel to each station, and the duration of process at each station.
In general such problems are NP-hard in nature, belonging to the class of Global Optimization (e.g., see [10] and references therein), and generic mathematical algorithms can only deal with small-scale instances of the problem. Many authors have developed heuristics algorithms to tackle moderate size problems [3-8] and some have claimed efficiency. However, because of the complexity involved and variations in practical problems at hand, simulation technology remains a viable approach. The focus of this paper is an application of facility layout design problem for a jet engine maintenance shop. The operation of this shop can be categorized as a hybrid combination of process-oriented and product-oriented facility layout.

PROBLEM STATEMENT

A particular maintenance shop supports two kinds of Pratt and Whitney engines, F100-200 and F100-229. This jet engine intermediate maintenance (JEIM) shop is approximately 340 × 90 feet with 3 docks consisting of 15 rails. 154 personnel are authorized but only 121are assigned. The personnel, depending on their seniority and experiences are divided into 4 levels: managers, floor managers, senior maintainers, and maintainers. Presently the shop consists of 3 managers, 47 floor managers, 31 senior maintainers and 40 maintainers. The test cell, where the jet engines are tested for quality includes 3 hush houses. The engine shop process is simply a series of parallel and serial operations cumulating in the hush house where the engines are tested before shipping out. If the engine doesn't pass the final inspection, it is sent back to the appropriate station for further maintenance. The main objective of this study was to evaluate and offer a new facility layout plan that maximized the output of the shop without additional cost. With the present number of rails and personnel, the JEIM shop is producing about 83 F100–229 and 59 F100-220 engines per year. The three test cells are manned by 11 personnel: 6 floor managers, 5 senior maintainers, and1 maintainer. In year 3, 242 engines (134 F100-229, 94 F100-220, and 14 non-production engines) and 91 aircraft (installed engines) were tested.

EVALUATION OF CURRENT CAPABILITY

Based on year 4 data, non-mission capability rate due to parts and labor, accounted for 70% and 58% of the time for F100- 220 and F100-229, respectively. Although reducing (or eliminating) these rates would increase the shop's production, it would not increase the total number of fully mission capable engines by a huge margin. With the current facility and no parts or labor, the JEIM shop would be able to send (generate) about 175 –220 and 195 –229 engines to the test cells, a total of 370 engines. However, the average test cell production, based on the data, is about 260 engines and 82 aircraft per year (21.6 and 6.8 per month respectively). Test cell production may be increased if all the test cells are operational during the critical demand periods. Based on the same historical data, we can see that the test cell is capable of handling about 324 engines and 120 aircraft per year (27 and 10 per month respectively). This is estimated by considering all the data points in the years 2 and 3 data and maximizing both the number of aircraft and engines tested given various priority to each one.

Personnel and Space Considerations

Currently, there are 15 rails (10 devoted to –229 and others to –220) taking about 28% of the shop space. The rest of the shop is divided as follows: Mod shop (25%), spare modules (7%), parts and tools (5%), and spare engines (15%). As we mentioned earlier, the bottleneck in the overall engine maintenance seems to be the test cell operation. However, in order to estimate the effect of full manning at the JEIM shop and the test cell, we used a simulation model [1] specifically designed for engine maintenance shop. We calibrated the model based on the data provided and ran the simulation using assigned and authorized manning for JEIM and the test cells. As expected the simulation model generated the similar numbers using current assigned personnel: about 136 –229 and 92 –220 engines per year. We increased the number of personnel to the authorized level (i.e., about 5 per rail) without any changes to the test cell crew and again as expected the test cell was the cause of bottleneck and the shop could only generate about 138 –229 and 93 –220 engines. Finally, we increased the crew size for the JEIM shop and the test cell and the result was a significant increase in the production levels: about 206 –229 and 139 –220 engines. This is about a 50% increase in the production capacity with only a 27% increase in the number of personnel.

CONCLUDING REMARKS

The numerical values of the decision variables obtained by the hybrid simulation model was implemented and well received by the clients. It was estimated that an increased efficiency of up to 30% was observed as a result of implementing the simulation results.

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