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Facility Design Variations using a Strong Component based Methodology

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Abstract

In this presentation is shown how a strong component-based facility layout design methodology addresses the design problem when some design relevant factors are adapted. The strong-component-based methodology proposes a unique structural design, a non-dedicated facility, capable of producing a family of products that require similar operations and workstations, which can be shared. Simultaneously, the methodology suggests that this structure can take advantage of both, known classical layout designs, product and process, in a single or multiple machine environments. In addition, adding or reducing a number of stations, adding feeding and storage facilities, considering qualitative and quantitative coefficients are some of the factors variations that can be addressed when using this methodology. In consequence, organisational impacts of the facility layout problem are addressed and solutions that can be obtained using the strong component-based methodology are suggested when the interrelations diagram are crated, an essential diagram which eases the facility design goals.

Keywords: Facility Layout; Graph Theory; Strong Components

Introduction

In this presentation the facility layout design (FLD) issues are addressed using a strong component-based methodology (SCB) when a non-dedicated facility is required to manufacture in a multiple product environment. This methodology proposes a single manufacture structure capable of producing various items that may share similar production characteristics as operation sequences and workstations that can help to reduce costs and ease material flows in production facilities when compared to production in dedicated facilities. This FLD problem was introduced as a quadratic assignment problem [1] that provides a mathematical programming formulation for this problem. This formulation suggests that it is an NP complete problem which requires more computing resources to solve it. As the number of facilities increases it suggests that a good heuristic procedure may provide a very good close suboptimal solution [2].

The facility design problem has been studied for many years since [3] proposed the Systematic Layout Planning methodology (SLP) that decomposes the problem into 4 basic phases to address it: data acquisition, interrelationship and interrelationship space diagrams, alternative generation and solution proposal. In current market conditions where innovation is suggested when considering changes in demand motivated by new customers´ needs that settles changes in product functionality and appearance. Nowadays, these changes occur more often and may motivate shorter product's life cycle which implies that changes have to be performed fast and in shorter time to be on time. Moreover, these new demand requirements make necessary to identify new improved and practical ways to produce these items and to more investment may be needed in machines and processes that may become almost impossible to recover under shorter production runs unless they share fabrication resources avoiding to be manufactured in dedicated production lines [4]. In this document a single structure that shares production resources is suggested as a relationship diagram which may have the following advantages:

- Takes benefits form a product and process layout designs
- Reduces the space and production resources required to elaborate a family of items
- Implies a flexible production scheduling
- sequence to attend demand variations
- It is very robust when product design and operations sequences remain stable
- Supports a multiple product environment

In consequence, some organizational impacts from FLD are addressed and solutions, in this case, that can be obtained using the SCB are proposed: An interrelations diagram is crated as a fundamental device which supports the facility layout design goals achievement. It has been widely accepted that a good layout design can help reduce costs and ease material flows in manufacturing facilities; for instance, it may help to reduce from 10 to 30% of the total operating expenses increasing the performance of a production and a material handling systems by improving production process strategies [5-7]. In this presentation, the interrelationship diagram constructed is deployed using a heuristic methodology. This single diagram is deployed using theory of directed graphs that may be capable of:

- Produce various products running under batch mode
- Share the same facilities (non-dedicated)
- Suggest production modules

However, the SCB methodology [8] is not discussed in this presentation but is used to explore some highlight facility design issues such as: the transfer batch size, input and output points and the single and multiple machine, explore these issues and to point out some of the implications in the design supporting production, maintenance and material handling matters. Additionally, the structure is presented as an interrelation diagram which is a fundamental stage to deploy a FLD implementation.

Methodology

Consequently, the SCB methodology provides a close to optimal solution procedure to the FLD which makes available a unique structure diagram in which the layout can be based in an environment where a shift from dedicated facilities to non-dedicated facilities is promoted by changes in product life cycles given modifications in new or other customer needs changes [9]. As mentioned, the structure (non-dedicated facility) design proposed may be capable of producing a family of products, one at the time and in a batch mode, combining each product operation sequence from this family since they can share the same production resources [8]. The specific cases addressed in this document, these are:

- To add more machines seeking to reduce returning flows
- To increase additional machines required when increment in the

demand
- To consider feeding and destination points for the whole structure

In the first case, this situation is addressed just following a visual inspection and adding a machine that will easy a forward flow as required. It should be highlighted that if the required machines are not available the backtracking should be present in the structure and to try to minimize possible bottlenecks do to unwant flows like these mentioned here. Since the initial structure is not balance, it will be required to balance considering processing times and batch mode and certain types of machines may be required. Of course, since at this time all the information is not available, the problem is not solved here and an assumption of hypothetical machines is suggested to consider the solution to this situation. In the third case, feeding and target destinations has been solved in other publication [8]. In this document is shown how the layout may be modified under these conditions.

Results

To obtain the interrelationship diagram, the heuristic method requires besides the production demand all the product operations sequences of those products that are expected to be manufactured in these facility and an adjacency table are deployed [10]. For instance, assume that three products are to be made as shown on (Table 1) [11]. Also (Table 1) shows the production demand, the activities sequence and the number of displacements between machines needed to produce each item. Moreover, each production sequence can be followed and can be different for each item to be manufactured. Also, it shows the production path required to obtain any of the items as dedicated facility.

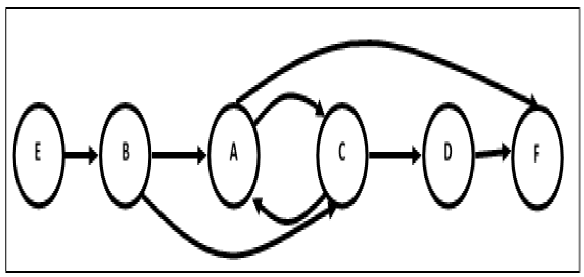
Table (1): Product Operations Sequences and Requirements

Product	Operation Sequence	Production Require - ments	Displacements Required
1	A-C-D-F	500	3
2	B-A-C-D-F	1000	4
3	E-B-C-A-F	300	4

Although it should be noted that any production sequence of the products can be followed in the diagram shown in (Figure 1). In this case and when comparing to dedicated facilities, it can easily be seen that unwanted flows are created such as:

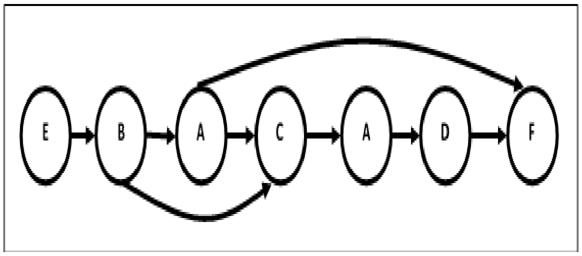
- By-passing displacements, between stations B and C, and between A and F
- Backtracking displacements have been produced, between stations A and C
- More displacements may be needed.

Figure (1): Interrelation Diagram



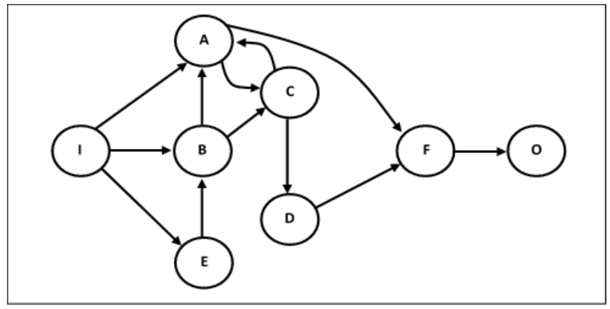
When combining various products into a single structure these unwanted flows are unavoidable but they can be reduced by adding in sequence new machines, as shown in (Figure 2). This addition may increase more displacements between machines, add more travelling distances and consequently, it may impact the material handling, production rates and product shipments that should be evaluated before implementing these sort layout modifications. By adding new facilities may increase the complexity of the problem to be solved. But should be mentioned that still may require less resources than those required by the dedicated facility design.

Figure (2): Forward Flow Interrelation Diagram



Since this is a combinatorial problem classified as NP Complete [1], this mean that more computer resources may be needed during its solution procedure; hence the suggested heuristic procedure to solve it. In (Figure 3), it is highlighted that the layout can be different when adding a supply (I) and a storage node (O). Usually, there are cases when these initial and final node are not considered and during the layout deployment or under operational conditions additional efforts are required to accomplish production arrangements. It should be underlined that the sequences in the original layout when compared to the design proposed in (Figure 3), initial machine arrangement and sequences are not affected; hence only the space and the initial and final feeding should be under consideration since more material flow is added and material handling resources can be required. These issues are because the layout distribution has to be modified since an initial and a final node are added. Furthermore, the interrelationship diagram shown in previous figures where obtained using the product operation sequences and assuming a transfer batch of size of one. The production demand for a given period should be taken into consideration to balance the production lines and to decide if more machines or work stations are required to accomplish supply and delivery concerns.

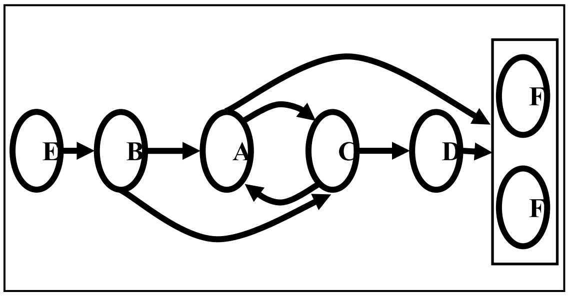
Figure (3): Interrelation Diagram with supply and storage facilities



In cases like these, the location place is defined by the interrelation ship diagram and consequently, the problem reduces to space availability, see (Figure 4). For example, if a second F machine is needed then its place is already defined (after machine D) and the problem reduces to determine if there is enough physical space available at that location and, if possible, should be placed besides the existing available machine. Another issue that is attached when a FLD is analysed is to attach weights to each displacement arc. The SCB methodology explained here only considers the links among machines but it can also include arc weights to distinguish the importance among the proximity between machines. These weights can be qualitative and quantitative or non-dimensional weights. In the qualitative case, the taxonomy proposed by Richard Muther can be used using the experience and knowledge of the layout designer and reflect it in a proper.

Conversely in the qualitative case, a from–to table can be used to aid the weights representation and distance, cost, time, demand can be used to do this [12-13]. In addition, displacements between machines can be taken into account as a non-dimensional representation. These displacements may lead to an equal weight in all the considered arcs. This representation will provide a mathematical programming formulation whose solution can be considered as trivial, since a the coefficients in both, objective function and restrictions are of weight one and where the SCB methodology can help to obtain a comprehensive solution [8], as shown in (Figures 1&3), in such case the table is called adjacency table and the interrelation diagram as adjacency diagram.

Figure (4): Multiple Machine Interrelation Diagram



Conclusions

In this document, the issues addressed through the SCB methodology were:

- Single piece transfer batch
- Non-dedicated facilities
- Batch production mode
- Product operation sequences as the data source to deploy the interrelationship diagram

Additionally, it was highlighted how this methodology can be used to ease the FLD analysis and solution under specific circumstances and it was explained its flexibility to handle them. Furthermore, it should be mentioned that the interrelationship diagram obtained using SCB methodology has other properties that can be explored such as to identify alternative production routes, to determine the number of displacements that may be needed to move a given item among machines in the arrangement to improve production, maintenance and material handling operations. Likewise, more research should be done to explore how production performance may be modified under specific structures, different scenarios and to anticipate possible limitations or contributions on the production performance before changes are made.

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