Optimization of Discrete Facility Layout with a Candidate Grouping Approach

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Abstract: Facility Layout Problem (FLP) is an important issue in plant design, which directly affects production costs as well as safety concerns. Hierarchical and integrated approaches are two main methods used for the formulation of FLP. In the hierarchical approach, FLP is solved after the completion of the process design and scheduling, while the integrated approach treats FLP simultaneously with other phases. This paper presents a new approach based on the candidate groups for interactive functions; incorporating the advantages of the previous approaches.

In the new approach, the design phases prior to FLP results in a set of models introducing by the engineering team in advance. Next, the models are solved such that instead of individual designs, a set of suggested structures are generated. These structures are then fed into the FLP as input data and solved by mixed integer programming technique. Some characteristics of the models are: presence of the hub stations, different and variable dimensions for each station, possibility of rotation for the stations and incorporating safety distances. Finally, test problems are solved and results are discussed. It should be noted that if a candidate group entails a different production flow then a different optimum solution might be obtained.

Keywords: Facility layout problem, Optimization, Candidate groups, Mix integer linear programing

Introduction: Simultaneous optimization of facility layout with process design, automation and scheduling has been the subject of many research studies (Taghavi & Murat, 2011), (Realff et al., 1996), (Barbosa, 2007).

The current research introduces a hybrid method for interactive phases of process and layout design. It starts with suggested cluster structures by process designers and attempts to decide among the choices while searching for optimum layout of facilities.

In the rest of the paper, after a short description of group structures, a formulation of the MILP model is presented and the constraints, parameters and variables are briefly defined. Finally, 7 sample problems have been solved by exact methods.

Then the developed model is solved such that instead of a single solution, a set of candidate groups are suggested. This set is later used as input to the layout problem. The innovation of this approach is a layout solution with the following characteristics:

- Obtaining different flow process in terms of candidate groups from the initial phase.
- The possibility of adding or removing the workstations in the candidate groups
- The possibility of various dimensions in the group structures
- MILP formulation for supporting the above characteristics

In this approach, the solution space for layout problem only contains the process designs which are previously defined by in the plant design phase. This has many advantageous over the hierarchical layout methods such as less expenses and faster modelling and solution and less computational

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complexity. It has also the advantageous of an integrated approach in workstation layout considering different functions and interactions.

Materials and Methods:

Model description: For layout design in discrete production lines, an MILP model is developed. Facility layout in this research is confined to a two-dimensional (x,y) space and has the following characteristics:

- One or more candidate groups can be defined, each consisting of at least two different connection structures, i.e. from-to charts with specified inner links and connecting structures (piping, conveyors or similar means of material flow).
- Group centres are well defined if present.
- Transportation costs and those costs related to cluster structures, e.g. extra equipment, semi-finished inventories, etc. are known in advance.
- Facilities are rectangular with related fixed length and distances between facilities are rectilinear.
- Facilities can rotate counter-clockwise by integer multiples of 90 degrees.
- Total available area is limited and pre-specified.

Objective function of the model is the sum of the investments on the physical connections, material flow costs and structural expenses of candidate groups. The constraints is related to the rotations status of the facilities, distances, available space, overlaps and safety concerns.
Cost matrix is a cross product of flow matrix and transportation costs matrix. The final solution contains optimum plant layout, facilities orientations as well as optimum connections inside candidate groups.
The model is solved by CPLEX which is mostly used for problem incorporating less than 15 workstations. Table 1 lists the solution time for 7 different problems. As can be seen in this table, the solution time for P7 is more than 40000 seconds with 6% gap. Therefore, the solution is used when limited number of workstations are aimed. For greater number of workstations, heuristic algorithms can be developed.

Table 1. Test problems solved by CPLEX

P.	Station Quantity	Candidate Group Quantity	Opt Slution	Time(sec)
P1	11	2	451	461.5
P2	6	1	1165	2.92
P3	9	2	1217	940.5
P4	11	2	1327.75	3943.8
P5	13	2	1641	25380.52
P6	14	3	1467.8	31803
P7	15	4	1850*	40000

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