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A PRODUCTION FLOW ANALYSIS AS A TOOL FOR FACILITIES LAYOUT

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ABSTRACT

Production flow analysis is effectively used in planning methods and tooling which are at present being used in the factory. It is also used in group technology when considering design features or shape of components.

One of the basic data for computerized facilities layout procedures is the interdepartmental flow. Most,if not all of such computerized procedures require such data in an almost one form- a matrix. It is often assumed that this matrix is readily available, which is not always the case. Moreover a change in the production programme would affect the current status of the layout and therefore appropriate changes are inevitable which normally take a long time to account for changes and its impact on the data and in turn the configuration of the layout. On the other hand the analysis of the problem of layout would require several computer runs with different data set for the same problem.

This paper uses the methodology of the production flow analysis with an ultimate objective of automated data preparation based on actual data of production e.g process sheet,operation sheet ..etc.
A computer model is designed and tested using a real life problem.The model requires data which normally used in the factory without ulteration. The flow matrix is obtained based on the pattern of component movements.Other outputs are also available by the model.

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INTRODUCTION

The establishment of an efficient flow has been dealt with in different ways. The problem has attracted people who are interested in the application of group technology or group layout as well as facilities or plant layout [1,2,3,4,5]. Although fundamental differences do exist regarding objectives other than the ease of flow, the conceptual methodology of flow pattern establishment could be similar in these areas.

One of the well known method is production flow analysis introduced by Burbidge in 1971 [1]. The main objective of this technique is to find families of components and associated groups of machines for group layout through three successive levels:

a. Factory Flow Analysis, concerned with the first major division into large groups of departmental size and into the very large families to be made in these departments.
b. Group Analysis, concerned with the division of plant assigned to each department into groups, and the division of components into associated families.
c. Line Analysis, concerned with the flow of materials between machines inside the group and with planning the best plant layout for the machines.

This technique is particularly applicable in those areas outside the engineering industry where the shape of components manufactured may bear little relationship to the manufactured method used, such as moulding, forming, casting [2]. The technique is therefore concerned solely with methods of manufacture, and does not consider the design features or shape of the component at all. These two points outline the differences between production flow analysis and group technology,(hereafter refered to as PFA and GT respectively).

This paper uses a similar approach to the conceptual methodology of PFA to establish an automated data preparation to serve as a first phase of computer models for facility layout similar to that presented in [3,4]. The ultimate objective of this paper is to establish the flow pattern associated with a specific production programme in a form of matrix.

The work presented in this paper differs from PFA regarding the following aspects:

a. groups of equipment and machinery are established based on their functions rather than a specified group or families of components as being done by PFA. Moreover it is assumed that they are known or proposed.
b. PFA achieves the efficient flow through the application of the three levels ,indicated above, where this paper arrives at that flow by the application of suboptimal procedures as presented in [3,4]. This is due to the basic difference of the layout pattern in the two cases.
c. handling of materials and parts is largly manual inside each group designed by PFA, where means of handling adopted here is assumed to be manual and/or powered i.e using a handling equipment.

Although these differences deviate PFA and the present work, this paper works out the analysis using the same set of flow data as required by PFA e.g route. process and/or operation sheets and also follow a quite similar approach of manipulating these data.

A computer model is designed to handle production data as they do appear

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in industry. The basic idea of having an automated approach to arrive at the flow pattern for a specific production programme is due to the current dynamic complexity encountered in modern industrial fields. Moreover new trends of research in universities as well as industry are concentrated now on the design of integrated systems for production. The model presented here serves as the first step towards building such models. It is efficient tool to support the production planner as well as layout analysts regarding the identifications of the impact of production programme changes on the performance of the production system.

DATA FOR FACILITIES LAYOUT

The facility layout problem is handled by most computerized procedures by virtually the same way. Procedures which utilize quantitative data use the same objective function, that is the minimisation of the Total Materials Handling Costs TMHC. The function is traditionally formulated in the following mathematical form:

minimise TMHC

such that,
$$TMHC = \sum_{1 \leq i < j \leq n} f_{ij} \cdot c_{ij} \cdot d(a(i),a(j))$$

where f_{ij} is the flow of materials between facilities i and j measured in an appropriate measure e.g unit load

c_{ij} is the cost of moving materials between locations of facilities i and j per unit flow per unit distance

$d(a(i),a(j))$ is the distance between the locations of facilities i and j in an assignment (a); and

n is the total number of facilities

According to the above formulation a three matrices of size n x n are required for the flow of materials, the cost of handling, and the distances between different locations in an assignment.
Most computerized procedures, if not all assume that these data are readily available. However in practice, this is not the case for many reasons:

a. the company may not hold records of any kind for production processes. Records here refere to formal and not informal records.
b. if records are available, informations included are in effect incomplete.
c. response of the records to alterations is slow and may not be registered in appropriate forms at all, resulting in old records are long been kept as indication of current status.
d. production costs are not effectively influence the policy of production as in the case of some military industries.

Values of the flow of materials are generated from the interdepartmental loads movements which associated with the production programes. Loads are related to the physical dimensions of parts and may represent a number of parts or components not necessarily for the same product. Also these loads can be represented by the number of trips a handling equipment travelling between deparments in a certain period.
The cost of handling presented in the C matrix is an indication of the type of materials handling means employed. While the distance matrix consists of the distances between every possible pairs of locations according to the relative locations of facilities or departments in the current layout configuration or simply the assignment.

THE COMPUTER MODEL

A computer model is designed to handle the type of data and establish the flow pattern in a form of a n x n matrix. It is written in Fortran IV and run under the O/S computing facilities situated in the Information Center in the faculty of engineering, Ain Shams University. The model requires the following data:

- The total number of facilities or departments as well as the name of each department. A code for each department is also required and is chosen manually in an alphabetic form.
- The number of parts and components currently into operation as indicated by the production programme.
- Designation or code for each part in numeric, alphabetic or alphanumeric.
- Dimension and weight of each part .
- Quantity per lot together with the load of production programme.
- The sequence of operation of each part indicated by using the departmental code .
- The layout configuration , although this piece of data can be considered optional , and is actually required by suboptimal procedures which seek improvements for the current assignment. It is required by the model in case a specified handling means is assigned to specific locations in the case under consideration.
- The cost of handling associated with means of handling materials.

The model first reads in data and checks are carried out for errors. if errors do exist, an error message is typed and the run is terminated. The model is then proceed to calculate loads between each pairs of department using the quantity per lot , the weight of each part as an average weight of part before and after machining, and the load of the production programme. The cost of handling is calculated based on three types of handling:

a. manual handling where loads are on average less than 300 kg. A hand truck is used in this case.
b. using a fork lift truck
c. using an overhead crane.

The average number of loads is therefore calculated based on the number of loads and the cost of handling. This average will indicate the weighted flow between every possible pairs of facilities. It is the vector product of the flow and handling cost matrices. This weighted flow will be assigned to every path of operations indicated by the sequence of operation for each product.
The model then operates a scanning routine to accumulate loads between pairs of departments for the whole set of the parts in the case.
The printout features of the model has the capabilities to provide the flow matrix, the flow related to one department, the flow between pairs of department, and also a Cross Chart which could be used in connection with procedure indicated in [5].

The model presented in this paper is applied to a case study of one of the leading manufacturing establishment for engineering products in Egypt. This company has reorganized the whole production facilities by applying intensive study of group technology technique.
It should be noted that the word facility has the same indication as the the word department throughout this work.

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THE CASE STUDY

A Gear Cutting workshop among others, is established as a result of the application of GT to the manufacturing establishment mentiond before. The workshop consists of 17 different departments including the raw materials store which lies inside the building of the workshop. Most of these departments have a general purpose machinery for gear cutting and manufacturing. The initial proposed layout is a functional layout i.e each department has a number of machines which perform the same type of machining process e.g milling machines are put together in a department refered to as milling department. The list of these departments and their associated code is given in Table 1. The table also indicates the number of machines inside each department. The department is treated as an integral unit within the context of this paper and no specification is given regarding the machines.

A 137 different parts and components present the production programme currently into operation. Most of these parts are gear blanks. A sample size of 15 parts is given in Table 2.

It was decided to apply one of the computerized procedures to a proposed initial layout shown in Fig.1, to check whether or not improvements could be achieved. Moreover ,it is believed that continuous monitoring of the layout of departments, in the view of chances of variation in the production programme is prudent. This could only be achieved by an effective tool to analyse the impact of changing the pattern of flow on the layout, which coincide with the objective of the model presented in this paper.

RESULTS AND DISCUSSION

The model presented here is applied to the case study and a sample of the output of the computer run is illustrated in Fig.2 and 3. The resultant flow matrix is shown in Fig.2. The expected number of loads in the period of the production programme is shown between every possible pairs of departments. The maximum load flowing through a single department is associated with the testing department ,with milling department comes second. The mean load of the current production programme is amounted to 777 loads with the total number of loads flowing in the workshop of 224478 loads. It should be noted here that loads are not representing unit loads, rather they are weighted regarding the handling equipment in charge of moving the part from a location to the other as indicated by the sequence of operations.

The flow dominance is calculated to give an indication to the degree of complexity of the pattern of flow of materials related to the case under consideration, and whether modification of the layout could be obtained by inspection and not by computer. The flow dominance is calculated using the following equations:

$$\text{Flow dominance} = 100\,(s/m)$$

$$m \text{ (the mean)} = \sum_{i,j} f_{ij} / n^2$$

$$s \text{ (the std. dev.)} = \sqrt{\frac{\sum_{i,j} (f_{ij} - m)}{n^2 - 1}}$$

The value of the flow dominance of the case study is amounted to 241. This value is grater than 200. Therefore the layout of departments could be treated by inspection. However in the view of the total number of department involved and the values of flow, it was decided to apply a computerized procedure, which would take the flow output automatically and check the proposed initial layout. On the other hand the case study could be manually inspected to assist the layout procedure in proposing a good feasible initial layout. For example, the flow analysis obtained by the model presented here indicates that the milling and testing departments could be placed in the middle of the layout space with others surrounding these two departments. To manipulate the case manually, we would have to spend a long time to achieve a proposed layout with no indication that that layout is the best regarding the set of data on hand. Moreover the building perimeters which act as constraint, and where departments should be accommodated would not allow us to arrive at a good solution for the layout configuration.

As heavy traffic of materials is associated with the testing and milling departments, analyst may wish to try to ease the case by proposing a new and different production plan. The model would allow him to do as many as he likes and give him results of each trial in terms of flow pattern as a form of flow matrix as well as feeding the matrix to a computerized procedure to get the solution of the case. This routine could be performed almost at a feasible cost of computing facilities.

Other information which is useful is illustrated in Fig.3. The loads between pairs of department can also be obtained by the model. A sample of Cross Chart is given in Fig.4. A '1' signifies that the part visits the department, and '0' that it does not. This output is particularly useful when considering grouping of departments and machines as in[5].

There is a limitation associated with the proposed model regarding the cost of materials handling. It is assumed that the part is handled by only one equipment of materials handling through out the path of operations required to manufacture it in the workshop. This assumption may not be valid in pratice. To account for such a requirement a more data is required than that already available in route, process, and operation sheets.

The new trends in layout planning are devoted to the design of integrated layout planning analysis packages require a similar model as that presented in this paper, as a basic introductory part of the system. In the auothors openion such a model serves effectively this objective of analysing the production data and automatically feed other segements of the model with data

CONCULSION

Acquistion and analysis of basic production data is an important phase in the process of designing integrated layout planning analysis computer software, as an approach to CAD/CAM systems. Nowadays computing using DP facilities are available at commercial scales in research centers as well as in industry, and the effective use of such facilities is prudent. The work presented here serves as an approach and initial step towards having a comprehensive planning model for facilities layout, which could be very useful in providing information to almost every managerial level in the enterprise and to keep the system of production under continuous control. The control will allow management to check alternative plans for production on elements of production planning and control and above all to monitor the performance the layout currently adopted.

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Table 1. List of Departments

No.	Code	Name of Department	No.of M/CS	remarks
1	ST	Raw Materials Store	-	
2	D	Drilling Machines	2	1 Radial
3	BR	Broaching Machines	1	Horizontal
4	TL	Turret Lathes	3	Type RN 60
5	LC	Centre Lathes SU50/1500	3	
6	LB	Centre Lathes SU50/1000	6	
7	LA	Centre Lathes 1A62	3	
8	IN	Inspection of Turning Work	-	
9	M	Milling Machines	3	1 Bench Drill
10	GR	Grinding Machines	2	
11	BV	Bevel Gear Cutting Machines	3	
12	H	Hobbing Machines	6	
13	SH	Shaping Machines	5	
14	F	Finishing Machines	4	Shaving & Rounding
15	GG	Gear Grimding Machines	3	
16	T	Gear Testing Machines	4	
17	HT	Heat Treatment	-	

Table 2. Sample of The Summary of Operation Sequence

Part No.	Blank Dimension	Quantity Per Lot	Wt. Before Machining	Wt. After Machining	Sequence Summary
162-08-27	D80x25	50	0.986	0.440	D BR LB T LB IN H M T F T
162-08-27	D85x25	50	1.114	0.520	D BR LB T LB IN H M T F T
162-08-27	D95x25	50	1.391	0.760	D BR LB T LB IN H M T F T
162-08-27	D130x25	50	2.600	1.500	D BR LB T LB IN H M T F T
162-08-27	-	40	2.038	1.090	D BR LB T LB IN H M T F T
162-08-27	135x25	40	2.809	1.590	D BR LB T LB IN H M T F T
162-08-28	D85x44	50	2.000	0.760	D BR LB T LB IN SH T F T
6M82-3-36A	-	50	25 .400	14.890	LC GR BR M LC IN H F T SH T
6M82-3-43H	-	60	8.800	2.660	LC BR M LC T LC D T IN M H SH F T HT T
6M82-3-54H	-	50	2.210	0.880	D BR LB T LB IN M H SH F T HT T F T HT T GR T LB D T
6H62-4-216	D32x500	50	0.350	0.110	TL LA IN M H T
11-7-161C	-	50	5.320	1.238	D LB GR LB GR IN H F M D T HT LB M T HT GR LB T
11-7-286	D56x500	50	1.610	0.250	TL LA BR M LA M IN H F T HT T GR T
11-7-252H	-	50	2.420	0.570	D BR M LA T GR LA IN M BV T LA T HT T LA HT GR T GR T
6M82-710A	-	50	0.800	0.260	LA TL LA BR M LA GR M IN H F T HT T GR T

Figure 2. The Flow Matrix

	ST GR	D BV	BR H	TL SH	LC F	LB GG	LA T	IN HT	M
ST	0	11315	0	2226	2282	1074	310	0	0
	0	0	0	0	0	0	0	0	
D	0	0	6124	57	4569	1771	300	160	1537
	0	0	0	0	0	0	1048	167	
BR	0	0	0	0	455	7117	422	0	6264
	0	0	0	0	0	0	0	0	
TL	0	0	1797	0	30	698	291	0	0
	0	0	0	0	0	0	0	49	
LC	0	288	1263	0	0	0	30	4161	2638
	1994	0	734	0	0	0	1293	0	
LB	0	461	2597	266	0	0	0	6439	2129
	804	0	0	0	111	0	9326	0	
LA	0	0	442	267	0	99	0	2582	668
	27	0	0	0	0	0	1802	75	
IN	0	0	0	0	0	0	0	0	7969
	0	240	5206	3623	0	0	0	0	
M	0	2909	42	0	3772	2625	1482	2634	0
	747	259	5792	2029	0	0	4480	58	
GR	0	0	1994	0	0	818	478	164	387
	0	0	0	0	0	1083	3859	0	
BV	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	499	0	
H	0	0	0	0	0	0	0	0	2838
	0	0	0	1700	6192	0	1098	0	
SH	0	0	0	0	0	0	0	0	10
	0	0	36	0	6501	0	1807	0	
F	0	0	0	0	0	0	0	0	457
	0	0	0	0	0	0	10485	5489	
GG	0	0	0	0	0	170	0	0	0
	0	0	0	0	0	0	1365	0	
T	0	759	0	0	778	7513	2577	899	1095
	3479	0	59	1001	3627	231	0	7407	
HT	0	0	0	49	515	344	130	0	837
	1731	0	0	0	0	222	9426	0	

MEAN = 776.88 , STANDARD DEVIATION = 1871.31

VALUE OF THE FLOW DOMINANCE =240.88

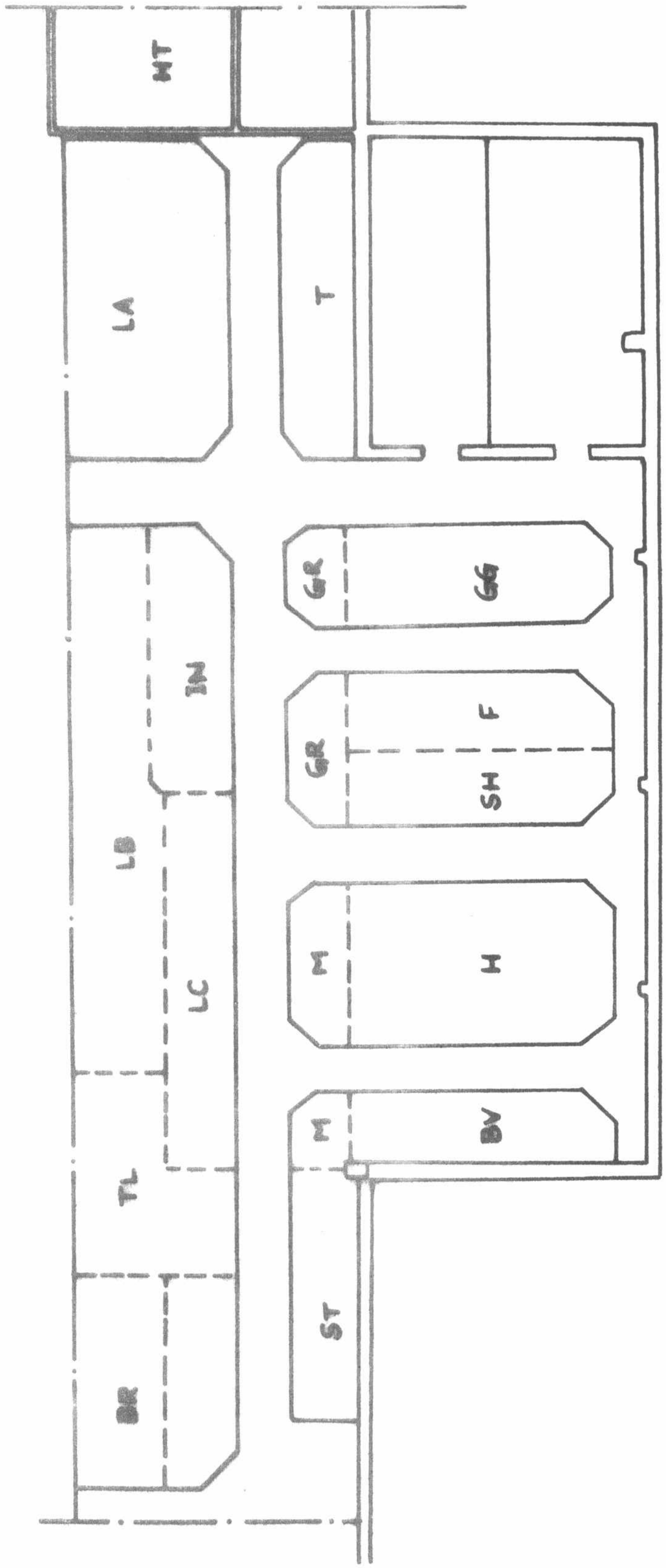

Figure 1. Initial Configuration of layout

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Figure 3. Loads Between Drilling Machines and Center Lathes SU50/1000

Part No.	No of Visit	Quantity Per Lot	Wt. Before Machining	Wt. After Machining	Average No. of Loads
162-02-66	1	50	3.770	1.750	138
162-02-68	1	50	8.480	5.140	340
162-02-71	1	50	4.712	1.930	167
162-02-72	1	50	6.165	2.433	215
162-06-55	1	50	2.326	0.520	71
162-08-23	1	40	2.000	0.610	52
6M82-4-49	1	50	6.230	3.640	246
6M82-3-53H	1	50	2.330	1.250	89
6M82-4-65H	1	50	3.610	1.420	125
6M82-4-676	1	50	4.720	1.800	163
11-7-1649	1	50	5.320	1.238	164

Figure 4. Sample of The Cross Chart

	D	BR	TL	LC	LB	LA	IN	M	GR	BV	H	SH	F	GG	T	HT
162-02-61	1	0	0	1	0	0	1	1	0	0	1	0	1	0	1	1
162-02-62	1	1	0	1	0	0	1	1	0	0	1	0	1	0	1	1
162-02-63	1	0	0	1	0	0	1	1	1	0	0	1	1	0	1	1
162-02-64	1	0	0	1	0	0	1	1	1	0	0	1	1	0	1	1
162-02-65	1	0	0	1	0	0	1	1	0	0	1	0	1	0	1	1
162-02-66	1	1	0	0	1	1	1	1	1	0	1	0	1	0	1	1
162-02-67	1	0	0	1	0	0	1	1	0	0	1	1	1	0	1	1
162-06-19	1	1	0	0	1	0	1	1	0	0	1	0	0	0	1	0
162-06-51	1	0	0	1	0	0	1	0	0	0	0	1	0	0	1	0
162-06-52	1	1	0	0	1	1	1	1	0	0	0	1	1	0	1	0
162-06-53	1	1	0	0	1	1	1	1	0	0	0	1	1	0	1	0
162-06-54	0	1	1	0	1	1	1	1	0	0	0	1	1	0	1	0
162-06-55	1	0	0	0	1	0	1	0	1	0	0	1	1	0	1	1
162-06-56	1	1	0	0	1	1	1	0	0	0	0	1	1	0	1	0
162-06-57	0	1	1	0	0	1	1	0	0	0	0	1	1	0	1	0