THE APPLICATION OF GROUP TECHNOLOGY AT THE PRODUCTION PLANNING PHASE OF A NEW PRODUCT

by

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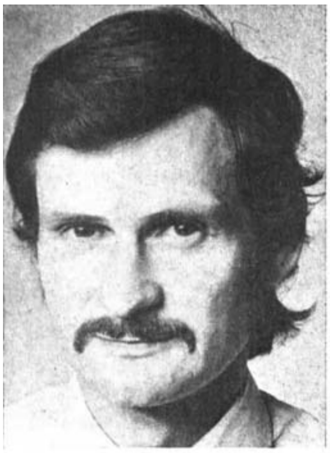

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J. D. TEDFORD first entered industry in 1960 as an apprentice electro-mechanical fitter with ICL. During this period he obtained his Ordinary and Higher National Certificates in Electrical Engineering. He subsequently studied at the Queen's University of Belfast on an engineering sandwich course where he obtained a first class honours degree in mechanical engineering. After a period of working in research and development with ICL, he was awarded a Ford Trust Scholarship to conduct a research programme sponsored by the Ford Motor Company into cumulative fatigue damage of automobile suspension components. For this work, he was awarded a PhD degree in 1971.

After one year as a research fellow at Queen's University, he joined the lecturing staff and was involved in the establishment of both Bachelors and Masters Degree courses in Industrial Engineering. In 1975 he took up an appointment in the School of Engineering at the University of Auckland, New Zealand, where he is currently engaged in the development of the industrial engineering content of the degree courses.

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He joined Short Brothers & Harland Ltd, Aircraft and Missiles, Reliability Engineering Group after an initial industrial training period of eight months with the Company in 1968. In 1972 he was selected to undergo special training with a view to a career in Production Management and as a result of this Management Scholarship he graduated from Queen's University, Belfast, with an MSc in Industrial Engineering.

He returned to Shorts in 1974 as Production Controller for a new contract within the Company and is presently employed as Production Administration Executive having responsibility for the Production Systems used on that contract.

Summary

This paper presents a novel application of the principles of Group Technology to the establishment of a machine shop facility for the production of a range of components which would not conform to any of the well established GT procedures.

The number of workpiece types involved in the production was small and it was thought initially that a coding and classification approach to the problem would suffice. However none of the standard macro-coding systems provided sufficient information for the establishment of families based on geometric characteristics. This being due mainly to the specialised nature of the components comprising the final product.

As production planning became more established for the various components making up the product, the formation of families based on the principles of Production Flow Analysis was attempted. This however again proved ineffective as few workpieces existed with similar process routes.

A proposed solution was eventually obtained through the combined use of material flow simplification based on PFA and the exercise of some sound common sense and judgement.

Introduction

The company concerned had been engaged in research and development and in the manufacture of specialised electro-mechanical equipment for a number of years. The R & D phase of a new product had recently been completed and was soon to go into full scale production. In all its previous operations, the company had used batch manufacturing on a functional layout within its machine shop. In setting up a production system for the new product however, it was intended to apply the principles of Group Technology.[1]

The new production set-up could be divided into two general areas, the manufacture and purchase of the electronic and mechanical components and the final assembly and testing of the product itself. The second of these two areas in the past had successfully been arranged along the lines of group working and because of the excellent industrial relations which existed in these areas, management wished to extend the philosophy to the machine shop.

With the aim thus defined, the immediate requirement was to obtain all available information concerning what workpieces had to be manufactured, how they were to be made, what facilities were required for their production (ie. machine tools, treatments, etc.) and what facilities were available. The first problem was solved relatively easily. Although the project was still very much in its pre-production phase, assembly drawings and their associated component lists indicated a total of approximately 500 individual items required per assembly. Of these however, it was determined that only 55 items consisting of 51 machined components and four sub-assemblies required operations in the machine shop. The second and third requirements of how and by what means the parts were to be produced, was unfortunately not so easily determined. Because of the rather unique characteristics of many of the workpieces, established production process techniques were in many instances unavailable. It was discovered in fact that the production planning department were quite often issuing three different production methods for the same workpiece depending on its priority. As the product was currently being produced in small quantities, mainly for testing and marketing purposes, on a job-shop basis, production planning information was readily available although inappropriate for a situation of 'volume production'. Secondly, as orders had already started to trickle in, an immediate production requirement existed in which conventional machines which were known to be available, were used for planning purposes. The third source of planning information which was available, was that based on a new generation of semi-automatic and automatic machines which were being purchased by the company to meet the expected future demand for the product. It was obviously this latter planning information which one would wish to base group formations on. Unfortunately it was also the one on which production planning were least prepared to commit themselves, due mainly to the lack of precise set-up and tooling information which was at the time available for the machines. However with the full co-operation of the machine tool manufacturers concerned and the planning department, the planning information for 'volume production' became more firmly established.

It was thus possible to compile a list of 26 types of new and conventional machines which would be needed for production in the quantities required. A survey of the existing machine shop confirmed that sufficient conventional machining centres already existed to meet the expected demand.

It had been decided that the production groups formed, should be as autonomous as possible with respect to such things as machining, fitting, tool storage, inspection, etc. However certain operations were deemed to be impractical from the point of view of incorporating them into each group. Such things as chemical treatments, epoxy-resin adhesion and flaw detection were found to require not only specialist personnel but also closely controlled environments which were not compatible with that of a machine shop. It was therefore considered inadvisable from a financial point of view to attempt duplicating these in the different groups. Consequently these areas were left intact.

Coding and classification

As the company had no previous experience in the use of geometric codes, this was undertaken by applying the Opitz code[2] to those components involved in the introduction of GT to the machine shop. In most instances this proved to be a simple exercise and a later study indicated that approximately 90 per cent of the components involved, were classified as rotational. Although a higher proportion than normally associated with workpiece statistics[3] it was not altogether surprising due to the fact that the finished assembly comprised essentially of a cylindrical package less than 80 mm in diameter.

An attempt to form groups on the basis of the code, provided five possibilities. These were:

(*a*) 14 disc type workpieces;
(*b*) 20 short cylindrical workpieces;
(*c*) 6 long cylindrical workpieces;
(*d*) 6 rotational, with deviation workpieces; and
(*e*) 5 flat workpieces.

The four groups of rotational workpieces exhibited similar problems in that each group consisted of workpieces which were only physically similar, in the very broadest sense. While further sub-division yielded only very small groups or in some cases, unique piece-parts. Each group required a wide range of machine types for manufacture and it was apparent that some of the expensive special purpose machines would be required for one operation only in each of the groups. In addition, virtually the full range of raw material sizes were required by each group which appeared to be the main reason for the need for so many machine types.

The group comprised of flat workpieces was distinct from the others in that no turning operations were required. However the work content of this group was not significant since most of the workpieces had a raw material shape not unlike that required in the finished product, consequently only simple operations were necessary. It was also noted that a large variety of machines were again required by this group. Despite investigations into changing production planning to suit the proposed groups of workpieces, little value could be derived from this as each group still required a wide range of machines to accommodate the various raw material sizes.

The technique of coding and classification had thus proved inconclusive due mainly to the fact that a multiplicity of workpieces did not exist and therefore families of similar piece-parts could not exist.

Production flow analysis

Two important questions had to be answered before this analysis could proceed. These were: in what batch sizes should the workpieces be manufactured; and, secondly, how many production groups was it desirable to have.

Batch quantities when determined analytically are normally based on the Minimum Cost Batch Size[4] which in this application would have involved considerable costing not easily or accurately available at that stage in the product development. Batch quantities were therefore selected by taking into account the primary considerations of this calculation and the experience gained on previous similar products. This indicated the simplicity derived from relating the batch size for a given workpiece to the number used per assembly. A basic batch size of 50 had in the past proved practical, thus if two of a given type of workpiece were used in one assembly the batch size for it would be 100. No material handling problems were envisaged for batches of these sizes. The calculation of Minimum Cost Batch Size depends primarily on two opposing factors. As the batch size increases the proportion of time which is non-productive time (set-up time) decreases thus decreasing the cost of manufacture per workpiece, conversely as the batch size decreases the capital tied up in finished goods and work-in-process decreases. The calculation aims to find the optimum batch size for these two opposing influences. In this application the ratio of set-up time against machining time was calculated as a percentage based on the estimated times and the batch sizes suggested previously. The calculation was done on the basis of providing enough workpieces to manufacture 50 assemblies and a figure of 21 per cent was obtained. This figure was surprisingly low and considered very satisfactory, it should also be remembered that reduction in set-up times was one of the primary advantages of Group Technology and therefore this figure could be further reduced. Workpieces were not costed but it was possible to indicate a few workpieces which might be relatively high value finished goods and as these were all manufactured in the smallest batch size, 50, the batch sizes chosen were considered suitable.

In order to estimate approximately how many groups the production facility should be divided into, the number of occupied hours (set-up and machine time) for machines to produce sufficient workpieces for 400 assemblies was calculated. The figure of 400 was selected by the authors and could be directly related to the expected production rate of the product to meet volume demand. The production rate has been referred to previously as volume demand due to the fact that the nature of the product is such that the figure must be treated as 'confidential' and cannot therefore be disclosed. It will be sufficient to say that 400 assemblies had to be produced in an undisclosed 'unit of time'.

Knowing the batch sizes and estimated times it was a simple matter to calculate the occupied hours on each machine type when making sufficient workpieces for 400 assemblies and from this, the theoretical number of machines required could be determined. Assuming one operator for each machine occupied and that operators were completely free to move from one machine to another, 86 operators were found to be necessary.

This figure is of course influenced by several factors:

(i) It may be possible to have one operator to control more than one automatic machine at any one time;
(ii) Group Technology should lead to a reduction in set-up times which would effectively reduce the number of operators;

(iii) the figure assumes 100 per cent production efficiency which could of course never be achieved;

(iv) the figure only accounts for machinists in the groups but fitters, inspectors, etc, would also be needed.

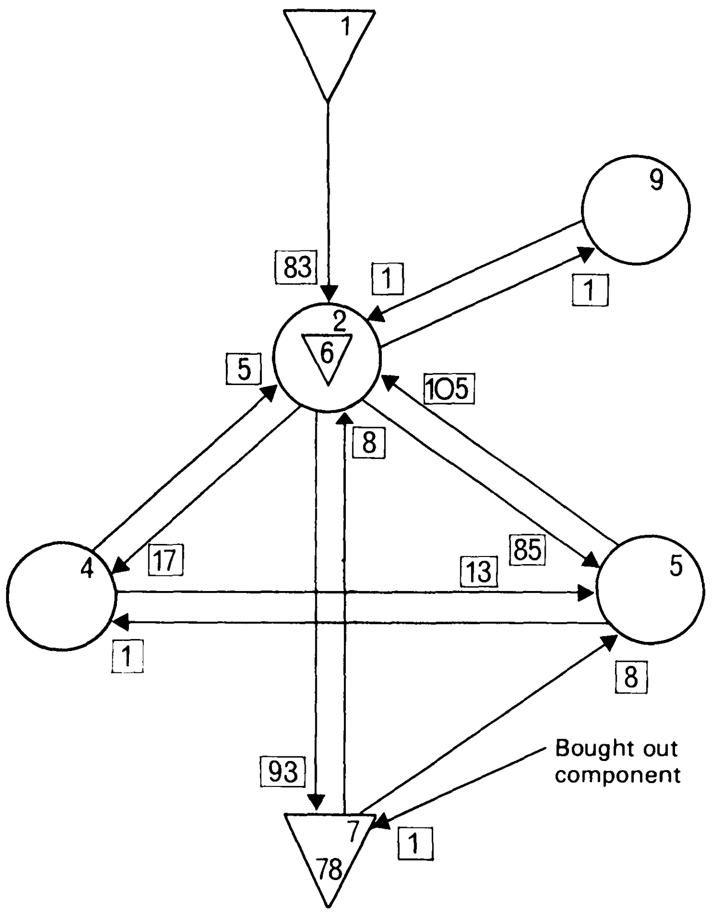
It was impossible to predict how much effect these various factors would have on the operator requirement but as only an estimate of the numbers of operators required was needed at this stage, a figure of 90 was chosen.

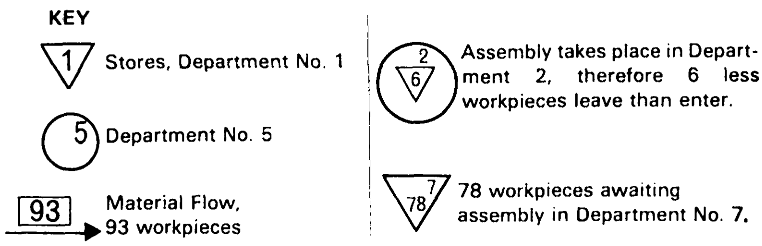
The optimum size for a group of workers as suggested by A. K. Rice[5] was eight, although production management in the company felt that 12 workers was a more realistic figure. Consequently, a compromise of 10 workers per group was chosen thus making a total of nine groups. In order to apply the technique of Production Flow Analysis, the first step was to decide on an optimum division of departments to minimise the amount of inter-departmental work flow. A detailed study of job requirements resulted in the flow chart shown in Fig. 1. Department No. 9 represented one workpiece which left the factory for a special treatment which it was undesirable to carry out within its confines, it therefore had to remain as a sub-contracted operation.

The subsequent subdivision by process route numbers as suggested by J. L. Burbidge[6] resulted in Table 1 for the number of workpieces per assembly. It is obvious from this that the third and fourth sorts were of no real value as they merely succeeded in dividing the workpieces into unique items. On closer examination even the value of the first two sorts were put in some doubt since in the second, 25 workpieces existed separately, while the first sort produced seven individual items out of a total of 14 groups.

The problem experienced when using the Opitz code to form groups, was that sufficient geometrically similar workpieces did not exist. A similar problem was indicated with the use of PFA in that the number of workpieces following the same or similar process routes, were not significant. The first sort had however, shown that a sufficient number of workpieces did exist which started life on the same production machine. It was therefore necessary to find some criterion other than process routes on which to base the division of workpieces into viable groups.

Fig 1. Departmental flow chart





FIRST SORT—13 GROUPS	SECOND SORT—36 GROUPS
1 group of 9 workpieces	7 groups of 2 workpieces
1 group of 11 workpieces	25 groups of 1 workpiece
2 groups of 5 workpieces	1 group of 4 workpieces
1 group of 7 workpieces	2 groups of 3 workpieces
1 group of 3 workpieces	1 group of 6 workpieces
7 groups of 1 workpiece	
THIRD SORT—49 GROUPS	**FOURTH SORT—50 GROUPS**
4 groups of 2 workpieces	3 groups of 2 workpieces
1 group of 3 workpieces	1 group of 3 workpieces
44 groups of 1 workpiece	46 groups of 1 workpiece

Table 1—Breakdown of sorting into groups by process routes

Unique solution

During the analyses certain practical considerations had become obvious and it was realised that these might apply constraints on the production set-up indicating practical groups. It was felt that the division produced by the first six groups of the first sort using the PFA technique could possibly be used as a basis for more practical group formations. A general principle of Group Technology and one which is written down specifically as a constraint in Group Analysis is that 'as far as possible each part should be processed in one group only', on this basis the case was strong for including a particular sub-assembly and its associated workpieces completely within one group. From the flow-chart it was observed that certain workpieces moved into the finished goods store when machined, subsequently returning to the department as necessary to allow the assemblies to be produced. Hence if a sub-assembly and its associated workpieces were placed in one group not only material movement between departments but movement between groups could be eliminated for these items.

Although high machine utilisation was not a primary objective, it would have been difficult to justify the purchase of more automatic and semi-automatic machines than were indicated would be needed for functional layout as these machines involved high capital expenditure. It would therefore be undesirable to have two or more of these machines each in different groups and

Revised Departmental Divisions	*Department No.*
Raw material issue including saw	1
Machine shop, Inspection, Coppersmith—includes all other metal cutting plant and fitting	2
Flaw/Crack detection	4
Treatments—includes heat and chemical treatments, rumble, paint shop, araldite room	5
Finished goods store	7
Sub-contract work	9

Group 1	workpieces	8, 21, 39, 41, 44, 46, 54
	machine types	ADNOPQTUVWX
Group 2	workpieces	1, 7, 12, 16, 17, 25, 28, 29, 33, 34, 42, 49
	machine types	CDEFKLOV
Group 3	workpieces	20, 27, 47, 48
	machine types	ADHINOPQTUVWXZ
Group 4	workpieces	9, 18, 24, 30, 31, 32, 35, 36, 37, 38, 51, 53, 55
	machine types	BCDJNUV
Group 5	workpieces	2, 11, 13, 19, 22, 26, 45, 52
	machine types	BDNOPQRTUVX
Group 6	workpieces	3, 4, 5, 6, 10, 14, 15, 23, 40, 43, 50
	machine types	BDFGMNOPQSTY

N.B.—Automatic and Special purpose machines A, E, F, I, R, S.

Table 2—Final group arrangement

each with low utilisation. Two further advantages which could accrue by having the semi-automatic and automatic machines of a given type grouped together would be:

(i) it provides the optimum possibility for reducing setting time on these machines within the groups; and

(ii) it becomes possible to reduce the number of operators by having one operator controlling more than one automatic machine (this however tends to conflict with the desire to have an operator progressing a workpiece through all operations from raw material to finished goods).

Consequently preliminary groups were established using the priority rules given below:

(i) a sub-assembly and the workpieces associated with it should be in one group;

(ii) each machine type with low utilisation should have the workpieces which visit it grouped together;

(iii) as far as possible, the remaining workpieces should be divided according to the first sort achieved with PFA.

This sorting procedure was easily carried out giving rise to eleven groups with five individual workpieces left over.

At this stage in the analysis it was considered advisable to assess the work content of the groups, and obtain some concept of the size of the groups being suggested. A check was also carried out on the machine usage of each type of machine in each group.

The work content throughout the groups was found to be very unbalanced with group sizes ranging from 3 to 22 machine operators, not including fitters, inspectors, etc. Previously when batch sizes were being suggested, some workpieces were described as high value finished goods and a study revealed that three workpieces fell into that category requiring on average 10 machine operators for continuous volume production. A decision had thus to be taken to either:

(*a*) allow these workpieces to move from one group to another which would considerably increase the throughput time. However as these were already the workpieces with the longest throughput times it was not a desirable solution; or

(*b*) manufacture these workpieces on a mass production basis or flowline basis. The output required was not considered sufficiently high for mass production techniques and the new tooling which would be needed. It would be possible to set up a separate group for each of these workpieces alone but this would lead to very poor utilisation on a wide cross-section of machines; or

(*c*) accept larger groups thus allowing a practical solution to be achieved. This in fact was the policy adopted.

Group	Machine operators	Fitters	In-spectors	Others	Total
1	16	4	9	—	29
2	12	1	9	—	22
3	20	2	7	—	29
4	11	5	8	1	25
5	20	2	8	—	30
6	9	3	10	—	22
Totals	**88**	**17**	**51**	**1**	**157**

Table 3—Manpower requirements for proposed groups

On the basis of the foregoing considerations, various group amalgamations and tranfers of individual workpieces were undertaken resulting in six groups containing all workpieces and sub-assemblies as shown in Table 2.

These new groups were reassessed on the basis of the principles previously outlined, thus:

(i) each workpiece visited one group only, although all workpieces left their group at some stage for treatment and/or flaw detection returning for more work and/or final inspection before proceeding to the finished goods store.

(ii) a sub-assembly and its associated workpieces were all in the same group.

(iii) most of the machine types existed in one group only and this included all those machines having low utilisation factors.

(iv) it had not been possible to ensure that each type of automatic machine existed in one group only. However in only two instances was a duplication necessary.

A summary of the final composition of the six groups is shown in Table 3 in which it can be seen that the total work force per group ranges between 22 and 30. With such group sizes it was deemed necessary to have group leaders acting in a strictly supervisory capacity rather than combining this activity with that of 'leading workhand'. It would still however, be his responsibility to encourage team effort within his group and to instil a feeling of group identity. The organisation and control of work within each group would also be the responsibility of the group leader and he would have complete authority to make changes when and where he saw fit.

Conclusions

A critical examination of the recommended solution might lead one to the conclusion that the principles of Group Technology had not been adopted and in the context of its usual definition this would appear to be a fair criticism.

It was a fact that the search for common attributes of workpieces on which families could be based was largely unsuccessful, however independent manufacturing cells or groups have been suggested which should lead to more efficient production than would be possible with batch production based on a functional layout. In most documented applications it has been possible to draw up numerical results comparing the operating Group Technology plan with the previous functional system, but in this study, results of this type would not be realistic for a number of reasons. The project involved the introduction of GT in a completely new production set-up for which a new generation of automatic machines were being purchased thus necessitating a new approach to production engineering of the workpieces. All the workpieces involved were of a completely new design and thus highly susceptible to change and finally production still had to go through periods of operator training, tool try-outs, etc, before any figurative assessment could be taken of the performance of any production plan introduced.

At the time of writing, it still remains to be seen just how effective the proposed system is in practice. However there is little doubt in the authors' minds that the scheme should prove beneficial to the company concerned.

REFERENCES

1. Mitrofanov, S. P. *Scientific Principles of Group Technology*, English translation edited by T. J. Grayson, National Lending Library, 1966.

2. Opitz, H. *A Classification System to Describe Workpieces*, Parts I and II, Pergamon Press, 1970.

3. Haworth, E. A. *Group Technology—Using the Opitz System*, The Production Engineer, Vol. 47, No. 1, 1968.

4. Wild, R. *The Techniques of Production Management*, Holt, Rinehart and Winston, 1971.

5. Rice, A. K. *Productivity and Social Organisation. The Ahmedabad Experiment*, Tavistock Publications, 1971.

6. Burbidge, J. L. *Production Flow Analysis*, The Production Engineer, Vol. 50, No. 4/5, 1971.