Group Technology: Amalgamation with Design of Organisational Structures

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ACKNOWLEDGEMENTS

The author acknowledges the support of Ferdi Faassen, Steven Gudde and Kumaran Sugumaran for collecting data for the empirical case studies.

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HIGHLIGHTS

- investigates three empirical cases and five archival cases on group technology;
- finds evidence for link design of organisational structures and group technology;
- cluster analysis and production flow analysis mostly used for grouping;
- other solutions for flexibility: defunctionalisation and virtual group planning;
- semi-autonomous groups as solution for complexity of planning and scheduling.

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ABSTRACT

Group technology has been studied extensively from an 'industrial engineering' perspective (layout, scheduling, workflow, etc.), but less often from an organisational design viewpoint. To study this implication of group technology, the approach of applied systems theory for the design of organisational structures as framework for analysis was used in three empirical cases. To increase the reliability of findings from the analysis of these three empirical cases, five more cases were drawn from archival search. Cluster analysis and product flow analysis were the methods used for forming groups of machines and employees in manufacturing cells, whereas the coding of parts was not employed to this end. Furthermore, the results indicate that the implementation of group technology generally meets shifts in performance requirements caused by competitive pressures, particularly flexibility and responsiveness, albeit the companies considered group technology only when under pressure of 'poor' business performance. However, group technology is not always a solution to challenges that companies experience; one empirical case shows that defunctionalisation and scheduling with virtual groups was more beneficial. Nevertheless, when the introduction of group technology is feasible, it also allows firms to consider delegating responsibility for production planning and scheduling to lower levels in the hierarchy and semi-autonomous groups as an alternative to 'complex' software applications (a socio-technical approach). Whereas the current study sheds some light on the relationship between group technology and design of organisational structures, further research is necessary into the design of these structures and their relationship to group technology.

Keywords: applied systems theory, case studies, cluster analysis, flexibility, group technology, organisational design.

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1 INTRODUCTION

To gain competitive advantage through manufacturing performance (improvements in production process and organisation, such as the implementation of group technology), it is vital that the manufacturing strategy aligns with the business strategy, a notion unchallenged since Skinner's seminal work (1966, 1969). For this to happen, a clear vision of the manufacturing strategy coupled with organisational flexibility, integrated planning and a responsive fulfilment system is necessary to cope with the magnitude of change in demand and speed of delivery (Gunasekaran et al., 2001, p. 212). To this end, many companies engage in some form of restructuring or re-engineering to become flexible production organisations (for a full treatment of flexibility for manufacturing, see Koste and Maholtra [1999]); the question is how group technology fits into approaches to re-engineering and redesign as a response to meeting this criterion of flexibility.

1.1 Research Objectives

Such re-engineering and redesign are normally achieved in an organisation by analysing and integrating sets of interrelated activities including primary processes (for example materials movements, production processes), control processes (for instance information flow, ICT), organisational structures (with grouping and job design being an illustration) and interrelations with customers and suppliers; this notion is also found in business process re-engineering (e.g. Kock, 2003; Kock and McQueen, 1996; Martin and Cheung, 2005) and methods for analysis and design of organisational structures (for instance Dekkers, 2008). Particularly, in the strand of research for analysis and design of organisational structures, an appropriate structure should align with the performance requirements encapsulated by the business strategy (for example Armistead et al., 1999; Ruffini et al., 2000), sometimes based on grouping of interrelated activities (see Dekkers, 2005, pp. 429–34). In the context of design of organisational structures, some organisational forms have been associated with flexibility, for example modular production networks (Sturgeon, 2002) and cellular forms (Miles et al., 1997), from which the latter might have precedence in group technology. Therefore, group technology could be considered part of the array of solutions for design of organisational structures.

This paper investigates the validity of group technology for production as one of the principal designs for organisational structures in a modern-day setting. Past studies into group technology (Bennett, 1970; Burbidge and Hallsall, 1994; Gunasekaran et al., 2001; King and Nakornchai, 1982; Wemmerlöv and Hyer, 1989) have reported fruitful benefits to the adopting firm, which include a reduction in throughput time, machine or job set-up time, operating costs, work-in-progress and a clearer definition of roles and responsibilities. Godinho Filho and Saes (2013, p. 1189) note the manufacturing cells have gained a prominent place in quick response manufacturing. However, most literature on group technology is directed towards fully automated manufacturing cells (e.g. Al-Ahmari, 2002; Klippel et al., 1999, pp. 367–8; Onwubolu, 1998, pp. 377, 379–80), routing optimisation (e.g. Askin and Subramaniam, 1987; Kannan and Ghosh, 1996) and quick response manufacturing (e.g. Caputo and Palumbo, 2005, pp. 199–200; Fernandes and do Carmo-Silva, 2006, pp. 76–80; Gunasekaran and Yusuf, 2002, pp. 1367, 1376). Despite this academic gravitation towards technological and engineering aspects of group technology, some works address specific organisational aspects, for example teamwork (e.g. Buchanan and Preston, 1992) and lean production (e.g. Bonavia and Marin, 2006). Notwithstanding these few writings, group technology has not been viewed in the context of design of organisational structures nor has it been sufficiently integrated in a management perspective (echoing Selim et al.'s [1998, p. 15] and Wemmerlöv and Johnson's [1997, p. 45] calls). Black (2007, p. 3650) underlines this starting point for the current paper by stating: ‘it is not simply a case of moving machines into a U-shaped configuration as many group technology and value stream mapping papers would suggest.’ For this reason, three research questions are directing the study:

- What is the position of group technology in the design of organisational structures for production? What are its capabilities and what are its limitations?
- What methods for group technology have to be preferred for the purpose of design of organisational structures? How effective are the methods?
- Which link exists between group technology and the implementation of organisational structures?

These research questions will be partially answered by empirical research into three case studies and in part by five additional cases drawn from literature.

1.2 Scope and Outline of Paper

The focus of the paper is on a conceptual approach to making group technology part of the design of organisational structures supported by evidence from case studies. So far, the integration of group technology in design of these structures has hardly been dealt with. It has only been mentioned in the context of lean production by Bonavia and Marin (2006), but they consider group technology a practice rather than a design of organisational structures; note that they did not find evidence of its use in the Spanish ceramic tile industry (ibid., p. 522). In addition, Yu et al. (2006) refer to grouping for organisational structures but divert their attention to using a genetic optimisation algorithm for clustering rather than going into more detail of principles for organisational structures. Furthermore, Huber and Hyer (1985) have looked at jobworker performance, attitudes and satisfaction to find no substantial difference between group technology and traditional functional production. Also, Bidanda et al. (2005) investigate as they call it ‘human issues’. However, the human aspect is only a specific aspect of organisational structures. Hence, this paper is a first-of-its-kind study to integrate group technology into approaches for design of organisational structures.

For this integration, Section 2 will explore theory for the design of organisational structures and group technology as separate topics. The same section also amalgamates the theory on the design of these structures and the concepts of group technology. Subsequently, Section 3 sets out the rationale for the case study methodology and shows how archival research will complement findings from the cases. Section 4 presents evidence from three empirical cases and five retrieved case studies from extant literature. Section 5 discusses the findings and finally Section 6 concludes.

2 ORGANISATIONAL DESIGN THEORY AND GROUP TECHNOLOGY

The design of organisations in order to improve performance has been a long-standing topic in academic literature and, according to Shirazi et al. (1996, p. 199), efforts in developing organisational structures date back to the 1940s but could also possibly be attributed to earlier periods; studies into group technology also date back to the same era. However, as it turns out, topics of design of organisational structures and group technology have been poorly connected in literature. To establish the relationship from a theoretical perspective, first, this section reviews the literature on the design of organisational structures before looking at group technology in more detail. This section concludes with a discussion of the commonalities between the concepts.

2.1 Main Strands in Design of Organisational Structures

When looking at theories and concepts for design of organisational structures as the first step of the literature review, most of the works on this matter restrict themselves to limited aspects of an organisation or specific perspectives. For example, Mintzberg (1980, 1993) describes archetypes for hierarchical structures, blending positions, superstructures, lateral structures and decision-making systems. In addition to the writings that emphasise hierarchical structures (e.g. Daft, 2009, p. 102), organisational design has been described as part of: (i) the application of information and communication technologies (e.g. Tushman and Nadler, 1978); (ii) approaches to business process re-engineering (e.g. Childe et al., 1994); (iii) the philosophy of socio-technical design (e.g. van Eijnatten and van der Zwaan, 1998); (iv) specific contexts, for example Anumba et al. (2002). Sometimes, they are based on simulations or assumptions that do not fit organisational structures. By way of illustration, Rivkin and Siggelkow (2003) use agent-based modelling on a fitness landscape for the internal organisational structure, whereas the original application of this type of modelling aims to describe the development of species (e.g. see Kauffman, 1993, 1995), that would be industrial sectors for the case of firms; hence, this approach might be rendered inappropriate for design of organisational structures. Others have focused on specific aspects, such as organisational learning (e.g. Curado, 2006) and quality management (e.g. Cao et al., 2000). Another strand of literature focuses on the design of manufacturing networks (for instance Leseure, 2010); however, this stream is considered irrelevant for the context of the current study, because the focal point is the design of operations in a single firm. Even for specific sectors the paucity of works on organisational design has been mentioned. For example, Lega (2007, p. 258) remarks that there is a significant lack of works on ‘design issues’ in the literature on organisational design for integrated delivery systems in health care. This deficit in literature has also been noted by Ruffini et al. (2000), though they attribute this to organisational theory and approaches of operations management being insufficient for the design of organisational structures, and by van Aken (2004, 2005) and Pandza and Thorpe (2010) in a generic perspective on the position of design science in management science; this means that an integrated approach for the design of organisational structures hardly exists that tackles all these facets.

From this perspective, both socio-technical design and systems approaches claim to have a more holistic view on the design of organisational structures. Socio-technical approaches to organisational design underpin two of the five and systems theories one of the five approaches mentioned for information systems design by Avison et al. (1999, pp. 94–5). The socio-technical philosophy has been stressing integration between technological and human aspects for the design of operational processes. Others, such as Love et al. (1998, pp. 945–7), also point to this. Nevertheless, the meeting of overall performance requirements seems to be a weakness of socio-technical design, because it is hardly addressed. Akin to socio-technical approaches, the focus of system theories has been on participatory processes rather than a systematic design approach. For example, soft systems methodology (Checkland, 1981) emphasises the steps for analysing 'human activity systems' and does not see it as a 'hard' systems approach with its focus on design; similarly, Morgan (1981, p. 99) sees the use of system theories as an extension of a dialogue to improve performance. Note that the popular viable systems model (Beer, 1979), based on system theories, has a conceptual orientation. However, the blending of socio-technical design and 'hard' system theories (as an aid to decision making, according to Laszlo and Krippner [1998], or information systems design [e.g. Mumford, 2000]) may prove an avenue for arriving at a basic approach for organisational design; particularly because socio-technical design and systems theories have been connected (e.g. de Sitter et al., 1997; Walker et al., 2008). Henceforth, the blending of these strands for a systematic design approach to organisational structures could serve as a starting point.

2.2 Approach Based on Applied Systems Theory

In this respect of systematic approaches to organisational design, the application of applied systems theory to organisational structures uses the explicit recognition of the organelle structure (Dekkers, 2005, pp. 432–4) as a key feature to bridge cybernetic approaches and design aspects, including socio-technical design. The organelle structure comprises the grouping of resources, including human resources and machines, to meet performance requirements. This notion is akin the socio-technical movement in the 1960s, especially the work of Emery and Trist (1972), but is also found in more recent works (e.g. de Sitter et al., 1997). Emery and Trist (1972, p. 293) use the terminology: differentiation, for what de Sitter et al. (1997, p. 507) call the functional concentration of resources into units, departments (without considering the hierarchy). Note that de Sitter et al. (ibid.) state that this is the most important design step since it links most directly to the performance of organisations. This means that forming the organelle structure connects the strategy to the product flow and the configuration of the primary process; it comprises the grouping of activities, for example in a process-flow orientation or a functional structure (but not viewed from the hierarchy and so-called vertical departmental silos). Focus on the primary process came about through the thought that merely the redesign of a hierarchy does not meet performance requirements, which had already become clear in the 1970s; organisational changes should affect working processes in order to be viable (Mirvis and Berg, 1977). Hence, design of the organelle structure is strongly linked to meeting performance requirements by organisations.

The design methodology for organisational structures by using applied systems theory follows this notion and consists of heuristics for restructuring an organisation. The first heuristic rule is that the primary process and its control processes are grouped into the organelle structure (Dekkers, 2005, pp. 432–3), according to performance criteria. Note that the redesign principles of the control processes and the cross-functional perspective (embedded in notions of the organelle structure) link applied systems theory to business process re-engineering (Dekkers, 2008). As a second heuristic rule the design of the organelle structure precedes the forming of the hierarchical and communication structure. Furthermore, as a third heuristic rule, the redesign of an organisation is based on analysis of the current situation (the ‘as-is’ state) and the design of the notional future structure (the ‘ought-to-be’ state); see Figure 1. Analysis of the current and revised strategy might end up in trade-offs for performance requirements (akin to the trade-off for manufacturing capabilities; see Boyer and Lewis [2002], Ferdows and de Meyer [1990] and Größler and Grübner [2006] for further discussion) or in reconsidering the ‘Soll’-policy. All three heuristic rules result in an iterative process for the design and redesign of organisational structures; see Figure 2.

[INSERT FIGURE 1 ABOUT HERE]

[INSERT FIGURE 2 ABOUT HERE]

The design of the hierarchical structure (command and communication structure), often the starting point for other approaches, is the final step in this methodology of applied systems theory. This contrasts with canonical approaches, such as those of Daft (2009) and Mintzberg (1980), where structuring the hierarchy seems more the focus than processes within the organisation. The focus on process is particularly found in business process re-engineering and the related concept of business process management. For example in the context of business process management, Armistead et al. (1999, pp. 100–1) refer only to restructuring along process lines (its meaning is not clarified), the necessity for matrix organisations (again a hierarchical solution) and pro-functions (again not very well defined, except that is aims at achieving a reduction in employees). Another instance is the work of Li (1997) who focuses on centralisation and decentralisation as a key dimension. And a recent work by Winter (2010) takes ICT as a starting point. Hence, the focus on grouping tasks and activities in the context of organisational design does not appear in more traditional works on organisational structures and hardly plays any role in business process re-engineering, since the latter focus on embedding processes in ICT.

2.3 Methods for Group Technology

Not directly a generic approach to organisational design, group technology is a production philosophy to batch manufacturing that originally stemmed from concepts developed during the 1920s and 1930s (it is mostly attributed to Flanders [1925]). Consequently, this manufacturing principle premiered during the 1940s using group layout for simplifying the material flow system in production plants (Petrov, 1968). In the 1960s, the technique was practised by firms in Germany, Japan, the Soviet Union, Sweden, the United Kingdom and the US (Gallagher and Knight, 1973, pp. 7–9, 17), which tried to break away from the traditional approach to manufacturing batches in production lines or job shops. The key for group technology to move away from the disadvantages of either production lines or job shops is the formation of cellular product groups or components for the rationalisation of processes in a high variety and low volume production to improve productivity (Burbidge, 1992; Persona et al., 2004).

Over the course of time three methods and their variants have been developed for the formation of cellular groups. Kao and Moon (1995, p. 171) state that the traditional approach to group technology consists of two main methods that were popularised by Burbidge (1971a, 1971b): the coding and classification system (CCS) and production flow analysis (PFA). The CCS uses symbols to assign a part in the coding system, whereas the classification technique groups parts based on a predefined criterion. An example of CCS is the process route number (PRN) technique; it is a descriptive technique that records the movement of components to determine the flow process (Burbidge, 1970, 1975). Burbidge (1970) explains that the PRN technique is widely used to analyse material flows in PFA. However, related literature challenges the suitability of the PRN technique. For example, Gallaghar and Knight (1986, pp. 20–21) argue that PRN is time-consuming, costly and requires a complete survey of the component population for the development of a coding system that identifies parts of similar shapes and sizes, which does not suit every industry. PFA in contrast permits the division of machine cells and part families (Burbidge, 1975). ‘However, the original PFA method did not provide us guidelines on how to rearrange the rows and the columns to obtain the block-diagonalised matrix’ (Kao and Moon, 1995, p. 172). It was in later years that cluster analysis was developed to fill this gap. Cluster analysis is based on the assumption that homogenous information is available in raw data. The literature on cluster analysis can be found in studies such as Al-Omary and Jamil (2006), Ang (2000), Bowers et al. (1995), Cheng et al. (1995), Han and Ham (1986), King (1980), Rajagopalan and Batra (1975) and Vannelli and Kumar (1986). The technique clusters analogous objects based on information that is available from the existing production system (Bowers et al., 1995; Chow and Hawaleshka, 1992; Kusiak, 1990; Kusiak and Chow, 1987; Miltenburg and Zhang, 1991). The question is how these three methods (CCS/PRN, PFA and cluster analysis) from operations research relate to implementing organisational structures for group technology and, consequently, which one is most suitable for this purpose.

2.4 Amalgamation of Group Technology and Applied Systems Theory

This means that the grouping of activities appears in both the methods for group technology and the systematic design of organisational structures for production. The approaches of group technology are very much directed at identifying one solution, whereas approaches to organisational design consider a range of principal solutions. For example, potential clusters might have many crossovers indicating the borderline between group technology and the functional organisation. Otherwise, a single cluster could point to production lines if all processes and products in that cluster are very similar. In this blending of the operations research approach of group technology, i.e. the methods for identifying cellular groups, and the broader approach of applied systems theory in the context of organisational design, the approach to grouping of resources and personnel carries similarities. However, the design of the hierarchical structure offers the possibility of considering different solutions, such as semi-autonomous groups (e.g. van Eijnatten and van der Zwaan, 1998) or traditional command structures, for the coordination of planning and scheduling. In turn, these solutions may affect the control structure (planning and scheduling) and organelle structures (reconsidering grouping). Hence, the similarities in both approaches point to a seamless integration, though the consideration of alternative solutions and an iterative design process are inherent in the design approach of applied systems theory presented in Section 2.2.

3 RESEARCH METHODOLOGY

Since the methods for group technology align with systematic approaches for design of organisational structures, but have not yet been investigated sufficiently in literature, an exploratory approach should be followed. Given the potential impact of contingencies, the use of case studies is the most appropriate for this purpose.

3.1 Case Study Approach

The multiple case study approach taken in this paper was to analyse and to reflect on organisational structures and their performance as a result of adopting group technology principles by firms. The purpose is to logically capture and understand complex phenomena (Yin, 1994, p. 2) through an in-depth study on underpinning processes, technology and productions methods that would have an impact on control mechanisms and organisational design in each of the cases. Hence, a qualitative research approach in the form of an explanatory case study method was adopted. The availability of three case studies as projects (following the guidelines set by Polonsky and Waller, 1999, pp. 71–5), to be considered, as well as action research (see Coughlan and Coghlan [2002], Meredith [1998], Voss et al. [2002] for its description), allowed an in-depth investigation focused on the performance of manufacturing as a result of the implementation of group technology. This means that the units of analysis in these three cases is found in the performance of the manufacturing unit affected by the implementation of group technology and in how such is related to the design of the organisational structure; in that respect the study in this paper is of type 4, according to Yin (1994, p. 39). Thus, three case studies as action research formed the basis for this research.

3.2 Data Collection

In this respect, each of the three cases represents an in-depth-study of typically 8–9 months, comprising both the analysis of a company's specific problems and the detailing of the solution. The analysis and the devising of the solution follow the thoughts of Sagasti and Mitroff (1973, p. 699). To collect qualitative data, interviews took place with management teams, relevant department managers and operational staff. The collection of (quantitative and qualitative) data and the interviews were repeated and complemented until a complete picture emerged of (i) the criteria used for organisational performance derived from the competitive strategy; (ii) analysis of the gap in performance; (iii) solutions to address the performance gap; (iv) the design of cellular groups, the implementation of operational control mechanisms for managing production; (v) organisational structures related to the improvements. Three remarks for clarification should be made with regard to the protocol followed. First, it should be mentioned that the analysis was continued until there was a clear relationship between the original problem statement and root causes. Second, the detailing of the group technology followed the thoughts of van Aken (2004, 2005) on 'technological rules'. The solutions based on methods and 'technological rules' were implemented, though on different timescales for the three cases. Third, during the analysis and the detailing of the solution monthly interim reports were produced that were discussed with (senior) managers and two academics; this ensured both relevance and rigour. Thus, the replication of the processes for analysis and design made it possible that, after the latest of the three case studies, results could be compared with regard to the implementation of group technology and the related design of organisational structures.

The multiple case study discussed in this paper employed the four criteria for evaluating the quality of empirical research design commonly used in social research, which can be found in Yin (1994, pp. 33–8) for case studies: construct validity, internal validity, external validity and reliability[1]. Triangulation (Jick, 1979, p. 602) was used for construct validity by using observations, quantitative data and interviews. In addition, triangulation provides 'greater insights than '... a single research methodology' (Mangan et al., 2004, p. 565) and helps to minimise potential self-reporting bias. Internal validity was found by comparing the results of this study with those of other published materials in academic literature to establish consistency of group technology and related concepts in literature. When results from the three case studies were inconsistent, discrepancies were clarified through further discussion with other academics and managers in the organisation. Subsequently, external validity was inherent to this study because of the research protocol, the starting point of the case studies being real-life problems and the comparison of the three cases. Finally, reliability was achieved as the data collection and case analysis were closely monitored by two academics supported by key personnel from the case organisations. In addition to the four criteria for the

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[1] Construct validity refers to the quality of conceptualisation or operationalisation of relevant concepts in a study so that it leads to an accurate observation of reality. Plausible argumentation and logical reasoning that warrants the inferences determine internal validity. External validity means that findings account for phenomena not only in the setting in which they are studied, but also in other contexts. And reliability results from whether other researchers would arrive at the same inferences when undertaking the same or similar study using the same research design.

quality of research, the design of the case studies is also commensurate with the principles of action research, particularly:

(a) The integration of theory and practice (see Brydon-Miller et al., 2003, pp. 16–7; Westbrook, 1995, p. 11). This was particularly achieved by using documented methods for forming cellular groups and by using the applied systems theory approach for organisational design. Moreover, collaboration with the companies ensured that theoretical conceptualisations were also grounded in reality and related to the actual problem being resolved.
(b) Planning and implementation of an intervention (Coughlan and Coghlan, 2002, p. 238). In this study the intervention is the implementation of group technology based on an analysis of the performance requirements in collaboration with key members of the firms involved.
(c) The development of emergent insight from the intervention (Coughlan and Coghlan, 2002, pp. 236–8). This emergent insight is achieved by the protocol for replication, the consultation with the companies, the involvement of two academics in each case to guarantee objectivity, and the use of observable data and explicit reasoning.

Note that the intervention in this study is the design of organisational structures for implementing group technology. Thus, the case studies provide a sufficient base for the in-depth investigation about the design of organisational structures in practice and the implementation of group technology.

3.3 Augmenting the Empirical Research

To enhance the analysis of the relationship between group technology and organisational structures, archival research has been undertaken to find additional case studies. A search of databases has been conducted to find more empirical data for connecting group technology to the analysis and design of organisations. The investigation used the databases Google Scholar and Scopus using the Boolean strings {(“group technology” OR “manufacturing cells”) AND (“case study” OR “case studies”)}. This search yielded papers such as Flynn and Jacobs (1986), Opitz and Wiendahl (1971) and Tatikonda and Wemmerlöv (1992); however, these were unsuitable, because they hardly contained any information about organisational structures. After inspecting retrieved papers on title, abstract and content, five studies were found that contained ample information about case studies that could be included in the analysis.

4 EMPIRICAL RESEARCH

The evidence from the three cases studies and the five cases from archival research is captured next, and the following subsection provides a detailed account of one of the case studies. The second subsection gives some more background on two more case studies; one of these two should be considered an atypical case (see Flyvbjerg [2006, p. 229] for this term), because the implementation of group technology was mulled over but not chosen. The third subsection discusses the five additional cases (Caputo and Palumbo, 2005; Chakravorty and Hales, 2008; da Silveira, 1999; Hyer et al., 1999; Onyeagoro, 1995) that were obtained through archival research.

4.1 Empirical Case Study A

The first empirical case (A) concerns a company of 45 employees, which produced glass fibre products. Knowledge of and relationships with customers of the two owner-directors had resulted in significant growth in the years preceding the case study. The success of the firm was attributed to the specific knowledge of production processes and the capability of delivering standardised products and customised products in small batches. To this end, the manufacturing of the products had been initially arranged as a production line. However, the growth started to increasingly pose challenges for processing orders, last but not least due to a greater variety of products. Late deliveries, overtime (despite matching sales with an expansion in equipment and work force) and ‘quality’ issues became more manifest. In addition to these problems, operators switched regularly between three to four positions to fulfil orders; also, the layout of the production facility had become poor from an ergonomic perspective, and new operators and equipment had led to inefficient use of space (see Figure 3). A further analysis attributed these symptoms to the organisational structure, its coordination mechanisms not being aligned with the greater variety of products, more fluctuating demand for individual product types and growth in new market segments.

[INSERT TABLE 1 ABOUT HERE]

[INSERT FIGURE 3 ABOUT HERE]

Subsequently, a cluster analysis pointed out the feasibility of group technology for Case A to reduce the complexity of control for the production of this wide variety of products with fluctuating demand. Table 1 shows process paths for typical products that were manufactured during a period of four weeks. For example, Base A passes through the processes of cleaning the mould and waxing but not polishing. From this matrix, it is also became evident that all products needed to go through cleaning the moulds, gel coating and final inspection. To simplify further analysis, these three processes were omitted to identify similarities for the remaining processes. The next step of the analysis, forming groups, could have been conducted using a computer assisted cluster analysis package (see, for example, dos Santos and de Araújo, 2003). There were reasons for not doing so. First, the available data was only a small set. Second, computer programmes are limited for capturing the processes and practicalities of glass fibre manufacturing; hence, part families or process groups would have to be assumed before entering data into the computer. Computer applications also ignore the level of demand, sequence of operations, distance between processes and ergonomics for maximum efficiency (Neumann et al., 2006, p. 917), and the cost involved in materials handling. Third, it is postulated that any production environment involved in small batch production will have natural divisions between processes. Therefore, the task was to find the existence of these natural divisions for product groups and families. Hence, this phase enabled the identification of three groups: bases, roofs and specials (see Table 2). During the next step of the analysis processes that had been omitted earlier were reinserted and the matrix rearranged to arrive at a final matrix as shown in Table 3. This matrix now clearly displays the existence of three main process groups and part families with one exception. This exception is caused by the mould for Roof O that needs waxing, so that this emulsion acts as a release agent; this should be considered as a standard process that takes place in glass fibre manufacturing intermittently for every four or five units produced. Table 3 demonstrated that two process groups would produce all bases and all roofs, whereas another process group would produce incompatible products; however, the requirement for elimination of exceptions in the production process to facilitate clustering analysis as mentioned in theory about group technology was not necessary in this case.

[INSERT TABLE 2 ABOUT HERE]

[INSERT TABLE 3 ABOUT HERE]

The formation of the three product families using cluster analysis allowed reallocating and re-routing the production processes. The previously separated clean mould, wax and gel coat operations were brought together in one department, known as the pre-laminate stage. The previous trimming, buffing and joining were amalgamated in a department called the pre-finishing stage. These simplifications in addition to the three product families formed the basis for making changes to the shop floor layout. Introducing changes to the shop floor layout involved undertaking some background studies and conducting risk assessments on various other related factors. These included meeting the requirements for fire regulations, health and safety, and storage of hazardous raw materials. Part of the background work also involved an ergonomics study for finding a suitable location to store raw materials and tools in a central position so that production operators had only to walk a short distance to collect them. Besides, a designated area was needed to protect moulds in storage from exposure to extreme weather conditions. Furthermore, the layout of the shop floor, which was rectangular in shape, posed limitations for positioning the local exhaust ventilation units in manufacturing cells. Hence, the most economic way to make changes to the shop floor utilising available resources and to implement a group layout was to isolate the processes of spray laminating, trimming and joining, and to have final inspection in a separate cell of its own; see Figure 4. Therefore, the original identification of product families had to undergo minor modifications to fit with regulations and to optimise the layout for both the flow of materials and the reduction in distance for retrieving and storing moulds.

[INSERT FIGURE 4 ABOUT HERE]

[INSERT FIGURE 5 ABOUT HERE]

After the implementation of the layout based on group technology and the associated approach to scheduling of orders, the improvements were evaluated. The implemented changes were carefully monitored through close collaboration with the production staff to measure the following key performance indicators:

- reduction in inventory levels;
- reduction in production time;
- increased production volume.

The results for the first indicator, reduction in inventory levels, appeared in contradiction to the reported finding by Gunasekaran et al. (2001, p. 220) that an increase in inventory levels may be expected due to overstocking at each manufacturing cell; however, it is commensurate with the generic finding by Wemmerlöv and Johnson (1997, pp. 37–9) that the implementation of group technology reduces work-in-progress. In Case A, the reduction in inventory levels issue was resolved on the shop floor by locating the raw materials and the tools storage in a centralised position. With this in place, the company was able to hold only very minimal levels of raw materials and would only have to purchase them as and when needed for production on a just-in-time basis. The effect of this approach was ascertained by relating the monthly material expenditures to the units produced; see Figure 5. Although the reduction in expenditure must be seen as a one-off, it can be concluded that the introduction of group technology after month 2 lowered inventory levels relative to the units produced. Furthermore, by looking at a representative base and roof Table 4 indicates that the overall production time reduced in comparison to the previous flow of materials. Simplification of the flow of materials and moulds, and grouping of operations were the main contributory factors. The introduction of a mould storage area helped greatly helped towards the overall reduction in lead time. By having adequate storage less time is spent on searching and cleaning moulds, which in turn reduced the set-up time. According to the results of a time and motion study (see Table 4), the number of job starts had increased by 89 per cent and number of jobs completed had increased by 100 per cent. This outcome combined with the units produced as shown in Figure 5 serves as indicator that the flexibility of the manufacturing system increased with an improved productivity (derived from the production time in Table 4). Hence, the implementation of group technology and related changes to the layout combined with an improved production planning method did lead to improved reliability, reduced throughput times and lowered inventory levels; additionally, the workload for planning and control for one of the owner-directors, who acted as production manager, was lessened.

[INSERT TABLE 4 ABOUT HERE]

4.2 Empirical Case Studies B-C

The second case (B) concerns a company that specialised in welding components and producing sub-assemblies for a limited number of original equipment manufacturers of high-precision industrial equipment. The company, employing 35 people, concentrated on a variety of specialised welding techniques performed for a base of clients, which had expanded during the past years. The shop floor, including the production manager and a production administrator, consisted of 28 people. The production manager of this job shop did ask the general manager for an assistant to support his position. This was based on the rationale that the production manager had regularly worked 14-hour days during the preceding months partially due to an increase in orders. In addition to this request, cost had become increasingly a concern, despite a relatively stable customer base. Given the size of the company, the interim manager did not consider a vacancy for an assistant production manager a feasible option and requested an evaluation of performance in conjunction with alternative solutions.

A first step of the analysis revealed that the delivery time had become the most important performance requirement for customers; many of them accepted the higher level of cost since they used the company for outsourcing, mostly for reasons of capacity, or they needed the technological capability of the welding job shop. About 50 per cent of the orders exceeded the agreed delivery time. Waiting time and shortages of materials caused 75 per cent of all late deliveries mainly due to a lack of overview by the production manager and the issue of all specific production orders by him (see Figure 6). All orders were split into job orders, varying from a few minutes to some hours. The production manager's workload was attributed to a lack of overview and the continuous stream of issuing instruction sets for each production employee, resulting in late deliveries that caused intense communication with customers.

[INSERT FIGURE 6 ABOUT HERE]

The characteristics of the flow of orders allowed a division into three sub-streams: orders for welded sub-assemblies; orders for sheets; and orders for a specific welding process (this concerned only one person); this latter was not considered further because the space for this welding process was separate and its orders never needed any other machining or welding. This division would reduce the workload by introducing manufacturing cells with semi-autonomous groups; these groups became responsible for meeting delivery dates of orders and related scheduling. Validation of this proposal yielded a match with 28 per cent of the orders requesting a close interaction between the two main groups on sharing resources. This was reduced to 11 per cent by shifting some basic equipment to each of the two groups and by a minor investment in machining for the group *Sheet Preparation and Finishing* (nine people). The group *Welded Sub-Assemblies* would consist of 15 people. The proposal for the two groups for equipment and personnel was carried out and the move to the new layout (see Figure 7) made during a weekend. The further implementation came along with the semi-autonomous groups becoming acquainted with the planning and scheduling process.

[INSERT FIGURE 7 ABOUT HERE]

An evaluation revealed that the late deliveries decreased to less than 5 per cent while maintaining organisational performance and that no assistant to the production manager was needed. The hierarchical structure for operations was simplified using the semi-autonomous groups. Half a year after implementation, the company reported an adjustment in planning concerning the crossover between the two groups; the production manager centralised the planning on this aspect. After one year, the production manager had taken over planning and scheduling, though complete reversal to the old situation had not happened.

Case C was a company where an interim managing director had put forward group technology as a solution to improving adherence to delivery schedules and reducing the complexity of production management. In this case, the company produced mostly sub-assemblies from sheet metal for a limited range of original equipment manufacturers. Production management was based on a functional structure, a job shop, with high degrees of specialisation for each of the machining groups. In the product repository, there were about 3,000 active products with 1,500 of them each year undergoing engineering changes. In addition, orders consisted of small batches, though as part of long-term contracts (with most of the customers focusing on lean production). An initial cluster analysis with a limited sample of products revealed that grouping of products was very difficult, and at the same time it became apparent that customers valued the flexibility of this supplier. Moreover, the initial cluster analysis indicated that there were large variations in workload in successive periods. After an in-depth investigation, the functional organisation was augmented by adding 'basic' operations to functional groups (one could call this defunctionalisation), thus reducing the flows between these groups, and by training some of the workforce to become multi-skilled. This rearrangement was combined with improved (virtual) workload control, based on 'group technology', similar to Mak and Wang's (2014) approach and Prince and Kay's (2003) description. Eventually, the reliability of delivery improved within the service levels agreed with customers.

4.3 Archival Case Studies (D-H)

Besides these three empirical case studies, five further studies (Caputo and Palumbo, 2005; Chakravorty and Hales, 2008; da Silveira, 1999; Hyer et al., 1999; Onyeagoro, 1995) drawn from the literature search provided information on additional cases. The description by Caputo and Palumbo (2005) focuses on cells, with each of them organised as production line; though the scope of the study was different, it was still used because it contained information about the functioning of manufacturing cells. For analysing the paper by Chakravorty and Hales (2008) the preceding work (Chakravorty and Hales, 2004) was used. Both Chakravorty and Hales (2004, 2008) and Hyer et al. (1999) are longitudinal studies about the implementation of group technology; the other three case studies are oriented at one-time interventions and an evaluation of their performance. It should be noted that these five case studies contained less information on the aspects considered here than did the three case studies in Subsection 4.2.

5 ANALYSIS AND FINDINGS

Although information about the archival case studies is less complete than that from the empirical case studies, the overview in Table 5 allows inferences to be drawn with regard to the research questions.

[INSERT TABLE 5 ABOUT HERE]

5.1 Analysis of Results

The eight case studies represent a wide array of industries and sizes. The industries in this sample include the glass fibre industry (Case A) and the fashion apparel industry (Case D); that means that the application of group technology has gone beyond the machining industry with which it has traditionally been associated (Cases B, C and H in the sample). Also, the size of the companies varies. In Case G, the investigation focuses on a production department that is part of a larger company, whereas Cases A and B are small companies. Except for Case D, the units of analysis, i.e. production departments, could be classified as small to medium-sized. Therefore, the first finding is that the implementation of group technology can be found in a wide variety of industries (albeit limited here by the eight cases).

Despite this variety in industry and size, remarkably, almost all cases seem to have a similar point of departure for considering and implementing group technology. At first sight all companies sought to implement group technology for different reasons; for example, Case D was searching for optimisation of planning and scheduling through insourcing. Nevertheless, 'poor' business performance drove organisational changes, sometimes caused by competitive pressures, sometimes caused by growth and sometimes caused by shifting demands (e.g. customisation). The need for change arrived mostly from (i) increased cost caused by overtime, underutilisation of resources and overhead; (ii) increased lead-times for processing orders; and (iii) lack of flexibility with regard to absorbing product variance. Any of these signals of weakness may appear in combination sometimes supplemented by specific other challenges, such as quality. The mostly traditional functional structures are insufficiently capable of coping with these changes (Cases B, C, E, F and H), whereas at the almost opposite line production is impossible due to product variations and fluctuations in demand combined with small batches and small series (Cases A, D). It should be noted again that in the case of C group technology was not introduced because of lack of flexibility in comparison to the existing functional structure. Thus, the cases confirm that implementation of group technology bridges the disadvantages of both opposite solutions, i.e. job shop and line production (perhaps because it is a compromise?) – a second finding; but also that firms only resort to the implementation of group technology once performance has fallen substantially – a third finding.

For analysing the feasibility of group technology, different methods were used for the cases. For A, B and C cluster analysis was used and for H the related product flow analysis; the method of cluster analysis was preferred because of its simplicity and ability to avoid elaborate coding of products and processes. In the case of D time motion studies underpinned the further development of the formation of cells. Cases E and G relied on heuristic approaches for identifying the product and part families. And the study of Case F used an enhanced method of the close neighbour algorithm. It should be noted that none of the studies used a CCS, the traditional approach to group technology. In terms of da Silveira's (1999, p. 470) overview, the methods used for all cases seem to fit its first two parameters: 'parts/machines variety' and 'grouping subjects' (see Table 6); for the other three parameters the information across cases was lacking. For the purpose of designing organisational structures, cluster analysis and product flow analysis were the most methods in the cases, whereas the coding of parts was not drawn on at all – a fourth finding; this implies that this overview of da Silveira may provide a guide for selecting the appropriate method for grouping parts, products and resources for processes – a fifth finding.

[INSERT TABLE 6 ABOUT HERE]

Implementation of group technology came along with changes in organisational processes and structures, even for Case C where group technology itself was not introduced (note that this was the research objective). Foremost for and inherent to group technology, the implementation led to changes in layout of the manufacturing facilities. In the description of Case E, layout changes are only indicated and in Case C there were changes to the layout, though group technology was not the base for the organisational changes. Also, as would be expected, group technology induced changes in control mechanisms for planning and scheduling; though not specified in all cases, planning and scheduling based on workload models happened in Cases B and C. The solution for Case C resembles that of Prince and Kay (2003), where flexibility requires a functional structure, but production planning and scheduling can use virtual groups. In terms of organisational structures, the studies showed a variety of approaches. In two cases semi-autonomous groups were selected as most appropriate to deal with the complexity of planning and scheduling, in two other cases there was emphasis on production personnel being multi-skilled and in another case job rotation was used. The implementation of group technology came along with traditional hierarchical structures as well as socio-technical approaches, albeit sometimes implicit. This shows that the introduction of group technology does not only concern the layout but also arrives with changes in planning and scheduling, and relationships between workers and supervisors (and sometimes managers), particularly through the introduction of semi-autonomous groups – a sixth finding.

Despite the extensive changes, all companies reported considerable improvements in performance, except for Case H where the information was lacking. Aligned with the lack of performance and organisational objectives that induced the implementation of group technology, after the intervention reduced overhead, shortened lead-times, reduced work-in-progress and inventory, and increased productivity were reported; this aligns with findings from Wemmerlöv and Johnson (1997, p. 45). Furthermore, a few studies (B, D, E) provided some information on longitudinal aspects of organisational change but are hardly decisive; they only show that the implementation of group technology is not an objective in itself but a step in further adapting organisations (see also Molleman et al., 2002). Thus, the cases confirm existing notions about the gains in performance when introducing group technology to enhance flexibility – a seventh finding; however, it should be noted that improvements in performance are self-evident (why else would firms introduce re-engineering of this kind for their processes?)

5.2 Discussion of Findings

Despite being more costly than production lines in terms of products and offering less flexibility than functional structures, such as the traditional job shop, group technology offers improved business performance for small batches and small series; for this purpose, when firms experience growth through increased variety of products and orders it offers a solution for adapting organisations. The empirical and archival cases support this argument. However, there are limits to the scope for flexibility, as shown by Case C. And sometimes, cost pressures also make it necessary to revert to production lines, as exemplified by Case D. However, the process for analysing and designing organisational structures is heuristic, meaning that limitations for implementing group technology are known but not set in stone. That implies that for every case contingencies and characteristics of products and processes should be taken into account and considered; such is the case for C, where partial amendment of the functional structure offered a more adequate solution than group technology. As another heuristic rule, it seems that a higher degree of coordination between potential groups or cells indicates gravitation towards job shop scheduling and control. Thus, there is a strong relationship between organisational design and methods for group technology, albeit this connection relies on heuristics – an eighth finding.

Across the case studies, three approaches to flexibility related to group technology emerged; these approaches address the call by Selim et al. (1998, p. 15) for flexibility as a design parameter. The first one could be called defunctionalisation of job shops, because its leaves the functional structure of the job shop intact, but augments its functional groups with other basic operations to decrease its complexity for planning and scheduling (Cases B and C). A second approach was found in case B, where planning was based on the use of groups for products and parts, but the organisational structures and layout were not adapted. Such an approach to creating more flexibility in planning and control is also found in Nomden et al. (2005) and Prince and Kay (2003); both studies use so-called virtual groups. The third approach is the implementation of group technology with adaptions in layout and organisational structure. In Cases C and G, another approach is visible: the use of multi-skilled workers. However, this is a generic solution for increasing flexibility and not directly related to considering group technology. It should be noted that in Case H job rotation was used. Note that all four forms are an expression of the design parameter flexibility and can be considered an operationalisation of the more abstract overview of Koste and Malhotra (1999).

Thus, flexibility can be achieved through (i) defunctionalisation of job shops; (ii) planning and scheduling of virtual groups; and (iii) group technology for layout and organisational structures – a ninth finding; in addition, flexibility can be enhanced by using multi-skilled workers and job rotation, albeit that these solutions are less related to group technology.

Most interestingly for designing organisational structures, the implementation of group technology seems to offer unique opportunities for delegating planning and scheduling to lower levels in the organisation. First, it is possible to delegate this responsibility to supervisors and foremen, as happened in the case of C and to a lesser extent A. Second, semi-autonomous groups were established in Cases B and G. Hence, it can be carefully concluded that the complex internal coordination for production and scheduling can be counteracted by this feature of socio-technical approaches (rather than relying on complex computing solutions). However, it is not a necessary condition and sometimes may be very dependent on leadership as well; see Case C where the production manager claimed a more prominent role and Case D where a more traditional approach to supervision seems to prevail. It also contrasts to the socio-technical approach (e.g. de Sitter et al., 1997), in which empowerment of employees is seen as the impetus for creating product and part families. Thus, group technology can be associated with socio-technical approaches, but as result of the design of the organelle structure and the hierarchy – a tenth finding.

6 CONCLUDING REMARKS

Henceforth, findings from the three empirical case studies and the five archival cases confirm the relationship between group technology and design of organisational structures. This is inherent in both the implementation of group technology and the design of organisational structures falling back on the grouping of resources as a core principle. It should be noted that across the case studies diverse methods for implementing group technology have been used, mostly without a sufficiently specified choice. It could be cautiously inferred that the simple method of cluster analysis suffices for the purpose of organisational structures. The need for redesign of organisational structures, including considering group technology, is mostly related to performance not meeting objectives, or to shifts in markets and customer base resulting in higher degrees of flexibility being needed. This process is reflected in Figure 1 where either lack of performance or shifts in performance requirements led to the analysis and redesign of organisational structures. Almost all cases demonstrate that contingencies influence the specific solution or implementation of group technology. It is important to note that this goes beyond the often two-dimensional approaches to structuring in textbooks about operations management; the figures found in Jacobs and Chase's (2014, p. 151) textbook and that of Slack et al. (2010, p. 92) are cases in point for this perhaps outdated, simplified view. Such a two-dimensional approach to design of an organisation reeks of a positivist approach and less befits the post-positivist approach of case studies and field studies. Therefore, it may be that organisational design has been undervalued, and with it group technology, because it relies more on both heuristic and systematic approaches to organisational structures. Thus, this study has not only shown the explicit link between organisational design and group technology, but also advocated a systematic approach to designing organisational structures.

In this context, does group technology constitute an alternative solution to line production and functional structures for introducing or maintaining flexibility in the context of analysis and design of organisational structures? The approach to analysis is also found in Miltenburg (1995), but as in many instances group technology is seen as a matter of layout rather than the design of organisational structures. From the perspective of studies into group technology it is the solution; from the perspective of analysing and designing organisations it is a solution. However, the case studies show that the contingencies have been investigated less, leading to some conclusions about flexibility, and planning and scheduling during the discussion of findings. One could argue that organisational design precedes layout, hence studies that only focus on layout and scheduling in the case of group technology may miss out on a wide variety of aspects to be considered that are integral to the design of organisational structures.

6.1 Managerial Implications

This means that in practice the implementation of group technology (or not) has a strong link with the competitive context and the subsequent business strategy. Even though not an explicit part of the study, particularly in Cases A and C, it became clear that the unique competitive positions limit the ‘freedom of design’. The approach to organisational design based on applied systems theory (Dekkers, 2005, pp. 432–4) follows Chandler’s (1977, p. 314) early work, where his conclusion is very clear: ‘unless structure follows strategy, inefficiency results’, reverberated Thompson’s (1967) call; that concurs with the philosophy of engineering that requirements guide the design and design process. It could be argued whether this is true (see Hall and Saias, 1980), but the notion that structure follows strategy may serve as inspiration for considering specific solutions in practice.

It seems evident that a systematic approach to organisational design is required. Key to these approaches could be the design of the organelle structure and in that sense group technology offers an alternative where many nowadays advocate lean production, though it is connected to manufacturing cells and group technology by some (e.g. Prince and Kay, 2003). During phases of analysis and design, alternatives for organisational design can be considered; in this case of group technology also other solutions, such as defunctionalisation and virtual group planning, came to the fore. Only by weighing the benefits and disadvantages of alternative solutions can the final solution be chosen or designed in the context of the competitive strategy and the contingencies of a manufacturing unit. Nevertheless, analysis and design of organisational structures remains a heuristic process that can derive insight from studies such as this one; this corresponds with the call of van Aken (2004, pp. 236, 241) for prescription-driven research.

6.2 Limitations of Current Study

Despite this study's attempt to contribute to the heuristics of organisational design, there are limitations, with the first one being that the number of case studies and their variety does not make it possible to draw indisputable conclusions. Some cases might be considered deviating, most of them deviating cases and one of them a 'black swan', using Flyvbjerg's (2006, pp. 224–5, 229–30) terminology. At the same time, the variety of cases also provides credibility to results and findings, showing that inferences are applicable across a range of contingencies and industries. Nevertheless, some would say that case studies should be followed by positivist approaches; however, the implementation of group technology is a design approach (e.g. van Aken, 2004, 2005; Dekkers, 2008) and this also implies that variables are not linear neither are they independent, two conditions for these approaches according to Woodside (2016, p. 6). Thus, the findings and inferences might benefit from further case studies and action research, focusing on specific aspects of the implementation of group technology.

The second limitation is that only reported evidence has been considered for the archival studies. Table 5 shows that for some aspects of organisational design information is missing; this is specifically the case for how process of planning and scheduling, the organelle structure and the hierarchy are affected by the implementation of group technology. In this respect, although the five complementary articles represent case studies, four out of these five do not refer to key works, such as Coughlan and Coghlan (2002), Flyvbjerg (2006), Westbrook (1995) and Yin (1994)[2]. In a more generic sense, Barratt et al. (2011, p. 340) note that qualitative studies should offer sufficient details in research design, data collection and data analysis; obviously, their remark extends to case studies about group technology and studies into organisational design. Also, the specific approach to organisational design, distinguishing between primary processes (affecting lay), control processes, organelle structures and hierarchy, necessitated the scrutinising of the archival cases on these aspects. Since the authors of those studies have not been aware of this approach, neither did they necessarily report on these aspects. Notwithstanding the lack of reporting on all aspects of the archival studies, for each aspect there were at least five cases, including the empirical ones, available. This means that whereas in the strictest sense the information was incomplete for all aspects of the cases, in the spirit of case studies and action research there was sufficient evidence for the findings and inferences related to design of organisational structures and the implementation of group technology.

The third limitation is that all the eight cases have been evaluated using only one approach to the analysis and design of organisational structures, i.e. Dekkers (2008). Part of the reason is the lack of studies on how to design organisations as a holistic approach in the context of prescription-driven research. The only direct alternative would have been the socio-technical design of organisations, but that would have put the focus more on semi-autonomous groups and leadership; see for example Cherns (1976). That would have implied that aspects such as control processes for planning and scheduling and the design of organelle structures would have moved into the background. Thus, a focus on the approach for analysis and design of organisations also created a wide scope of organisational aspects to be considered.

[2] Or later editions of this popular textbook for the case study methodology.

6.3 Further Research

Because this study is a first look at a range of case studies for organisational structures and contingencies for group technology, one might have expected that issues surrounding group technology should have been settled by now, given its historical precedence in both building theory and implementation in practice. Whereas there is a vast literature on layout and solutions for planning and scheduling, with respect to organisational implications, there is still further research necessary:

- From the perspective of Kusiak (1987), Selim et al. (1998, p. 15) and Yang and Deane (1994, p. 95), there is a diversity of opinions in academic literature about group technology and a large number of approaches. Whereas this study is an attempt to amalgamate organisational design and group technology, it is incomplete, for part due to the limited number of studies on this relationship. Furthermore, the selection of methods for group technology as captured in Table 6, based on da Silveira (1999, p. 470), needs more evidence for its appropriateness. Hence, further studies should be undertaken to address this gap.
- In addition, there is little written about prescriptive-driven research for organisational design when implementing group technology. Some of these contingencies have emerged from this work; for example, there are different approaches possible on how to achieve flexibility and under which circumstances. These contingencies and specific solutions are only indicative and need further refinement in further studies.
- Moreover, the implementation of group technology seems to indicate that the complexity of planning and scheduling may be mitigated by semi-autonomous and delegation of responsibility to lower levels in the organisation. Which of these solutions are preferable and under what conditions needs to be looked at in more detail.

Within this study, the implementation of group technology has been placed in the context of analysing and designing organisational structures; this strand of research also needs further clarification:

- A systematic comparison between different approaches for the design of organisational structures is missing from the academic literature. Little has changed since de Sitter et al. (1997, p. 528) remarked that there is a lack of 'evaluation research' for the process of organisational design and development as a design-oriented approach. The study in this paper constitutes only one step in this direction, but more studies need to follow.
- Furthermore, there are different philosophies towards organisational design in general. One approach is that of Ruffini et al. (2000), who focus more on stakeholders' engagement and less on the steps for structuring organisations. In this current study the emphasis was on a more analytical design approach. For this purpose, there needs to be more research on the appropriateness of stakeholders' engagement and the analytical design approach, and, possibly, on their integration for achieving optimal interventions.

This brief agenda for further research implies that both the organisational implications of group technology and the approach to design of organisational structures need further attention; in particular the latter might provide further impetus for research into the application of group technology.

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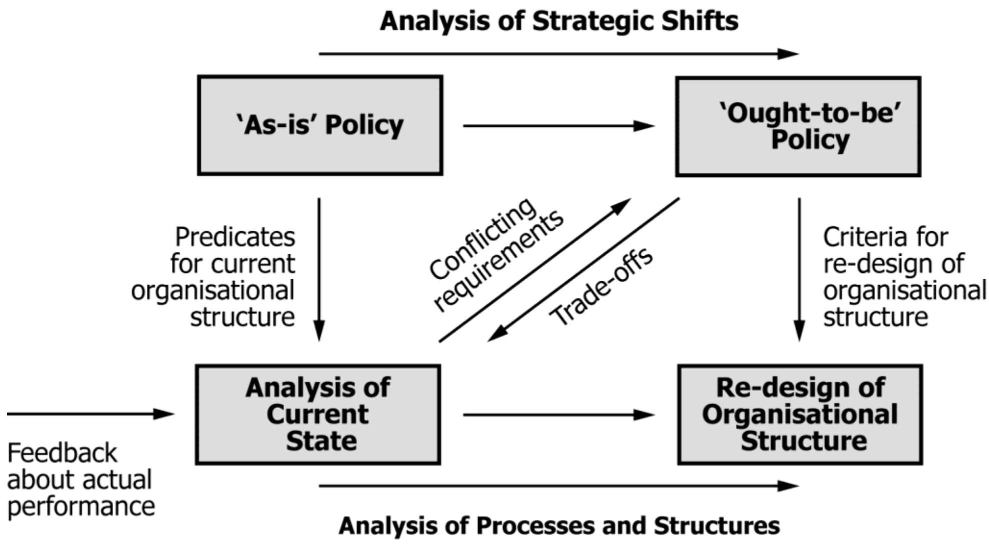

Figure 1: Methodology for analysing and designing organisational structure. The first trajectory investigates the prevailing strategy for the 'as-is' state and the aspired 'ought-to-be' state. The second trajectory analyses the current organisational structure (primary process, control process, organelle structure, hierarchy) based on actual performance and arrives at a redesign of the integral organisational structure. The two trajectories are intertwined through the (development and assessment of) criteria for analysis and redesign.

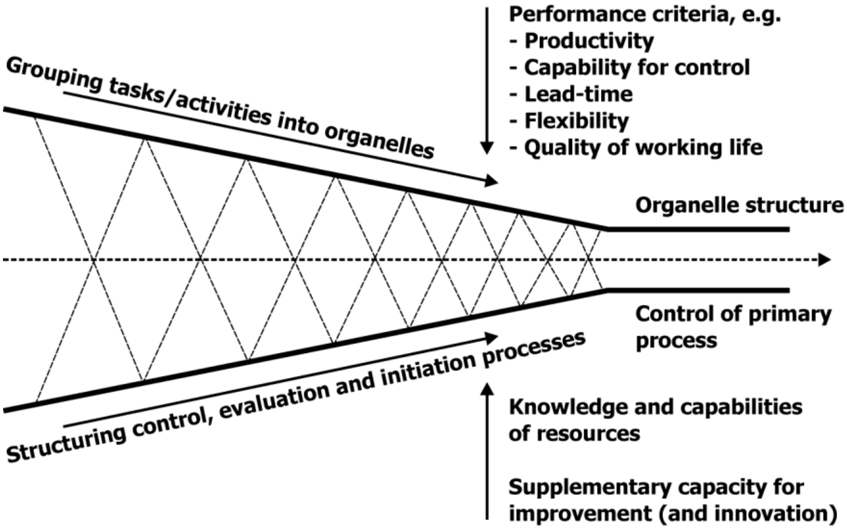

Figure 2: Iterative process for design of organisational structures. The design of the organelle structure affects the grouping of tasks in the primary process as well as in the control processes. Through subsequent integration and iteration, the design of the organelle structure meets performance requirements.

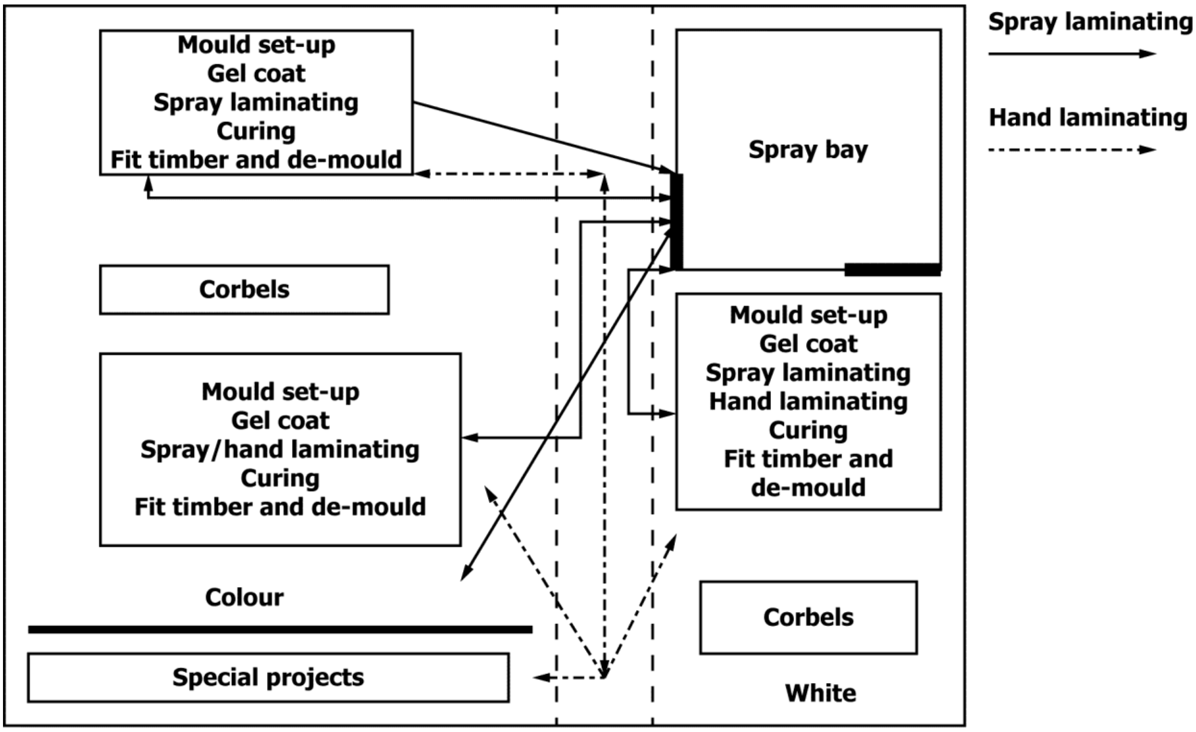

Figure 3: Layout of production for Case A. Though three groups are visible, they are interrelated due to variety of products. The flow of materials is different for hand laminating and spray laminating.

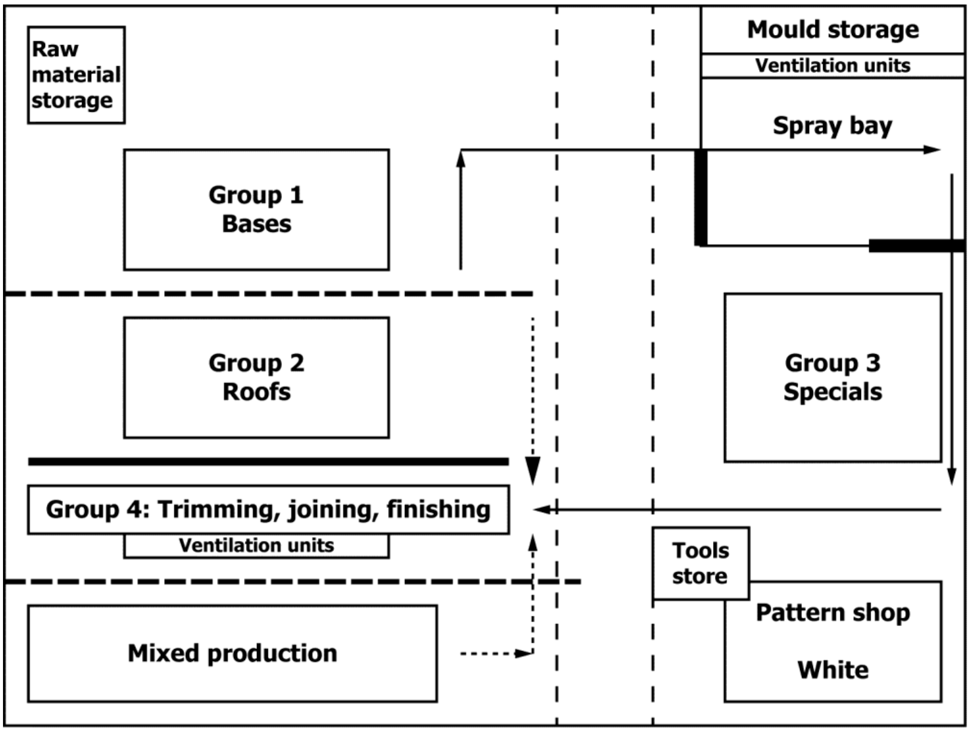

Figure 4: Layout of Case A after introducing group technology. Indicative flows of materials and orders have been indicated in the figure.

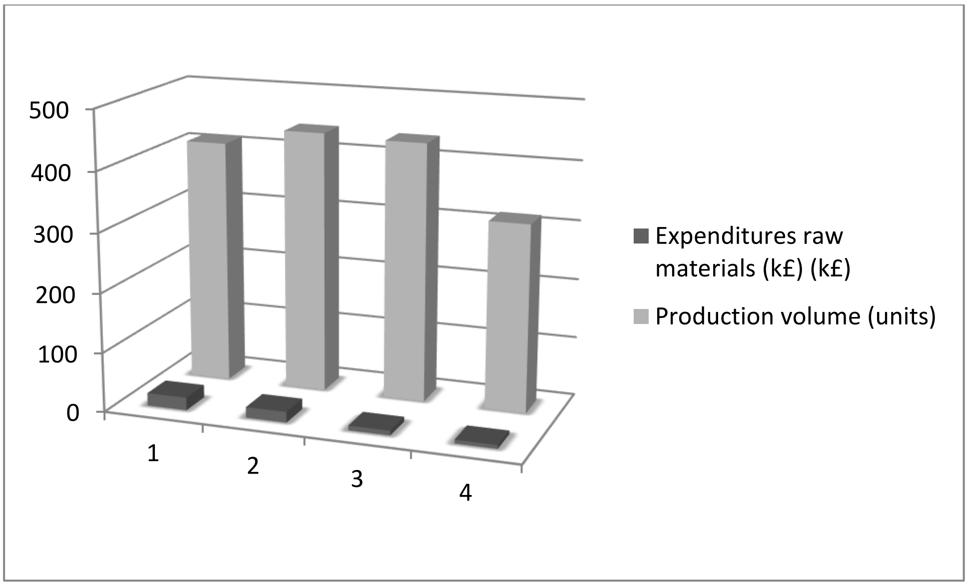

Figure 5: Monthly raw material spend in relation to production volume. Group technology was introduced between months 2 and 3.

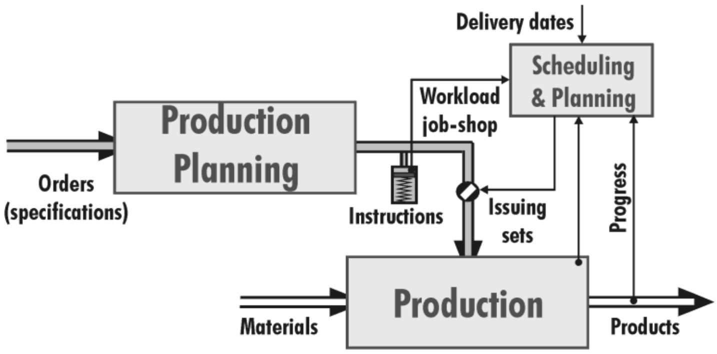

Figure 6: Primary process and control process for Case B. Job orders (sets) are released for production when capacity becomes available; these sets are instructions for specific machining operations and welding.

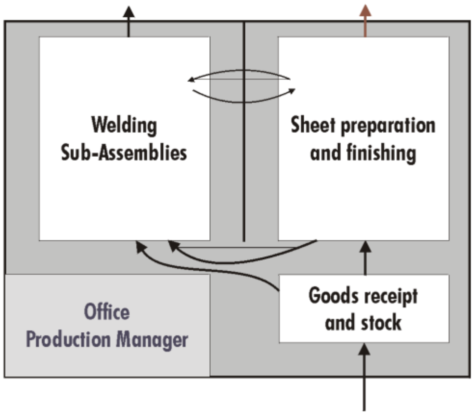

Figure 7: Layout for Case B after implementing group technology. Orders are allocated to the welding group or the sheet group; some of the orders initially allocated to the sheet group will be passed over to the welding group to complete the sub-assemblies.

Table 1: Process-product incidence matrix for Case A.

Process	Base A	Base F	Base J	Base O	Roof A	Roof B	Roof F	Roof J	Roof O	Type C	Type L	Type M
Clean mould	■	■	■	■	■	■	■	■	■	■	■	■
Waxing	■	■	■	■				■	■			
Polishing						■				■	■	■
Gel coat	■	■	■	■	■	■	■	■	■	■	■	■
Hand laminating					■		■		■	■	■	
Spray laminating	■			■	■			■			■	■
Trimming and sanding		■	■	■	■	■			■			■
Fit timber	■	■		■					■			■
Knock test						■				■		■
Trimming and joining	■	■	■	■		■		■		■	■	■
Final Inspection	■	■	■	■	■	■	■	■	■	■	■	■

Table 2: Process-product matrix after rearrangement

Process	Base A	Base F	Base J	Base O	Roof A	Roof F	Roof J	Roof O	Roof B	Type C	Type L	Type M
Waxing	■	■	■	■				■				
Polishing									■	■	■	■
Hand laminating					■	■		■		■	■	
Spray laminating	■			■	■		■		■		■	■
Trimming and sanding		■	■	■	■			■	■			■
Fit timber	■	■		■					■			■
Knock test									■	■		■
Trimming and joining	■	■	■	■					■	■	■	■
Product family	Bases				Roofs				Specials			

Table 3: Final process-product matrix

Process	Base A	Base F	Base J	Base O	Roof A	Roof F	Roof J	Roof O	Roof B	Type C	Type L	Type M
Clean mould	■	■	■	■								
Waxing	■	■	■	■				■				
Gel coat	■	■	■	■								
Spray laminating	■			■								
Trimming and sanding		■	■	■								
Fit timber	■	■		■								
Trimming and joining	■	■	■	■								
Final inspection	■	■	■	■								
Clean mould					■	■	■	■				
Gel coat					■	■	■	■				
Hand laminating					■	■		■				
Spray laminating					■		■					
Trimming and sanding					■			■				
Final inspection					■	■	■	■				
Clean mould									■	■	■	■
Polishing									■	■	■	■
Gel coat									■	■	■	■
Knock test									■	■		■
Hand laminating										■	■	
Spray laminating									■		■	■
Trimming and sanding									■			■
Fit timber												■
Trimming and joining									■	■	■	■
Final inspection									■	■	■	■
Product family	Bases				Roofs				Specials			

Table 4: Key performance indicators before and after implementation of group technology

	Production time (min.)		Jobs	
	Roof	Base	Started	Completed
Before group technology	198	185	9	6
After group technology	158	161	17	12
Improvement	20%	13%	89%	100%

Table 5: Overview of evidence collected from the empirical and archival case studies about methods for group technology, changes in the organisational structure and performance

Case		Empirical case studies			Archival research				
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Source					Caputo and Palumbo (2005)	Chakravorty and Hales (2004)	da Silveira (1999)	Hyer et al. (1999)	Onyeagoro (1995)
Description of company		• Glass fibre products (standard and customised). • MTO, small batches. • Employees: 45.	• Components and sub-assemblies for OEMs. • Welding and sheet-forming. • MTO, small series. • Employees: 38.	• Sub-assemblies, mostly from metal sheets. • MTO, small batches. • Employees: ca. 150 (production: 80).	• Apparel and accessories. • Employees: ca. 1000.	• Millwork: residential and commercial building products. • MTO. • Employees of unit: 20.	• Wood and plastic toys, stationary and home utilities. • MTS. • Employees: 400 (production: 250).	• 200 types of electronic products. • Employees (production): 200.	• Capstan lathes, machine vices, lathe chucks. • MTS. • Employees: 130.
Focus of study		• Production costs increasing. • Delivery schedules for orders increasingly difficult to meet.	• Production scheduling becoming increasingly complex. • Increasing cost caused by overtime and need for assistant.	• Group technology perceived as solution to reducing complexity of planning and scheduling.	• 'Manufacturing cells' existing for developing single product lines. • Outsourcing resulting in long lead-times and quality problems.	• Detoriation of lead time during past years. • Utilisation of workers: 75%.	• Increasing product and part variety. • Difficulties meeting competitive pressures of cost, quality, speed and reliability of delivery.	• Redesign of organisation because of poor business performance (costs, market share, delivery, low morale).	• Increasing productivity. • Reducing lead time.
Method for group technology		Cluster analysis.	Cluster analysis.	Cluster analysis (but not feasible).	Time studies for insourcing manufacturing.	Degree of complexity for distinction of product families: doors, windows, grills and mouldings.	Close neighbour algorithm in conjunction with visual analysis and coefficients of similarity.	Visual analysis for determining product families and groups (no formal analysis).	Product flow analysis, complemented with direct inspection.
Organisational aspects	Primary processes	• Three groups, separate 'cells'. • Layout changed.	• Two separate cells. • Adding 'basic' operations to cells. • Re-arrangement of goods receipt. • Layout changed.	• Adding 'basic' operations to functional groups. • Minor changes in layout.	• Each cell is production line, based on volume. • Standardised processes.	• Layout changed.	• Layout changed.	• Layout changed. • Cells created for product families.	• Separate cells for four major components. • One cell for all other components.
	Control processes	• Improved methods for planning and scheduling.	• Workload control. • Production and scheduling by semi-autonomous groups.	• Workload control with adaptive release.	-	• Changed production planning and control; no details reported.	• Changed production planning and control. • Changes in inventory management.	• New processes for planning and scheduling. • Interfaces with other departments.	
	Organelle structure	• Three groups formed consisting of machines and workers.	• Two semi-autonomous groups formed.	• Multi-skilled personnel (covering mostly 'basic' operations).	-	-	-	• Multi-skilled personnel.	• Job rotation.
	Hierarchical structure	• No changes.	• Later reduced autonomy of groups.	• Supervisors more say in planning and scheduling.	• Traditional approach to supervision.	-	-	• Semi-autonomous groups. • Including generation of procedures, etc.	-
Performance		• Improved throughput. • Reduced lead time.	• Improved performance for reliability of	• Improved performance for reliability of	-	• Reduction of lead time.	• Overall improvement in performance noted.	• Improved productivity.	-

	• Reduced overhead.	delivery. • No increase in overhead.	delivery.		• Reduction of scrap rate. • Reduction of WIP. • Improved productivity.	• Improved health and working conditions.	• Improved scrap rate. • Reduced lead time. • Reduced overhead.
Additional notes				• Insourcing to lead to greater autonomy and flexibility.	Evolution described by Chakravorty and Hales (2008).	• Participatory process for redesign.	• Socio-technical approach. • Participatory process for redesign.

Table 6 Methods for group technology and used for cases. The overview is derived from da Silveira (1999, p. 470). Note that for Case D the information about the method is missing and that in Case E it is not very clear how the degree of complexity could be classified in this table

Parameter		**Visual analysis**	**Codification systems**	**Coefficients of similarity**	**Clustering algorithms**	**Mathematical programming**
Parts/machines variety	Low	■		■		■
	High		■		■	
Grouping subjects	Parts	■	■	■		■
	Machines		■	■		■
	Both				■	■
Cases		E(?), F, G		F	A, B, C, H	F