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Production flow analysis—Cases from manufacturing and service industry

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ABSTRACT

Production flow analysis (PFA) is a well-established methodology used for transforming traditional functional layout into product-oriented layout. The method uses part routings to find natural clusters of workstations forming production cells able to complete parts and components swiftly with simplified material flow. Once implemented, the scheduling system is based on period batch control aiming to establish fixed planning, production and delivery cycles for the whole production unit. PFA is traditionally applied to job-shops with functional layouts, and after reorganization within groups lead times reduce, quality improves and motivation among personnel improves. Several papers have documented this, yet no research has studied its application to service operations management. This paper aims to show that PFA can well be applied not only to job-shop and assembly operations, but also to back-office and service processes with real cases. The cases clearly show that PFA reduces non-value adding operations, introduces flow by evening out bottlenecks and diminishes process variability, all of which contribute to efficient operations management.

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1. Introduction

The late Professor John L. Burbidge (Grubbström, 1996) used to ask his students why Adam Smith ignored the challenges related to efficient operations management in his otherwise all-encompassing book the "*Wealth of Nations*." Even in the famous pin-factory example, Smith fails to refer to the problems of layout design, throughput and operations management in general and only treats the benefits stemming from the division of labor. By keeping his audience in suspense Professor Burbidge eventually revealed that the factories at the time of Smith were nothing, but the size of a group, so the problems related to the management of operations were not of immediate importance to the father of capitalism. In the middle of the 17th century, manufacturing took place in small shops of artisans, where everything was based on visual control and simple material flow, with little need for complex planning and control (Jaikumar, 2005). Since the days of Smith, manufacturing units have grown in complexity and scale, most of them have grown into functional layouts with non-trivial material flows setting the challenge for Professor Burbidge to develop his approach aimed at turning them back to product-driven layouts as in days of old.

Production flow analysis (PFA) was developed and detailed by its inventor during late 70s and early 80s. The method is well documented (Burbidge, 1989) providing practitioners and consultants with a step-by-step approach to apply the method in environments with multiple operations and machines. In short, PFA is a well-established methodology used for transforming a traditional functional layout into a product-oriented layout (Fig. 1). The method uses part routings to find natural clusters of workstations forming production cells able to complete parts and components swiftly with simple material flow, and simpler manufacturing systems have been seen to be more efficient than more complex ones (Sarkis, 1997). The same approach can be used to analyze production units as well as the line layouts within a cell. Once implemented, the scheduling system is based on period batch control aiming to establish fixed planning, production and delivery cycles for the whole production unit. In addition to PFA, the same analogy can be applied to other levels of the business, namely the corporate level to analyze flows between companies (company flow analysis) and departments (factory flow analysis).

The method was born in a job-shop environment and therefore most of its applications are traditionally in that industry. The cases documented in detail report significant improvements in the general control of the previously complex material flow system, reduced lead times and improved punctuality (Wemmerlöv and Johnson, 1997, 2000; see also Nahm et al., 2006). In some cases, the number of organizational levels is diminished due to the formation of autonomous groups and cells. Taming of the bull-whip effect has also been reported (Lee et al., 1997). This article aims to detail the benefits of PFA not only in job-shop environments, but also in service businesses. To achieve this, the paper is structured in the following way. First, a review of the concerned literature on PFA and operations management is presented. After this, the methodological issues and research objectives are discussed. Then the cases are presented followed by a discussion on PFA and its benefits once implemented.

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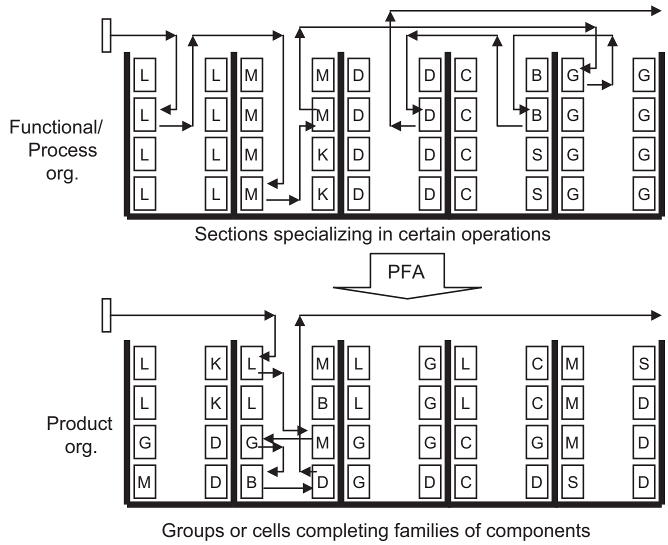

Fig. 1. Transforming traditional functional or process-based layout into a product layout simplifies material flows resulting in shorter lead times and less work-in-process.

2. Literature review

The first part of the literature review casts light on Professor Burbidge's early work and how he set out to develop PFA. Then the review broadens to include studies on group technology and cellular manufacturing, with a short review of different group formation methods. Studies related to the use of cellular production in industries other than manufacturing are then reviewed, including those on the use of product layouts in health care and service industries.

Following the increased introduction of Economic Order Quantity (EOQ) in various industries, Burbidge (1961) demonstrated that traditional stock control procedures based on EOQ logic would tend to amplify variations as demand passed along the value chain. Burbidge's "law of industrial dynamics", which is in line with the work of Forrester (1961), states that "If demand for products is transmitted along a series of inventories using stock control ordering, then the demand variation will increase with each transfer" (Burbidge, 1961). This profound insight shed light on the practical implementations and research to come. The simplification of production and supply flows was the essential starting point to improve efficiencies in value creation processes. In his main work (Burbidge, 1989, 1992, 1993), the culmination is in period batch control (PBC), where groups finishing specific parts, act according to fixed production cycles similar to just-in-time production control based on demand pull. Since Forrester and Burbidge's work, industrial dynamics has become a significant research subject in its own right (for an overview, see Geary et al., 2006).

Burbidge's stance towards theoretical lot-sizing and batching based on the EOQ theorem formulated by Harris in Chigago in 1915, has often been quoted, and should be reprinted here "The EOQ theory is pseudo-scientific nonsense" (Burbidge, 1989, p. 166). The theorem with its reality repelling assumptions has led to longer lead times and stock building, while creating an illusion that there is an economic trick by which companies can overcome the disadvantages of long set-ups and operating lead-times (see also Hopp and Spearman, 1996). Despite this, EOQ theorem is very much alive and is still the motivational force behind hundreds of academic articles per year reporting various refinements to this fundamentally flawed model. Being fully aware of the insightfulness of economic models, this line of work seldom relates to reality, which has and always will be the true focus of the PFA.

PFA is linked with Group Technology (GT), which, in turn, is often wrongly understood as a method of forming production groups based on the geometry of the parts that are to be produced. This is a one-sided view and only reflects one aspect of the production facility analysis. GT is an engineering and manufacturing philosophy, which identifies not only the sameness of parts, but also equipment and processes that are used to make them (Burbidge, 1979; Groove, 1980; Wemmerlöv and Hyer, 1989; dos Santos and de Araujo, 2003). It deals with the identification of similar parts from a manufacturing point of view and groups them for the purpose of manufacturing and design. Machines are grouped according to the routing required for a family of parts rather than by their functions (Burbidge, 1989). PFA results in a cellular layout with independent production cells, which often form the unit for capacity planning and production allocation. Different cells together operate according to a rhythm, which usually in job-shop cases feeds the parts for final assembly or downstream supply chain. On a more theoretical note (Hyer and Brown, 1999), the resulting cell incorporates the work tasks and those that perform them through time, space and information, of which information is the most significant determinant for effectiveness.

Although GT can be regarded as a means of improving productivity, its successful implementation requires special consideration to a wide variety of features within a particular production environment (Bauer et al., 1991). In addition, it is difficult to create practicable groupings, particularly for job shops of high product varieties and low volumes. Hendry (1998) takes this argument even further by stating that a process-oriented layout may still be the best option in some job-shops. This could be supported by the fact that the majority of the job shops in practice have process-oriented layouts, as opposed to the cellular-oriented or continuous flow layouts (Wisner and Siferd, 1995). Managing product variety is closely linked to lot sizing and especially set-up issues as fast set-up enables cost-effective changeover. Kekre and Srinivasan (1990) show with empirical data that large product variety may lead to greater market share and for this reason the inventories or immediate costs will not necessarily rise, thus creating prospects for higher profitability. They suggest that the explanation for this is the increasing use of advanced manufacturing techniques, such as group technology, flexible manufacturing, setup-time reduction and just-in-time practices (Burbidge, 1994a, 1994b).

Different models and algorithms have also been introduced to complement and improve the PFA approach. Finding clusters between machines and parts needing machining has been widely studied within the PFA framework resulting in numerous algorithms and techniques. Zolfaghari and Liang (2004) present a comprehensive genetic algorithm to solve the machine cell-part family formation issue considering processing time, lot size, machine capacity, and machine duplication. They apply the algorithm to randomly selected machine-part matrixes with satisfactory results. As the machine-part matching into production cells is a well-defined issue, many researchers have proposed several different clustering methods to perform it efficiently (see e.g. Yang et al., 2006; Angra et al., 2008; Defersha and Chen, 2006). For a comprehensive analysis of different approaches with a real world application, see also Kumar and Motwani (1998). This large body of clustering literature is sadly missing the true challenge of dealing with the exceptions, i.e. parts that do not fit into any group of machines that would satisfy the majority of the parts. The clustering itself is not difficult, but treating the exceptions is the real challenge and requires technical and managerial experience from the concerned industry. Following the PFA approach (Burbidge, 1989), the traditional options to treat these exceptional parts are to change the product design and/or machining procedures, or to buy the part from a supplier, yet very seldom are new

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