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A study on the cost of operational complexity in customer–supplier systems

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Abstract

This paper reports on the application of the operational complexity index [Frizelle, G., Woodcock, E., 1995. Measuring complexity as an aid to developing operational complexity. International Journal of Operations and Production Management 15(5), 26–39]. The aim is to address what is the relationship between costs and the complexity index. The investigation carried out measurements on two types of supplier–customer systems in the UK. One is make-to-stock with low product variety but high volume, while the second is make-to-order with high variety but low volume. The research found some evidence that inventory costs are associated with operational complexity. Moreover, while the index is generic to both case studies, there seemed to be a direct link between the index value and cost only in the make-to-stock case.

Keywords: Complexity; Entropy; Operational cost; Simulation; Supply chain

1. Introduction

Manufacturing industry is suffering from an increasing requirement for more flexibility and agility to deal with the variety and uncertainty in the markets it serves. The effects of uncertainty and unpredictability are also manifest at the interfaces between customers and suppliers, i.e. along the supply chain. In order to adapt to uncertain and unpredictable changes from customers, manufacturers and suppliers need to be flexible in the product range they offer and in the volumes they supply. Lee (2004) studied top-performing supply chains and identified the keys to success to be agility to deal with sudden changes, adaptability over time as market structures and strategies evolve, and alignment of all the firms in the supply network to optimise their interests. Specifically, many manufacturing managers view product range flexibility as a core competence for competitive success (De Meyer et al., 1989).

A few researchers found the level of flexibility to influence the choice of one or more performance measures, although others found the contrary. Banker et al. (1990) observed that product complexity (defined as number of moving parts in the mould) had a significant impact on the cost of supervision, quality control, and tool maintenance.

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Kekre and Srinivasan (1990) reported that significant increases in market share and company profitability were associated with broadening product variety, but the widely believed association of production costs to variety were not supported by empirical results. MacDuffie et al. (1996) studied 70 assembly plants and concluded that the impact of product variety on performance is much less than is generally assumed. In contrast, it was found product complexity to have a persistent impact on productivity. Guimaraes et al. (1999) utilised replies to a questionnaire sent to 500 plant managers to test the impact of manufacturing system complexity on performance. They defined manufacturing system complexity as comprising system complexity, operator task complexity, operator behaviour complexity, supervisory task complexity, training effectiveness, and man–machine interface effectiveness. They measured nine variables such as productivity, turnover, manufacturing costs and quality. The survey showed man/machine interfaces to be a significant contribution in reducing the negative effect of systems complexity. Randall and Ulrich (2001) investigated the bicycle industry and found that some types of product variety incur high investment costs and high logistic costs in order to achieve the required flexibility. The authors refer to these as "market mediation costs", because of uncertainty of demand. Their empirical results suggest that the firms that match their supply chain structure to the product variety type outperform the firms that fail to do so. Chandra et al. (2005) modelled a major automotive company in terms of capacity planning, flexibility, and part commonality. The experimental results showed that increasing level of flexibility and part commonality yielded improvements in production profitability.

Although flexibility or agility is widely accepted as a core competence in coping with variety and uncertainty, being flexible is not, by itself, the whole answer to coping with the variety and uncertainty inherent in a supply chain. It was observed that 40% of flexibility-improvement projects were unsuccessful due to "failure to identify precisely what kind of manufacturing flexibility was needed, how to measure it, or which factors most affected it" (Upton, 1995, 1997), or "what level the and type of flexibility do we require" (Hill, 1991). Jordan and Graves (1995) found that offering limited flexibility yielded most of the benefits to be had from being flexible. In order to achieve this, a measure of how well a supplier adapts to changes of demand is needed, Simply being flexible in an unspecific way is insufficient. Adaptability is also achieved through implementing appropriate planning and scheduling procedures.

Failure of production planning and scheduling to cope with customers' requirements for product and volume variety also exposes the limitations of undifferentiated flexibility. Lauff and Werner (2004) addressed complexity of scheduling problems in dealing with variety and uncertainty. Uncertainty comes not only from the customer, but also from the shop floor and suppliers. Shop floor disturbances make scheduling very difficult in practice, exacerbated by the dynamic nature of the environment. The disturbances and the complexity of scheduling cause deviations from a plan that is often overoptimistic (Stoop and Wiers, 1996).

Three points emerge from this literature. First there is a need for a clearer understanding of the nature of the complexity created by the performance of a plant or supply chain. Are all forms of complexity equivalent or does one need to be more specific? For example what, if anything, do system complexity, operator task complexity, operator behaviour complexity, and supervisory task complexity have in common (Guimaraes et al., 1999)? Is it possible to identify a "footprint of complexity"? Second if there is no obvious common mechanism, are there common consequences that arise from the presence of these forms of complexity? Finally, if the answer to either is "yes", does this lead to the development of a suitable measure?

However, so far there is no satisfactory and generally admitted definition of complexity (Perona and Miragliotta, 2004). In manufacturing and supply chain management, complexity implies number of elements or subsystems, degree of connectivity and interaction among the elements, unpredictability, uncertainty, and variety in products and in system states. Some researchers applied the metrics approach to measure individual aspects of a complex system (Perona and Miragliotta, 2004; Lauff and Werner, 2004; Blecker et al., 2005). For instance, Perona and Miragliotta (2004) proposed three indices, such as a supply relationship index to measure type and stability of connectivity, the number of components and products to measure product variety, and the annual quantity production orders to measure information and planning complexity. Another approach to answering above questions is to take an information-theoretic view. Frizelle, Woodcock and Suhov (Frizelle and