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Climbing the Complexity Hill: An Operations Management Case Study

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CLIMBING THE COMPLEXITY HILL: AN OPERATIONS MANAGEMENT CASE STUDY

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Abstract

Grounding on complexity management literature, this paper argues that the amount of internal manufacturing complexity is linked to firm manufacturing performance through an inverted U-shaped relationship. Performance increases as complexity increases, till reaching a tipping point, after which an overburden of complexity starts to sink improved performance. This article proposes a framework for quantitatively measuring manufacturing complexity and performance. Finally, the test on a case study on Alf Group SpA, an Italian company in the furniture industry, provides a first evidence on the complexity curve shape.

Keywords

Manufacturing Complexity, Complexity Dilemma, Firm Performance, Complexity Management

The problem

The complexity dilemma

Nowadays, the variety of products, markets, customers, competitors, suppliers, technologies, and processes is exploding. This, summed up with rate of changes, market instability, consolidated companies crisis, and continuous rethinking of existent assets, calls for a stance on complexity. Complexity does not sleep but continually increase (Größler *et al.*, 2006; Windt *et al.*, 2008).

A complex system is made of several interconnected aspects such as:

- (1) diversity: number, heterogeneity and variety of elements or subsystems (De Rosnay, 1977; Sivadasan *et al.*, 2006; De Toni *et al.*, 2005; Steger, 2007);
- (2) uncertainty: degree of predictability, ambiguity and uncertainty within the system and of the environment (non-linearity of interconnections) (Sivadasan *et al.*, 2006; De Toni *et al.*, 2005; Steger, 2007);
- (3) interdependence: degree of interaction or connectivity among the elements, sub-systems and between elements and the environment (De Rosnay, 1977; Sivadasan *et al.*, 2006; De Toni *et al.*, 2005; Steger, 2007);
- (4) dynamism: flux, rate of changes and co-evolution between the system and the environment (De Rosnay, 1977; De Toni *et al.*, 2005; Steger, 2007).

As, diversity, uncertainty, interdependence, dynamism, and thus complexity of the external environment increase, organizations have to face a complexity dilemma. Organizations could increase organizational complexity (internal complexity) following the law of requisite variety proposed by Ashby (1958), or could reduce the level of complexity making a complexity selection as argued by Luhmann (1990). To solve the dilemma organizations have to understand the effects of internal complexity on performance. Thus, this article is a first step forward on the solution of the dilemma.

In fact, due to its innate properties, complexity is difficult to quantify. Therefore, understanding how complexity affects firm performance is still an open challenge. Getting to the point: how complexity affects firm performance?

Little theoretical literature on the shape of the complexity curve exists (Collinson, 2011) and it is still in its infancy and it is controversy. Firstly, Davis *et al.* (2010) found an inverted U-shaped relation between the amount of internal structure (rules) and performance, then Collinson *et al.* (2011; 2012) have recognized such a similar behavior between EBITDA and internal level of organizational complexity, but concrete empirical evidence is still missing.

We hypothesize, and find, that the amount of complexity is linked to firm performance through an inverted U-shaped relationship. Performance increases as complexity increases, till reaching a tipping point, after which an overburden of complexity starts to sink improved performance.

As showed by the complexity curve (Figure 1), “in medio stat virtus”. Thus, companies have to find the correct level of complexity that resolves the Ashby-Luhmann tradeoff which is the foundation of the complexity dilemma.

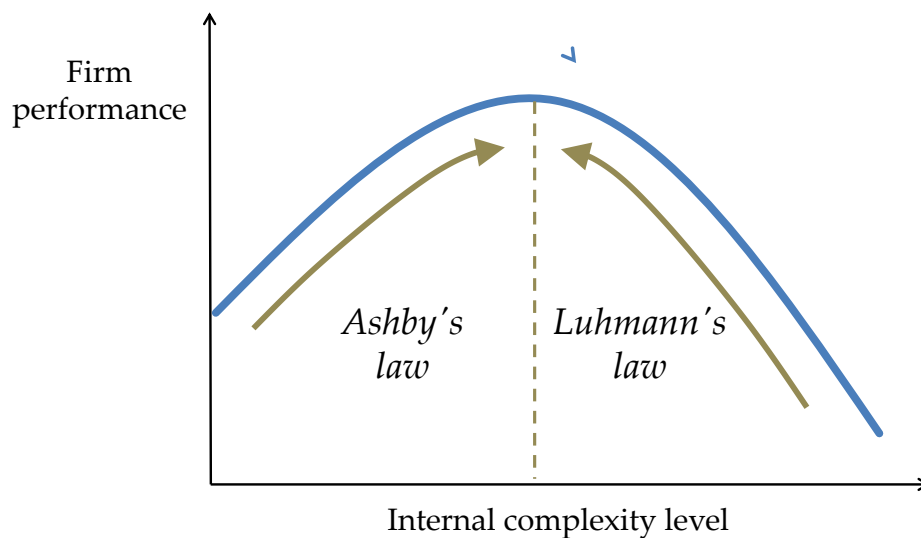


Figure 1 - The complexity curve

The complexity dilemma in operation management

Regarding operations management field, few authors investigated the complexity curve which correlates manufacturing complexity and performance.

Huaccho Huatuco *et al.* (2002) underline that is necessary for firms to cope with a sensible level of complexity; organizations have to estimate a desirable level of complexity and differentiate value-adding complexity (good complexity) from not-value-adding complexity (bad complexity) (Huaccho Huatuco *et al.*, 2002; Collinson *et al.*, 2011; Collinson 2012).

Many approaches to manufacturing complexity measurement ground on Shannon (1949) entropy concept such as Deshmuk *et al.* (1998), Frizelle (1998), Frizelle and Woodcock (1995), Jones *et al.* (2002), Karp and Ronen (1994), Sivadasan *et al.* (2006), Suh (1999), and Isik (2010). According to them, as the system complexity increases, the number of elements and relationships among them increases and then, more information is needed to describe the system and its state.

Generally, complexity can be subdivided into internal and external complexity. According to Größler *et al.* (2006) internal complexity is composed by internal processes configuration, products (portfolio), technologies, and structural organization. While external complexity (complexity out of the system) consists of products (customer demand), clients and logistics.

Manufacturing complexity regards internal complexity of firms. According to Calinescu *et al.*, (1998) manufacturing complexity integrates key dimensions of the manufacturing environment within the organization such structural aspects, decision-making processes, dynamical aspects and firm's objectives

According to Calinescu *et al.* (1998) and Calinescu (2002), manufacturing complexity drivers are: product structure, the structure of the shop or plant, the planning and scheduling functions, the information flow, dynamism, variability and uncertainty of the environment, and other functions within the organization (such as training activities, political information etc.).

Moreover complexity can also be subdivided into static or structural complexity, and dynamic or operational complexity. The structural complexity is defined by Frizelle and Woodcock (1995) as that associated with the static variety characteristics of a system while operational complexity, can be defined as the uncertainty associated with the dynamic system. A measure of operational complexity should accordingly capture behavioral uncertainty of the system with respect to a specified level of control (Sivadasan *et al.*, 2006).

This paper proposes a set of metrics grounded on complexity management literature to assess manufacturing complexity and performance. Then it measures how complexity affects performance of production planning system of Alf Group S.p.A., a leading company in the furniture industry.

Through the case study, we make evidence for the shape of the complexity curve (complexity hill) that relate the level of manufacturing complexity with firm performance.

Design/methodology/approach

The research strategy is a single case study (McCutcheon and Meredith, 1993; Handfield and Melnyk, 1998; Yin, 2003). The company, located in Treviso (Italy) is a leading player in the furniture industry: Alf Group SpA. The organization has a total of 300 employees and a turnover of 55 million Euros. We measure the level of manufacturing complexity and performance with reference on the production planning and scheduling of the Alf Uno plant.

Measurements system

The measurement system considers four dimensions of manufacturing complexity: (1) products, (2) processes, (3) clients, (4) sub-contractors. Products and processes are proper elements of internal complexity while clients, and sub-contractors are elements of external complexity. However clients demand produces internal orders that increment internal complexity and sub-contractors outsourcing activities increase the complexity of manufacturing processes and so increase internal complexity. Thus, we consider the four dimensions as attributes of internal complexity. As number and variety of the these dimensions increase, the amount of information needed to describe the system increases, and so, according to Shannon's entropy concept, complexity increases.

Moreover, we consider only the static component of complexity, defined by Calinescu *et al.* (1998; 2002), as the number and the non-linearity of relationships between resources, products and processes, and the definition of the possible resources states planned by the production scheduling.

For measuring performance, literature considers four main classes of performance (Wheelwright, 1978; Hayes and Schmenner, 1978): cost, quality, time, flexibility.

For our scope, in base of the typology of the analyzed process, we choose two parameters (1) effectiveness: time (market responsiveness) and (2) efficiency: cost. Then, according to De Toni et al. (1990), we analyzed performance in terms of excellence, defined as:

$$\varepsilon = e * E , \quad 0 \leq \varepsilon \leq 1$$

Where e stands for efficiency, and E for effectiveness, which are defined as:

$$e = \frac{EO}{EI} = \frac{EO}{\frac{EO}{DI}} , \quad 0 \leq e \leq 1 \quad ; \quad E = \frac{EO}{DO} , \quad 0 \leq E \leq 1$$

Where EO = Effective Output; EI = Effective Input; STD = Standard, ratio between Desired Output (DO) and Desired Input (DI).

As complexity measurements, we used metrics proposed by Frizelle (1998), Frizelle and Woodcock (1995) and Calinescu *et al.* (1998; 2002) and transposed them to the case study. So, we measure manufacturing complexity as: (1) Sub-contractors complexity; (2) Clients complexity; (3) product-process complexity; (4) Static complexity. Finally, according to Kuzgunkaya and ElMaraghy (2006) we define Structural complexity level as product of the previous four metrics.

Findings

With reference to the production planning system of Alf Group plant, the analysis confirms the predicted complexity curve shape (Figure 2). As complexity increases, performance increases till reaching the tipping point, then performance start to decrease. This behaviour is showed by all 9 scenarios tested. For instance, each scenario consider a combination of firm capabilities that act on process operative variable: people charged on process (one work shift, overtimes, two work shifts), and priority of product scheduling (3 typologies), for a total of 9 possible scenarios.

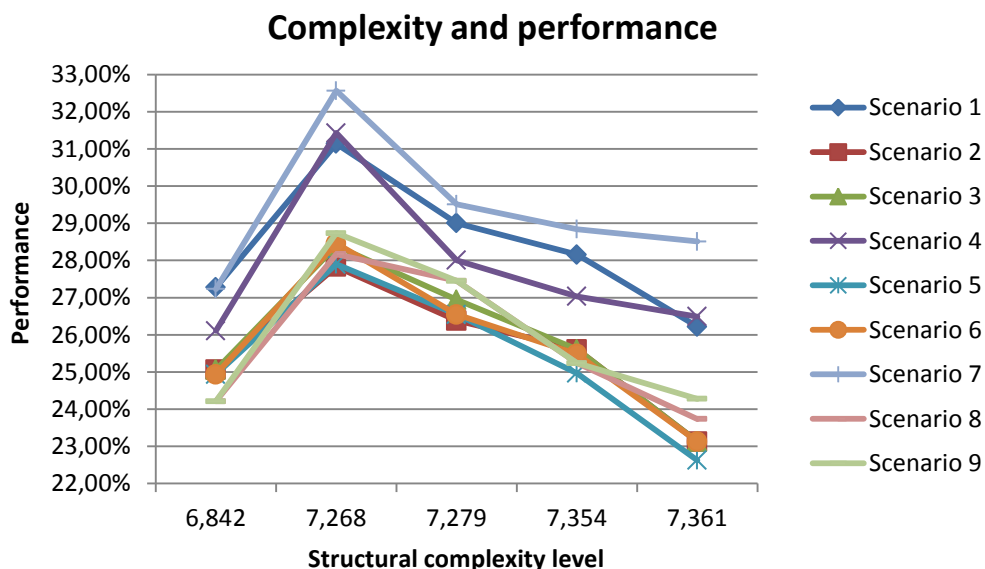


Figure 2 - The complexity curve of Alf Group SpA

As shown by Figure 2 as complexity increases, performance of excellence (product of efficiency and effectiveness) firstly increases and then, after reaching a tipping point, decreases. This behaviour confirms the hypothesis about the shape of the complexity curve.

Contribution and practical implications

Defining a set of metrics for measuring manufacturing complexity and performance, this article hypothesizes and finds an inversed U-shaped relationship between excellence performance and level of manufacturing complexity: the curve of complexity. Before this research a practical evidence for the complexity curve shape was missing.

The complexity curve is a step forward into the complexity dilemma. How companies have to cope with external complexity? Answering this question managers have to keep in mind that living at the extremes of the complexity curve could be dangerous.

For a practitioners' point of view, the approach at the base of the methodology represent a promising potential solution to the major dilemma of companies: is complexity eroding our performance? The methodology could be a basis for companies who would like to understand how complexity affects its manufacturing performance so to derive possible answers to complex times.

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