AGILE MANUFACTURING: 21ST CENTURY STRATEGY FOR MANUFACTURING ON THE PERIPHERY?

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Introduction

The globalisation of markets, growing interpenetration of economies and increased interdependence of economic agents are prompting farsighted companies to re-examine and modify their competitive strategies. Larger companies, powerful industries and whole economic trading blocks exert pressures from which small and medium-sized enterprises are not exempt (Ghobadian and Gallear, 1996). Continuous improvement effort needs to be coupled with an awareness of the pervasive changes in customer requirements, competitive factors and wider variations in the business environment. This paper discusses the development of agile manufacturing as a concept, separate from the lean manufacturing paradigm.

The original concept of agility was popularised in 1991 by the Iaccoca Institute of Lehigh University in USA (Kidd, 1994). The concept builds on the enduring features of previous paradigms of manufacturing from Taylorism, through, *inter alia*, MRP, JIT, WCM, OPT, TQM to Supply Chain Management and Lean Manufacturing (Voss, 1995). Academics agree that the concept is still only a vision and that further refinement is required. There is no company that can yet be said to be truly agile, if defined by characteristics emanating from the growing body of literature (Yusuf, Sarhadi and Gunasekaran, 1999; Dove, 1999). A review of the current definitions around agile will form part of this paper.

The underpinning principles of agility comprise: delivering value to the customer; being ready for change; valuing human knowledge

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and skills; and forming virtual partnerships. The first three of these are also attributes of lean manufacturing (Goldman, 1995). It is through a thorough review of the lean manufacturing paradigm, and particularly the limitations of it, that agile emerges as an enhancement and subsequently as a paradigm shift in its own right (Cusumano, 1994).

The assessment of the level or presence of agility in any manufacturing company through a definitive set of metrics is not possible at present. A staged assessment is therefore advocated. A concept is broken down into several principles, which, in turn, lead to practices and techniques that are the activities undertaken to change the organisation (Karlsson and Ahlstrom, 1997). Their study highlighted that the major studies were undertaken with large multi-national companies, most commonly the automotive industry (Womack et al., 1990; Karlsson, 1992, Womack and Jones, 1994). This may seriously reduce the chances of developing broadly applicable theory into small and medium-sized enterprises across diverse industries (New, 1996). The impact on technology transfer in this regard is relevant and the empirical work undertaken demonstrates that the continuum from a traditional manufacturing paradigm to an agile paradigm need not necessarily go through a lean model.

As a concept lean manufacturing has some strong underpinning principles, operational practices and techniques. Knill (1999) contends that, while a clear, concise definition is difficult, five high-level initiatives can be attributed to the concept of lean, namely: supplier programmes; continuous improvement; flexibility; elimination of waste; and zero defects. The basis of lean is the elimination of waste at all levels within the organisation as espoused by the Toyota Production System (Levy, 1997). Waste is defined as anything that does not add value to the product. The Toyota model of lean production has been around for 30 years and has been refined and updated regularly. Extending the lean model to include customer input into product design and developing partner relationships with key suppliers and outsourcing forms the basis of a prescriptive model of lean supply (Lamming, 1993). **Table 1** below summarises the basic principles of lean production inside the factory and in the supply chain. (Oliver et al., 1996)

TABLE 1: LEAN PRODUCTION INSIDE AND OUTSIDE THE FACTORY (OLIVER ET AL., 1996)

Inside the Factory	The Supply Chain
• Lean factory practice • Team-based work organisation • Active problem solving • High commitment human resource policies	• Tightly-integrated material flows • Active information exchange • Joint cost reduction • Shared density relations

The pursuit of ongoing continuous improvement in some Japanese industries has illuminated some of the limitations of lean manufacturing. In the specific situation in Japan, JIT deliveries of material were responsible for gridlock with resulting pollution, late deliveries, difficulties with suppliers and a shortage of workers (Cusumano, 1994). In the headlong rush for perfection in the efficient use of resources, improvement can become an end in itself. The lean organisation can become "static" and extremely fragile to the impact of change. The drive for the elimination of excess resources leads to a notional "single best method", which can reduce flexibility and limit the ability to react as circumstances change (Dove, 1999). Lean production is regarded as an enhancement of mass production methods, where continuous improvement is exerted on resources within the organisation's control. Agile manufacturing requires an enterprise-wide view and embodies such concepts as being receptive to changes in the business environment, rapid formation of multi-company alliances and breaking out of the mass production mode by producing more highly-customised products (Sheridan, 1996). While many of the principles are the same and both lean and agile paradigms draw from the same pool of practices and techniques, Dove (1999) defines the concept of agility as the "ability to thrive in a time of uncertain, unpredictable and continuous change". The issue for SMEs is that, while it is important to be efficient whenever possible, it is more imperative to be effective in aligning the organisation, its resources and product offerings to meet the market needs.

The present research seeks to address this gap. Unfortunately, no methodologies exist to differentiate between lean and agile organisations and checklists as devised by Panizzolo (1998) and Yusuf

et al. (1999) do not provide definitive metrics to measure success or failure. Although comprehensive in terms of concept and principle, the extent of their application and level of success or failure remains subjective nonetheless. This leaves differentiation of the paradigms to the discretion and opinion within the organisation. Application can be assessed as a movement or re-alignment over time within the broad concepts and principles of the paradigms. This research takes a lateral approach in that the case companies, one large and two SMEs, are highly successful. They are located in regions that are defined as economically disadvantaged. If lean and agile paradigms are indeed the manufacturing strategies for the 21st century, as envisaged by Kidd (1994) and Yusuf et al. (1999), then substantial elements of either paradigm should be in evidence within the organisations. In assessing how these companies have developed and reacted to business forces over the last number of years, while remaining highly successful, it may be possible to assess the extent to which they embody the concepts associated with lean or agile organisations.

The findings of the research demonstrate that the paradigm shift is a continuum from traditional manufacturing towards the agile enterprise. In large companies, lean manufacturing is a stage towards agility, while SMEs can bypass many of the elements of lean enterprises. Companies are positioned on the continuum and develop along it as a result of contingency factors such as industry competitiveness, technology, size and economic environment that impact on it.

The paper reviews the many definitions of lean and agile manufacturing and proposes a comprehensive definition of the key concepts of agile manufacturing. Empirical examination of the case study companies will provide support for discussion on the validity, rigour and extent of both paradigms in successful companies. The initial findings will highlight areas where further research will be necessary.

Development and Definitions of Lean Manufacturing

The search for competitive differentiation has led firms to move from a dominantly cost-based focus during the 1950s to 1970s period, to quality and cost during the 1980s. Cost and quality have become market entry qualifiers in the globally-competitive 1990s and firms are now turning to agility and lean manufacturing to achieve customer satisfaction and expand market share (Narasimhan, 1999). The origins of lean manufacturing came to the fore in the West after a five-year

study of the global motor industry. The study revealed huge productivity differences between car assembly plants in Japan and the West, which were attributed to lean production practices such as reduced lead-times, material and staff costs and increased quality (Womack et al., 1990). This study was strongly influenced by Toyota and the work of Taiichi Ohno. His Toyota Production System (TPS) was the collected wisdom and experience of 30 years' "trial and error", which was distilled into key attributes and many crucial formative influences such as systems from the Ford plants of the 1920s remain hidden from view (Williams et al., 1994).

In simple terms, lean manufacturing is defined as having the following guiding attributes:

- Integrated, single piece production flow, small batches, just-in-time giving low inventory
- Defect prevention not fault rectification; Production pull not push with smoothed demand; Flexible, team-based work organisation with multi-skilled workforce and few indirects
- Active involvement in "root cause" problem-solving to maximise added value
- Close integration from raw material to customer through partnership
- Reduced overhead burden through matrix teams, simplified information flow and processing, enabling flatter organisation structures. (Womack et al., 1990; Clarke and Fujimoto, 1991)

These attributes represent the best practice principles that could be expected in a high-volume lean manufacturing company and are the outcome of recognising the external business environment facing an individual sector. There is a strong link, therefore, between drivers in the business environment and the strategic responses to them. Lean manufacturing practices and measures can be viewed as the response by "best in class" companies to their changing environment (James-Moore and Gibbons, 1997).

There are many attributes of a lean enterprise with a structure to demonstrate a hierarchy of lean. The lean enterprise is a "concept", which contains a number of principles, as outlined above, which in turn consist of a set of practices and techniques (Karlsson and Ahlstrom, 1997). Other researchers advocate a multi-layer approach to defining lean. Panizzolo (1998) advocated interpreting the lean

production model at three different levels: the individual firm; the relationship between firms and between firms and their customers; and the role of contingency factors in the sector. Lewis (2000) described lean production as a process with three key principles, beyond which a deeper definition became vague and confused. Voss (1995) comments on the evolution towards lean production as illustrated by three key elements of Operations Management in the 1990s as developing the core, the interfaces with other disciplines and convergence where new approaches result in the convergence of many new and existing approaches.

Limitations of Lean Manufacturing

There has been considerable criticism of lean manufacturing. The measurement process of the original five-year study has been criticised, claiming that at an aggregated level the figures for USA were not as poor as had been stated (Williams et al., 1994). It has been claimed that the IMVP (International Motor Vehicle Program) study highlighted the performance of the Toyota Production System, which was not representative of the remaining Japanese manufacturers (Pilkington, 1998). Lewis (2000) contends that, the more successfully any firm applies lean production principles, the less it will engage in general innovative activity. He further contends that establishing causal linkages between inputs and outputs is notoriously difficult in any complex system. Benchmarking studies have benefited from close attention to actual practice, while other elements such as domestic and global economic and market conditions have been largely ignored (Katayama and Bennett, 1996). Economic difficulties encountered by Nissan (forced to merge with Renault), Honda and Mazda (bought by Ford) suggest that the lean production model may have reflected particular market conditions at a specific point in time. Other limitations of lean manufacturing appeared when practices and techniques were taken to the extreme. For example, traffic congestion resulted from frequent deliveries due to forcing suppliers to produce in smaller and smaller batches. It proved increasingly more difficult to source suppliers willing to take on such work and was compounded by the shortage of "blue-collar" workers (Cusumano, 1994).

Katayama and Bennett (1996) argue that the lean production model may not be robust enough as an approach to cope with changing and volatile economic and market conditions. The high value of the yen, outsourcing now providing competition for Japanese domestic plants

and reduced domestic demand are putting strains on the lean paradigm, which excelled in the Japanese "bubble" economy of the 1980s. Richards (1996) contends that lean producers set their sights explicitly on perfection: continually declining costs, zero defects, zero inventories and endless product variation. To do this without placing equal emphasis on improving interaction with the outside world can be dangerous.

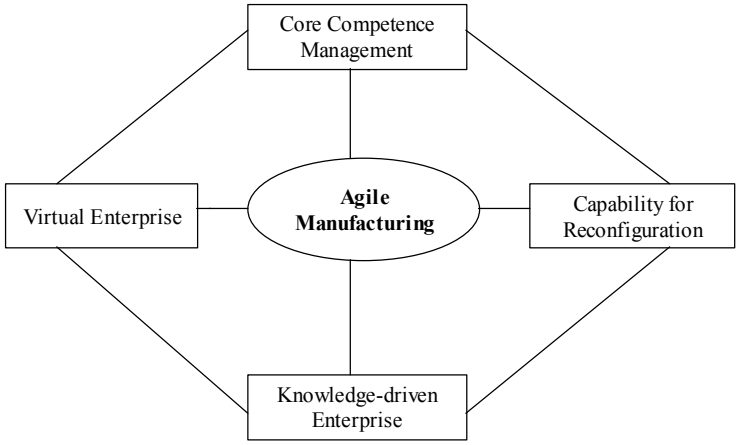
In summary, the limitations of lean can be reduced to two primary elements: inability to deal with turbulent and consistent change; and the pursuit of perfection to the extent that any scope for flexibility has been eliminated. Lean depends on a stable environment in which to maximise efficiencies of scale.

Development and Definitions of Agile Manufacturing

Agility was coined as a concept in manufacturing by a group of researchers at the Iaccoca Institute, Lehigh University, USA in 1991. The thrust of the report by the group was to convey an industry-led vision for a possible profound shift in manufacturing paradigm. The view of agile manufacturing enterprise included components, infrastructure and operating mechanisms as well as identifying competitive foundation, characteristics, elements and enabling sub-systems of agility (Iaccoca Institute, 1991). The main drivers of agility include: quality and speed to market; widening customer choice and expectation; competitive priorities of responsiveness, new product introduction, delivery, flexibility, concern for the environment and international competitiveness (Goldman and Nagel, 1993). Agility has four underlying components: delivering value to the customer; being ready for change; valuing human knowledge and skills; forming virtual partnerships (Goldman, 1995).

The core concepts of agile manufacturing are outlined in **Figure 1**. The core competence management relates to the organisation's workforce and products at the level of the individual and the organisation. Individual core competencies include skills, knowledge, attitude and expertise and have been described as the critical resource (Kidd, 1994; Goldman et al., 1995).

FIGURE 1: THE CORE CONCEPTS OF AGILITY (YUSUF ET AL., 1999)



A virtual enterprise can be formed in two ways:

- A large corporation can re-organise its business units, re-focus on core competencies and operate as a virtual enterprise
- Small companies can come together and deliver the quality, scope and scale of products and services that they could not have provided individually.

There is great potential for SMEs in this regard through rapid partnership formation (Yusuf et al., 1999). The capability for re-configuration can be accomplished by agile enterprises easily making a significant shift in focus, diversity, configuration and re-alignment of their businesses to take advantage of a window of opportunity. By organising to take advantage of speed to market, new product introductions and pro-activity, Goldman and Nagel (1993) strongly suggest that management invest in technologies that confer operational flexibility. However, they caution against placing excessive premium on technology for its own sake. The concept of knowledge-driven enterprises derives from increasing recognition of knowledge and information as the main differentiators of successful business. The success of any organisation ultimately depends upon its ability to convert the collective knowledge and skills of people into solution products (Kidd, 1994).

Sheridan (1996) quotes Goldman at the 1996 conference of the Agility Forum as promising a generic systems level model for an agile enterprise, linking market drivers, business processes, and enterprise level attributes (competencies). The strategic model would not be a game plan. Companies would need to develop their own game plan based on the system-level model.

Measures of Lean and Agile Enterprises

Measuring lean and agile enterprises is proving a difficult task. According to (Bartezzaghi, 1999), once beyond the general principles of lean, the definition is rather vague and confused. Attempts to assess progress towards lean production empirically have had to develop metrics linking together a wide variety of tools and techniques. Karlsson and Ahlstrom (1996) describe 18 different elements, each with their own sub-elements. Nick Oliver found that one consulting company's Lean Enterprise Research requested forms that took firms five-and-a-half days to complete (Oliver et al., 1996). Similarly, attempts to measure agile have been equally thwarted. Yusuf et al. (1999) constructed a table of some 32 attributes of an agile enterprise in 10 decision domains. Lewis (2000) produced a table of characteristics of lean enterprises under 21 headings and under three sub-sections of manufacturing processes, human resources and supplier inputs. The measures did not provide any information as to implementation success but provided an approximate metric for "richness of adoption".

Consultant Brian Maskell of BMA Inc. has produced "Journey to Agility" on BMA's web-site, which traces the evolution of agile manufacturing from "Traditional Manufacturing", to "Gaining Control", to "World Class Manufacturing" and on to "Agile Manufacturing".

Mason-Jones et al. (1998) suggests that lean and agile paradigms specifically address different marketplace environments. While the core elements may appear to be the same, the end results tackle significantly different market demand predictability issues. They argue that agile manufacturing is adopted where demand is volatile and lean manufacturing where there is stable demand and go on to suggest that both paradigms can be used at different points in the same supply chain. They call this the "Leagile" paradigm.

Sample Companies

Prelimiary investigations into the sample companies were particularly useful in focussing attention on real issues. Between the literature review and interviews conducted with the three organisations, many serious questions were raised and these have resulted in some interesting preliminary findings. The real outcome of this paper is not in a breakthrough in new management thinking derived from conclusive research but in the quantity of questions raised and the scope of further research needed to even begin to address them.

The original hypothesis was that, ''if lean and agile manufacturing paradigms were the manufacturing strategies for the 21st century, then successful companies, operating in economically disadvantaged regions, should exhibit the features of these paradigms''. Very successful companies should not thrive in economically disadvantaged regions. Therefore, in doing so, they must be doing something extra special and the essence of that is the objective of this paper. Was success related to lean and agile principles?

Company A: Profile

Industry:	Garment Manufacturer
Employees:	2000+
Turnover:	£130M
Customers:	1 with many High Street Outlets
Legal Status:	Private company. No loss of control on business decisions.
Competitive Position:	Increasing share of declining market by offering customer higher margin than competition.
Offshore Strategy:	Move stable, high labour products offshore to company factories in E. Europe and Turkey to keep marketing and customer support in N.Ireland or risk losing all business. Retain high value-added at home and carefully manage flexibility. Move if opportunity permits.
New Product Design:	Close to customer's head office
Order Volatility:	Typical 40% volume swings in contract life. Fashion uptake dependent.

PRODUCTS	**Jeans**	**Formal Trousers**
Product Type	**Commodity**	**Fashion**
Labour/Material Ratio	High Labour	Very High Material
Order Winner	Keen Price	High Quality, Speed of Response
Market Pressure	Reduce Cost	Flexible delivery, style mix and sizes
Market Stability	Stable	Highly volatile.
Materials Focus	Purchase Prices	Pipe line management
Business Risk	Lose cost Advantage	Product dies suddenly
Continuous Improvement	Material yield, Efficiency, Waste reduction.	Team working, investment in flexible manufacturing systems

Company B: Profile

Background:	Founded 7 years ago (1994) as result of an MBO. Turnover started with £2M with 60 employees. Main customer is original MNC parent (60%).
Industry:	Contract Cable Assembly
Employees:	250 +
Turnover:	£20M
Customers:	5. (Largest 60% of business)
Legal Status:	Private company. Advantages for strategic decision making and quick response.
Competitive position:	Niche contract manufacturer of low volume, high added value cable assemblies. Business increasing as OEMs outsource non-core activities. Developing new business through suppliers.
Off-shore Strategy:	Manufacturing plant/warehouse in USA close to main customer. Precautionary preliminary investigation of low cost locations in Mexico and Far East with a view to quoting on larger volume work.
New Product Design:	Upgrading design and engineering resources to add value to customer products. Close contact at senior levels with OEM design teams.
Product Family Types:	25 family types. All low volume, high value products, short life cycles. Material value and labour content high.
Order Winner:	Keen price and quality are order qualifiers. Order winners are very high service levels and quick response. Design capability will become an order qualifier soon.
Market Stability:	Volatile. Speed of technology advances and change capability. Low cost suppliers set ceiling on margins. Large, unpredictable swings in demand.
Materials Focus:	Materials supply. World shortage of connectors.

Capacity Strategy:	Use of casual/temporary contracts. Outsourcing and temporary partnership arrangements.
Business Risk:	Competition will catch up and compete on quality and service
Competitive Advantage:	Only short-term competitive advantage over competition. Very close liaison with customer at senior level helps with very quick response. Open to and preparing for change and opportunities. Very high service levels.
Ongoing Improvements:	Heavy investments in manufacturing and information technology. Fully integrated MRPII/ERP system. Waste reduction, WCM, Cellular manufacturing, EFQM and Vendor Managed Inventory programmes. Sustained investment in Training and Education. Web-based EDI from customer and to main suppliers. CAD system and E-Mail.

Company C: Profile

Background:	Founder-owner-manager. Established in 1985 as custom coach converter and builder. Main customers are private coach owners with small fleets. In the past supplied mid-sized buses to Dublin Bus but was unable to source a chassis for low access vehicles and missed out on one full order cycle of 2 years. A typical order is for one or two buses and is therefore an infrequent high value capital purchase.
Industry:	Custom Coach Builder/Converter
Employees:	50 + 25 contractors
Turnover:	£2M (20 – 25 buses per year)
Customer Base:	20
Legal Status:	Private company. Advantage is total control.
Competitive Position:	Niche, custom coach-builder. Low volume, high added value bus conversions and mid size bus builder. Custom business expanding steadily and has received several larger contracts in recent years. Just received an order for 50 mid sized buses for Dublin Bus. This will justify an assembly line with purpose built dedicated jigs and fixtures. Major competitors in UK not as good on quality but very poor on delivery.
New Product Design:	Bought a design from Spanish firm in receivership. Bus interior custom design and mould making capability in house. Essential to reduce turn around time and control. Innovative seat design.

Order Winner:	High quality safety engineering is order qualifier. Quality workmanship and adherence to delivery schedule is order winner. Value for money required with custom build coaches but keen pricing is an order qualifier for larger orders.
Market Stability:	Stable growth and predictable. Realistic delivery expectations from customer. Change to low floor design and up-grading of luxury coaches to EU safety regulations.
Materials Focus:	Materials purchasing. Large bought in elements. Materials control and co-ordination. Vendor managed inventory system in place for chassis. Source components from Spain.
Capacity Strategy:	Expand with lower skilled employees (non-tradesmen) on dedicated lines. Outsourcing and subcontract agreements in place.
Business Risk:	Low risk at present. No competitor in Ireland for fleet buses.
Competitive Advantage:	No other custom builder in Ireland set up for fleet production. Limited in house interior design capability. Quality image and reputation for safety and anti-corrosion. High level of on time delivery. Flexible workforce. Buy in new technology rather than design in-house. Strongly focussed on product and market requirements. Ready for change. Advantage based on proven product design
Ongoing Improvements:	Heavy investment in mid-sized bus design. MRP stock control system. CAD and job costing/job allocation systems. Video conference, internet, web-site.

Preliminary Findings

To place some kind of order on the preliminary findings, they are discussed in three broad areas: Lean or Agile; Assessment and Measurement; Influence of Contingency Factors.

Lean or Agile

The literature review has demonstrated that lean and agile are different in concept and in principle. Lean looks towards maximising the efficiency of resources that are within the control of the organisation and works best in high-throughput and stable environments. Agile is concerned with preparing the organisation to take maximum business advantage in a turbulent environment of change and unpredictability. The aim of agility is to position the organisation to adjust quickly and effectively to issues not in their control.

Lean or agile paradigms cannot be portrayed as a panacea for all the problems in Western enterprises. While they share many techniques and practices, it is clear that neither of these two paradigms, separately or even together, can form a manufacturing equivalent of the "Unification Theory". Advances over the last 50 years, and especially with the processing power of computers, have resulted in more diversification of operations management theories and practices. The evolution from traditional manufacturing practices to agility form a continuum that starts with fulfilling customer orders, moves to effecting more control over resources, then to maximising efficiencies and finally preparing for turbulence and change. Lean and agile are not about describing a perfect company but they are about equipping the organisation for where it needs to be. Lean and agile can be simplified into the difference between effectiveness and efficiency, or could be compared to Michael E. Porter's generic strategies of cost leadership and focussed differentiation.

Assessment and Measurement

There are very real problems associated with measurement of the up-take and degree of leanness and agility within an organisation. There are certainly hierarchies within the paradigms at conceptual, at informing principle and at practical technique levels. These can be equated to strategic, tactical and operational areas. At conceptual and at principle levels, both of these paradigms grab the attention of senior management. Resources can certainly be aligned within organisations. However, at operational level, is it almost impossible to

provide a definitive set of criteria to assess whether indeed leanness or agility has been achieved or the extent of it. There is a plethora of practices and techniques, the distilled wisdom from Taylor to the present, in the areas of management, materials, human resources, machinery and systems enabled by technology developments as they evolved. There is no "one best way" for all, but an "a la carte" menu of practices and techniques from which the organisation can determine the most appropriate. It is clear that, if these paradigms are to be of practical use, an organisation can only assess the appropriateness of their programme by the results achieved over a period of time against criteria set by themselves within their own industry. Questions arise here whether there is a real need for a model against which success can be compared or whether a "richness of adoption" approach is sufficient.

Influence of Contingency Factors

Contingency factors have a huge influence on the business environment. Even from the limited sample of companies interviewed, it is clear that there are a wide range of factors that impact the context within which the companies and industries compete. Issues of age, size and technology in the industry, the economy, the legal environment and the technological imperative all effect the competitive arena and the stability of the marketplace. It is within this context that the paradigms of lean and agile co-exist. It may be too simplistic to suggest that stability provides the arena in which leanness is an appropriate methodology and that instability requires a more agile approach.

Conclusion

In conclusion, the preliminary investigation has raised many questions and identified a fertile area for intense academic study. It appears that a significant gap exists between lean and agile concepts as they apply to large companies and SMEs. The study area is immense, with many practices, techniques, programmes and myriad issues to be adequately defined. Assessment and measurement is where these paradigms are encountering major problems. At a conceptual level, they are both attractive and appealing to those who like neat packages with catchy labels. There is a need for deeper study at industry specific, regional or SME level, if knowledge transfer is to have any impact.

Is there a true paradigm shift? Is it just a fad or a convenient label on which to hang the complex and expanding range of practices and techniques available to modern managers?

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