

Fit Manufacturing

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Abstract

Despite the increasingly challenging demands being placed on companies involved in the manufacturing sector, successful operations, both new and old, are seen to be flourishing where they can take advantage of a gap in the market. This demonstrates that the constantly changing manufacturing economy is still creating opportunities which can be exploited. However, there is currently no structured approach to enable companies to do so. This paper describes a generic structure of elements common to the identification, characterisation and realisation of opportunities for sustainable growth. The paper subsequently uses the elements discussed to contribute to the new Fit Manufacturing paradigm. This is a manufacturing strategy linking the improvements in manufacturing efficiencies and/or effectiveness achieved through Lean and Agile Manufacturing with the ability to break into new markets through integrated marketing and product innovation strategies to achieve long term economic sustainability.

Keywords: Fit Manufacturing, Agile, Lean, Sustainable manufacturing, Integrated Manufacturing Systems

1. Introduction

The rapidly changing global information and communication systems convey the reality of a turbulent and complex world, the dynamic nature of which calls into question the manufacturing or operational strategies so far adopted. The implication of this is that previous frameworks with regard to company organisation, staff management and manufacturing structures require constant rethink [1] and improvement in order to be able to meet emerging challenges such as the compression of product life cycles.

To achieve competitiveness in this complex turbulent situation, new manufacturing strategies such as Lean [2] and Agile [3] Manufacturing have been devised, the former promoting efficiencies through the elimination of waste and the latter enhancing a manufacturing system's ability to deal with change and uncertainty by building in measures that increase flexibility and responsiveness.

Fit Manufacturing [4] is defined as the integration of three major business process strategies namely Lean, Agility and Sustainability. However it is not clear to many practitioners of these best practices how Fit Manufacturing achieves more than the sum of the parts drawn from these paradigms. It is proposed that Fit Manufacturing is an approach born out of necessity when enterprises are forced to consider fundamental changes in their operating environment. The immediate pressures of the variable customer base encourage a more proactive resource management strategy, but the overall approach must also be structured to adapt to systematic changes imposed by issues such as diminishing world resources and environmental problems.

The paper begins by describing sustainable manufacturing in terms of its constituent elements, hence proposing a set of criteria which are met by a fit organisation. The existing paradigms are then

considered in terms of their ability to satisfy these criteria. Finally, the strategy required to adopt fit manufacturing successfully is described, approaching the adoption issue from a 'top-down' perspective using an integrated systems model, in place of the traditionally linear continuous improvement approach.

2. Characteristics of Current Best Practice

2.1 Sustainable Manufacturing

The term sustainability can be applied to a variety of concepts and is often taken out of context [5]. For many people sustainability translates to the looking after of the environment by waste management, protecting wildlife, recycling and use of renewable sources of energy. While interest in the concept of sustainability appears to be increasing within the business circle, the ideas behind the initiative appear elusive. It is suggested that sustainability is some kind of process rather than an end-state [6]. There is no evidence or well researched theory to show that either of these interpretations is wrong. What is however clear is that most organisations want to be economically sustainable so as to remain in business for the long-term. More so, manufacturing firms and other businesses are witnessing increasing pressure placed on them by competitors, shareholders, legislators, the investment community, and stakeholders in general. The increase pressure is being intensified by the extreme competition in which combined forces of global competition, technology, interconnectivity, and economic liberalisation make life for companies tougher than ever before [7].

Sustainability has been defined as "the ability to meet the needs of the present without compromising the ability of the future to meet their own needs" [6].

Early discussions regarding sustainability have been devoted to understanding the various dimensions of sustainable development, namely human, social, economic and environmental. However, little research has been devoted to exploring how this philosophy can be integrated with business processes, including manufacturing systems. What is evident is that a manufacturing organisation striving to be sustainable will have to make informed choices on all fronts of the four main dimensions of sustainability [8]. At the same time, the organisation needs to make commitment towards *people, product, process, partnership, place and profit*. These are critical success factors instrumental to the meeting today's manufacturing business challenges and also important to their long-term growth and economic survival.

An organisation determined to be sustainable must make a commitment to *people* in order to

develop strong employee links required to achieve both its short-term and strategic long-term goals. This means recognising that the continuous development of the entire workforce, both management and subordinates, and everyone within the organization's supply and distribution chain contributes towards achieving the organisation's long-term economic survival.

An organisation striving to be successful and sustainable in today's competitive and dynamic market environment must focus on its products or services. Focusing on *product* offerings requires ability to maintain a balance between product performance, in terms of quality and reliability and (technical) innovation in terms of functionality and cost. Equally important is the time to introduce new products so as to achieve time-to-market profitability [9].

The product creation *process* is concerned with creating and adding value in the forms of products and services through the transformation of a range of inputs such as people, land, machinery, IT infrastructure, business process strategies and raw material. The value created must meet the needs of sustaining the future of the business through sales and profit, and that of the customer through quality products and services, at the right time, at competitive price.

In the age of rapid technological advancement, with the effect of declining product life cycle coupled with the boom in out-sourcing and job movement from Western economies to lower cost economies, the development of strategic *partnerships* in the form of collaborative manufacturing, contract manufacturing and out-sourcing will be crucial in determining the economic survival and sustainability of manufacturing firms [10]. The ability to form strategic alliances will play vital role in the journey towards sustainable future of manufacturing firms.

With greater prominence being placed on the manufacture of products in lower labour cost countries, a manufacturing organisation must consider seriously the global positioning of its design, manufacturing and sales departments. In today's global environment and with the use of increasingly sophisticated web-based systems a company does not have to have all its business functions in one place and it may decide to move its manufacturing operations to a labour efficient country whilst retaining its intellectual property (its design departments etc) closer to its core business point. *Place* is therefore a key consideration. The strategic placement of a company's manufacturing operations is also important from an environmental perspective and this will become increasingly important to companies in the future whilst maintaining the need for a strong focus on the bottom-line results and

profits [5]. Paying attention to the environment represents the organisation's ability to learn and adapt while remaining in harmony with the world around it, enabling the organisation to be able to react in a timely fashion to the conditions of the society surrounding it [11]

Profit is a crucial indicator of economic sustainability. Contributors to sustainable profits include good customer service (before and after sales), customer retention, continued patronage and brand loyalty, customer satisfaction, so also is the ability to create innovative value that meet and exceed customer needs and expectations.

2.2 Lean Manufacturing

In an effort to tackle the causes of economic failure of companies, the Lean methodology has been widely implemented in manufacturing. However, not all aspects are now so appropriate, as shown below.

LEAN	Strengths	Weaknesses
Internal Factors	<ul style="list-style-type: none"> • Low cost of running program • Reduction of waste • Streamlining of process • Continuous improvement 	<ul style="list-style-type: none"> • Continuous improvement • Need full dedication of all levels of workers
External Factors	<ul style="list-style-type: none"> • Less WIP in whole supply chain • Dedicated suppliers 	<ul style="list-style-type: none"> • Needs co-operation from customers and suppliers • Buffer still within supply chain • Market changes
	Opportunities	Threats

Fig. 1: SWOT analysis of Lean Manufacturing

It can be seen that the main strength of lean is its reduction of waste principles [12], as a by-product of which, the process is streamlined. Another strength of lean is the Continuous Improvement (CI) program in which every improvement is worked on to be further enhanced, basically leading to a never ending cycle of improvements. An attraction of lean is that the cost of running the programs is relatively low and the ideas are simple and based on the fact that spending too much for little gain is once again wastage.

On the other hand, the CI program can also be a weakness with lean as it can lead to low morale among the workforce which is continually asked to

improve working patterns or systems. In general, this is a weakness with lean because it needs the dedication of the whole workforce, being a system-wide strategy where improvement in one area will not produce a gain unless every part of the system is 'lean-ed'. Thus a lean system best shows its effects if the whole supply chain is involved, with the benefits being passed on to all the players within the supply chain. It is not surprising that the best lean systems in place are when suppliers are also involved with the initiative. There are also cases where suppliers have set up virtually on the door steps of their customer to minimise wastage in transport and information exchange between the customer and the supplier.

One of the major threats to a lean system is with a drastically changing market that can force it to be redesigned to handle new product lines. This is also a challenge to workers who have to restart the improvement initiative, which can both be beneficial as it poses a fresh challenge and negative with loss of morale. The redesign will also take longer to improve due to the time required to understand the new setup.

To a smaller extent the lean initiative needs the cooperation of suppliers and customers for the system to show real differences and be maintained in the long term. One of the main problems with some lean companies is that suppliers will purposely hold buffer stock to meet the strict delivery time of lean customers. This in effect is just passing on the buffer stock elsewhere rather than eradicate the buffer as part of reducing waste.

2.3 Agile Manufacturing

AGILE	Strengths	Weaknesses
Internal Factors	<ul style="list-style-type: none"> • Quick Reactions • Flexible • High Technology • Product Variety 	<ul style="list-style-type: none"> • Complex setup • High costs
External Factors	<ul style="list-style-type: none"> • Market changes • Larger variety 	<ul style="list-style-type: none"> • Mature market • Unskilled workforce
	Opportunities	Threats

Fig. 2: SWOT analysis of Agile Manufacturing

The application of Agile Manufacturing was introduced into companies some years later in order to deal with the issues of volatile markets and irregular demand patterns [3]. In this case, high levels of responsiveness and flexibility are required in order to cope with these demands.

The weaknesses of the paradigm lie in its 'disposable' approach, sacrificing cost or simplicity in favour of

time, a by-product of which is the necessity for a skilled workforce who can feel frustrated with frequent change and complexity. In addition to this, in many markets today, quality is always paramount and time might not be the most critical factor.

3. Fit Manufacturing

Fit Manufacturing (or simply 'Fit') adopts an integrated approach to the use of Lean, Agility and Sustainability to achieve a level of fitness that is unique to each company. 'Fit' does not only develop a company's latent potential to meet new market requirements. It actively encourages companies to seek new markets and to operate in unfamiliar areas knowing that the technological, human and financial aspects of the company are robust enough to enable the company to achieve continued market breakthrough. Suspected examples of highly 'Fit' companies are currently being analysed in terms of the sustainability criteria described in this paper. Results will be disseminated in future work.

The Fit approach to sustainable manufacturing represents a long-term approach based on continuous attempt at adding value in terms of *people, product, process, partnership, place and profit*. The fittest organisation survives the best. Table 1 describes the basic building blocks for making informed choices on all fronts of building a sustainable manufacturing system. Critical to building a sustainable manufacturing system is the ability of the enterprise to monitor its effort and measure its performance in the journey towards long-term economic success. The indicators identified under each dimension of sustainable manufacturing (see table 1) are primary measures that can be used to provide detailed guidance on how to build sustainability into manufacturing systems. The indicators are common issues that businesses including manufacturing need to focus on, and are linked with the long term objective of the organisation. It is important, however, that management adopt a holistic approach towards adding sustained value to the business economic survival objective.

'Fit' will integrate key business process strategies together with a company's existing and future technology platforms and operational strategies [4, 13]. This integration does not just provide a single new business approach but leads to an integrated manufacturing system that combines the systemics of a range of business process concepts into one model that has low operational and systems complexity.

Fit does not prescribe that every aspect of the Lean, Agile and Sustainable methodologies must be applied to every company, but that a selective mix of components will provide the optimum conditions for a manufacturing company to prosper. The key

difference is that in place of the steady increase in the amount of best practice tools being adopted, the system is able to select the most appropriate action at the key times, which necessitates a wide-ranging spectrum of knowledge to be available to the company in an integrated package as opposed to the fragmented nature of the individual themes.

3.1 The Need for an Integrated Approach

The dictionary definition of 'integrating' is "combining two or more things so that they work in concert to achieve greater effectiveness". Integration can be vertical, horizontal or conglomerate and can take place at different levels. Vertical integration, which can be backward or forward, involves assembling together elements that form a chain (such as a supply chain) and share a task or function sequentially, each element being unable to complete the task or fulfill the function on its own. Horizontal integration joins elements carrying out approximately the same type of work, perhaps with a view to increasing throughput. Conglomerate integration occurs when elements with entirely unrelated functions are linked up usually for the purpose of diversification and risk spreading.

It is seen that within any manufacturing organisation there are examples of each type of integration required, such as vertical integration of the business processes that result in delivery of materials to coincide with order fulfillment, horizontal integration of work stations, machines or teams, and conglomerate integration of the various business streams. It is the integration of a company's manufacturing operations with its business strategy, its marketing strategy and its technological capabilities that is required to enable it to achieve sustainable economic growth.

3.2 The Change from Implementation to Integration

For the correct application of any independent strategy, a company must first develop a strong foundation and infrastructure for their business. Therefore, there is a need for any company to develop its knowledge base amongst its workforce, align its various strategies to focus on improving manufacturing performance, and ensure that the company has the financial capability to facilitate change and that its manufacturing system is integrated with other key business areas within the company. Once these foundation elements have been embedded into the company, it is then possible for the company to embark on implementation of the operational elements of the company.

Through the continual enhancement of a company's technology will come the need to ensure that its workforce are suitably trained. However, this does not extend simply into the manufacturing aspects

of the company. Since changes in the manufacturing environment demand continual development of new and innovative products in order to attract new markets, a company's design and engineering team must also be continually trained to meet market needs, again in terms of both product and process but also attitude and adherence to strategy and procedure.

The long-term aim is to achieve more sustainable results than those attained by steady continuous improvement of existing practice. One principal difference is the ability to maintain the results of the improvement initiative without the level of extra work so often associated with it. The substitute for extra 'maintenance' of a system is often an added degree of complexity to the existing systems, another side effect of merely bolting on components. This must also be countered by means of integration by truly embedding the improved systems into the company procedures.

Figures 3a and 3b demonstrate the opposite ends of the spectrum, and how integration can be considered to provide more consistency in approach than utilizing aspects of several different mechanisms. This approach is demonstrated by many leading companies where it can be the brand, the process, the technology or purely the strategy that is the key to successfully winning an order. The products may not be cheapest, best quality or delivered the most quickly, but the customer selects that company on the strength of the approach.

5. Conclusions

- When new market opportunities arise, companies have to be quick to react and reconfigure their operation to meet the demand. The alternative is to introduce new technologies and capabilities as a matter of operational routine. Either way, the company requires a systemic procedure to incorporate a continual state of change.
- The key to achieving more than can be done with established practices is integration of the various required elements within a strategic framework.
- Fit Manufacturing, the new paradigm discussed in this paper, aims to provide a 'total manufacturing' solution to the problems encountered in the highly volatile and increasingly complex manufacturing environment.
- Work on the Fit Manufacturing paradigm is being directed at developing simple but useful fitness metrics and a toolbox to assist practitioners with realising the potential of Fit Manufacturing.

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7. References

- [1] Warnecke H.-J., (1993) 'The fractal company: A revolution in corporate culture', Springer-Verlag, New York.
- [2] Womack J. P., Jones D. T. and Roos D., (1990) 'The Machine that Changed the World', Rawson Associates, New York.
- [3] Kidd P. T., (1994) 'Agile Manufacturing: Forging New Frontiers', Addison-Wesley, Boston, MA.
- [4] Pham D. T. and Thomas A. J., (2005) 'Fighting Fit Factories', IEE Manufacturing Engineer, April, pp 24-29.
- [5] Interface sustainability:
<http://www.interfacesustainability.com/>
(visited April 2007).
- [6] Byrch C., Kearins K., Milne Markus and Morgan R. Sustainable (2007) "'what"? A cognitive approach to understating sustainable development. Qualitative Research in Accounting and Management', Bradford: 2007, Vol. 4, Issue 1; pp 26-52
- [7] Huyett W. I. and Viguerie S. P (2005) 'Extreme Competition', McKinsey Quarterly, 1, 2005.
- [8] Bartelmus P., (1994) 'Environment, Growth, and Development: The Concepts and Strategies of Sustainability, Routledge. New York.
- [9] Lu Y., Loh H. T., Ibrahim Y., Sander, P. C., and Brombacher A. C., (1999) 'Reliability in a time driven product development process', Quality and Reliability Engineering International, Vol. 15, Issue 6, pp. 427-430.
- [10] Sturgeon T. J., (2002) 'Modular production networks: A new American model of industrial organisation', Industrial Performance Center (IPC), Massachusetts Institute of Technology, Cambridge, MA.
- [11] Geus A. de., (1997) 'The living company: Habits for survival in a turbulent business environment', Harvard Business School Press, Boston, MA.
- [12] Hines, P., Holweg, M. and Rich, N., 2004 'Learning to evolve: A review of contemporary lean thinking', International Journal of Operations & Production Management, Vol. 24, No. 10, pp. 994-1011.
- [13] Small M. H. (1999) 'Assessing manufacturing performance: an advanced manufacturing technology portfolio perspective', Industrial Management and Data Systems, Vol. 99, No. 6, pp. 266-278.

Process	People	Profit
Manufacturing/Operations strategy Waste reduction Manufacturing lead-time Scheduling, capacity and set-up reduction Maintenance control and efficiency System re-configurability and flexibility Production and information systems Complexity and responsiveness Supply chain and supplier development Risk management	Continuous learning Level of skills and Scope of roles Empowerment Incumbent employee knowledge Loyalty, commitment and adaptability Innovation Strategy Deployment Incentive Scheme Teamwork and Co-operation Productivity	Commitment to meet customer needs and expectations Customer retention and continued loyalty Innovative products at affordable prices Marketing and sales strategy Customer services (presales and after sales) Market and customer research
Place	Product	Partnership
The global positioning of core and peripheral business units in company Environmental impact including product and waste disposal and energy usage Market dynamics and response to customer's changing needs Location of knowledge base and Intellectual Property positioning	Innovative Product Design, Variety and Complexity Quality, Cost and Delivery Reliability Standardisation Product Lifecycle management Customer Focus Demand and Sales Management Profit Customer retention	Collaborative manufacturing Contract manufacturing/Out-sourcing Supply and distribution networking Collaboration with research organisations and wider technology community

Table 1: Indicators for sustainable manufacturing

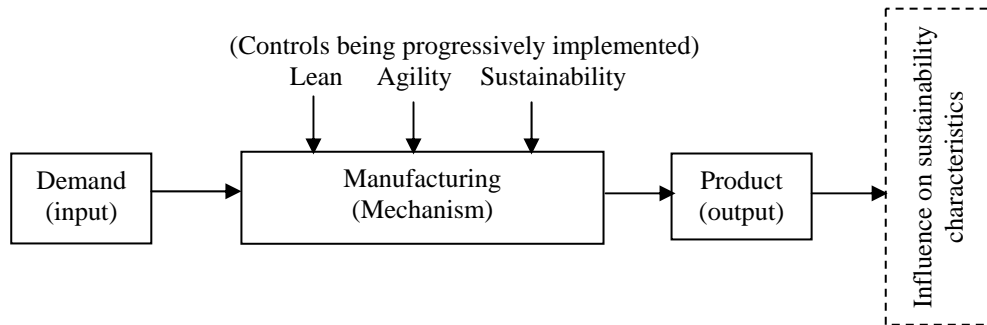


Figure 3a: Implementation of improvement activity on traditional manufacturing process

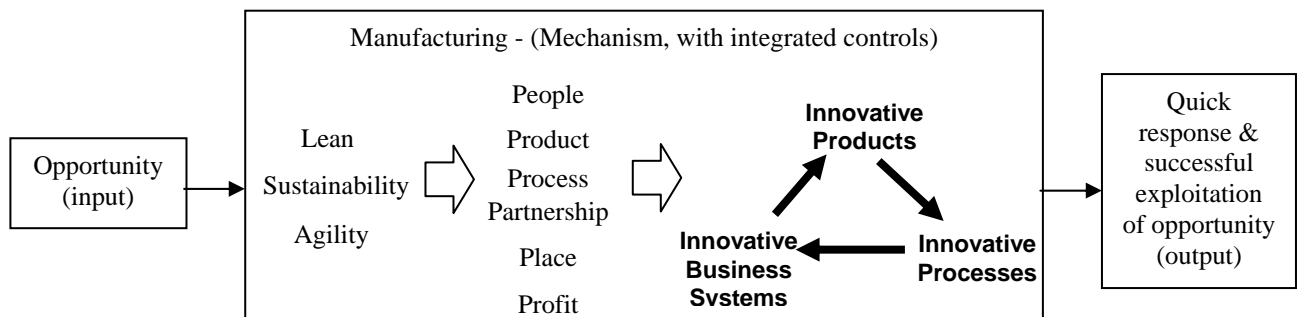


Figure 3b: Integration of improvement strategies to create a fit company