Sustainable Development Strategies for Product Provision and Manufacturing Approaches

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Abstract

Manufacturing firms are under many pressures both financially and competitive which focus attention on the performance of their manufacturing processes. In this paper the opportunities for improving the environmental impact of products within the constraints of existing manufacturing infrastructure are examined. Approaches which support sustainability in two aspects are proposed, firstly, the provision of products to the users in ways which extend the product life and secondly, manufacturing approaches which reduce resource usage.

The provision and manufacture of products in ways that are truly sustainable are inhibited by three issues: firstly, decisions are predominantly made solely from the perspective of the "vendor" (and do not consider the wider perspective); secondly, that generally the scope of business planning is still rooted in production/manufacturing costs (and not consumption costs) and thirdly, the current performance measures (e.g. KPIs) mainly focus on profitability.

The rationale for this conference paper is the argument that there is a need to raise the awareness during the earliest stages of business planning that there may be alternative approaches which are more sustainable. The concepts presented here will underpin further research into performance measures which encompass sustainability and resulting business planning implications.

1. Introduction

Our focus in this paper is on identifying strategies which will assist manufacturers to achieve 'sustainable product development' which has a wider scope than reducing materials and other resources in the product design (Van Weenen, 1995). We recognise that many manufacturing firms have invested in existing infrastructure and have well established practices to enable them to compete in a highly demanding environment. Given this we are looking to innovation as the means for examining this. By innovation we are referring to *"the deliberate modification, or transformation, by an organisation of its products/services, processes or structures"* (Hislop, 2005, p158).

Various parties have identified the drivers and challenges of sustainability and proposals for sustainability management have been published such as the standards ISO 14001 (Donnelly et al, 2004). Previous research and manufacturing firms have made efforts to improve the sustainability of their products which range from reducing materials used in products (Ljungberg, 2007) to self-sustaining energy management systems (Mann and Jones, 2002). Similarly, firms have been encouraged to assess their key operations and working practices to make improvements to power requirements; energy usage and handling of waste and reducing the levels of these items.

Given all the above efforts by governmental and industrial firms and organisations it still seems that the manufacturing sector needs to do more in terms of sustainable manufacturing. This is currently limited in its achievements due to the business model currently in use which is focused around product creation (and hence sales) by the manufacturers rather than the more holistic view of the life-cycle. The current mode of operation is that product usage by users consists of purchasing an item and then using it until such a point where it typically is replaced. From the users perspective the replacement decision is based on a number of situational influences (such as wear and tear) which lead to a comparison between the actual condition of the currently owner product and the new purchase (van Nes and Cramer, 2003).

A move towards more sustainable product strategies requires that manufacturers consider the overall life-cycle and not be restricted in scope to the creation of the product (Schmidt and Butt, 2006) but also the user stages and end stage as shown in Figure 1.

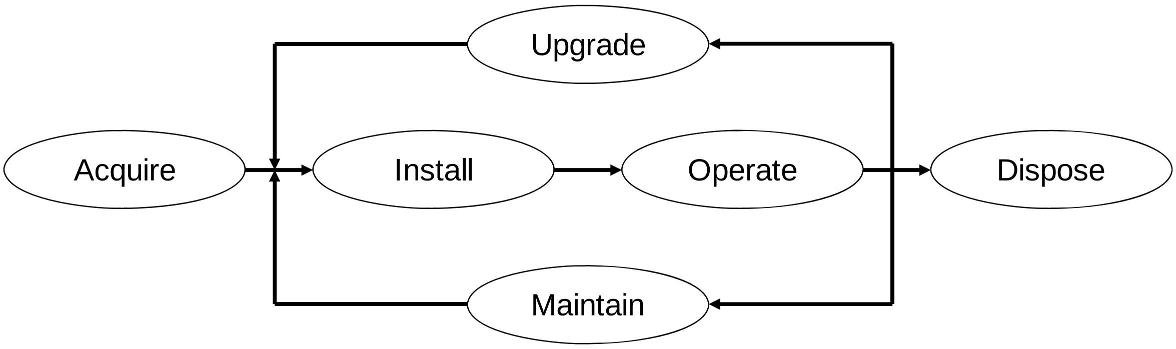

Figure 1. Life cycle stages

2. Background

Manufacturing firms are facing the dilemma of utilizing increasingly complex technology to meet their business needs whilst trying to operate cost effectively in a globally competitive environment. Opportunities for manufacturing sustainable products need to be realistic and adapt a manufacturing firm's operations rather than disrupt ongoing business operations.

2.1 Product design emphasis

Product design has been well reported in the main stream literature (Cooper, 2000) with recent emphasis on faster time-to-market (TTM), open learning and improved ergonomics each of which is now discussed.

Faster Time-To-Market (TTM)

Manufacturing firms are increasingly pressurised to deliver new products to the market in shorter timescales which is challenging as technology advances and becomes inherently more complicated to engineer and manage new product development. Firms have invested in solutions such CAD systems which provide 3D visualization solutions that enable the new product development process to be reduced. The benefits of fast development processes are that firms are in a position exploit new or emerging applications. These new or emerging applications may arise from the interaction among components once new technologies are in place i.e. it is hard to anticipate and plan for these emerging opportunities.

Open Learning

The resources required to develop new technologies are prohibitive even for the larger companies and cause many firms to look outside the firm to access technology. A firm may organise their product modules or structures into "building blocks" to efficiently support platform development projects. However, they may still need to make use of other firm's knowledge and even acquire specialist technology companies with a technological competence in an emerging area which may enhance or improve the functional performance of their product or system. Competitive advantage based on core competencies has become a recognised part of strategic thinking where the development of the necessary competences (technological or otherwise) of a firm involves accessing external knowledge as well as relying on internal knowledge building activities.

The benefits of innovation strategies involving collaboration is one which is driven by resource limitations. As technology advances it becomes increasingly difficult for firms to have resources of sufficient breadth and depth in the required technological areas. This is problematic as the extent literature on strategic management and how firms compete puts great emphasis on a firm's capabilities. This perspective is the resource based view (RBV) of the firm and is based around the recognition and development of core competences (Prahalad and Hamel, 1990).

Improved Ergonomics

The brand of many major vendors of consumer products (e.g. Nokia), need protecting which requires product concepts whose design and user friendliness is going to attract consumers across global markets. Manufacturers with expertise in Global DFM (design-for-manufacture) will require a competence in product design which is highly ergonomic as consumers increasingly are time pressured and mobile thus wanting products which are highly intuitive. Gone are the days when consumers will accept purchasing video recorders which were so involved to program that the majority of consumers either were unable to record a television program or were unwilling to expend the required effort. Not only is ease-of-use a key issue for consumers but also the visual product aesthetics (Noble and Kumar, 2010) which must fit today's lifestyle conscious consumers.

2.2 Customisation

The increasing complexity of the business environment has led many consumer product producing organisations to look for strategies and methods to allow them to give consumers greater levels of choice in their products as customers are no longer satisfied with low-cost mass-produced products that lack a unique identity (Bye 2004). The term Mass Customization (MC) describes a strategy which aims to give such organisations the abilities to meet the challenges inherent in producing a greater range of products but at the same time trying to keep the economies-of-scale benefits of mass production and has been developed by many researchers from its first use by Davis in (1987), expanded by Pine (1993) and further developed by others like Da Silvera et al (2001) and Duray et al (2001).

Piller and Sotko (2001) point out that every interaction between the customer and the supplier generates a high level of data (compared to traditional mass production) especially about the customer design, which then must be co-ordinated with manufacturing, production planning and control and external suppliers, etc., making the value added directly related to this customer data – therefore *"…mass customization can be seen as more closely related to e-business and the new possibilities connected with the Internet economy …"*. Also, mass customization cannot be based solely on flexible manufacturing technologies, but must also include developments of material products and customized services into customized '*bundles*'. This concept of 'bundling' has been further defined by MacCarthy et al. (2002) who distinguished between a number of types of customization as shown in Table 1.

MacCarthy et al (2002) also point out the dynamic nature of mass customization and the importance of identifying product areas where customers really value choice and differentiation and thus where the mass customization approach is truly appropriate, and suggest that one such method is by utilising the *Key Value Attribute* (KVA) concept. KVA's are product attributes that the customer values most highly and can be used by producers to decide the *customization potential* and the *customization desirability* – i.e. what the customer is likely to want to differentiate and how they will want to differentiate it.

Type	**Description**
Dimensional fit/size:	Part or all of the product is adjusted, cut or scaled to fit the dimensional requirements specified by the customer.
Hardware Functionality:	The functionality of the product is altered by changing, adding or subtracting hardware features.
Software Functionality:	The functionality of the product is altered by changing, adding or subtracting software features – typically by altering or replacing the programming in some part of the product.
Property of the whole product:	Altering or changing properties that relate to the product as an entity – e.g. corrosion resistance, vibration characteristics or noise emission.
Quality grade:	This relates to the quality category of a product. Components are upgraded or downgraded, without intentionally altering the function, property or quality level of the product. There may be objective standards that define categories or it may be subjective but possibly can be benchmarked.
Quality level:	This relates to how well the product conforms to the grade to which it aspires. An aspect such as the reliability, precision, tolerance of the product is customized. This is not a common form of customization.
Aesthetics and style:	Changing the shape, look or feel of a product, such as by selection of interior décor for a vehicle. Typically colour will fall into this category, but colour may fulfil other customization requirements such as functionality or personalisation.
Identification and personalisation:	Altering a product by adding a unique identifier for corporate customers or an individual customer, for example embroidering an individual's name onto a garment, adding a corporate logo to a product or altering the colour (livery) of a product.
Literature:	Documentation is an important part of the product-service package for many consumer and industrial products and often must be customized for the specific product variant, specific market or specific type of customer.
Packaging:	Many products are differentiated by packaging. Customization may mean changing packaging design, appearance, physical performance or functionality, but can also mean packaging other items with the product.
Service customization:	The previous definitions refer to physical products, but from the customers viewpoint the idea of value is often related to the product and its related service(s) as a 'bundle'. In this context, customization on the service side can thus be perceived by the customer as every bit as important as the physical customization of the product. Possible types of service customization include different payment terms and warranty deals, or the type of training given. The management of such mass customization of services may generate many service operation challenges.

Table 1. Types of customization (MacCarthy et al., 2002)

2.3 Traditional product development process

In the seventies successful technology firms comprised large vertically-integrated firms. The advantages were that technically advanced products could be developed by carefully coordinating interface specifications and other design parameters between departments (Jiao and Tseng, 1999). A generic traditional product development process is shown in Figure 2.

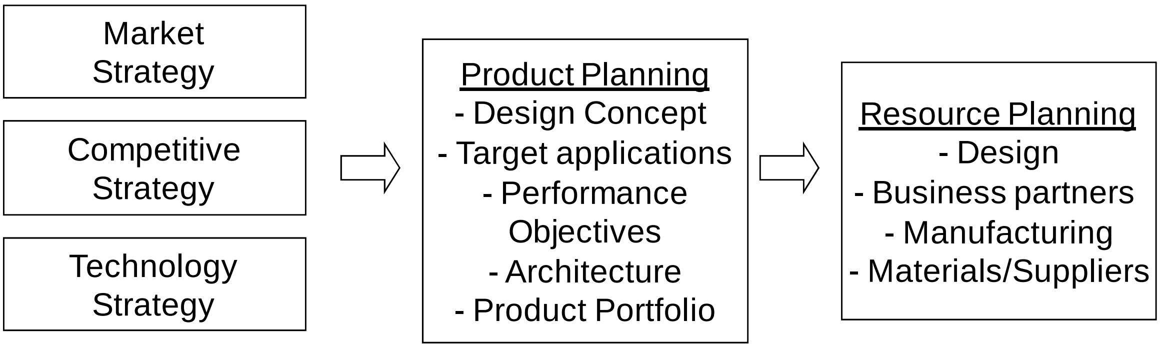

Figure 2. Generic traditional product development process

The advancement of technology is a major environmental factor for firms with the organisational model of traditional businesses becoming irrelevant. In the Internet era the loose organisational structures require mechanisms to ensure successful innovation including the transfer from design to production.

External factors of the marketplace factors with three general factors identified comprising price sensitivity; performance expectations and regulatory constraints along with organisational factors are the general factors that influence product design (Noble and Kumar, 2010).

The ability to renew competences in order to achieve congruence with the changing business environment (Fahy, 2000), is referred to as dynamic capabilities. These dynamic capabilities are the engine which enables a firm to achieve new and innovative forms of competitive advantage (Eisenhardt and Martin, 2000). Dynamic capabilities are argued to be a key part of the rationale underpinning strategic management according to Teece et al (1997). They argue that a firm's focus should be on developing the firm's capabilities – not its products.

3. Sustainable Development Strategies

The approach being advocated here is to broaden beyond the approach of reviewing existing products and improving their environmental performance, for example, reducing the materials utilised in the product or its packaging. Although this has its merits this incremental approach is limited in that it is modifying an existing product and hence is limited in its scope. Instead the approach being proposed in this paper has a broader remit i.e. that of 'sustainable product development' which has a wider scope than reducing materials and other resources in the product design (Van Weenen, 1995). The elements of the sustainable development strategies for manufacturing firms comprise firstly, product provision and secondly manufacturing process configuration as shown in Figure 3.

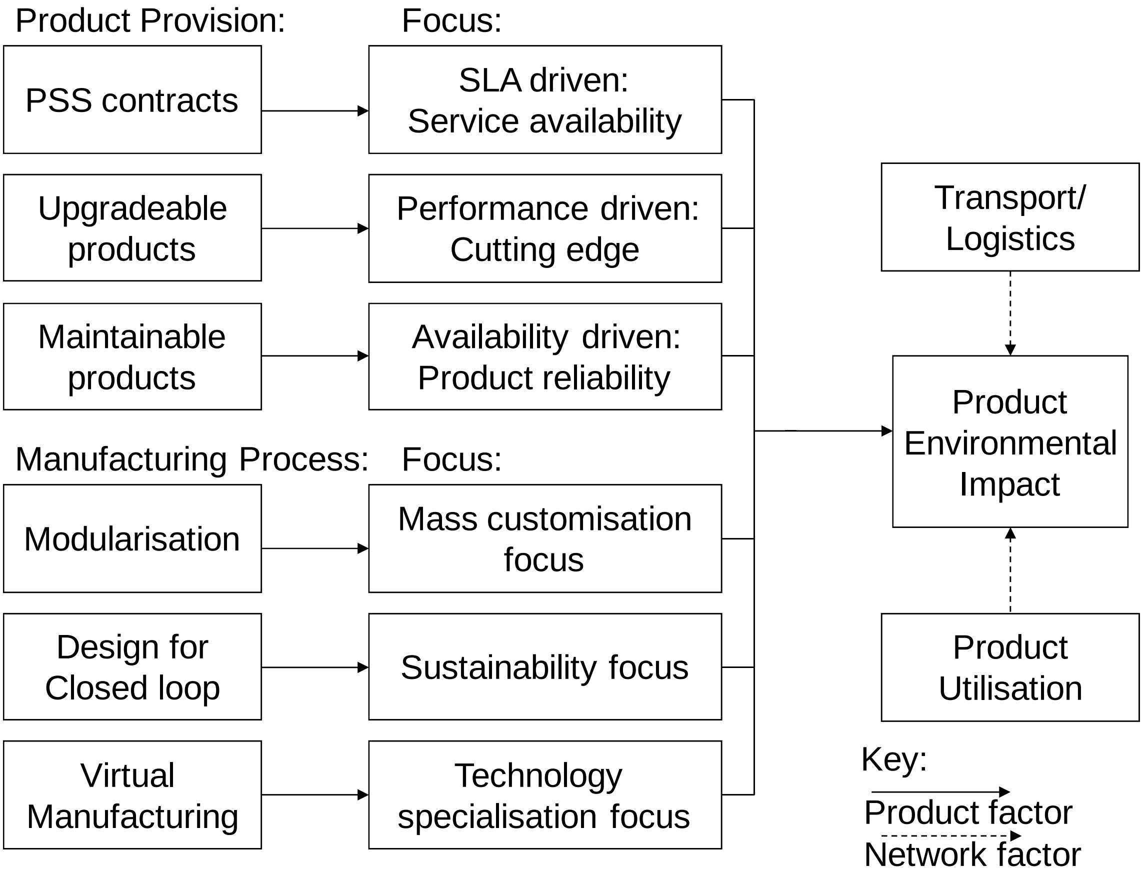

Figure 3: Sustainable development strategies

This recognises that different sustainable development strategies are required for different types of products (Hanssen, 1999). The first strategy for product provision is where equipment is leased rather than purchased – either by service providers or end users. This approach is known as Product-Service Systems (PSS) and the focus is service availability for the user. The second strategy for product provision is one where the focus is on high performance products and this is achieved by providing products which are upgradeable. In contrast, the third strategy for product provision is on products where their availability is of paramount importance and hence product reliability is the major concern to the user and this is achieved by providing products which are maintainable. Although this may seem "obvious" consider many consumer devices where this is not the case, for example, the majority of the UK population own and carry a mobile phone however few of us are able to keep it maintained or get it repaired when part of it becomes damaged and it is environmentally wasteful to have to replace an entire mobile phone handset when the screen becomes damaged due to user wear and tear.

Convincing manufacturing firms to adopt or even consider for adoption these sustainable product development strategies will require an examination of the implications to the business case particularly the cost aspect. For PSS strategies the defining of deliverables and the parties responsible during contract negotiations will have an impact on the cost benefit analysis. Thus, a generic cost model for PSS firms is not very useful as the costs involved are not only sector dependent but also very context dependent as it depends on the contractual deliverables. Notwithstanding this a framework is shown in Figure 4 which will be used to examine the cost elements for each of the sustainable product development strategies. Three cost elements are identified which represent three stages of the life-cycle from the viewpoint of a manufacturer: the up-front "cost"; the ongoing "costs" and the "costs" incurred by other parties.

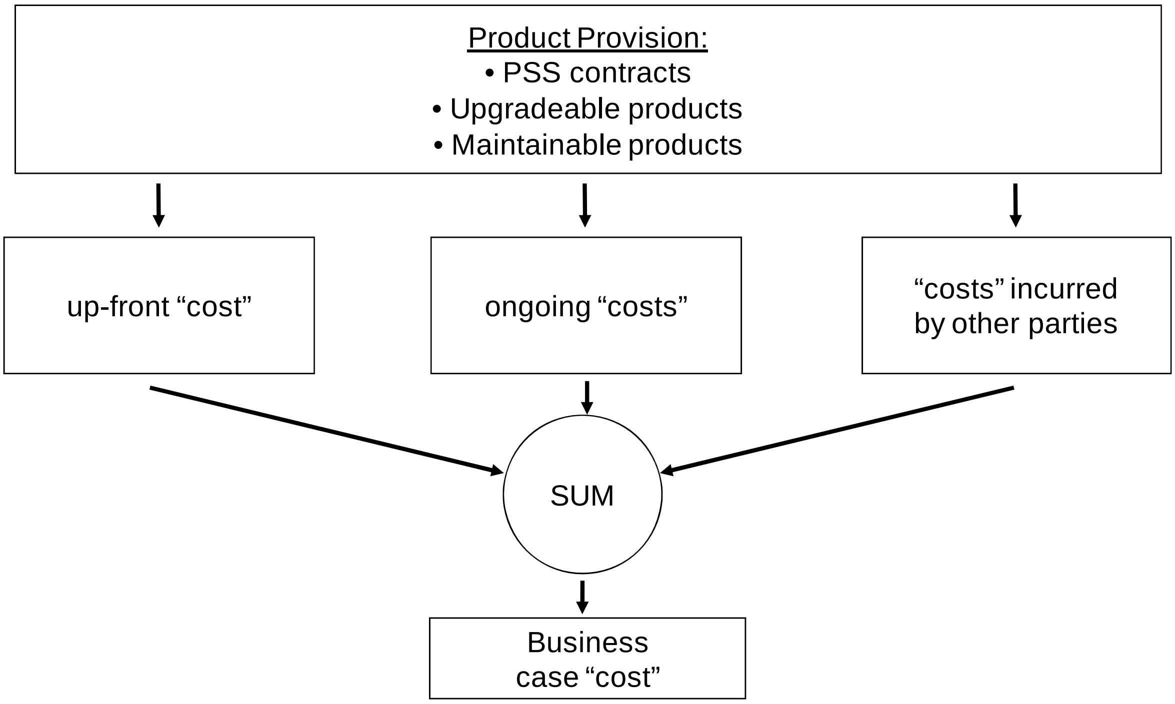

Figure 4. Cost Elements of Sustainable Product Development Strategies

The support activities for PSS during the user phase are carried out by specialists in different functions and this requires coordination across the various functions for successful service delivery. To obtain visibility of the various activities it is necessary to develop business processes and information systems to make information retrieval both fast and sufficiently accurate. Essentially there is a cost to ensure that PSS operations interface to corporate information systems to ensure the smooth flow of business operations. The cost elements identified which represent three stages of the life-cycle from the viewpoint of a manufacturer are now examined in Table 2.

	Business case "cost" implications		
Product Provision:	**Up-front "cost"**	**Ongoing "costs"**	**"Costs" incurred by other parties**
PSS contracts	• Capital investment • Manufacturing activities	• Logistics activities • Customer lifecycle support	• Specification of the SLA • Management of the SLA during the contract period
Upgradeable products	• Technical data provision • Interface	• Platform solutions • Managing product releases	• Upgrade execution • Problem resolution • Payment handling
Maintainable products	• Subsystem scope • Functionality of subsystems	• Integration of the subsystems • Provision of technical information	• Sourcing parts • Servicing • Problem resolution • Factory interface • Payment handling

Table 2. Cost Implications of Sustainable Product Development Strategies

In all three strategies for product provision there is a need to involve other parties who need to be suitably qualified and knowledgeable with the appropriate resources and organisational capability (Aurich et al, 2010). Further, there needs to be ongoing sharing of information so that problems are resolved which may involve accessing knowledge and expertise from the other party. A review of the ability of organizations to innovate and successfully achieve technological and organizational change (Dittrich and Duysters, 2007) highlighted the complexity involved of knowledge transfer across organisations.

3.1 Product Provision Approaches For Sustainability

PSS Contracts

At a generic level a manufacturing firm supplying equipment for product-service system applications will be incurring costs in order to provide the necessary pre and post sales functions for the product-service system activities. The main cost elements comprise: capital investment; manufacturing activities; logistics activities and customer lifecycle support (De Coster, 2010).

The barriers to product-service systems that have been recognised in the extant literature relate to relationships amongst the different parties in the value chain (Mont, 2002). Establishing business relationships with external partners is increasingly necessary to meet market requirements; however, business processes are context dependent (Gilbert and

Cordey-Hayes, 1996) which makes it more challenging to provide PSS applications using business partnerships. The level of interaction amongst the parties involved does vary as product-service systems are of different types (Tukker, 2006) so whether this issue is a barrier or not will depend on the product concerned.

The additional expenditure on services for the provision of product-service system applications has the benefit that manufacturing firms will be working more closely with their end users and hence, get greater insights to their needs. This can become the basis for competitive advantage as markets become global companies look to differentiate themselves from their competitors (to avoid losing market share or having to reduce prices and hence, margins (Bigne, 2000). This shows that it is hard to compare the "costs" involved as other benefits may be realised which are less tangible and hard to quantify.

Upgradeable products

The cost implications are less for the second and third strategies for product provision and for the manufacturer focus around the need to redefine subsystems as functional or structural modules and specify its interfaces. Arguably these approaches are more likely to be acceptable to both manufactures and consumers for who ownership of a product is the normal form of business transaction.

The complexity of protocols, standards and interfaces which are prevalent in the high technology sectors (such as mobile phones for example), means that customers are themselves often uncertain on the most appropriate applications/technologies to adopt for their application. The manufacturing companies need to have a clear view "to the protocol/method", on the interoperability aspects when proposing applications/technologies that provide customers with upgrade and new applications or system solutions.

The key benefit for a manufacturing company that utilises their legacy products and market experience to offer product upgrades is that they already have established a market presence. This is necessary to gain credibility with other firms that they deal with including supply chain partners and financiers i.e. the benefit is not only limited to customer acceptance but also other firms in that sector. Further, they have a reduced risk in terms of engineering the required product upgrades as they will already possess part of the required product functionality and necessary technological skills.

Maintainable products

The third strategy (of maintainable products) also has product development implications for manufacturers as it necessitates that they examine a product and allow for the need for repair which may involve (to some extent) disassembly. Product redesign is normally required for disassembly (Jones et al, 2003) so that difficult jobs such as instrument panel removal can be made much simpler, cutting service time. This requirement also applies to product-service systems where maintenance has now become the responsibility of the manufacturer (e.g. aircraft maintenance) who will now have the incentive to design easy-access to key systems.

It is easiest to examine an example application to appreciate the various elements involved. Here we consider the example of mobile handsets which are used by people to provide communications; entertainment; corporate and other applications. There are an increasing number of mobile user devices which need to be supported – both for industrial purposes and for consumer electronics. There has been a gradually evolving range of mobile devices which is extending as different groups of users see the benefits of wireless connectivity, for example, healthcare for home patient monitoring. The design aspects for each device, service and application need to address the service concept aspects and the mobile user interface design to ensure usability. The growth in diversity of mobile devices is yet to occur and includes Smartphones, PDAs, Portable Media Centers, retail point-of-sale systems, Global Positioning System-based devices and industrial robots. This increasing number of user devices are challenging to support as they each have different interface requirements.

3.2 Manufacturing Process Approaches For Sustainability

Re-configurable Manufacturing

As outlined earlier, Mass Customization (MC) is a strategy which aims to give organisations the abilities to meet the challenges inherent in producing a greater range of products but at the same time trying to keep the economies-of-scale benefits of mass production. Much work has been done (e.g. Piller, 2001) on how to develop re-configurable manufacturing systems to enable mass customisation, often through use of methods designed to increase flexibility in manufacturing processes such as cellular manufacturing, flexible manufacturing systems (FMS), computer-controlled and reconfigurable machines, which when allied to internet or web-based technologies allow very close interaction with customers (often allowing the customer to become an integral part in the design process).

Many early proponents of the mass customization approach like Davis (1987)**,** Pine (1993) and Toffler (1970) prophesied its adoption into general manufacturing with the advent of new manufacturing technologies like CIM and flexible manufacturing systems but recent research by Piller and Möslein, (2002) based on 250 ‘mass customizing’ companies suggests that to date the (successful) take-up has lagged behind these early predictions, largely due to a lack of appropriate technologies to handle the large amounts of information flows connected with mass customization and that new Internet based technologies will go some way to enable the successful implementation of mass customization in more and more consumer markets.

Although the initial driver of the mass customisation concept was as a reaction to the increasing desires of consumers for products which are ‘different’ or ‘unique’ (and therefore of higher perceived value) but without the associated higher costs of low volume manufacture, this quick adaptability to market demand, producing (in theory at least) only the correct amount of products (thereby reducing waste) and only when ordered by real customers should allow any organisation to make significant steps in the direction of sustainability.

One of the major problems for any manufacturing organisation is movement towards a goal of sustainability when that goal is difficult to define. What and where is the sustainability? Increasingly manufacturers talk of producing ‘sustainable’ products as their route to sustainable manufacturing however both products and their manufacturing processes need to be sustainable for any approach to be called truly sustainable. For example the use of timber source from sustainable sources (e.g. bearing the Forest Stewardship Council (FSC) mark) may be used to promote the 'green credentials' of a company but the equipment, methods and processes used to manufacture the products may have remained unchanged for decades.

Sustainability is broader in scope than making a more environmentally friendly product as it needs to encompass the whole lifecycle. A drive towards lower energy and resource usage (e.g. through lean manufacturing) is not necessarily the same as a sustainable approach - simple reduction of energy and/or resources used in manufacture with no attempt to 'close the loop' will effectively only result in resources and energy taking longer to 'run out'. Exactly what sustainability is, is not clear and the problem of defining sustainability remains (Scholtz and Tietje, 2002). In fact Jacques et al (2010) concluded that *"… pointing out the reasons why products are not sustainable is typically easier than defining all the attributes that would make a product so…"*.

Design for closed loop

A number of concepts and ideas for sustainability have been developed like green design for manufacturing, design for the environment (DFE) or environmentally conscious design and manufacturing, which attempt to consider all environmental aspects of the materials, products operations and processes with the intention that they can be considered at the very earliest stages of design and manufacture.

Design for Recycling (DFR) uses processes from the natural world to conceptualise recycling activities. For example, the 'biological' cycle - where organic materials naturally degrade into new 'soil' to allow the growth and development of new life (product which function for their life and then can be safely discarded) and the 'industrial' cycle in which the materials in the product are recycled and reused continuously (as in the recycling of aluminium drinks cans reducing production costs by 60-70% and pollution by up to 90%).

Cradle to cradle (C2C) is a term coined in the 1970s and has been developed by a number of researchers since (McDonough, et al 2002) and considers the impact of each stage from mining of raw materials through to recycling, paying particular emphasis on:

- sustainable and efficient manufacturing using clean technologies;
- waste free production;
- use of non-hazardous and recyclable materials;
- reducing energy consumption;
- renewable energy sources;
- minimisation of environmental impact; local sourcing of materials and energy;
- continuous review of the possibilities of reuse and recycling of materials.

Virtual Manufacturing

The conventional mass manufacturing approach typically requires the grouping together of manufacturing capability into one location to take advantage of the productivity gains to be had when dividing the manufacturing process into a number of steps, each of which uses dedicated machinery specifically designed to perform that one part of the process in as efficient a manner as possible. This method of manufacturing gives huge performance (and therefore cost) benefits over craft based manufacture but is not without its weaknesses.

Two important weaknesses of conventional mass production are (i) the built in dedication of the manufacturing machinery used can make it extremely difficult to change the products produced without large (and therefore expensive) changes to the machinery, and (ii) low costs of production are directly driven by four factors (Johnson et al, 2009) - economies of scale, supply cost, level of experience and product/process design (Figure 4).

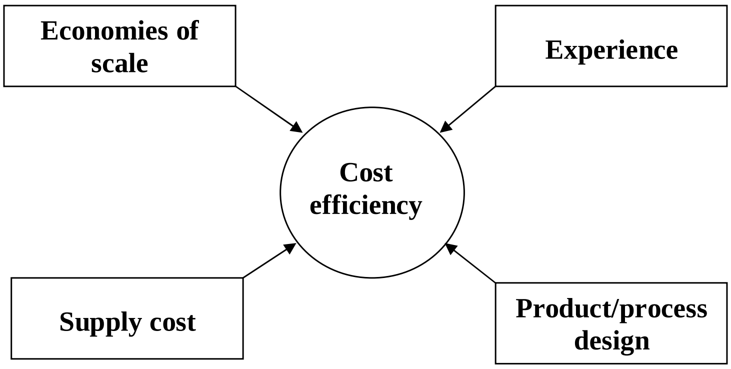

Figure 5. Sources of cost efficiency (Johnson et al, 2009)

The continuous pressure to improve cost efficiency led many manufacturers to seek a step change in cost efficiency (over and above the normal gains to be made by squeezing suppliers and making minor modifications to production processes) by moving their entire manufacturing operations to parts of the world where it is cheaper to manufacture - so-called *offshore* manufacturing – however, this approach to manufacturing has in many cases meant that that distribution to customers becomes more difficult, costly and time-consuming, possibly moving major sustainability issues from manufacturing to logistics.

Outsourcing of one or more parts of their business is now common (particularly so with IT and logistics), leaving companies to focus on the areas where they have specific expertise. It is now viable (rather than merely technically possible) to find third-party organisations which can perform one or more of the tasks in every stage of the production of a product including research and development, design, manufacturing, delivery, sales, marketing, etc. The term *Virtual Organisation* has been used to describe an organisation where almost all tasks have been outsourced, leaving only a small core which has the task of managing the various outsourced parts of the process to ensure they successfully function together. Hale and Whitham (1997) identified a number of characteristics of a virtual organisation:

- Physical structures such as offices are reduced in number; perhaps they do not exist for the organisation
- Workers are provided with electronic workspaces rather than physical workspaces
- Where office space is required workers are encouraged to 'hot-desk' – i.e. to share office facilities on a booking basis.
- Physical documentation is discouraged; electronic documentation is promoted
- Work is organised in loose projects which workers join and leave in a flexible way.
- The members of the organisation communicate using information and communication technology (ICT). The network *becomes* the organisation.

Although the concept of a virtual organisation seems particularly suited to information based industries, with regard to manufacturing it has implications relating to skills transfer and a number of management implications (such as quality control). However as early as the 1990's, researchers based at INSEAD published their European Manufacturing Futures Survey (De Meyer, 1992) which reported on manufacturing trends in the previous decade and compared these with other similar surveys from other parts of the world (Miller et al, 1992). The report concluded that the various trends and issues they had identified suggested that their respondents were preparing for the Virtual Factory, which "…*gets its task of transforming materials and components into value for the customer done by using resources outside the manufacturing function proper* …". Sawney et al (2001) argued that some industries will be specifically reorganised around these supporting communication network systems.

It is not hard to imagine that outsourcing of specific parts of the whole manufacturing process could have both positive and negative ramifications on an organisations drive towards sustainability – positive in the sense that it can be built in to the specifications and contract and thus perhaps 'easily' achieved, but negative in the sense that control of suppliers or sub-contractors may prove problematic. This highlights the need for sustainability metrics which will be discussed next.

4. Proposals for sustainable development strategies

4.1 Metrics and processes for sustainable development strategies

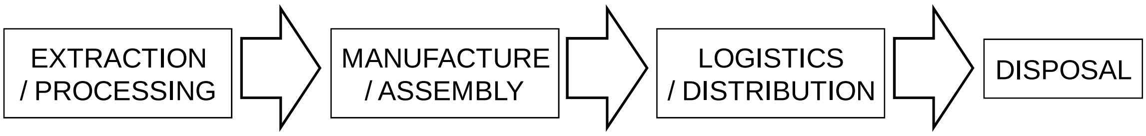

Figure 6. Conventional Lifecycle Stages For Manufactured Goods

The typical lifecycle stages for manufactured goods are shown in Figure 6 and although environmental improvements can be made during these stages greater improvements can be made by viewing the lifecycle stages as a "closed loop" rather than an "open loop". Figure 7 identifies the main lifecycle stages for manufactured goods such that sustainability is optimised in a "closed loop" manner. The figure for closed loop production of manufactured goods emphasises that sustainability metrics need to be identified and committed to by each of the parties involved in the lifecycle.

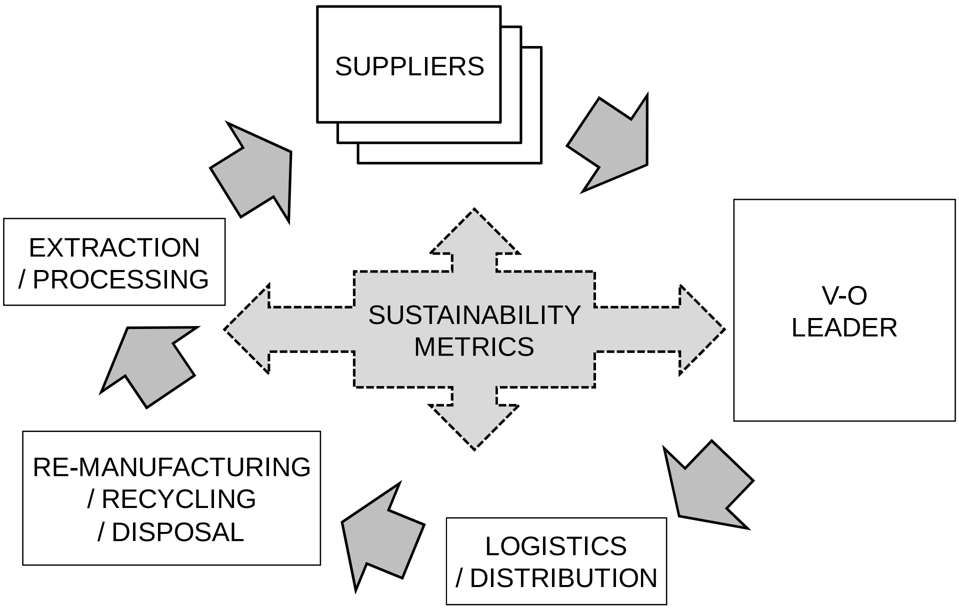

Figure 7. Closed Loop Production: Stages and Metrics for Integration

When business models are based on virtual organisations (V-O) the V-O Leader (the organisation with which the consumers typically identify with) needs to develop a strategic response to sustainability drivers (legislative etc..) which is reflected in their mission statement and product strategy. Further, the V-O Leader will have reporting responsibility on the sustainability of the final product which entails placing sustainability metrics on the other firms in the lifecycle. Metrics will become the driver for management attention in the other firms who may have to look at new and alternative technologies in order to achieve energy and resource efficient approaches. Figure 7 highlights that management effort based around metrics is required to ensure integration

4. Product development process for sustainable development strategies

Innovation strategy is a part of a firm's overall strategy and develops strategies for managing technology and innovation as identified by Cooper (2000) in his work on product innovation and technology strategy (PITS): the need to identify and specify the types of markets / applications / technologies and products which a firm's new products will follow. This strategic level may utilise a number of planning tools such as the product-technology roadmap which encompasses the more recent strategic management literature concerning a firm's competences (Prahalad and Hamel, 1990).

Recent interest in including ecological aspects into product development has highlighted a number of tools such as an "Eco-Roadmap" which is comparable to the product-technology roadmap but with a focus on sustainability (Tischner and Nickel, 2004). This "top-down" strategic approach has its merits however the reality of product development in many firms is that other tools or methods are required which do not rely on sustainability at a strategic level.

Environmental life cycle assessment (LCA) as a method to enable environmental product informational needs has been recognised fairly recently (Miettinen and Hämäläinen, 1997). It enables quantification of product specifications so that alternate designs can be assessed in terms of the ecological impact by characterising product attributes and key elements.

This approach can be compared to the use of simulation tools which are used to characterise manufacturing processes and then examine various process configurations. The end results of the simulation calculations are often displayed visually as this emphasises the differences of the configurations tested. The development of a simulation model is tailored to a given situation and this will also be the case for environmental LCA where each product type will need a tailored assessment.

The proposed product development process is one that includes LCA at the concept development stage of the design process which enables assessment of environmental performance (Maxwell et al, 2006). The model proposed here is one that utilises life cycle assessment at a number of key "decision points" for product planning as shown in Figure 6. These are shown as three "circles" which use LCA to assess the potential environmental impact at different levels of detail to support product planning decisions.

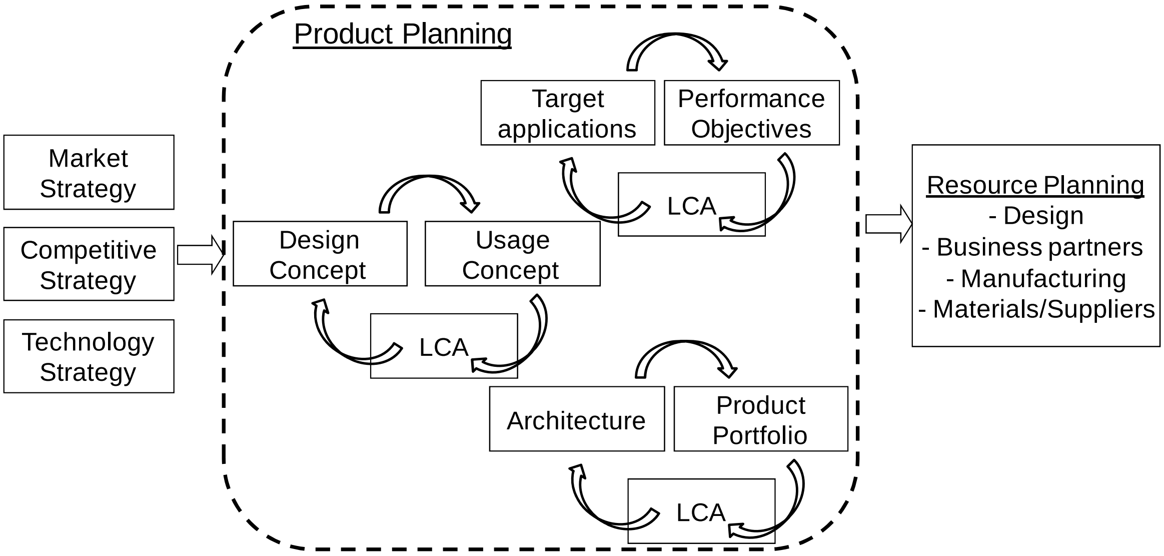

Figure 6. Sustainable product development process

The proposal is to perform life cycle assessment at three key decision points during the product planning phase as these decisions will provide opportunities for environmental improvements. High technology firms already have to weigh up a number of resource and technological constraints during the product planning phase as well as external considerations such customer value provision and competitive pricing. The use of life cycle assessment will provide a structured way of enhancing the decision making i.e. it will bring sustainability to the forefront of the product development process without disrupting the established practices of a firm.

The first LCA assesses the attributes of a product which may be represented as a decision tree where alternatives are identified (Miettinen and Hämäläinen, 1997). This is a less detailed life cycle assessment with the use of categories (of high vs medium vs low) to make a “relative” assessment rather than an “absolute” (quantitatively based) assessment. This provides a more general valuation of alternative design concepts which is commonly used in the early stages of new product development by the use of weighting systems. The intent here is to encourage the consideration of alternatives which may be more sustainable at this early design stage and the less detailed analysis has the advantage in that it encourages an assessment that has a wider scope.

The second LCA takes the proposed product and makes a more detailed assessment of the environmental impact from production onwards which may comprise three main life cycle aspects (Schmidt and Butt, 2006): production of the product; the user phase and the end of life environmental costs. The environmental cost of the production of the product is not discussed here as it was discussed earlier. The assessment of the user phase will vary depending on the product concerned, for example, it will examine the environmental impact of the use of the product such as emissions from vehicles. It will also need to assess user maintenance and other running costs which will require modelling typical scenarios based on anticipated usage patterns (for example, annual mileage and typical vehicle speeds).

These detailed assessments will need to identify the life-cycle stages and the resources used (materials; energy and other resources) to conduct a detailed assessment of the environmental impact. For example, a study comparing the life-cycle environmental performance of steel and plastic automobile fuel tank systems assessed nearly thirty items along each of the life-cycle stages (Joshi, 1999). Studies report that the end of life environmental costs are usually below 5% (Schmidt and Butt, 2006), however, for industries with large production volumes these are still significant.

The third LCA addresses the more strategic aspects relating to technology management – architecture decisions and product portfolio planning. Architecture decisions can provide a competitive advantage to firms whilst product portfolio decisions should support a firm's market plans. These decisions can either support or restrict a firm's position as some architecture types lend themselves to supporting sustainable initiatives than others. Clearly defined modules or components and their interfaces support equipment upgrades epitomised by the computing sector and the design of personal computers which anticipated the need to upgrade disk drives and other key components.

5. Conclusions

The legislative and consumer pressures on manufacturers to improve sustainability are increasing and this necessitates that manufacturers consider the overall life-cycle and not be restricted in scope to the creation of the product. The field of sustainability literature is relatively new and whilst there is a growing consensus on what sustainability is the routes to attaining this are not yet well established. This paper contributes by proposing methods and analytical models to better understand sustainable development strategies for manufacturing firms. This paper examines three product provision approaches and proposes a sustainable product development process which uses lifecycle analysis (LCA) at three key points to improve sustainability.

Given that production facilities are already in place and are not easily altered we need to recognise that sustainability in the manufacturing sector is more likely to be a journey rather than a destination. It is argued here that virtual organisations will be a business model for which we must establish sustainable manufacturing which requires the use of sustainability metrics. The V-O leader will have a key role in establishing the strategic necessity as well as facilitating the interaction amongst the different parties involved.

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