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The Ecological Modernisation of the Automotive Industry

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Introduction

Few can doubt that the contemporary automotive industry is one of the most obvious manifestations of the difficulty of reconciling environmental, social and economic goals simultaneously. Nonetheless, there are indications that the internalisation of ecological responsibility, the implementation of anticipatory planning practices, and the switch to the use of cleaner technologies are happening in the context of the auto business. These practices characterise the phenomenon of *ecological modernisation* (Cohen 1997; Orsato 2001).

For those interested in sustainable industrial development, the question then is not about whether or not improvements have been made in the auto industry but rather whether the improvements are conducive to ecological sustainability. Indeed, the methodological rigour of scientific research leaves little room for studies attempting to guide decisions over *what might be* (i.e. as a prescriptive tool to guide innovative strategy) a transformed – or as we prefer to use, an ecologically modern – automotive industry.

Finally, the sheer size and complexity of the sector makes for a problematic and political policy arena, and indeed limit the chances we have to do full justice to the sector in this article. Nonetheless, we challenged ourselves to create one possible view of what a sustainable automobile industry could look like. By exploring the business concept of Micro Factory Retailing (MFR), we attempt to demonstrate that a new paradigm of production and consumption for the car industry is not only possible but has already been seeded by several empirical examples. Importantly, business models have been relatively neglected within the overall theme of industrial transformations, which as we argue in this chapter is a significant oversight from a policy perspective.

Traditional Manufacturing and Distribution: 'locked in' large scale

The current business model for vehicle manufacturing involves the construction of large car plants able to manufacture and assemble all-steel cars in large numbers. Manufacturing economies of scale are realised and per-unit ex-factory costs are low. In order to sell this many cars, geographically extensive markets are required – which in turn means long logistics chains and dense networks of retail outlets. To date, most vehicle manufacturers have not had to bear a great deal of the investment cost in the dealer network because these have been independent, franchised retail concerns. Neither have the vehicle manufacturers sought to capture a high proportion of the total lifetime revenue stream created by a car in use: revenues have been earned primarily through the sale of new cars and through associated finance packages for consumers. Between the manufacturing plant and the customer are stockpiles of cars throughout the system, build to order is only achieved by long customer lead times. The essence of lean production has been to seek compliance from the supply base and the vehicle distribution network to the demands of the vehicle manufacturing process thereby reducing stock levels in the system– not to optimise the system as a whole.

Despite many measures, the traditional manufacturing and distribution business model faces problems (Wells and Nieuwenhuis, 2000). The high capital costs with very 'lumpy' investment in plant and models inherent in all-steel body technology are high risk. There is a chronic tendency to over-supply, resulting in discounting and rapid erosion of residual values in cars already sold. This rapid depreciation in economic value results in reduced economic lifetimes for the car, and in turn reduced product longevity: hence rates of material usage and vehicle scrappage are much higher than optimum. At the same time, the introduction of a new model can often lead to long waiting times for customer-ordered cars.

The inflexibility of manufacturing is leading to an inability to adjust output to demand and difficulties in switching from one model to another – responding to increasingly violent market fluctuations is difficult with existing production technology. In essence, the prevailing business model is best suited to market conditions of continuous steady expansion, and profits achieved via reduction in per-unit manufacturing costs. As market conditions have changed, so the business model has come under greater pressure. The reliance on the continued expansion sales of cars as the main source of revenue is increasingly untenable in saturated developed markets, while costs rise as shorter model lifetimes lead to lower per model volumes.

Eco-modernisation in the Auto Industry

The automobile constitutes an industrial product that engenders both considerable economic wealth creation and serious burdens to the natural environment. Although governments worldwide regard the capacity of the auto industry to generate jobs as a political asset to be preserved, they have also pressured car manufacturers to improve environmental performance. The industry has responded to stricter governmental regulation, voluntary agreements, and collaborative R&D initiatives by seeking to adopt cleaner manufacturing technologies and investing in environment-related research. In addition, competitive pressures ensure that every major high-volume car manufacturer is working towards increased levels of resource productivity. They have targeted energy and material conservation for both financial and environmental reasons (Knibb *et al.* 1998; Rogers 1993). From the mid-1990s, most world carmakers have also started to release annual environmental reports containing detailed information about improvements in vehicle manufacturing, emissions reduction in vehicle use, developments in hybrid and fuel cell powertrains, and recycling strategies for end-of-life vehicles.

There are no doubts that improvements have indeed been made by car assemblers. The average environmental performance of most fleets has significantly improved in the last quarter of the 20th century (Graedel & Allenby 1998), at least in terms of toxic emissions. With respect to fuel economy and carbon dioxide emissions the industry has not performed as well, because the benefits of more efficient engines have been offset by increased vehicle weight, along with the favouring of performance characteristics such as acceleration and top speed (Wells, 2003a). Such improvements as have been made, however, have not alleviated the pressure faced by firms operating in the industry. Regulatory measures on air emissions from exhausts have continuously intensified. During the 1990s, although the industry in Europe lobbied against the imposition of direct regulations on end-of-life vehicles (ELVs), the European Parliament approved a new Directive on ELVs in September 2000 (CEC, 2000). In order to satisfy standards of environmental performance, the industry has also been obliged to invest in increasingly expensive research and development activities. Environmental issues have certainly become an important economic issue for the automotive industry.

Vehicle manufacturers have responded to the regulatory and market pressure but the technological paradigm orientating car design and manufacture substantially limits the alternatives available to them. Most actions have been designed to reduce costs by reaching greater economies of scale in all aspects of the vehicle production industry including R&D, purchasing, production, distribution, marketing and sales. Platform consolidation whereby many visibly different models are derived from substantially common underpinnings, supply chain management and modular assembly constitute the most widely adopted management initiatives pursued among vehicle manufacturers in this direction. Additionally, the industry has sought cost-savings through consolidation with mergers and acquisitions to create 'multi-brand constellations' or groups with a portfolio of brands that straddle the major markets of the world. Such rationalisation practices have the potential to generate substantial cost savings in systems of design, component supply, production, and distribution and marketing. As a result, industry consolidation has assumed such a pace that many expect that by 2020 only six global corporations, each one producing around 15 million cars per year, will be competing worldwide (Eggleston *et al.* 1999; Feast 2000).

The current approach adopted by industry players can be seen as indicative of an appreciation that the contemporary business model is under threat. What is less clear is whether these actions represent the last gasp of the technological regime that was framed by and for the automobile industry during the 20th century. Although no one can forecast who will be the key players in an ecologically modernised industry, most within and outside the industry would agree that the technology used in the vehicles of the near future will differ substantially from that currently used. The reason for such conviction is contained in the word 'efficiency'. After more than one hundred years of technical improvements, current automobiles are absurdly inefficient – if efficiency is measured in terms of the conversion of energy (fuel) to the functional purpose of the car (transporting people and items). It is unlikely that these changes in the technology that constitute the car will occur in an industry that is otherwise exactly the same as today. Rather, these technologies in the car will allow, enable and require a change in the terms of competition, and alter the balance of the industry.

Vehicle manufacturers are already aware of the poor efficiency of their cars, and in various ways are working towards major shifts in design and manufacturing technologies. The problem, for most of them, is that they lack the core competences required to produce radically more efficient vehicles, and are struggling to escape from their own embedded business models. Moreover, a shift away from the current all-steel, internal combustion engine car requires automakers fundamentally to reform their systems of production – something not so easy for those who have sunk investments in current car manufacturing technology. That is, there is a deeply entrenched sense of the need to change, but rather less clarity on how to change.

Barriers for the Transformation of the Automobile Industry

Isolating the variables influencing the transformation of the automotive industry has been tried from several scientific disciplines and perspectives. Studies based on evolutionary and quasi-evolutionary economics in constructivist sociology suggest that a 'lock in' situation have been created around the ICE technology (Kemp 1994; Schot *et al.* 1994). The socio-technical context of the modern automobile is embedded in a self-reinforcing system of rules and beliefs of design and engineering practices, characterising what Nelson and Winter (1977) called a *technological regime*.

Orsato (2001; 2004) analysed the socio-technical context of the automobile from a multi-disciplinary perspective and identified seven factors fostering or inhibiting the industry to develop environmentally sound strategies and practices. These are: (i) organisational commitments, competences and constraints, (ii) market demand and patterns of utilisation, (iii) environmental policies and programmes, (iv) competitive forces and collaboration (v) industrial ecology conditions, (vi) positioning of related businesses, and (vii) interest groups and organisations. These are the main influences in a process that can eventually result in changes in the automobile field. However, the factors should not be seen as independent entities. They are immersed in what Orsato and Clegg (1999) termed 'the circuits of political ecology' – the terrain political and strategic actions in which the environmental strategies and practices are embedded. From such perspective, transforming the automobile industry requires a redefinition of its *circuits of political ecology*.

At the organisational level, while not seeking to deride or belittle the very real progress made by global vehicle manufacturers, it is hard to escape the conclusion that these companies are to some extent trapped within their own paradigm (Niewenhuis & Wells, 1997; 2003). Our contention is that a vital missing ingredient is the *business model* that underpins 'normal' practice within the car industry. In our view, there is an intimate causal relationship between the characteristics of product design, the manufacturing processes used to create those products, and the consumption patterns that result. Surrounding and reinforcing these characteristics, the pervading business models in the automotive industry consist of a set of assumptions, practices and norms that define and constrain what is 'possible'. Thus far, most studies have concerned with process, and to a lesser extent with product design, in a multiple organisation context. However, in order to achieve industrial transformation at an aggregate level there is a need for it to be achieved at a business level, either by new entrants or by existing businesses.

The Micro Factory Retailing Approach for Industrial Transformation

The concept of Micro Factory Retailing (MFR) is in essence a business model for the automotive industry in a distributed economy: in this sense it is an attempt to define a business model that allows the transition to be made from the current condition to some (more sustainable) future.. The MFR concept is <u>not</u> an account of an existing business. It is an idealisation, a vision, a view of what might be rather than what is, a hypothesis that could be tested by the tools of IT or worked towards from a 'backcasting' perspective. MFR is an attempt to provide an individual understanding of how a specific industry could try to meet the many and varied demands of sustainability. As such, MFR represents a radical reshaping of the relationships between product technology, process technology, business organisation, and the purchase and use of cars.

If new patterns of production and consumption are to emerge, MFR might be one means of achieving these new patterns. Despite these comments, the MFR concept is grounded in contemporary reality, it is based upon the reality that parts of the MFR concept are in evidence in the industry today – albeit not in one single place. In this respect the MFR concept seeks to identify a business model that can transform the automotive industry today.

Thus far, eco-modernisation in the automotive industry has foundered on being unable to compete in economic terms with the existing vehicle manufacturers and their prevailing business models: there is therefore a need to redefine the terms of competition, to find a business model wherein eco-modernisation can flourish. This transformative business model needs to embrace several aspects. These may include a radical (and more sustainable) product technology that is less polluting, less energy intensive, longer product lifetimes and so forth. In turn there will be a radical manufacturing technology and strategy with reduced environmental burdens and no or reduced tendency to over-supply. New ways of reaching customers will be needed, alongside new ways for people to own and use vehicles to allow greater overall efficiency in vehicle use. The key is for the innovative business model to allow market entry, to overcome existing barriers erected by the contemporary industry and its surrounding technological regime.

Micro factory retailing refutes the logic of matching the high-volume, low unit cost approach of traditional manufacturing and distribution by placing small factories within the markets they serve and so eliminates the distinction between production and retailing (see Wells and Nieuwenhuis, 2000). For example, rather than having one large plant producing 250,000 cars per annum (an average break-even point in traditional car manufacturing) the MFR approach would involve 50 plants, each assembling 5,000 cars per annum (i.e. 250,000 in total) and distributed spatially to match concentrations in population. Importantly this approach makes feasible alternative materials and design concepts that are only viable at 'low volume', and which in many ways allow significant improvements in the industrial ecology of the automobile, but which in traditional business model thinking are not economically viable at 'high volume'. It does so through the mechanism of multiple low volumes generating economies of scale in different ways to the traditional centralised factory. There would be no separate distribution channels or sales outlets: the factory is also the sales, maintenance, service and repair location. Powertrain components and other generic items could be centrally produced in conveniently located highly automated facilities for distribution to the decentralised assembly plants, thus allowing small scale assemblers to benefit from externalised economies of scale.

The MFR concept is not just normal car manufacturing on a small scale, it necessarily involves a radically different product technology and body production process, as the case of TH!NK, in the next section, will make it clear. This was a vehicle built on a folded steel platform onto which is fixed an aluminium body frame, which holds thermoplastic outer panels. Virtually any type of non-steel unitary body technology is suitable for this type of low volume, modular, low investment devolved assembly. Despite this, the idea of factory retailing itself is not entirely new to the automotive industry and there are parallel lessons to be learned from other sectors (such as steel mini-mills, specialty chemicals and micro-breweries that have already experienced some aspects of MFR in action (see: Johanasson & Holapa, 2003). In other sectors, such as computers (see for example Dell Computers) consumers deal direct with the factory, a practice likely to become more prevalent with Internet shopping.

The combined fixed cost of traditional manufacturing and distribution, including the franchised dealer network, is indeed substantial and represents a formidable barrier to entry or to change. Compared with this, the fixed costs for MFR are probably an order of magnitude lower. Perhaps more important than the simple investment cost comparison are the many strategic possibilities which flow from MFR (Wells, 2001a) that collectively create the strategic space to redefine the business model and thereby obviate or negate the barriers to transformation.

Before we provide some empirical examples of MFR (next section), we emphasise that we make no claims here that our concept of Micro Factory Retailing (MFR) is 'the' answer i.e.: that it will make the automotive industry ecologically and economically sustainable. Indeed, the logical conclusion of our analysis that economic activity needs to be embedded in locality and context means that there can be no prescriptive, generic solution of the type purveyed by the business gurus to be found on the shelves of airport bookshops around the world. Diversity means just that, a multiplicity of solutions that might all co-exist in time and possibly space. Moreover, our understanding of the significance of organisational fields is such that there are huge impediments to any process of change that might lead from the automotive industry as currently constituted towards something like the vision we have for MFR. An interesting issue, though one that cannot be explored here, is whether the demise of the existing automotive industry is inevitable, that the alternative structures envisaged under the MFR concept will triumph purely because of economic (competitive) superiority over existing business. However, in order to give some illustration of the ways in which the automotive industry could be transformed through a re-design based on industrial ecology we here outline the basic concept of MFR – though other accounts could also be consulted (Wells and Nieuwenhuis, 2003)

Empirical Examples of MFR

Research into the MFR concept has identified several instances where the approach, or parts thereof, have been tried. The various examples illustrate one or more aspects of transformative business models that challenge the existing set of assumptions and norms. It is interesting to note that thus far the larger suppliers to the automotive industry, be they materials companies or component suppliers, have not attempted direct involvement – perhaps because of fear that they would not like to appear as competitors to their customers, the vehicle manufacturers. Rather, most of the examples listed briefly below come from those who are outside the industry or on its periphery in various ways. One example is presented in a little more detail, but are several ways of thinking about product technology, manufacturing process, industrial inter-linkages, scale, and business models that go beyond 'fire and forget' production.

TH!NK: radical innovations in manufacturing

One version or approach was the TH!NK[1]. This example illustrates new product and process technology, and new ways of reaching customers while foregoing the use of franchised dealerships. That is, the factory with a low break-even point, is also the point of sale. The basic design concept was a two-seat city battery electric vehicle with a thermoplastic body for urban commuters and utilities (Wells and Nieuwenhuis, 1999). The TH!NK employed a lower frame constructed from 90% high strength steel cut, folded and welded rather than pressed into shape – the design for which was developed in co-operation with British Steel Automotive Engineering Group. Normal steel pressings would have required large investments in tooling. Mounted onto the lower frame was an upper frame constructed from aluminium extrusions, seam welded at the joints - this time Norsk Hydro provided useful expertise. The thermoplastic body was moulded in one operation, with separate mouldings for the doors,

1 For a detailed account of the evolution of the TH!NK enterprise, see Chapter 10 of Orsato (2001b).

roof and a few smaller parts, and was non-structural. The factory in Norway had a design capacity of 5,000 units per annum. The wider business plan included the use of internet sales and mobile service delivery to obviate the need for dealerships. Furthermore, the intention was to supply potential new markets such as California by locating a 'cloned' factory in the market.

Ridek: Sharing vehicle parts

This example illustrates the ways in which an innovative product design can also liberate an innovative approach to vehicle ownership and use. It does not illustrate innovative manufacturing techniques, but the original concept was designed around the need to use large and heavy battery packs for a zero emissions vehicle. The example highlighted here is that embodied in the Ridek concept (Wells, 2003b). The Ridek consists of two parts: a motorised deck (or 'Modek') that combines the chassis with the powertrain in one integral unit; and a self-contained body module (or 'Ridon') that is mounted onto the motorised deck via four fixing points. Under the proposed business model only the Ridon would be purchased and owned by the consumer. The Modek would be owned by the municipal authority, which would have to retain sufficient numbers to allow Modeks to be exchanged as required. Modeks would then be rented or leased out to consumers, but could be serviced, repaired, maintained or upgraded at a central urban facility.

MDI Air Car: a new business model for card design, production and distribution

This particular business idea provides a good illustration of an attempt to combine in one innovative package a new approach to vehicle design, vehicle production, and exploitation of the market with a rapid approach tomarket entry and expansion through franchising of production. Motor Development International (MDI) is the company formed to bring to market the ideas of the inventor of the compressed air engine, Guy Negre (Wells, 2002). The technical concept and the business plan have generated much controversy in the automotive industry, and doubts over both remain.

However, the case is reported here as indicative of a different means of combining product technology and business model. In this vehicle, compressed air is held in a suitable canister. As such, compressed air represents stored energy. The compressed air is then fed into a cylinder and allowed to expand, and in so doing the expansion provides the motive force to push a piston and hence turn the engine. There is no combustion, so there are no emissions at the point of use other than air- though of course overall emissions performance depends upon the energy source used to compress the air. A useful attribute of the technology is that any sort of dedicated infrastructure would not be technically difficult or expensive to install – air refilling points could easily be added to existing petrol stations for example. Simple air compressors could be run from domestic electricity and re-charge the cylinders overnight. The detailed design of The Air Car is more complex than the above suggests, for example it involves an innovative articulated connecting rod to allow the piston to be positioned at top dead centre for a longer duration in the cycle than is normally the case with an internal combustion engine. The engine develops maximum power at 3,500 rpm and maximum torque at just 800-1,300 rpm. The slow speed and low temperature of operation (air in the cylinder head reaches 400 C maximum) mean than vegetable oil is sufficient for lubrication, and the oil will last up to 50,000 km.

The car is positioned and performs rather like a battery electric vehicle without the weight and cost penalty of high performance batteries. Compared with contemporary petrol and diesel cars the range, top speed and acceleration are limited. An interesting by-product of the technology is that the exhaust air is at minus 15 Celcius, so air conditioning for the cabin is easy to obtain.

The engine concept has various non-automotive applications. However, MDI have designed a vehicle structure within which the engine and tanks can be placed. The vehicle is available in four basic body styles that reflect the urban / commercial vehicle focus of the product: family car; van; taxi; and pick-up.

However, of equal interest is the business plan developed by MDI. With many innovators, the core problem is usually lack of investment resources allied to the need to break the hold of the existing market leaders. MDI is no exception, but rather than seek to persuade an existing vehicle manufacturer to take up the technology, MDI have tried a quite different approach. The core of the MDI approach is to grant licences to third parties that in effect take on an MDI franchise for a defined territory in return for the investment needed to create the factory to serve that territory. MDI has designed a standardised or modular factory, and claims that 50 factories have already been allocated in various locations around the world. In addition, the standardised factory includes office space and a showroom, because in the MDI concept the point of manufacturing is also the point of retail and service / maintenance delivery. A prototype factory is claimed to exist in Nice. The factory therefore includes 4,200 m^2 of workshop space; 500 m^2 of offices; and 300 m^2 of showroom space. On a single shift, with 70 workers, the factory is expected to produce about 2,000 vehicles per annum. In terms of operations, the factory would manufacture and assemble engines, car parts, the chassis, and undertake final assembly. The large plastic body panels would be manufactured at the factory as well. Of course, in addition the factory would undertake promotion and sales, and distribution, sale of spare parts, repairs and service within the zone allocated to them.

The MFR Approach as a *Business Model* to achieve Industrial Transformation

It is worthwhile to consider how far this re-thinking of a major industry fundamentally changes the terms of comparison and performance, in business, social and environmental terms. These issues are treated in several themes below.

Customers, brands and market success

In order to be sustainable a business must be commercially viable, and the way to achieve this is to deliver superior customer satisfaction than rival approaches. A key problem for new market entrants, and one that is not entirely resolved by the MFR concept, is that of brand value. Particularly in large, complex and expensive products such as cars it is the case that consumers tend to be risk averse. Of course new brands have been introduced into the market over recent years by the existing vehicle manufacturers, but at great cost and over a long period of time. The MFR concept may allow some of this risk to be reduced because customers do not necessarily have to buy the product, they might well just buy the mobility service. However, the MFR business model offers a mechanism to deliver superior customer satisfaction in many different ways if sufficient credibility can be established. For example, the consumer will benefit from a reduction in depreciation of the vehicle (reflected as lower lease rates), because of reduced over-supply.. One interesting aspect is that customers can visit the plant, can meet the workers on the production floor who will make their car, and can thereby have an affinity with the product (a practice already used to sell prestige vehicles in Europe). The factory gains valuable market data direct from customers, with insights into customer life-styles, aspirations and mobility needs. In turn this might help shape new product development, because the factory has daily dealings with those buying, servicing and repairing their cars: even modifications to the production process can be instituted quickly and cheaply. The inherent production flexibility and geographic proximity of MFR is the practical basis upon which new levels of customer care can be built. MFR makes possible flexible response, shorter lead times, and late configuration that in turn yield shorter times to market, and quick responses to customer orders.

Sustainable growth strategies

Existing industry grows by producing more and selling more. This in itself is not sustainable, while the actual growth patterns are severely disruptive. Investments with a MFR framework in assembly capacity can be relatively small-scale and incremental, either by adding (subtracting) more units or by the expansion (contraction) of existing units - and thereby supply can expand or contract in line with the market. A chronic problem with industries that have sought ever-increasing economies of scale is large fluctuations in demand relative to supply. Each additional capacity increment or new plant is very large, a step-change in supply, so the industry comes to be characterised by poor capacity utilisation and low margins. Conversely, each MFR unit would have an investment cost well below that of a traditional manufacturing plant – although the cumulative investment cost for the same production capacity may be higher. The incremental expansion of capacity can also have a geographic component in that new plants can be added to develop new market territories. The environmental benefits or the economic benefits of this sort of 'smoothing' are by no means proven, but are at least suggestive and worthy of further detailed research.

The Social Value of MFR

One potential avenue for theoretical development is to bring in the concepts to be found in the debate on the decentralised economy and on the phenomena of 're-localisation'. In particular, the social value of production and work is of importance as an oft-neglected aspect of sustainability. The work on eco-industrial parks represents one (environmental) basis for understanding the character of localisation. Our first starting point for this analysis is that of Schumacher (1973), and that quite simply, 'small is beautiful'. By changing spatial scale it is possible to create wealth, useful products and 'rewarding' work to the community in which it is based – a goal that has value in its own right (Shuman, 1998).

With this combined product-service function and social applicability, the MFR factory becomes the location for repair, spare parts, in-use modification (e.g. external panel refresh, power-train upgrades, refitting of interior trim) that allows the manufacturer to benefit directly from profitable aftermarket activities. The factory becomes the centre for trade-ins, used vehicle sales, and End of Life Vehicle recycling and hence becomes the embodiment of product stewardship within the local community.

The MFR concept has potential to liberate communities and meet their social and political objectives by creating local employment and wealth creation in high-value manufacturing activities, countering the disenfranchising impacts of globalisation. Those purchasing the product or service would know that there would be direct local economic benefits and, equally, there would be fewer concerns over e.g. exploited labour in far-off locations. The MFR concept further embodies the growing desire to increase the use of skilled labour and reduce fixed investment in order to reduce cost, increase flexibility and increase social cohesion. Given that sustainability does not and can not mean the ossification of social or economic structures, it is incumbent upon those advocating a different future to consider the adaptability of the business solutions they propose: adaptability is a key facet of the MFR approach. In the longer term the business model assumes a transition from pure manufacture of new product into a greater reliance on service, support, re-manufacture, etc. and this offers a means to escape the 'production growth equals business growth' trap.

Transitions for Emerging Economies

One of the initial stimuli to the work undertaken in industrial ecology was the basic concern that it would be impossible for the planet to support a standard of material consumption attained by highly industrialized countries if the emerging economies attained the same level. In other words, emerging economies desperately need 'development', but the terms by which this is achieved must be different – this is the essential message of the Bruntland Report after all. In addition, emerging economies tend to suffer from chronic under-capitalisation, high levels of national debt, and surplus labour. While some materials may be abundent, these economies often lack local processing capabilities and export only the raw material: there is insufficient local added value. The MFR approach makes some contribution to these issues. For example, the approach is conducive to the creation of products that are appropriate to the locality. Of course it is debatable whether different places have different needs in terms of cars and mobility, but a cursory glance at the cities of the world would suggest that they do. Furthermore, the reduced capital requirements and high labour content implied is ideal for the structural conditions in many emerging economies, while simultaneously providing for a substitution of expensive imports.

The Environmental Footprint of MFR

In any industry or activity there is a choice to be made between concentrating or dispersing that activity, and which is 'better' for the environment. With fewer, larger plants there are various efficiencies (equivalent to economies of scale) in processes that will mean lower per-unit burdens in terms of e.g. energy consumption, water pollution, etc. However, a large facility can also mean that for the locality in which it is placed there are very real environmental consequences both with normal operations and with catastrophic events.

The environmental advantages of MFR are slightly different to this debate. For example, compared with traditional car manufacturing, the MFR approach makes viable low-volume production. This type of production often utilises technologies other than the all-steel body, pressed, welded and painted. Therefore the MFR approach enables the traditional paint-shop, one of the environmental 'hot-spots' in car manufacturing, to be abandoned. Other advantages might follow. The MFR plant does not require a large, flat dedicated site with extensive support services. A modern car plant occupies several square kilometres of land. Compared with this, MFR requires a classic 'light industrial' facility and could even be used in 'brownfield' sites needing industrial regeneration.

Another interesting aspect is that the factory can undergo a transition over time from an essentially new car production focus, to one more involved in service and repair. That is, the factory does not depend absolutely on the continued sale of new cars. This helps to mitigate the tendency to over-production with all manner of associated environmental and market benefits. The environmental cost of over-production is rarely addressed by environment-related studies, but we believe it to be crucial in the long term. Finally, the MFR can work as a point of collection of end-of-life vehicles, with the option to become a dismantling facility. This can certainly facilitate reuse and recycling of materials.

Concluding Remarks

In this article we not only analyse why the current system of production and distribution of automobiles is unsustainable but also presented an alternative for such paradigm. The MFR was introduced as an ideal typology. By doing so our 'ideal model' can be used as a basis for the evaluation of existing and future alternatives that combine environmental demands with those of business and society. Our experience in the industry taught us that the environmentally-sound processes and products will not become common practice unless they are anchored in a sustainable business model. Although we believe the MFR provides exactly this, we contend that this article is just the opening of a dialogue for advancing research and practice in this area.

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