Journal of Cleaner Production 95 (2015) 232–241

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

More sustainable automotive production through understanding decoupling points in leagile manufacturing

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ARTICLE INFO

Article history:
Received 31 July 2014
Accepted 26 February 2015
Available online 10 March 2015

Keywords:
Lean
Agile
Leagile
Automotive
Manufacturing
Economies of scale

ABSTRACT

Attempts to link 'lean' and 'green' have a long history, yet they mostly remain wedded to an eco-efficiency agenda. The question addressed here is to what extent lean can inform more radical change towards greater sustainability in industrial systems. The automobile is one of our least sustainable systems and the main issue is overproduction. Yet, the current automotive business and manufacturing models depend on high levels of production due to the need for economies of scale determined by the chosen production technologies. These technologies center on the internal combustion engine and the all-steel body. This paper shows through a review of the 'leagile' literature, that a new understanding of the factors that determine the 'decoupling point' between lean and agile processes can be used in order to bring about a radical shift in economies of scale in car production such that lower volume production becomes feasible thereby reducing the need for overproduction and enabling a move towards more sustainable car production and hence consumption. A case study of the Morgan Motor Company is included to illustrate how such an approach could work in practice.

1. Introduction

There have been several attempts over the past twenty years or so to link, or even fuse the concepts of 'lean' and 'green'. Although early pioneers of lean production and subsequent 'lean thinking' (Womack et al., 1990; Womack and Jones, 1996) on the whole failed to make this connection, some, including Romm (1994), immediately saw the potential to combine the 'lean' with the 'green', or 'clean' as Romm put it, while others instead highlighted the potential negative environmental impacts of some 'lean' practices such as Just-In-Time (JIT) (Nieuwenhuis, 1994). The following twenty years saw a series of studies attempting to integrate the two concepts, exemplified most recently by works like Dües et al. (2013) and Wong and Wong (2014). A particularly useful contribution is the recent literature analysis surrounding these themes by Martinez-Jurado and Moyano-Fuentes (2014), who also identify automotive as the most studied sector in this context, possibly reflecting the fact that lean thinking originated in the automotive sector, although it could also be argued that nowhere is this fusing of lean and green more relevant than in the case of the automobile.

In the automotive sector, both products and processes have been the subject of considerable efforts to reduce their impact, yet it is also clear that annual worldwide production and sales of some 70–80 million vehicles is not environmentally sustainable as presently understood, however environmentally optimised both products and production may have become. In fact, the automobile is probably one of the least sustainable of human systems. Yet it has also become tightly interwoven with modern societies and economies, making it particularly challenging to entice towards greater sustainability. Progress made so far in product terms has focused primarily on emissions and fuel consumption and should be categorised as 'eco-efficiency' measures rather than moves towards genuine sustainability, while, similarly, in production terms the focus has been on the reduction of paint-shop emissions, energy efficiency measures and reduction of waste. The problems are wide-ranging, but the most obvious is this sheer annual production volume, amounting to some 63 million cars and light trucks in 2012 alone (OICA, 2014). Having adopted mass production, it has become near impossible to produce cars at low volume, thereby creating significant barriers to change (Wells and Nieuwenhuis, 2012). However, these barriers within the mass production system are not insurmountable.

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http://dx.doi.org/10.1016/j.jclepro.2015.02.084

The present study attempts to progress the discussion of how to link lean and green and extend it towards a sustainable production approach by incorporating not only recent advances in lean thinking, particularly its embracing of 'agility' as a concept, but also the recognition of the limitations inherent in an eco-efficiency approach. In the process, an attempt will be made to summarise developments in lean and agile thinking and then extend this to apply it to a model of potentially more sustainable production of automobiles at lower volumes. A case study of the Morgan Motor Co. is included as an illustration, although this is used merely to explore how the principles of 'leagile', and in particular how the core concept of the 'decoupling point' could be used to inform a more sustainable, lower volume and hence lower environmental impact system that can nevertheless deliver personal mobility as it has come to be understood.

1.1. Background

The need to reduce new car production volumes will come into even starker focus in the coming years as a result of technological developments, as a consequence of which the ratio of embedded carbon to in-use carbon emissions will change dramatically. This will make the environmental argument for making fewer, more durable cars even more compelling than it is today. The notion of product durability has long been on the margins of environmental concern (OECD-MIT, 1994; UN, 1997; Cooper, 2005), although some durability work has focused specifically on the car (Porsche, 1976; Stahel and Reday-Mulvey, 1981; Nieuwenhuis, 1994b, 2008; de Groot and McCrossan Maire, 1998). The issue of a car's life expectancy has come to the fore again due to work on embedded (or 'embodied') carbon in cars, notably that by Ricardo on behalf of the UK Carbon Trust (Ricardo/Carbon Trust, 2011) and also the work by Hawkins et al. (2012). It is clear from these contributions that as we move towards greater electrification of the automotive powertrain from hybrid, through plug-in hybrid, to battery electric vehicle (EV), and possibly fuel cells, the proportion of embedded carbon increases in relation to carbon emissions in the use phase from the current typical ratio of 20:80 (embedded: use), to a possible future ratio of 60:40. Embedded carbon in the case of a car includes the mining of raw materials, their transport, production of semi-finished products, of components, as well as the production of the car itself.

The Ricardo study shows that the body contains the largest proportion of embedded carbon (30%), followed by the engine (20%), which, by optimising existing technologies, could be reduced by around 50%. However, there is also an increasingly strong case to be made for extending the useful life of the car itself. The analysis by Hawkins et al. (2012) focuses specifically on the difference between what they term 'conventional' and electric vehicles. They calculate that the global warming potential benefit of EVs as a result of this amounts to 10–24% with the average European electricity generating mix, assuming a lifespan of 150,000 km. Increasing the lifespan to 200,000 km increases this benefit to 27–29% relative to petrol cars and 17–20% relative to diesel. However, decreasing the lifespan to 100,000 km reduces the benefit to 9–14% against petrol, and no discernable difference with diesel. They suggest, therefore, reducing the impact along the supply chain while also reducing in-use emissions through lower carbon energy generation. Neither study advocates a longer lifespan, but this would seem a more logical conclusion. EVs already are likely to last longer than IC engined vehicles. This is based on historical experience with older EVs, as well as more recent experience in countries like Norway and some specific commercial fleets, which have shown them to be very reliable and long-lived (Nieuwenhuis, 2014). However, will consumers be able to adjust to keeping cars for longer, and will the car industry be able to handle such a transition towards making fewer longer-lasting cars? The answer to the latter may well lie in some of the strategies outlined in this analysis.

2. Lean and green

Martinez-Jurado and Moyano-Fuentes (2014) provide a useful summary of works attempting to link the lean with the green and they distil a number of themes from their analysis. They explain that while initially the focus was on greening single sites or firms, later arguments in favour of greening supply chains come to the fore (e.g. Mason et al., 2008). They show that in recent years most of the focus in the literature has been on the impact of lean practices on environmental sustainability, which they define as meeting the needs of current stakeholders without compromising those of future stakeholders – possibly a rather narrow definition, which depends crucially on how 'stakeholders' are defined in a particular context. They identify some recent contributions, notably Vinodh et al. (2011) and Aguado et al. (2013) that begin to link lean management and green manufacturing, which, combined with works adapting lean concepts to environmental concerns along the supply chain as a whole, such as Mason et al. (2008) have moved the debate forward towards a more integrated approach. However, they also highlight problems with this approach, notably the concept of *heijunka* or production levelling, which highlights the tension between the needs of the production system with those of the market (Naylor et al., 1999; Mason-Jones et al., 2000) that forms the basis for the discussion here.

On the whole, as outlined by Martinez-Jurado and Moyano-Fuentes (2014), the approach taken by such studies can best be categorised as 'eco-efficiency', whereby the 'lean' priority of removing 'muda' or waste in the broadest sense from any process, can easily be extended to apply equally to the wasteful use of natural resources, whereby a 'green' approach prioritises the reduction or removal of such waste; a very similar concern. An eco-efficiency approach is predicated on the assumption that there is nothing inherently wrong with the product or process under consideration, but that carrying it out in a less wasteful manner is itself environmentally beneficial. To some extent this may be a valid assumption; however, we are also then often dealing with 'low hanging fruit' in terms of wider environmental benefits; further, more fundamental change is inevitably needed in due course.

Such eco-efficiency benefits are then extended to the business side whereby the 'double bottom line' at least can be hit: eco-efficiency is thus easily combined with business efficiency: saving costs. Walker and Salt (2006) warn against over-use of efficiency as it is often understood, arguing that instead, natural systems favour a degree of 'redundancy' in order to achieve 'resilience' and therefore often appear to us as inefficient. Within a wider sustainability context, therefore, many of such eco-efficiency initiatives provide at best partial results. For example, where a process or product is inherently unsustainable, it is still offered, only with a reduced environmental impact. Instead, an attempt is made here to revisit the lean concept, combined as it has become in the more recent literature with the notion of 'agility' to create a creative fusion now known as 'leagile', and to assess to what extent this concept can then be used beyond the context of an eco-efficiency brief in order to make a serious contribution to a genuine sustainable production and consumption agenda – although the emphasis here will be on the former: production.

3. Lean and agile

With the introduction of lean production, originally as the Toyota Production system, mass production became more efficient