

An Engineering Systems Approach to Strategic Change: the case of the European Automotive Industry

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Introductory Sentence: The paper presents the methods developed by the European Automotive industry to build cars to customer order and uses an engineering systems approach to communicate the required transition in industry structure.

Key Points:

- Detail of an EU automotive Build to Order strategy is presented
- An Engineering Systems approach is introduced, named Enterprise Architecting, which structures complex enterprises
- Enterprise Architecting is used to applied to the strategic implementation of BTO in Europe
- Industry experts validate and critique the work

Brief Biographical Notes

Dr Glenn C. Parry is Associate Professor in Strategy and Operations Management at Bristol Business School, University of the West of England. His work focuses within three industrial sectors: Aerospace, Automotive and Music. Glenn currently works with BAE Systems, GE and MoD on through life costing for aircraft provision and also with leading aerospace firms on strategies for through life capability provision. Glenn works with a global music sector firm, exploring the transition from a focus on physical distribution to offering a range of digital services. He was a Leader for the £22m EU 5 Day Car Automotive project, is editor of the project book

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Dr Jens K. Roehrich is Lecturer at the School of Management, University of Bath, UK. His research focuses on the management of long-term inter-organizational relationships, including the dynamic interplay of contracts and trust, inherent in integrated solution provision. Jens' research also explores innovative multi-utility service provision and value co-creation in urban infrastructure redevelopment projects and investigates innovation in the delivery of health infrastructure projects in Europe. Jens' research has been published or is forthcoming in Industrial Marketing Management, International Journal of Operations and Production Management and the Journal of Purchasing and Supply Management.

Abstract

Build to Order [BTO] refers to a demand driven production approach where the majority of products and components are scheduled and built in response to a confirmed order received for it from a final customer. A £23m EU project involving leading automotive experts developed strategies and processes to realise an automotive BTO system in Europe. Despite significant investment and research to establish the required approaches the strategic vision has yet to be achieved. A holistic Engineering Systems approach, developed for complex engineering enterprises, provides an overview for strategic transformation. The current and future BTO state of the industry are described using the eight lenses of Enterprise Architecting, namely strategy, policy, organization, process, knowledge, IT, products and services. An expert panel of practitioners and academics validate and critique the detail and content of the industry transformation described and the Engineering Systems approach to strategic implementation. Following consultation and amendment the experts agree with and support both the content of the automotive BTO strategic vision and the Engineer Systems lenses as an approach to guide strategic change.

Key Words

Innovation, New Product Development, Build to Order, Lean, Engineering Systems Approach

Focus Areas

Innovation and new product development

Introduction

Enterprise transformation concerns fundamental change that substantially alters an organisation's relationships with its key constituencies, involves new value propositions in terms of product and service, and redefines how the enterprise is organised (Ackoff, 1974; William, 2005). The transformation or 'architecting' of complex large-scale enterprises tends to be explored from a single viewpoint such as IT, process, human resources, but the developing field of scholarship in Engineering Systems provides an integrative holistic approach. From this field, a process described as Enterprise Architecting (Rhodes et al., 2009) offers a systematic framework for the development of holistic strategy development and execution (Richardson, 2008). Working closely with the automotive community and global suppliers, this paper applies this Enterprise Architecting engineering systems approach to the challenge of developing a strategy for the transformation of the European automotive industry towards adoption of a full Build to Order (BTO) strategy, such that all vehicles can be built and delivered at the rate of demand (Parry and Graves, 2011; Roehrich et al., 2011).

BTO is a successful strategy employed in other sectors, for example within the electronics sector companies such as Dell hold stocks of final components and configure them to form products allowing them rapid responsiveness. The variety of components required for the final products offered by automotive original equipment manufacturer (OEMs) make such a 'late configuration' strategy challenging for the automotive industry (Holweg, 2005). An automotive BTO strategy would extend through the enterprise, integrating many suppliers and providing a strong model upon which car companies could build a sustainable world leading automotive industry (Holweg and Pil, 2004).

Development of innovative Build to Order products and processes requires a significant investment in research and broad access to expert resources. The prohibitively high risk and cost associated with developing such an innovative approach to manufacture was too great for a single company to bear, so the EU Commission, in partnership with industry, provided \$23 million to fund this research. It was agreed to set a challenging target of 5 days from order to delivery for the European context (3DayCar, 1999-2001). The four year project involving 30 organisations in 12 countries produced methods and processes for BTO, described in this paper. A validation exercise of the proposed Build to Order strategy showed delivery of 50% of EU vehicles could be achieved within the five day target time; 97% could be achieved within six days and 100% within eight days. Whilst short of the five day target this improvement exceeds the current industry capability of 40 days (Parry and Graves, 2008).

Despite the significant successes of the project, the adoption of the strategy across the EU has been slow, with only one engine plant adopting a predominantly BTO approach to date. Organisations are compelled to transform to achieve their strategic objectives (Nightingale, 2009) but implementation of a BTO strategy challenges convention and disrupts established practice and has so far been difficult to implement (Stone et al., 2006). Engineering Systems research focuses upon gaining an understanding of how to transform large-scale complex enterprises (Ng et al., 2011), creating structures which work within their context – a process described as Enterprise Architecting (Rhodes et al., 2009). The term “enterprise” used here is a boundary-defining term to identify a complex system of interconnected and interdependent activities undertaken by a diverse network of stakeholders for the achievement of a common significant purpose (Purchase *et al.*, 2011). Whilst numerous approaches to enterprise architecting are available they are typically oriented towards simpler enterprises than are found for automotive OEMs (Schekkerman, 2006). For more complex enterprises a broad perspective is needed as complex engineering systems involve tightly coupled parts; changing one component affects many others, leading to unintended consequences. The interactions between them are often highly complex and non-linear (Parry *et al.*, 2010). Complex enterprises are not necessarily based around large firms. Companies choose to outsource functions that are outside their core competencies (Prahalad and Hamel, 1990) and perform only functions that confer competitive advantage (Christiansen and Maltz, 2002). Hence, smaller entrepreneurial firms may also assemble large complex enterprises, drawing together numerous resource providers to deliver service to their market.

In order to structure complex enterprises from a holistic engineering systems perspective Rhodes *et al.* (2009) identified eight view points, described as ‘8 lenses’, as vital in building a comprehensive picture. These include: *Strategy*, which sets the goals, vision and direction of the enterprise, including business model and competitive environment; *Policy/ External Factors*, which include the external regulatory, political and societal environments in which the enterprise operates; *Organization*, which includes structure as well as relationships, culture, behaviours, and boundaries between individuals, teams and organizations; *Process*, which captures the core processes by which the enterprise creates value for its stakeholders; *Knowledge*, both implicit and tacit which frame capabilities, and intellectual property resident in the enterprise; *Information Technology*, to include the information needs of the enterprise, including flows of information and systems/technologies for information availability; *Products* produced by the enterprise for use by its stakeholders; and *Services* of the enterprise, including services as a primary objective or in support of product. These lenses are arranged in a framework,

with solid lines showing primary and dotted lines secondary relationships, show in figure 1 (Nightingale and Rhodes, 2007).

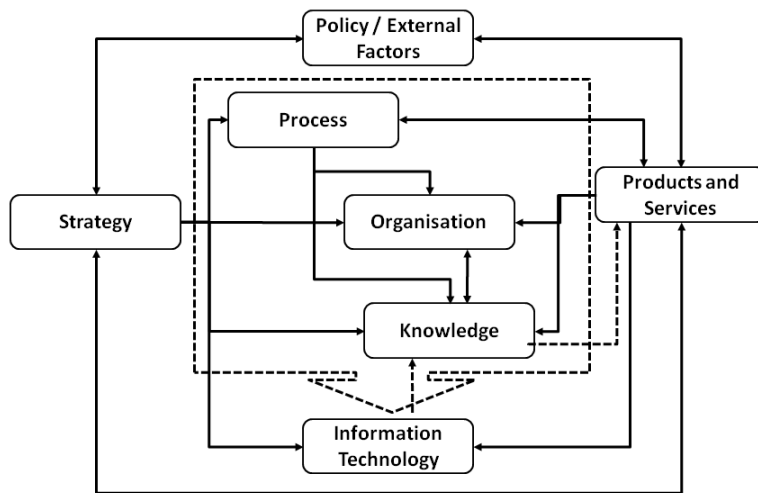


Figure 1. The holistic enterprise architecture framework (adapted from Nightingale and Rhodes, 2007).

To explore transformation the approach utilises Epoch-Era Analysis to introduce a temporal element when considering systems in the context of a changing world (Ross and Rhodes, 2008). Eras represent the full lifespan of the system which is decomposed into Epochs. Epochs are defined as time periods when significant needs or context are fixed or the rate of change is slowed creating a plateau of stability with identifiable characteristics along the journey of continuous improvement (Schonberger, 1986; Rhodes et al., 2009). The framework is proven to be a useful structure for communication of the approach as well as understanding synergies and interrelationships across views (Sisto, 2010).

To apply and test this approach to the challenge of European automotive BTO the paper is structured as follows: First, we outline the research methodology employed in the paper. Second, how vehicles may be built to order within 5 days, presented from the perspective of the 8 lenses of engineering systems. Third, a critique of the approach from an expert panel drawn from industry and academia. Finally, we outline conclusions and future work.

Research approach

In this work two epochs describe the current and desired future state of the EU automotive industry creating a time line from present into a possible future. For each lens the detail of the two epochs are populated to describe a single transition, from the current, predominantly build-to-stock (BTS) state to future BTO-dominant

state. To populate the information required for the 8 lenses, this paper draws upon the significant body of research undertaken for the £23m ‘Intelligent Logistics for Innovative Product Technologies’ (ILIPT) research programme. This was a pan-European research project representing a vast European effort to develop innovative new concepts to realise Build to Order within the EU automotive industry. To achieve this vision a significant consortium of leading automotive experts was convened from across industry and academia. Project participants were drawn from all over the world. From the automotive industry leading companies include Daimler, BMW, Lear Automotive, Dana Corporation, ThyssenKrupp Steel, Siemens VDO, and Saint Gobain Sekurit, representing the complete supply chain. Subsequent interactions with the automotive firms in their path towards implementation of a full build to order system have been incorporated. Detail is given of current and future state with required innovations in product and process, as well as potential routes to implementation.

The verification and validation of the work is undertaken using a Delphi methodology (von der Gracht, 2010). The work was circulated sequentially to six leading members of the ILIPT programme, representing three senior managers from leading automotive companies and three academic viewpoints. Two iterations of the paper were circulated such that broad agreement was given as to the validity of the structure and strategy. A post-case review of the approach was undertaken based upon the analysis of strategy formulation developed by Platts (1994), which identifies procedure, participation, project management, and point of entry, as desirable characteristics of methodologies. This was undertaken by circulating this paper with a questionnaire to the expert panel. To test the generalisability of the approach, during the post-case review an additional three senior leaders from multinational engineering sector firms outside the automotive sector joined the panel, representing aerospace, domestic goods, and wind turbine manufacture.

Application of Enterprise Architecture

Table 1 provides an overview of the 8 lens and the transformation from current and future state for each. In this section more detail is provided for each state.

Lens	Current State		Future State
Strategy	Stock push with limited build to order capability and dysfunctional product lifecycles.	→	Full build to order capability
Process	Lean manufacture	→	Lean Enterprise
Organisation	Hierarchical	→	Decentralised

Knowledge	Localised, sequential	→	Expert systems with autonomous agent negotiation
Information Technology	Linear through supply chain	→	Integrated across enterprise
Product	Platform sharing with monocoque chassis. Many shared systems and some modularity	→	Extensive modularity. Body frames separate to styling surfaces
Services	Dealer network hold significant stocks to deliver rapid customer response	→	Dealer network hold very limited 'sample' stock and guide customer order specification
Politics / Environment	Approach has required intervention by governments to prop up system. Overcapacity in business model	→	As systems sustainable; BTO model delivers upon triple bottom line of social, environmental and economic sustainability

Table 1. Overview of transformation from current to future state

Strategy

Strategy: Current State

Many automotive firms offer a Build to Order service, but currently a customer specifying a car has to wait around 40 days to receive their desired vehicle, or alternatively buy one from stock (3DayCar, 1999-2001). To mask the delay, the current automotive strategy is for dealers to hold tens of billions of dollars worth of stock – namely finished cars - to provide the customer with a vehicle which closely matches their specification more quickly. Reported US stock figures between 2006/7 ranged from an average of 25 days for BMW, 85 days for GM and 35 days for Toyota (Automotive News, 2006/7). This enabled companies to find a 'best match' from stock to meet the purchaser's requirement, whilst creating a market for instant gratification. However, customers frequently do not receive what they really want. Incentivised by manufacturer discounts they purchase a vehicle that is a compromise, whilst manufacturers erode their own profits (Holweg and Pil, 2001). It has been proposed that competitive advantage is afforded companies who can provide a product at the right price and quality to the customer within the shortest lead time (Stalk, 1988; Bower and Hout, 1988).

Strategy: Future state

The final customer is a known individual purchaser. Our definition excludes all orders by national sales companies (NSC), car dealers, fleet orders or other supply chain intermediaries. We also exclude the order amendment function, whereby vehicles in production are amended to customer requirements, as this is another

level of sophistication for a build to stock (BTS) system. A BTO system does not mean that all suppliers in the supply chain should be producing only when a customer order has been confirmed. Clearly, it would not make economic sense for a manufacturer of windscreen wiper blades to employ BTO. These components should be built to a supplier order, effectively BTS. However, a large expensive item, such as an engine, would be BTO. The point in the supply chain when this BTO/BTS change occurs is called the 'decoupling point' (Mandel, 2008). Part of the challenge for each segment in a supplier network is in the identification of the BTO/BTS boundary; which suppliers should be BTO and which BTS.

Product and Service

Automotive OEMs seek to provide products that address the needs of as many customers as possible, thus providing market coverage. The visual, external differences between vehicles play a significant part of defining their market segment. Internal differences, such as fuel injectors or windscreen wiper motors, are less significant and common parts and modules may be shared across vehicles in many segments. Automotive manufacturers seek to minimise their product part variance, which would drive up cost, and maximise part commonality whilst maintaining an individual product integrity and segment differentiation within the market (Gneiting and Sommer-Dittrich, 2008). Within the ILIPT project we identify the service element of the enterprise as consisting of the dealer network which delivers the product and services it.

Product and Service: Current State

Currently it is the dealers who are a major stock holder for the OEM, and the service provider. Of the 114 dealers for a single leading OEM in the UK, the average stock holding was £1.2million in finished cars. The multiplier effect across the major markets of Europe, China and the US indicates the sums involved run to billions of pounds. A modular approach has already been employed extensively in automotive product design, where great focus has been placed upon common platform strategies (Untiedt, 2008). Here many common parts, including much of the main chassis, are reused over different vehicle variants. However, the current body architectures are monocoque based, with styling surfaces forming part of the load bearing structures. To produce variation in the appearance of the vehicle, different panels are used across common underpinning platforms which can frequently only be assigned to one product variant [saloon, estate, convertible, hatch back], increasing cost. Colour remains a major variant which adds cost as coloured parts such as body panels, bumpers and door trims are made of different base materials e.g. plastic, alloys, steel grades and galvanised coatings, which is

challenging as different paint types are required to adhere to the material, but must be of the 'same' colour (Untiedt, 2008).

Product and Service: Future State

Efficient BTO is based on maximising the modular content of product. Modularisation requires extensive collaboration within the automotive enterprise which introduces strong dependencies between firms which drives greater collaboration (Howard and Squire, 2007). There are three core aims behind the strategy for BTO automotive body design: a reduction in production time; a simplification of the order and delivery network - facilitating logistics; and a reduction in the required fixed capital within the whole process.

Building on research done by Daimler AG (Truckenbrodt, 2001) a generic vehicle was developed which had a load bearing body structure which was separate from the visual styling surfaces. This concept was used commercially for the BMW Z1, a low volume sports car. The generic body structure followed an approach developed by Daimler AG known as "quartering the car". The vehicle thus comprised a set of four modules: front module which is the primary bumper/impact protection; the engine module which holds the engine and front axle; the cabin front, which includes the windscreen and front door area; and the cabin rear which includes the rear seating area, doors, axle and tailgate. By following this approach eight different modules could be combined to produce four different variants of final vehicle: a five-door, three-door, estate/wagon, and convertible. The combination of modules and subcomponents meant that compared to the 5-door base case: the 3-door variant shared 100% parts commonality; the station wagon had 87% commonality; and the convertible 70%. The cost reduction in areas such as complexity, handling, and storage is significant.

Styling surfaces are made from pre-coloured thermo formed plastic panels. These 'clip-on' to the steel body frame chassis to complete the car, removing the need for a paint line at the main vehicle assembly and saving significant time and cost. Whilst not designed to bear substantial mechanical loads they perform to legislative requirements for crash and impact protection (Gude and Hufenbach, 2008). The commonality in the body frame meant that significant commonality also exists across styling surface panels.

To maximise efficiency of service a key aim is the removal of stock held by car dealers, the key service providers in the value chain. A stockless vehicle supply system removes billions of dollars worth of stock from the service providers and increases their return on capital employed. BTO refocuses the service provider upon aiding customers in choosing their vehicle options and looking after the customers experience through the

vehicle life, providing service maintenance to vehicles and informing customers of new products. Car dealerships remain important to the enterprise as they show the vehicle offering, guide customer choice in vehicle specification, capture customer order data and maintain the relationship with the customer base.

Organization

A cornerstone to the proposed transformation to a BTO strategy is the development of collaborative planning and execution. Automotive organizations are already closely linked as current strategies such as 'just in time' delivery requires strong collaborative links and rapid information exchange. Two organizational approaches are discussed with regard to feasibility, the current hierarchical approach and a novel decentralised approach (Fischer and Gneiting, 2008).

Organisation: Current State

In the current hierarchical organisation an OEM co-ordinates an entire enterprise, defining the enterprise boundaries and requiring all suppliers to align to their plan. The OEM plans all production quantities, required capacity and warehousing and communicates this to their suppliers. Such an approach functions most effectively with long planning times and stable demand and is similar to the current system in operation for ship building and most car producers who have small build to order volumes. This centralised approach creates organizational tensions as it results in conflicting objectives. An enterprise that seeks to be optimised for an individual OEM necessarily limits the efficiency of its suppliers, such that they are responsive to that customer. Many automotive suppliers work with more than one OEM and a firm with several customers experiences conflicts of interest between allocations of capacity which can cause individual networks to experience delay. Planned optimisation of a hierarchical network may not be possible as the information required of suppliers can create confidentiality issues. Any changes, such as introducing a new product or a modification of a product, can require a complete renegotiation across the enterprise; an extremely difficult and costly process.

Organisation: Future State

A solution to the issues arising from a hierarchical organisation is the implementation of a decentralised strategy. The assumption underlying this approach is that to be sustainable and feasible, individual firms within an enterprise must be able to plan for themselves (Fischer and Gneiting, 2008). This planning work depends upon their direct customers and direct suppliers. An enterprise is built up of equal but interdependent partners who are in control of their own planning will work in mutual interest to solve conflicts. This distributes the

potential complexity of introducing change across the network. If forthcoming change is communicated to all parties, the required negotiations may happen simultaneously and thus more quickly.

Information Technology

IT: Current State

Currently customer orders received by dealers are passed into national sales channels, regional scheduling, sequencing and purchasing offices within OEMs before the bills of materials are given to the highest level suppliers and passed down supply chains. This significantly contributes to the order delays in the current process. The system is hierarchical and interoperability of systems across the enterprise is generally poor, with integration often limited to the OEM and its major suppliers.

IT: Future State

To achieve BTO in 5-days requires an automated and rapid exchange of relevant data between specific parties in a network. The OEMs need information streams to keep them constantly aware of their suppliers' available and utilised production capacity. Whilst local planning must be undertaken by each plant to optimise the productivity of their internal processes, collaborative planning is undertaken to optimise for the production capacity of the networked enterprise. Central to achieving the goal of collaboration in planning is the Virtual Order Bank (VOB) (Mandel, 2008). This combines customer demand directly with production capacity throughout the supplier network. The VOB provides a common interface, providing access to information residing in distributed, possibly even heterogeneous, systems. Thus, the VOB acts as a façade to transparently and securely access capacity data, such that the data is still securely kept in possession of the responsible stakeholders on an individual and independent basis. A VOB would give visibility of customer orders, providing data from dealers, OEMS and suppliers and integrating order management and scheduling etc. To protect confidentiality the VOB limits the visibility of data, providing only relevant data to negotiating parties within a framework contract. All BTO partners define their maximum and minimum production capacity or stock level for BTS suppliers, such that they may remain viable businesses. These maximum and minimum define capacity 'corridors' where the trade-off in negotiation is between maximum reliability and a wide corridor, and stability in output with a narrow corridor.

Process

Process: Current State

Current state automotive process exhibits many features of leading practice. The automotive industry has a history of recovery from crisis through development and adoption of leading innovative practice and processes. 'Lean production' was documented when the auto industry in the US and European automotive manufacturers set out to employ Japanese automotive best practice and close the productivity gap which had opened up between East and West (Womack et al., 1990). Through rigorous application of lean thinking Western automotive companies implemented process excellence and significantly reduced the productivity gap identified by Womack *et al.*, but none have, as yet, delivered on its heralded promise of zero inventory or just-in-time approach to final customer orders (Stone et al., 2006). Whilst lean has enabled the automotive industry to optimise processes for mass production with minimal waste, it has not tackled the problems of capacity and demand. The industry suffers from global overcapacity and rising stock levels and exhibits inherently low profitability. Following leading practice, a car can be built from flat steel within 11 hours, but a customer specifying a car in a dealership has to wait at best around 40 days to receive their desired vehicle, or alternatively buy one from stock (Miemczyk and Holweg, 2004).

Process: Future State

A shared strategic vision has to be maintained across the automotive enterprise: stocks must be avoided, order to delivery times reduced, queries answered rapidly and planning order data shared rapidly. These elements strongly reflect the lean principles (Womack and Jones, 1996; Liker, 2004). Whilst planning autonomy ultimately remains with production partners, process integration is required to achieve BTO. This is done through the implementation of virtual order banks and autonomous agent negotiation to facilitate the rapid assignments of orders to suppliers (Fisher and Gneiting, 2008).

Pre-negotiation of a supplier's production capacity maximum and minimum levels, or 'bandwidth', along with conditions for temporarily extending or reducing capacity [cost, times etc], is central to the automated collaborative process. Any violations of capacity limits imply that the collaborative plan breaches the agreed capacity limits set within the supplier network. The automated process seeks to redress the capacity violation. The virtual order bank identifies plants that contribute to the violation and capacity may be re-directed to a plant with spare capacity or a 'capacity agreement add on' initiated, where capacity may be adjusted within a pre-

agreed restricted scope and timescale. This process ensures collaborators within the networked enterprise remain economically viable and negates contractual arguments over time, order levels and cost, usual when 'rush jobs' are encountered. This process operates autonomously and hence more quickly than is currently possible, as the current approach would require individuals at OEMs contacting many suppliers and negotiating separate contract amendments. This concept has been trialled and found to be achievable using current IT systems, linked through innovative supporting systems (Fischer et al., 2008).

Knowledge

Knowledge: Current State

Consciously or otherwise OEMs are already employing strategies to attain competitive advantage by coordinating suppliers in processes of innovation that recognise their knowledge in delivering customer value (Parry *et al.*, 2010). In current automotive supply chains implementation of Just in Time (JIT) which refers to the movement of material to the right place at the right time, relies on exchange of information and functions through shared knowledge (Wafa *et al.*, 1996). JIT operations are becoming the dominant method of OEM supply service (Von Corswant and Fredriksson, 2002). Whilst there is debate as to the requirement for suppliers to be in close proximity of the OEM for JIT to function (Schonberger and Gilbert, 1983; Dyer and Singh, 1998) JIT capability is linked to the development of knowledge sharing and additional capability development (Saxenian, 1994; Howard et al., 2006).

Knowledge: Future State

A dynamic Build to Order process integrates supply chains and their knowledge base forming a value creation network (Parolini, 1999). The design of value creation networks considers logistics strategy, supplier selection, relationships and location. To optimize planning and execution schedules knowledge is necessarily transferred through networks (Leger et al., 2006). The network is efficient when the knowledge transferred is explicit (Grant, 1996). A model BTO process and network uses customer demand data for a current vehicle, created with the same variants as the ModCar (Toth et al., 2008a). To function, the model requires information transparency such that knowledge is successfully shared across the enterprise (Toth et al., 2008b). This was challenging - though achieved - as individual firms knowledge needs to be protected from an IP perspective, but shared to facilitate integration. Network design as an independent task determines suitable conditions for planning and

execution that ensures that chosen pathways are economically efficient and viable in terms of the knowledge and IP strategy for each individual firm (Chopra and Meindl, 2009).

Politics and Environment

Politics and Environment– current state

The financial crisis of 2008 crippled sales and a lack of availability of capital stilted cash flows. Comparative reported sales for February 2008 and 2009 showed a fall of 41.3% for major automotive manufacturers, leading analysts to declare an automotive recession (Thompson, 2009). Companies saw an almost doubling of stock level during the worst of the downturn and there was a suggestion that figures were under reported (Webster, 2006). Reported US stock figures for December 2008 showed significant stock increases with an average of 44 days for BMW, 139 days for GM and 90 days for Toyota (Automotive News, 2008). The reaction of the vehicle OEMs was to halt production, with Honda shutting its UK base for four months (BBC, 2009) and Toyota halting Japanese production for 2 months (Ryall, 2009). Government backed packages incentivised new car purchases, with the \$4 billion US Car Allowance Rebate System (Congressional Budget Office, 2009) and European scrappage schemes (Allen, 2009). However, these activities simply supported the current BTS model. German sales rose 40% as a result of the scheme, but shares in automotive OEMs fell as investors were unconvinced that the measures created sustainable change (Reuters, 2009).

Politics and Environment; Future state

Ohno's vision for Toyota was the building of vehicles at the rate and variety demanded by the customer – building to customer order – such that each vehicle was paid for before it was built (Monden, 1983). Build to Order would provide financial protection to automotive companies and tax payers from market downturns. Similar to the lean approach, the implementation of Build to Order is expected to gain momentum as investors realise the potential of the strategy. The Build to Order approach outlined allows automotive firms to be fully sustainable, achieving the triple bottom line of economic, environmental and societal prosperity (Elkington, 1994). This is achieved and further enhanced by the holistic approach to product development which focuses on production logistics as well as performance in use. Modular product innovations reduce logistics costs by 45% (Seidel and Huth, 2008). The potential economic impact of Build to Order is the removal of stocks [inventory] throughout supply chain, freeing billions of dollars of cashflow which may be reinvested in product development. The environmental impact comes from the removal of waste through both unnecessary transport

and in the production of unwanted vehicles (Ohno, 1988). The societal impact is founded on the fact that the industry provides more than 12 million skilled jobs and generates \$548 billion in tax revenues across Europe (ACEA, 2009). The Build to Order approach requires that the vehicles are manufactured close to the customer, which would mean that this approach would maintain production and assembly within the major markets, protecting employment and tax revenues and hence bringing benefit to society.

Post Case Review

Having detailed the Enterprise Architecture for a BTO transition the content and approach were tested and critiqued. A panel of nine industry and academic experts reviewed the work. Six automotive partners examined the content of the paper to develop the automotive strategy. Once agreed the work was sent to an expanded panel, to include three industry experts from non-automotive complex engineering multi-national firms. The viability, validity and generalisability of the proposed Engineering Systems approach to Enterprise Architecting was explored using Platts' (1994) four characteristics for strategy formulation: procedure – the steps taken; participation – who should be involved?; project management - how should the process be organised?; and point of entry - how do we get buy in, when should it be done? The results from the expert panel follow.

Content: Automotive experts made a number of changes to the text of the paper with regards the detail of current and future state before this was agreed. General support and agreement from all the experts was given for the eight lenses, as they were seen to all be necessary for strategy formulation. However, whilst they were all seen as necessary, two experts questioned if they were sufficient. Of particular concern was the role of finance. *“...The lenses all seem sensible, but where is finance. Why isn't that a lens?”*. Follow up discussions were held to explore this concern which centred on the addition of finance as a necessary lens in enterprise architecting. The result was inconclusive as there was a split between the view that finance is tied to the firm level and responsive to enterprise and the view that finance is a determinant of enterprise strategy. Further work is required to develop an analysis of finance as an additional lens.

Procedure: The individual steps proposed for the formulation of the enterprise were accepted by all participants and the overall approach was seen as clear. Questions were raised as to the nature of the interaction of the components. Discussions were centred upon how this interaction manifests and if the arrows were too limited, as the ubiquity of a component may differ according to the nature of the enterprise created. *“...I think more work may be needed to address the concerns as a 'contribution network' – for example, hitting one area contributes*

to (or enables) hitting another...". However, in discussion it was proposed that interactions were likely to be context specific. Further work is required to develop experiments to test the interaction and ubiquity of lenses.

Participation: Senior management buy-in was recognised as a necessity for the proposed approach to enterprise architecting, particularly amongst OEM and 1st tier suppliers. Experts proposed the use of workshops to both educate and inform managers from across the enterprise "*...all views through the 8-Lenses will need to be taught to increase both the awareness and understanding of the journey to be undertaken...*". It was noted that field practice frequently differed from documented practice so interviews with senior teams in each area would be required, as well as seeing the activities being performed to ensure understanding of current and future state was captured. Due to the holistic nature of the approach this would require a broader engagement, involving more parties than was perhaps usually undertaken. This was seen as a strength of the approach as it required an early consideration of multiple aspects of the enterprise which would facilitate significant change such as the transformation to BTO; "*...Involvement would be pervasive!*". Further, as the approach comes from a systems engineering perspective the application and language used was seen as more easily acceptable for these domains. "*...I can see how that would work well in aerospace and I like that its holistic...*", "*...I'm a systems engineer and strategy from a systems perspective provides good traction for broad application in an engineering environment, we speak the same language...*".

Project management: Automotive experts believed that the established vehicle development project management template used by automotive OEMs is a suitable basis for this work. More generally, the use of either epoch or current and future state was seen as useful in setting and agreeing an underlying chronology for the project. A flexible developmental approach was proposed to facilitate implementation "*...one can imagine a six-month rolling plan paradigm where the plans are detailed and beyond the 6-month horizon the plan is less defined but continues to drive towards the goals of the next epoch...*". The resources and timescales were seen as dependent on the nature and size of the business.

Point of entry: Transformation of an industry was recognised as a significant challenge, particularly one as large and conservative as the automotive industry. It was proposed that there was significant inertia in trying to change institutionalised mindset and such a transformation should be undertaken initially in small volume production to demonstrate capability before more widespread application. "*...Piloting the approach on a "small" project, with a senior manager as a sponsor is probably going to provide the assurance that the CEO would need...*". Such a start point would also allow organisation learning. "*...you should start with implementing*

the new structure on a vehicle with low volumes, just to learn how to make the assembly and logistics physically work. In this stage there would only be oncost, the benefit comes with expanding to high volume vehicles...". It was recognised that the holistic enterprise approach went beyond the firm and the process complexity and its coverage of multiple companies would only create benefit by active collaboration. Hence, it is not down to a single stakeholder, but a number who must agree on their willingness for transformation. Compelling evidence would be required to co-ordinate and initiate change across multiple firms and here the approach was seen as beneficial. *"...Getting it started would require a well constructed business case; this is where the 8-lense view appears to be extremely useful..."*.

Conclusions and Implications

This paper presents the development of an Enterprise Architecting approach to strategy formulation in the European automotive industry. The work describes current and future states for the industry, which acts as a guide for transition. The original lean vision of building vehicles at the rate and variety demanded by the customer has not yet been achieved. Lean has improved productivity, but not yet achieved Build to Order. Similar to the lean approach, the implementation of BTO is expected to have a slow start but rapidly gain momentum as investors realise the potential of the strategy. Through addressing three of the seven wastes within automotive production identified by Taiichi Ohno, namely overproduction, unnecessary transportation and inventory (Ohno, 1988), the BTO approach outlined allows automotive firms to be fully sustainable, achieving the triple bottom line of economic, environmental and societal prosperity.

The case for adoption of a BTO strategy is strong and implementation has already begun within some of the OEMs of the European industry. Initially adoption is targeted upon low volume vehicles, in line with comments from the expert panel. Early adoption is challenging, but the longer term benefits of a transition to the new paradigm bring the potential for longer term sustainable competitive advantage. The 8 lenses of Enterprise Architecting were recognised as necessary and useful in setting the vision when undertaking enterprise transformation on the scale required for BTO. The language of engineering systems was seen to make the approach more accessible to the multiple domains engaged, thus facilitating buy-in.

Further work was identified in two areas. First, work is required to test the potential of including finance as an additional lens. Second, work is required in the development of experiments to test the interaction and ubiquity of lenses such that their relationships may be better understood.

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